Assessing Green Innovation Competencies for Sustainable Construction Practices in Nigeria: A Delphi Survey

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This study employed a Delphi survey to evaluate the importance of various green innovation competency components identified from the literature. The Delphi method was utilized for its effectiveness in achieving consensus among experts on complex issues. The participants included academics and registered professionals in practice such as Architects, Builders, Engineers, Estate Surveyors, Quantity Surveyors, and Town Planners, with at least 10 years of experience sustainability. A total of 30 experts were purposively selected, with 23 actively participating in both rounds of the survey. Consensus in this study is defined as a substantial majority agreement (70% or more) among the Delphi panel members. The mean score of ≥ 7 on a 10-point scale, a coefficient of variation (CV) ≤ 0.3, and an interquartile range (IQR) ≤ 1.5 were used as statistical measures, analysed with SPSS Version 20. Drawing from existing literature, 38 competencies were identified, encompassing social, environmental, economic, and technical dimensions important for decision-making in green projects. These competencies enhance adaptability, collaboration, and compliance with sustainable development goals. Of the identified components, 26 were rated highly by the experts. The findings showed strong intra-rater reliability (ICC of 0.941) and significant agreement among raters, supporting the validity of the results. The findings show the need for increased focus on these competencies in both academic and professional settings, because of their role in promoting adaptability, collaboration, and alignment with sustainable development goals. The study concludes that these competencies can be positioned as benchmarks for trainings and professional developments within the construction industry.
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Introduction

Sustainable construction practices have evolved as a concern in the global push for environmental protection, particularly in the context of developing countries such as Nigeria (Windapo *et al.,* 2021). Central to this change is the concept of green innovation, which implies the development and application of new technologies, processes, and practices aimed at reducing the environmental impact of construction activities while promoting sustainable development (Alohan & Olatunji, 2021). Because construction is a significant contributor to environmental degradation, addressing its ecological footprint through green innovation has become imperative (Trott, 2015). However, the success of green innovation efforts depends on the competencies possessed by professionals within the industry (Sousa, 2015). These competencies, which span social, environmental, economic, and technical dimensions, are essential to drive sustainable construction forward (Adedeji *et al.,* 2021; Owolabi *et al.,* 2019; Waziri *et al.,* 2015).

According to Frempong *et al.* (2021) and Abdullah *et al.* (2015), green innovation competencies encompass the skills, knowledge, and abilities necessary for construction professionals to effectively implement environmentally sustainable practices and technologies in their projects. Studies have shown that firms that invest in sustainable construction practices not only reduce their environmental impact but also improve their marketability with the growing demands for green buildings (Owolabi *et al.,* 2019). Therefore, improving the competencies of construction professionals has a potential to increase the competitiveness of the construction industries worldwide. However, research suggests that while there is a growing recognition of the importance of green innovation, construction professionals in Nigeria often struggle with its implementation due to insufficient expertise in areas such as renewable energy systems, sustainable design, and resource conservation (Afolabi *et al.,* 2015; Edomah *et al.,* 2019; Usman *et al.,* 2021).

This gap presents a significant barrier to achieving the nation's sustainable development goals and addressing the pressing environmental challenges posed by urbanization and population growth. However, existing studies have not sufficiently explored how the institutional and regulatory framework influences the development of these competencies (Li *et al.,* 2013). While such competencies are critical, an enabling environment supported by policies, incentives, and regulatory structures is equally essential to promote the uptake of green innovation competencies. Without examining these aspects, it becomes challenging to fully understand and address the barriers that professionals

face in implementing sustainable construction practices effectively.
Hence, this study aims to identify key components of green innovation to equip construction professionals with the skills needed to promote sustainable development in Nigeria's rapidly growing construction industry. The study used a Delphi survey methodology to gather opinion from green innovation experts, in order to understand the core competencies necessary to advance green construction practices in the country.

Literature Review
Based on literature explored four critical dimensions of green innovation competencies necessary for sustainable construction were identified these include: social, environmental, economic, and technical. The social competencies focus on communication, stakeholder engagement, and ethical decision-making, highlighting the need for collaboration and community involvement to promote green practices (Sang *et al.,* 2008; Waziri, 2016, Li *et al.,* 2013). While the environmental competencies emphasize skills in managing resources sustainably, including pollution prevention, energy efficiency, and the use of renewable technologies to minimize the environmental footprint of construction activities and promote ecosystem restoration (Frempong *et al.,* 2021; Alohan & Olatunji, 2021; Nguyen *et al.,* 2019).
However, economic competencies involve assessing and capitalizing on green business opportunities through methods like cost-benefit analysis, market research, and financial management (Waziri, 2016; Usman, 2015). These competencies enable construction professionals to align business profitability with sustainable practices by identifying market trends and developing innovative models (Li *et al.,* 2013). Technical competencies, on the other hand, focuses on skills in engineering, technology, and design necessary for implementing green technologies. This includes expertise in renewable energy systems, sustainable building practices, and environmental monitoring, integrating technology and design principles to support eco-friendly construction solutions (Li *et al.,* 2013; Afolabi *et al.,* 2013; Quang, 2022; Waziri, 2016). In summary, the four dimensions identified and their sources are presented in Table 1.

Table 1: Summary of the sources of variables for this study

s/n	Dimensions	Sources	Remarks
1	Social Competencies	Tubra & Humgra (2020), Sun *et al.* (2020)	Adapted
2	Economic Competencies	Sun *et al.* (2020), Tang *et al.* (2018)	Adapted
3	Environmental Competencies	Fang *et al.* (2018), Ahn *et al.* (2016)	Adapted
4	Technical Competencies	Pervez *et al*. (2021), Ren *et al.* (2019)	Adapted

Research Methodology
This study is a Delphi consensus-seeking exercise. Skulmoski *et al*. (2007) define the Delphi method as a structured communication technique used to gather expert opinions and achieve consensus on a specific issue. It involves multiple rounds of surveys or questionnaires where experts provide their views anonymously. In this study it was used as a mixed iterative survey of experts in the built environment in order to gain deeper understanding from registered professionals in practice and lecturers in the academia with vast knowledge of green innovations in the Nigerian Construction Industry. The participants included: Architects, Builders, Engineers, Estate Surveyors, Quantity Surveyors, and Town planners with a minimum of 10 years' experience. The use of professionals with at least 10 years of experience ensures that the study draws deep findings from experts with relevant expertise. Such professionals are likely to have encountered various aspects of green innovation, both in theory and practice, and have a good understanding of the industry's challenges and opportunities. This experience level helps ensure that the insights gained are from individuals with substantial exposure to and knowledge of sustainable practices within the construction industry, thus enhancing the reliability and depth of the findings.
Eligible participants were identified and selected to participate in the study through phone calls. Phone calls were used as a direct method to ensure timely communication and to establish rapport with potential participants. This method allowed the researcher to clearly explain the study objectives, clarify any doubts, and verify eligibility before participation. Phone numbers were obtained through professional associations, regulatory bodies, and networks, ensuring that the contact information was from verified sources, maintaining the credibility and relevance of the expert pool. Considering that some participants could be experts in more than one category (academic or practice), a total of 30 experts for the Delphi survey were contacted. However, only 23, were able to participate actively in both rounds of the survey. According to Diamond *et al*. (2014) and Musa *et al.* (2015), there is no universally acceptable sample size for Delphi survey, however, a minimum of 20 experts are usually adopted as a benchmark in most studies. All questions were evaluated on a 10-point Likert scale, from 1 (Not significance) to 10 (Very high significance) and participants were asked to choose the level of

significance for each green innovation competencies component. A 10 - point Likert scale was employed to provide a higher level of granularity, allowing participants to express their opinions on the significance of green innovation competencies with more precision (Musa *et al.,* 2015). This scale enhances the sensitivity of the responses, enabling the differentiation of varying degrees of importance, which supports more variations in analysis of consensus levels among experts. The study uses purposive sampling, a non-probability sampling approach, to deliberately select professionals and academics with significant expertise in green innovation. This approach is appropriate for a Delphi study, as it ensures that only those with relevant knowledge and experience contribute to the consensus-building process.

The first round of the Delphi exercise lasted 14 days. The second round was conducted 4 weeks later, using a modified questionnaire based on iterative feedback and consensus during round one. In round 2, participants were provided with the mean of respondents that chose a particular answer and a reminder of their individual answer in round 1. In the second round the responses from round one was aggregated and analysed. Items for which there was consensus and lack of consensus were identified. Panel members were asked to reconsider the criteria for which consensus were not reached. Also, in both rounds, Delphi panel members were asked to suggest rephrasing, provide any rationale for their choices, and suggest new items (if any). For the purpose of this study, consensus is defined as general agreement of a substantial majority (70% or greater) of Delphi panel members. The mean score of ≥ 7 on the 10 - point scale, coefficient of variation (CV) ≤ 0.3, and Interquartile range (IQR) ≤ 1.5 are employed for this study as statistical measures using SPSS Version 20.

The following formulae were adopted for this study

$$\text{Mean} = \Sigma(fi - xi)/\Sigma fi \quad (i)$$

Where: x = Each value in the dataset; n = total number

$$\text{CV} = Standard\ deviation/Mean\ (ii)$$

Where Standard deviation measures dispersion of the dataset

$$\text{IQR} = Q3 - Q1 \qquad (iii)$$

Where Q_1 is the first quartile (25^{th} Percentile) and Q_3 is the third quartile (75^{th} Percentile)

Also, Intraclass Correlation Coefficient (ICC) was performed to assess the reliability of the panellist in the Delphi rounds using both the two-way random-effect model and a two-way mixed-effect model based on single rating assessed the intra-rater repeatability for either rater. Mean estimations along with 95% Confidence Intervals (CI) were conducted for each ICC. The following are the Interpretation for the ICC results < 0.50, Poor; between 0.50 and 0.75, Fair, between 0.75 and 0.90 Good; and above 0.90, Excellent (Cohen 1989). The methods of data analysis, including the use of mean scores, coefficient of variation (CV), and Interquartile Range (IQR), were chosen to quantify consensus levels systematically. These measures help identify the level of agreement among experts and determine the consistency of responses. Additionally, the use of Intraclass Correlation Coefficient (ICC) ensures the reliability of the panellists' feedback across the Delphi rounds, which is vital for validating the stability and reproducibility of the results. SPSS Version 20 was utilized for these analyses to provide statistical rigor and standardization, enhancing the robustness of the study's findings.

Results and Discussion

Delphi first round sub-indicators

Thirty-Eight (38) indicators obtained from the literature to assess the four (4) dimensions of green innovation competencies were subjected to Delphi survey to determine their relevance. Table 2 presents the result of round one Delphi response on the indicators relevance. The panel assessment was statistically analysed to determine their consensus based on three (3) defined criteria of Mean score of ≥ 7 on Scale of 1 -10, Coefficient of Variation (CV) of ≤ 0.3 and inter-quartile range (IQR) of ≤ 1.5. Items are considered for consensus if the set criteria are simultaneously achieved in collective panellist sampled (n = 23). The result in first round shows that at the end of Delphi round one, 17 out 38 items did not gain expert consensus, while twenty (21) items gained consensus. In the social competencies' dimension, 6 out of 9 items gained consensus. This includes 'Inclusive collaboration and teamwork' (M =8.00; CV = 0.24; IQR = 1.0), 'Good communication' (M =7.43; CV = 0.20; IQR = 1), 'Leadership and influence' (M =8.18; CV = 0.20; IQR = 1.0), 'Good negotiation' (M =8.56; CV = 0.2; IQR = 1.5), 'Cross-cultural competence' (M =8.36; CV = 0.21; IQR = 1.5), and 'Adaptability and flexibility' (M =7.78; CV = 0.19; IQR = 1.0) while 3 components 'Good empathy', 'Good engagement' and 'Conflict resolution and mediation' (M =7.17; CV = 0.27; IQR = 3.0), (M =6.04; CV = 0.33; IQR = 3.3) and (M =6.74; CV = 0.22; IQR = 2.4) respectively did not gain consensus. Also, in the economic competencies' dimension, 6 out of 9 items gained expert consensus these include 'Cost-benefit analysis of green technologies and practices' (M =7.64; CV = 0.11; IQR = 1.0), 'Renewable energy sources and their economic viability' (M =7.82; CV = 0.10; IQR = 1.0), 'Economic assessment of lifecycle analysis for green construction projects' (M =7.04; CV = 0.13; IQR = 1.5), 'Navigating green financing options and incentives' (M =7.57; CV = 0.17; IQR = 1.5), 'Carbon footprint measurement and reduction strategies' (M

=7.61; CV = 0.17; IQR = 1.5), and ‘Regulatory frameworks and policies promoting green construction’ (M =8.56; CV = 0.20; IQR = 1.5). However, ‘Sustainable materials procurement and management’ (M =4.79; CV = 0.19; IQR = 1.0), ‘Innovative green technologies’ (M =4.93; CV = 0.19; IQR = 2.0) and ‘Feasibility studies for green construction projects’ (M =7.94; CV = 0.16; IQR = 1.8) were adjudged non-consensus components in the first round.

In the environmental competencies dimension, 5 out of 10 indicators: ‘Energy- efficient design’ (M = 7.78; CV = 0.19; IQR = 1.0), ‘Sustainable materials selection’ (M = 7.57; CV = 0.17; IQR = 1.5), ‘Waste management and recycling’ (M = 8.0; CV = 0.63; IQR = 1.5), ‘indoor air quality optimization’ (M = 8.56; CV = 0.20; IQR = 1.5), and ‘Green building certifications (e.g., LEED, BREEAM)’ (M = 8.18; CV = 0.20; IQR = 1.0) gained consensus, with the exception of ‘Water conservation’ (M = 6.04; CV = 0.33; IQR = 3.3), ‘Renewable energy concepts in designs’ (M = 7.94; CV = 0.16; IQR = 1.8), ‘Life cycle assessment’ (M = 7.17; CV = 0.27; IQR = 3), ‘Environmental impact assessment’ (M = 7.94; CV = 1.28; IQR = 1.8), and ‘Environmental policy and regulation’ (M = 4.82; CV = 0.17; IQR = 1.0) that fail to reach consensus from the response of the panel experts. Lastly, for the technical component 6 out of 10 indicators failed to reached consensus while 4 indicators gained consensus. The indicators that failed consensus are ‘Sustainable Architecture and design’ (M = 7.94; CV = 0.16; IQR = 1.8), ‘Circular economy and waste management’ (M = 7.17; CV = 0.27; IQR = 3.0), ‘Energy efficiency management’ (M = 5.07; CV = 0.19; IQR = 1.8), ‘Green chemistry and biotechnology’ (M = 4.93; CV = 0.19; IQR = 2.0), ‘Green project management’ (M = 5.08; CV = 0.19; IQR = 1.8) and ‘Technology integration (such as BIM, cloud computing and 3D printing)’ (M = 4.68; CV = 0.17; IQR = 1.0) however, ‘Renewable energy technologies’ (M = 8.56; CV = 0.20; IQR = 1.5), ‘Environmental management’ (M = 7.64; CV = 0.11; IQR = 1.0), ‘Sustainable supply chain management’ (M = 7.57; CV = 0.17; IQR = 1.5) and ‘Waste and air quality management’ (M = 7.66; CV = 0.17; IQR = 1.0) gained consensus. Overall, 17 items did not gain panellists consensus in round one.

Table 2: Results of Delphi Round One Responses

Indicators	N	Min	Max	Mean	Std dev	CV	IQR	REM
Social competencies dimension								
Inclusive collaboration and teamwork	23	6.0	10.0	8.00	1.92	0.24	1.0	C
Good communication	23	7.0	9.0	7.43	1.48	0.20	1.0	C
leadership and influence	23	8.0	9.0	8.18	1.66	0.20	1.0	C
Good negotiation	23	8.0	10.0	8.56	1.73	0.20	1.5	C
Cross-cultural competence	23	8.0	10.0	8.36	1.73	0.21	1.5	C
Adaptability and flexibility	23	6.0	8.0	7.78	1.48	0.19	1.0	C
Good empathy	23	6.0	8.0	7.17	1.95	0.27	3.0	NC
Good engagement	23	6.0	7.0	6.04	2.03	0.33	3.3	NC
Conflict resolution and mediation	23	6.0	7.0	6.74	1.48	0.22	2.4	NC
Economic Competencies dimension								
Cost-benefit analysis of green technologies and practices	23	7.0	9.0	7.64	0.83	0.11	1.0	C
Renewable energy sources and their economic viability	23	7.0	10.0	7.82	0.77	0.10	1.0	C
Sustainable materials procurement and management	23	4.0	6.0	4.79	0.92	0.19	1.0	NC
Economic assessment of lifecycle analysis for green construction projects	23	6.0	8.0	7.04	0.92	0.13	1.5	C
Navigating green financing options and incentives	23	6.0	8.0	7.57	1.29	0.17	1.5	C
Carbon footprint measurement and reduction strategies	23	7.0	8.0	7.61	1.31	0.17	1.5	C
Regulatory frameworks and policies promoting green construction	23	8.0	10.0	8.56	1.73	0.20	1.5	C
Innovative green technologies	23	4.0	6.0	4.93	0.94	0.19	2.0	NC
Feasibility studies for green construction projects	23	7.0	9.0	7.94	1.28	0.16	1.8	NC
Environmental competencies dimension								
Energy- efficient design	23	7.0	10.0	7.78	1.48	0.19	1.0	C
Sustainable materials selection	23	6.0	8.0	7.57	1.29	0.17	1.5	C
Waste management and recycling	23	7.0	10.0	8.00	0.63	0.08	1.5	C
Water conservation	23	6.0	7.0	6.04	2.03	0.33	3.3	NC
Indoor air quality optimization	23	8.0	10.0	8.56	1.73	0.20	1.5	C
Green building certifications (e.g., LEED, BREEAM)	23	7.0	9.0	8.18	1.66	0.20	1.0	C
Integrating renewable energy concepts in designs	23	6.0	8.0	7.94	1.28	0.16	1.8	NC
Life cycle assessment	23	6.0	8.0	7.17	1.95	0.27	3.0	NC
Environmental impact assessment	23	6.0	8.0	7.94	1.28	0.16	1.8	NC
Environmental policy and regulation	23	4.0	6.0	4.82	0.82	0.17	1.0	NC
Technical competencies dimension								
Renewable energy technologies	23	8.0	10.0	8.56	1.73	0.20	1.5	C
Sustainable Architecture and design	23	6.0	8.0	7.94	1.28	0.16	1.8	NC
Environmental management	23	6.0	8.0	7.64	0.83	0.11	1.0	C
Circular economy and waste management	23	7.0	8.0	7.17	1.95	0.27	3.0	NC
Sustainable supply chain management	23	7.0	9.0	7.57	1.29	0.17	1.5	C
Waste and air quality management	23	6.0	8.0	7.66	1.28	0.17	1.0	C

Energy efficiency management	23	5.0	6.0	5.07	0.94	0.19	1.8	NC
Green chemistry and biotechnology	23	4.0	6.0	4.93	0.94	0.19	2.0	NC
Green project management	23	4.0	6.0	5.08	0.94	0.19	1.8	NC
Technology integration (such as BIM, cloud computing and 3D printing)	23	4.0	5.0	4.68	0.77	0.17	1.0	NC

Key: Where C means among panel members and NC means No Consensus among panellists

Delphi second round sub-indicators

Twenty - Six (26) out of Thirty - eight (38) items across the four (4) components of green innovation competencies gained panel consensus in the second Delphi survey. Table 3 present the result of the second Delphi survey responses on the weight of the items significance. As in the first round, consensus is determined if set criteria is achieved simultaneously. The set criteria include Mean score of ≥ 7 on Scale of 1 -10, Coefficient of Variation (CV) of ≤ 0.3 and inter-quartile range (IQR) of ≤ 1.5 as defined earlier.

In the social competencies' component, 7 out of 9 items gained consensus. These include: 'Inclusive collaboration and teamwork' (M =8.36; CV = 0.13; IQR = 1.0), 'Good communication' (M =7.54; CV = 0.14; IQR = 1.0), 'Leadership and influence' (M =8.25; CV = 0.13; IQR = 1.0), 'Good negotiation' (M = 8.39; CV = 0.12; IQR = 1.0), 'Cross-cultural competence' (M =8.82; CV = 0.12; IQR = 1.5), and 'Adaptability and flexibility' (M =7.50; CV = 0.13; IQR = 1.0). 'Good engagement' that failed consensus in the first round with (M =6.04; CV = 0.33; IQR = 3.3) gained consensus in the second round with (M = 7.29; CV = 0.15; IQR = 1.0). Whereas, 'Good empathy' and 'Conflict resolution and mediation' were adjudged non-consensus items by the panel members both in the first and second rounds of the survey.

The economic competencies component has 6 out of 9 items that reached panel consensus in the second round. Some items reached consensus in both rounds, while other items failed to reached consensus either in the first round or in the second round. The item that reached consensus in the first round but failed to gained consensus in the second round is the 'Navigating green financing options and incentives' with (M = 7.57; CV = 0.17; IQR = 1.0) in the first round and (M = 8.32; CV = 0.12; IQR = 1.8) in the second round. While 'Feasibility studies for green construction projects' that failed consensus in the first round (M = 7.94; CV = 0.16; IQR = 1.8) gained consensus in the second round (M = 8.82; CV = 0.12; IQR = 1.5). 'Innovative green technologies' failed to gained consensus in both rounds while indicators such as 'Cost-benefit analysis of green technologies and practices', 'Renewable energy sources and their economic viability', 'Economic assessment of lifecycle analysis for green construction projects', 'Carbon footprint measurement and reduction strategies' and 'Regulatory frameworks and policies promoting green construction' all got panel consensus in both rounds.

7 out of 10 indicators of environmental competencies component gained consensus in the second round of the survey. They are 'Energy- efficient design', 'Sustainable materials selection', 'Waste management and recycling', 'Water conservation', 'Indoor air quality optimization', 'Green building certifications (e.g., LEED, BREEAM)' and 'Integrating renewable energy concepts in designs'. Though, 'water conservation' with (M = 6.04; CV = 0.33; IQR = 3.3) and 'Renewable energy concepts in designs' (M = 6.04; CV = 0.33; IQR = 3.3) failed consensus in the first round, they gained consensus (M = 7.57; CV = 0.14; IQR = 1.0) and (M = 7.29; CV = 0.15; IQR = 1.0) respectively in the second round. components such as 'Life cycle assessment', 'Environmental impact assessment' and 'Environmental policy and regulation' failed to gained consensus in both rounds of the survey.

Finally, in the second round, 6 out of 10 indicators of the technical component of green innovation competencies gained consensus. Items that got consensus in both rounds are 'Renewable energy technologies', 'Environmental management', 'Waste and air quality management' while items that failed to gained consensus in both rounds of the survey are 'Sustainable architecture and design', 'Green chemistry and biotechnology' and 'Green project management' as indicated by the low rating scored on a scale of 1-10 as shown in Table 3. 'Circular economy and waste management', 'Energy efficiency management' and 'Technology integration (such as BIM, cloud computing and 3D printing)' that failed consensus in the first round gained consensus in the second round. However, 'Sustainable supply chain management' that gained consensus in the first round failed consensus in the second round. Overall, 26 components gained panel consensus while 12 components out of 38 did not meet the criteria for panel consensus in the second round of the survey.

Table 3: Result of the Delphi Round Two Responses

Indicators	N	Min	Max	Mean	Std dev	CV	IQR	REM
Social competencies dimension								
Inclusive collaboration and teamwork	23	7.0	9.0	8.36	1.12	0.13	1.0	C
Good communication	23	6.0	8.0	7.54	1.04	0.14	1.0	C
leadership and influence	23	8.0	10.0	8.25	1.08	0.13	1.0	C
Good negotiation	23	8.0	9.0	8.39	1.03	0.12	1.0	C
Cross-cultural competence	23	8.0	9.0	8.82	1.02	0.12	1.5	C
Adaptability and flexibility	23	7.0	8.0	7.50	1.00	0.13	1.0	C
Good empathy	23	7.0	8.0	7.17	1.95	0.27	3.0	NC
Good engagement	23	6.0	8.0	7.29	1.12	0.15	1.0	C
Conflict resolution and mediation	23	5.0	7.0	5.14	0.97	0.19	2.0	NC
Economic Competencies dimension								
Cost-benefit analysis of green technologies and practices	23	7.0	10.0	8.25	1.11	0.13	1.0	C
Renewable energy sources and their economic viability	23	8.0	9.0	8.75	1.00	0.11	1.0	C
Sustainable materials procurement and management	23	8.0	10.0	8.32	1.02	0.12	1.8	NC
Economic assessment of lifecycle analysis for green construction projects	23	8.0	10.0	8.00	0.63	0.08	1.5	C
Navigating green financing options and incentives	23	8.0	9.0	8.32	1.02	0.12	1.8	NC
Carbon footprint measurement and reduction strategies	23	6.0	9.0	7.43	1.00	0.13	1.0	C
Regulatory frameworks and policies promoting green construction	23	8.0	10.0	8.50	0.75	0.09	1.0	C
Innovative green technologies	23	4.0	6.0	5.14	0.80	0.16	1.0	NC
Feasibility studies for green construction projects	23	8.0	9.0	8.82	1.02	0.12	1.5	C
Environmental competencies dimension								
Energy- efficient design	23	8.0	10.0	9.21	0.79	0.09	1.0	C
Sustainable materials selection	23	8.0	9.0	8.46	0.92	0.11	1.0	C
Waste management and recycling	23	8.0	10.0	8.82	1.02	0.12	1.5	C
Water conservation	23	7.0	9.0	7.57	1.07	0.14	1.0	C
Indoor air quality optimization	23	8.0	9.0	8.68	1.06	0.12	1.5	C
Green building certifications (e.g., LEED, BREEAM)	23	7.0	9.0	8.00	0.63	0.08	1.5	C
Integrating renewable energy concepts in designs	23	7.0	9.0	7.29	1.12	0.15	1.0	C
Life cycle assessment	23	8.0	10.0	8.32	1.02	0.12	1.8	NC
Environmental impact assessment	23	5.0	6.0	5.29	0.81	0.15	1.0	NC
Environmental policy and regulation	23	4.0	6.0	4.89	0.83	0.17	1.0	NC
Technical competencies dimension								
Renewable energy technologies	23	8.0	10.0	8.75	1.00	0.11	1.0	C
Sustainable Architecture and design	23	6.0	8.0	7.94	1.28	0.16	1.8	NC
Environmental management	23	8.0	10.0	8.25	1.11	0.13	1.0	C
Circular economy and waste management	23	7.0	9.0	7.36	0.87	0.12	1.0	C
Sustainable supply chain management	23	7.0	9.0	8.18	1.09	0.13	1.8	NC
Waste and air quality management	23	6.0	9.0	8.11	0.79	0.10	1.0	C
Energy efficiency management	23	7.0	9.0	8.00	0.63	0.08	1.5	C
Green chemistry and biotechnology	23	7.0	10.0	8.79	1.10	0.13	2.0	NC
Green project management	23	7.0	10.0	8.18	1.09	0.13	1.8	NC
Technology integration (such as BIM, cloud computing and 3D printing)	23	6.0	8.0	7.43	1.00	0.13	1.0	C

Key: Where C means consensus among panel members and NC means No Consensus among panellists

Discussions of findings

The analysis of the Delphi survey rounds on green innovation competencies in construction highlights important trends and expert opinions across social, economic, environmental, and technical dimensions. The findings reflect both consensus and areas of disagreement, providing insight into the strengths and gaps in green innovation practices.

Social competencies

Social competencies had significant focus on "Inclusive collaboration and teamwork" and "Leadership and influence." This aligns with Windapo *et al*. (2021) who emphasized the role of communication and collaboration in promoting green innovation. However, there was no consensus on indicators like "Good empathy" and "Conflict resolution," which Usman *et al.* (2021) also identified as challenging to prioritize and measure in the construction industry. The second round showed a shift, with increased consensus on collaboration and leadership skills but continued divergence on "Good empathy" and "Conflict resolution." This suggests that while these soft skills are recognized, they are not yet fully integrated into professional development programs. Frempong *et al*. (2021) and Li *et al. (*2013) call for comprehensive training programs to address these interpersonal skills, indicating a need for industry-wide initiatives to enhance social competencies as found in this study.

Economic competencies

The economic dimension showed strong consensus on indicators such as "Economic analysis" and "Regulatory frameworks," confirming the emphasis on financial viability and regulatory adherence in green innovation projects, as supported by Dania (2016). However, "Sustainable materials procurement" lacked consensus, reflecting challenges highlighted by Owolabi *et al.* (2019) and Dania (2016) around market limitations and procurement processes. In the second round, economic competencies further highlighted the importance of skills like "Cost-benefit analysis" and "Lifecycle economic assessments," with a notable shift towards the importance of "Feasibility studies for green construction." The lack of agreement on "Navigating green financing options" in the second-round echoes the findings of Adedeji *et al.* (2021) suggesting a need for clearer guidance on accessing green finance and integrating innovative technologies, as also noted by Usman *et al.* (2021) and Windapo *et al.* (2021).

Environmental competencies

Environmental competencies saw mixed results, with only half of the indicators reaching consensus in the first round. Indicators like "Energy-efficient design" and "Green building certifications" gained support, while items like "Water conservation" and "Environmental impact assessment" did not. These results are consistent with Abdullah *et al.* (2015), who highlighted challenges in consistently applying and measuring these environmental practices. The second round showed a growing focus on "Water conservation" and "Renewable energy concepts in design," indicating increased attention to comprehensive sustainability. However, ongoing disagreement on "Life cycle assessment" and "Environmental impact assessment" suggests a need for more standardized frameworks and training, as supported by Dania (2016) to promote broader adoption of these environmental practices.

Technical competencies

The technical dimension revealed the lowest level of consensus, with agreement on "Renewable energy technologies" and "Environmental management," but a lack of consensus on "Green project management" and "Technology integration." This reflects a potential gap in technical capacity, as observed by Li *et al.* (2013) and Adedeji *et al.* (2021). In the second round, consensus improved on areas like "Circular economy and waste management" and "Energy efficiency management," suggesting growing recognition of these technical aspects. However, non-consensus on "Sustainable architecture and design" and "Green project management" implies that these areas require further development and standardization, a sentiment echoed by Dania (2016) and Li *et al.* (2013).

Generally, the Delphi survey findings across both rounds indicate that while progress has been made in identifying and achieving consensus on 26 indicators related to green innovation competencies, gaps remain in several key areas. Social and economic competencies are recognized as crucial, but certain interpersonal skills and financial mechanisms require further attention. The environmental dimension shows growing recognition of sustainability practices, though more clarity and training are needed for broader adoption. The technical dimension, especially in areas like "Green project management" and "Technology integration," requires targeted capacity-building initiatives. These findings underscore the need for standardized frameworks, clearer guidelines, and comprehensive training to fully integrate green innovation competencies into the construction industry, as suggested by Dania (2016), Li *et al.* (2013) and other researchers.

Intra correlation coefficient (ICC) test of the two Delphi rounds

Table 4 presents the Intraclass Correlation Coefficient (ICC) results from the Delphi survey, which measures the consistency or reliability of ratings provided by different experts both rounds. Results from the table shows that for the single measures which represents the reliability of a single rater's (expert's) ratings. The ICC of 0.832 suggests a high level of agreement among individual raters. The 95% Confidence Interval (CI) for this ICC is from 0.759 to 0.898, indicating that the true ICC lies within this range with 95% confidence. The F-test value (10.567) with degrees of freedom (df1 = 80, df2 = 80) and the significance level (p = 0.000) indicate that the ICC is statistically significant while the average measures represent the reliability when the ratings are averaged across multiple raters. The ICC of 0.902 suggests an even higher level of agreement when considering the combined judgments of the experts. The 95% Confidence Interval for the Average Measures ICC ranges from 0.860 to 0.941, showing a strong level of agreement. Again, the F-test value (10.567) is significant with p = .000, confirming the robustness of the results. Therefore, both ICC values indicate a strong agreement among the experts across Delphi rounds.

While the Single Measures ICC (0.832) suggests that individual expert ratings are reliable, the Average Measures ICC (0.902) indicates that the overall reliability increases when considering the average ratings of all experts. The statistical significance (p = .000) confirms that the observed agreement is unlikely due to chance. Therefore, the findings from the results of ICC conducted indicates a good and excellent reliability as the fall within the recommended for good to excellent (Cohen, 1989; Koo & Li, 2016).

Table 4: Intraclass correlation coefficient (ICC) Test between Delphi rounds

	Intraclass	95% Confidence Interval		F Test with True Value 0			
	Correlation	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.832[a]	.759	.898	10.567	80	80	.000
Average Measures	.902[c]	.860	.941	10.567	80	80	.000

Model: Two-way mixed effects where people effects are random and measures effects are fixed.
Footnotes:
a. The estimator is the same, whether the interaction effect is present or not.
b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.
c. This estimate is computed assuming the interaction effect is absent because it is not estimable otherwise.

Table 5 shows the summary of the twenty – six (26) indicators based on the four (4) dimensions of green innovation competencies selected and adopted as the core competencies indicators in this study because they were rated highly by the panellist. The social and environmental dimensions have seven (7) components each while the environmental and technical dimensions have six (6) components each.

Table 5: Summary of Required Green Innovation Competencies

	Dimensions			
	Social Competencies	**Economic Competencies**	**Environmental Competencies**	**Technical Competencies**
Indicators	Inclusive collaboration and teamwork	Cost-benefit analysis of green technologies and practices	Energy - efficient design	Renewable energy technologies
	Good communication	Renewable energy sources and their economic viability	Sustainable materials selection competence	Environmental management
	Leadership and influence	Economic assessment of lifecycle analysis for green construction projects	Waste management and recycling	Circular economy and waste management
	Good negotiation	Carbon footprint measurement and reduction strategies	Water conservation	Waste and air quality management
	Cross-cultural competence	Regulatory frameworks and policies promoting green construction	Indoor air quality optimization proficiency	Energy efficiency management
	Adaptability and flexibility	Feasibility studies for green construction projects	Green building certifications (e.g., LEED, BREEAM)	Technology integration such as BIM, cloud computing and 3D printing)
	Good engagement		Integrating renewable energy concepts in designs	

Conclusion

This study employed a Delphi method to identify and achieve consensus on key green innovation competencies required for sustainable practices in the Nigerian construction industry. Construction experts with over 10 years of experience in the field participated in the two rounds of surveys, providing insights and feedback to refine the list of competencies. The process ensured that the competencies identified were well-vetted by experienced professionals in the industry. The methods of data analysis, including the use of mean scores, coefficient of variation (CV), and Interquartile Range (IQR), were chosen to quantify consensus levels systematically. 38 competencies were identified however only 26 achieved consensus among experts across four dimensions which are: social, economic, environmental, and technical areas. Indicators such as renewable energy technologies, sustainable materials procurement, cost-benefit analysis of green technologies, and waste management proficiency were among those that gained strong agreement. The study further reveals that while many competencies are already well recognized by professionals, areas such as green project management and environmental impact assessment, require further attention to reach industry-based wide consensus.

The study has therefore contributed to the body of knowledge on green innovation competencies by providing a consensus-based framework applicable to Nigeria. It highlights the areas that need more academic and practical focus, creating a foundation for further research in the field. For construction professionals and organizations, the identified competencies would serve as a benchmark for training and professional development, ensuring that the workforce is equipped with the necessary skulls to implement sustainable practices effectively. Finally, the study underscores the need for sustainable materials selection and effective waste management systems, as vital components for reducing environmental impact of construction projects.

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