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An Empirical Study on Data Validation Methods of Delphi and General Consensus

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Abstract: Data collection and review are the building blocks of academic research regardless of the discipline. The gathered and reviewed data, however, need to be validated in order to obtain accurate information. The Delphi consensus is known as a method for validating the data. However, several studies have shown that this method is time-consuming and requires a number of rounds to complete. Until now, there has been no clear evidence that validating data by a Delphi consensus is more significant than by a general consensus. In this regard, if data validation between both methods are not significantly different, then just using a general consensus method is sufficient, easier, and less time-consuming. Hence, this study aims to find out whether or not data validation by a Delphi consensus method is more significant than by a general consensus method. This study firstly collected and reviewed the data of sustainable building criteria, secondly validated these data by applying each consensus method, and finally made a comparison between both consensus methods. The results showed that seventeen of the valid criteria obtained from the general consensus and reduced by the Delphi consensus were found to be inconsistent for sustainable building assessments in Cambodia. Therefore, this study concludes that using the Delphi consensus method is more significant in validating the gathered and reviewed data. This experiment contributes to the selection and application of consensus methods in validating data, information, or criteria, especially in engineering fields.

Keywords: Delphi consensus; general consensus; group decision making; decision support tools; Cambodia sustainable buildings; criteria review; data collection; data validation

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1. Introduction

Data collection and review are considered important in gathering, reporting, and summarizing the existing literature in the field [1], while conducting experimental research based on existing literature is recognized as a building block of all academic research activities regardless of discipline [2,3]. The collected or reviewed data sometimes need to be validated in order to obtain accurate information, especially in engineering fields [4,5]. Toward obtaining precise information these days, general consensus methods through a group meeting are popularly used. Delphi consensus has also been used to obtain accurate information and handle complex problems that require a judgmental analysis [6–9]. More recently, Delphi has been widely used to validate the data in the building and construction fields. However, by studying issues and analysis of the use of the Delphi technique as a forecasting tool by looking at its effectiveness, Gene and George [10] showed that there is no consistent evidence that the technique works beyond other structured group procedures. Norman and Olaf [11] conducted an experiment of the Delphi method to obtain the most reliable opinion consensus of a group, but with controlled opinion feedback. The controlled opinion feedback enables concentrating the objectives of the Delphi technique rather than focusing on winning the argument by certain members [12]. On the other hand, the Delphi consensus methods were found to be limited for use in prioritizing urban sustainability assessment criteria and indicators [13]. Furthermore, its anonymity characteristics have disadvantages, such as the lack of accountability for opinions expressed by participants due to unknown identifications, the limitations of exploratory thinking, and the exclusion of idea stimulation [14]. Yet, the Delphi methods were found to be useful in obtaining accurate information that is unavailable, in handling complex problems that require more judgmental analysis, and in defining areas where there is considerable uncertainty and/or a lack of agreed knowledge or disagreement [15,16]. More recently, several studies have shown that the Delphi consensus method is a useful approach for the management of chronic pain during and after COVID-19 [17], for the development and validation of a graded motor imagery intervention for phantom limb pain in patients [18], for the design and validation of the scale to measure aquatic competence in children by evaluating aquatic competence in children from three to six years old [19], and for the development of an environmental health sciences COVID-19 research agenda [20].

Quite commonly, the Delphi consensus methods were found to be time-consuming and required more rounds to reach an agreement [13,21] even though the number of rounds can be based on the objectives of research [22,23]. Likewise, while the Delphi consensus methods need more rounds to be achieved, Gunhan and Arditi [24] argued that most changes in responses took place in the first two rounds and that little was gained after that. Hallowell and Gambatese [25] pointed out the advantage of, and suggested having, Delphi in three rounds, which facilitates obtaining reasons for outlying responses from Delphi round two and reporting them in Delphi round three. The process could facilitate the consideration of all options and feedback, as well as the attainment of a consensus about the correct value instead of conforming to an incorrect opinion [21,23]. The Delphi consensus methods are also quite useful for validating an ecosystem services assessment technique [26], a planning approach for foresight and strategic management [27], and identifying the benefits of integrating building information modelling (BIM) and sustainability practices in construction projects [28]. However, several studies [13,21,23,24] showed that users of the Delphi consensus methods took a lot of time to complete the procedure, while many studies [21–24,29–34] have employed this procedure for no less than three rounds. Until now, there has been no clear evidence that data validation by using a Delphi consensus method is more significant than by using a general consensus method, especially when the Delphi consensus method is time-consuming and requires at least three rounds to reach an accord. In this regard, if data validation results from both consensus methods are not significantly different, then just using a general consensus method is sufficient, easier, and less time-consuming. Hence, this study aims to find out whether or not data validation by using a Delphi consensus method is more significant than by using a general consensus method. Accordingly, the hypothesis of this experiment is as follows:

Hypothesis 1. *General and Delphi consensus validation results are of the same significance.*

Hypothesis 2. *General and Delphi consensus validation results are of different significance.*

This means if the experiment results reach H1, a Delphi consensus method is not necessary to use for data validation—just using a general consensus method is sufficient. However, if the experiment results reach H2, a Delphi consensus method is more significant to use for data validation in order to obtain accurate information. This study will significantly contribute to the selection and application of consensus methods in validating data, information, and/or criteria. The comparative experiment in this study will help in making decisions for consensus method selection, especially in engineering fields.

2. Experimental Fields

As the aim to find out whether or not using the Delphi consensus method is more significant than using the general consensus method in validating the collected data, especially in engineering-related data, this study conducted an experiment by applying both Delphi and general consensus methods to validate the collected data on sustainable building criteria, which covered the following fields: sustainable urban engineering, architectural engineering, civil engineering, and construction engineering.

As we know, buildings generally have impacts on environments and human health, and their impacts have been seen clearly in cities [35]. According to the study of De Munck and her colleagues, increasing the use of air conditioning systems for cooling inside buildings generally releases the waste heat into the atmosphere [36]. For example, the waste heat from air conditioners at night can raise urban temperature by more than 1 °C [35,37]. The buildings were also found to significantly contribute to urban heat island (UHI) effects, making the city center become hotter than its surrounding areas [38].

Cities generally have limited green and open spaces, where it is difficult to plant more trees and construct more urban gardens or water parks to reduce urban heat and environmental impacts. Therefore, planning and design for constructing new buildings and for renovating existing low-performance buildings in a sustainable way are a better solution to reduce environmental impacts and heats in cities. Although the concept of sustainable building design and construction has been used worldwide, how to apply this concept is still challenging because every country has different context and development priorities, particularly between developed and developing countries [39,40].

Cambodia, a developing country in Asia, is also facing these challenges while its building construction is rapidly growing. The construction is currently one of the key development sectors, and thousands of buildings in the main cities, such as Phnom Penh and Sihanoukville, are operating and being built [41]. However, most building design and construction have not yet been considered to include sustainability concepts while the building sector was found to be the most significant final energy consumer, with an estimated share of about 52 percent [42]. Energy consumption in the buildings will more than double until 2040 [41]. Therefore, promoting sustainable building design and construction in Cambodia is necessary for saving energy and reducing environmental impacts.

By recognizing the importance of sustainable buildings and realizing that buildings should be planned and designed based on sustainability concepts, the Cambodian National Council for Sustainable Development (NCSD) through its General Secretariat and the Department of Green Economy is implementing a sustainable building guideline and certification project. This guideline and certification project is currently funded by the Mekong–South Korean Cooperation Fund [41]. The project plans to develop green and sustainable building assessment criteria based on, and adapted from, the United States LEED, German DGNB, Vietnamese LOTUS, and Excellence in Design for Greater Efficiencies (EDGE) of the World Bank International Finance Corporation (IFC) [43].

Developing sustainable building criteria is not an easy task, especially where there has not been any research exploring and discussing these criteria in Cambodia, even on the above-mentioned sources of criteria. This gap shows a missed contribution from scientific research to sustainable building criteria development in Cambodia, while there has been a lot of research conducted in many developed and developing countries around the world [44]. The lack of scientific research and discussion can be seen as a missed important input for developing assessment criteria because the nature of research usually provides comprehensive data and information, including the verification of the context related to topics, which is very important and useful to the government committee and policy makers, as a baseline or evidence, to support decision making.

Hence, this study will collect and review the existing relevant sustainable building criteria for Cambodia. Then, this study will firstly validate the collected–reviewed criteria by a general consensus method. Secondly, this study will validate the collected–reviewed criteria by using a Delphi consensus method. Finally, this study will make a comparison of validation results by using both consensus methods in this experiment. As explained earlier, before conducting the experiment, this study collected and reviewed data of sustainable building criteria according to a research problem on sustainable building criteria development in Cambodia, which means the experiment was conducted in a necessary condition. This was to make sure there that was not any error in applying it to unnecessary or unsuitable conditions, which may lead to a lack of interest by respondents.

3. Experimental Methods

This study conducted an experiment to find out whether or not the validation results by using a Delphi consensus method are more significant than by using a general consensus method. A total of twenty-five participants who specialized in the relevant fields, such as sustainable urban, architectural, civil, and construction engineering, joined this experimental study. The experimental procedure of data validation toward comparing validation results of both methods is summarized in Figure 1.

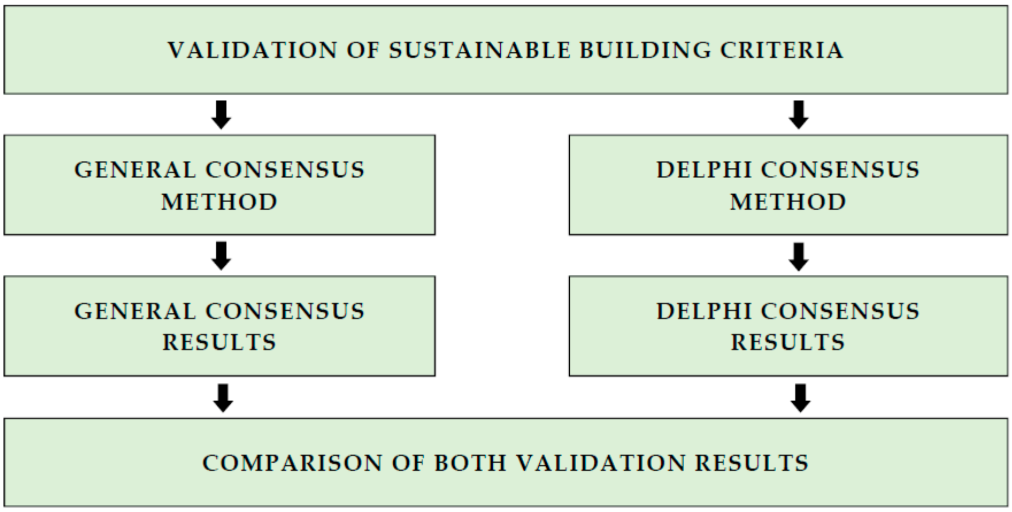

Figure 1. Experimental procedure of data validation.

First, all participants were introduced to the sustainable building criteria with the two comprehensive guidebooks [45,46] as references for sustainable building criteria review. After two weeks, all participants were asked to provide their reviewed criteria to the group. All the gathered reviewed criterial data are shown in the Table S1 in supplementary file. After the criterial data were gathered, the general consensus method was conducted to validate these reviewed criterial data. This criterial validation was processed through two major meetings. The first major meeting was to combine and improve the gathered reviewed sustainable building criteria for Cambodia. The second major meeting was to validate the improved reviewed sustainable building criteria for Cambodia.

The Delphi consensus method was also to validate the improved reviewed sustainable building criteria with the same twenty-five respondents in three rounds. Delphi round one was to preliminarily assess the criteria by simply indicating "important or not important". Delphi round two was to identify the level of importance of the criteria by using a 5-point Likert-type scale (1 = not important; 2 = less important; 3 = important; 4 = very important; 5 = extremely important). Delphi round three was to confirm the level of importance of the criteria by using a 5-point Likert-type scale and mean values of the criteria obtained from Delphi round two as statistical evidence for final judgment.

Weidman et al. [47] did not explain the exact number of Delphi respondents, but a minimum size should be at least seven or eight respondents. Mitchell and McGoldrick [48] stated that the number of respondents should be no less than eight to ten people. Therefore, twenty-five respondents participated in this experiment met the Delphi consensus method's requirements. During the survey, respondents were explained the purposes and process of this Delphi study in e-mail and briefed on how to complete the questionnaire on the cover page. In Delphi round one, questionnaires were designed with the improved reviewed criteria to be simply assessed “important or not important” by the respondents. In Delphi round two, the questionnaires were developed by using a 5-point Likert-type scale. In Delphi round three, questionnaires were developed by adding the round-two mean values (average) in front of the 5-point Likert-type scale.

The Delphi consensus was usually analyzed after the criteria were validated [21]. According to Hughes [49], the Delphi consensus is to measure how the respondents agreed on a given criterion. Sourani and Sohail [23] stated that the consensus, for each criterion, should be based on the obtained mean value, standard deviation, and percentage of respondents agreeing on that criterion. Chan and Lee [21] measured the Delphi consensus based on the mean value (confirmed level of importance) and the percentage of individual respondent agreed on each criterion. On a 5-point Likert-type scale, consensus should be measured by (i) the mean value is equal to or above 3.00 and (ii) the percentage of respondents agreed on the criterion reached 75.00% or above [21,23]. Therefore, this study measured the Delphi consensus based on these principles.

4. Results and Discussion

The gathered data of reviewed sustainable building criteria were first validated by using the general consensus method. Furthermore, these sustainable criteria were validated again by using the Delphi consensus method. Both validation results are shown in Table 1. All the criteria shown in this table are the validated criteria (valid criteria) through the general consensus method. The columns of Delphi round one, two, and three show the results of Delphi round one, two, and three, respectively. The columns of the Delphi consensus show the Delphi consensus results obtained from the Delphi consensus method. The detail of the Delphi consensus analysis is shown in Appendix A.

According to the tabled results, some improved criteria for sustainable building planning and design in Cambodia were assessed as not important by some respondents in Delphi round one; however, most respondents assessed that all the improved criteria should be brought into the validation process in Delphi round two for identifying the level of importance and for confirming the level of importance in Delphi round three. For example, sustainability brainstorming in the sustainable project orientation category was considered important by 24 panelists (96.00%). Similarly, whole-building design in sustainable project planning category was considered important by 21 panelists (92.00%).

In Delphi round two, some improved criteria were found to be strongly important, such as civil engineer criterion (mean value = 4.72), mechanical engineer criterion (mean value = 4.36), electrical engineer criterion (mean value = 4.32), and design professional criterion (mean value = 4.28). However, three criteria were found to be “not important”. In Delphi round three, other fourteen criteria were found to be “not important” as well. All the founded “not important” criteria were bolded in the tabled results below.

According to the Delphi consensus results, all the criteria assessed as “important” by respondents have met the consensus principles (mean value > 3 and consensus rate > 75%). Therefore, these criteria are the valid criteria obtained from the Delphi consensus method. According to Figure 2, the number of valid sustainable building criteria obtained from the Delphi consensus method is equal to the number of valid criteria obtained from the general consensus method in only two categories, but less than in eleven categories.

In the category of sustainable project orientation, the general consensus method obtained eleven valid criteria whereas the Delphi consensus method obtained only nine valid criteria. According to Delphi consensus, “code of behaviors and key dimension integration” were not the valid sustainable building criteria. Consistently, setting conventional principles and expectations of a particular group and integrating sustainability dimensions inclusively are not yet necessary for current sustainable building assessments in Cambodia. Based on a comparison of green building criteria of five rating systems [50], these criteria were also not indicated as necessary criteria. In the category of sustainable project planning, the general consensus method obtained eight valid criteria, whereas the Delphi consensus method obtained only seven valid criteria. Referring to the Delphi consensus, "perspective reflection" was excluded from the valid criteria. Reliably, taking all relevant stakeholders' perspectives into account is not effective and necessary for currently promoting sustainable building assessments in Cambodia. Likewise, looking at the sustainable construction industry [51], this also was not shown to be a necessary criterion. In the categories of sustainable team formation and potential stakeholder involvement, the Delphi consensus method also reduced one criterion, for each category, from the general consensus-based valid criteria. Practically, "collaborative session" and "in-house employees" are not really necessary criteria for sustainable building assessment.

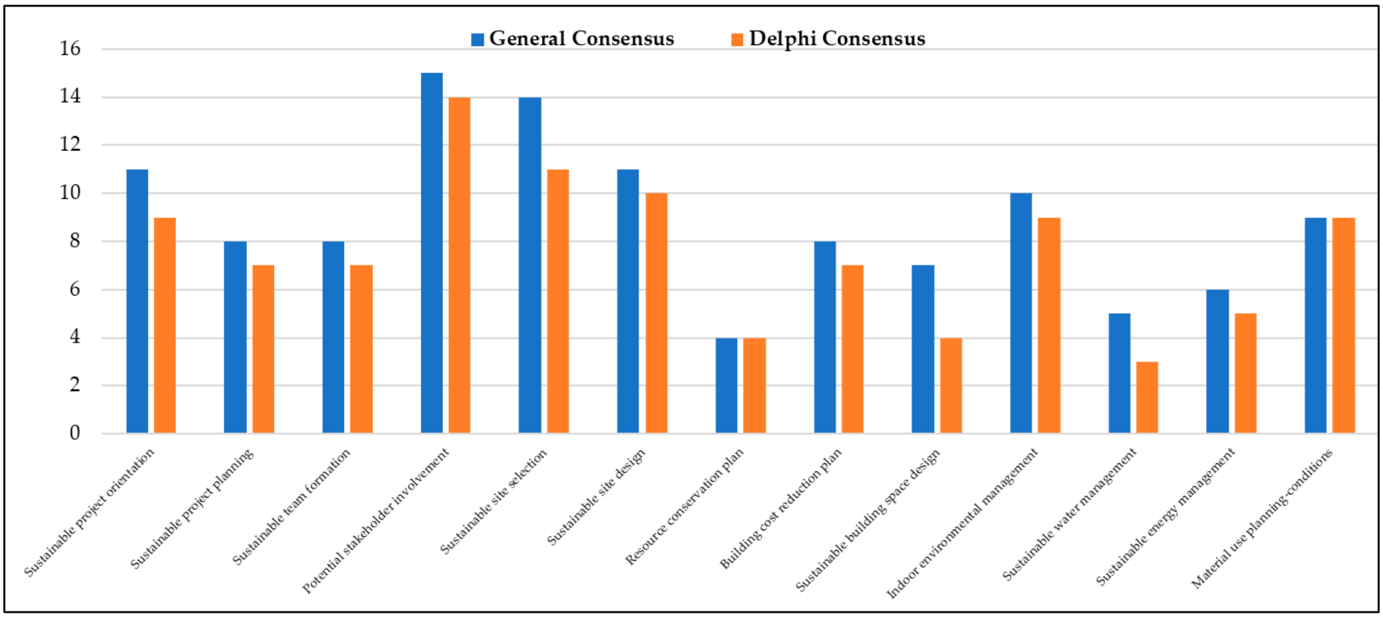

Figure 2. Number of criteria validated by Delphi and general consensus methods.

Table 1. Data validation results by Delphi and general consensus methods.

Category	**General Consensus**	**Delphi Round One**		**Delphi Round Two**		**Delphi Round Three**		**Delphi Consensus**	
	Validated Criteria	**N**	**%**	**x̄**	**σ**	**x̄**	**σ**	**%**	**C**
Sustainable Project Orientation	Sustainability brainstorming	24	96.00	4.04	0.77	3.96	0.62	95.65	√
	Sustainability goal setting	22	88.00	3.76	0.99	3.61	0.57	100.00	√
	Sustainable project briefing	21	84.00	3.48	0.75	3.39	0.71	91.30	√
	Sustainable project baseline	18	72.00	3.36	0.79	3.09	0.50	91.30	√
	Code of behaviors	**15**	**60.00**	**2.84**	**1.12**	**2.61**	**0.97**	**x**	**x**
	Management rule orientation	19	76.00	3.72	1.11	3.57	0.71	91.30	√
	Key dimension integration	**15**	**60.00**	**3.12**	**1.07**	**2.91**	**0.58**	**x**	**x**
	Stakeholder orientation	23	92.00	3.52	0.85	3.35	0.56	95.65	√
	Project cost intimation	17	68.00	3.80	0.75	3.83	0.87	91.30	√
	Incentive support provision	14	56.00	3.20	1.10	3.13	0.74	86.96	√
	Available material briefing	15	60.00	3.48	1.24	3.30	0.62	100.00	√

Table 1. *Cont.*

Category	General Consensus	Delphi Round One		Delphi Round Two		Delphi Round Three		Delphi Consensus	
	Validated Criteria	**N**	**%**	**$\bar{x}$**	**σ**	**$\bar{x}$**	**σ**	**%**	**C**
Sustainable Project Planning	Early engagement	19	76.00	3.60	1.10	3.65	0.63	100.00	√
	Design charrette	21	84.00	3.68	0.79	3.61	0.71	95.65	√
	Working together	17	68.00	3.64	1.09	3.57	0.77	91.30	√
	Inclusive documentation	16	64.00	3.60	0.94	3.61	0.64	95.65	√
	Commissioning process	18	72.00	3.20	0.94	3.13	0.61	91.30	√
	Whole-building design	23	92.00	3.60	1.06	3.52	0.58	95.65	√
	Perspective reflection	**21**	**84.00**	**3.00**	**0.94**	**2.83**	**0.48**	**x**	**x**
	End-user reflection	19	76.00	3.32	0.97	3.09	0.72	86.96	√
Sustainable Team Formation	Sustainability qualification	24	96.00	3.88	0.91	4.00	0.51	100.00	√
	Competence qualification	21	84.00	4.16	1.12	4.17	0.64	100.00	√
	Individual qualification	23	92.00	3.92	0.74	3.96	0.46	100.00	√
	Integrated project team	21	84.00	3.64	0.74	3.61	0.57	95.65	√
	Sustainability missions	24	96.00	3.76	0.86	3.70	0.55	100.00	√
	Sustainability bureau	19	76.00	3.20	1.02	3.09	0.83	82.61	√
	Collaborative session	**24**	**96.00**	**3.16**	**0.78**	**2.74**	**0.61**	**x**	**x**
	Progress meetings	22	88.00	3.60	0.85	3.65	0.63	95.65	√
Potential Stakeholder Involvement	Lenders and investors	24	96.00	3.68	0.97	3.70	0.69	95.65	√
	Construction managers	24	96.00	4.12	0.77	4.35	0.56	100.00	√
	Sustainability coordinators	21	84.00	3.80	0.94	3.91	0.50	100.00	√
	Facility managers	18	72.00	3.68	0.68	3.70	0.55	100.00	√
	Local stakeholders	19	76.00	3.64	0.74	3.70	0.62	100.00	√
	After-design stakeholders	17	68.00	3.68	1.05	3.48	0.58	95.65	√
	Civil engineers	21	84.00	4.72	0.53	4.74	0.53	100.00	√
	Mechanical engineers	19	76.00	4.36	0.69	4.30	0.75	100.00	√
	Electrical engineers	20	80.00	4.32	0.79	4.17	0.87	100.00	√
	Plumbing engineers	17	68.00	4.16	0.67	4.04	0.81	95.65	√
	Design professionals	15	60.00	4.28	0.72	4.30	0.62	100.00	√
	Interior designers	19	76.00	3.96	1.00	4.13	0.68	95.65	√
	Landscape architects	21	84.00	4.00	0.63	3.91	0.65	95.65	√
	In-house employees	**13**	**52.00**	**3.36**	**0.84**	**2.96**	**0.55**	**x**	**x**
	Market representatives	19	76.00	3.16	1.01	3.09	0.65	86.96	√

Table 1. *Cont.*

Category	General Consensus	Delphi Round One		Delphi Round Two		Delphi Round Three		Delphi Consensus	
	Validated Criteria	**N**	**%**	**x̄**	**σ**	**x̄**	**σ**	**%**	**C**
Sustainable Site Selection	Environmental goals	24	96.00	3.96	0.87	3.78	0.59	100.00	√
	Retrofitting building	**15**	**60.00**	**3.16**	**1.01**	**2.96**	**0.86**	**x**	**x**
	Brownfield location	19	76.00	3.32	0.97	3.17	0.87	82.61	√
	Energy-saving location	24	96.00	4.04	0.77	3.96	0.81	91.30	√
	Geographic accessibility	17	68.00	3.60	0.94	3.52	0.58	100.00	√
	Environmental impacts	19	76.00	3.88	0.86	3.87	0.80	95.65	√
	Livable infrastructures	21	84.00	3.28	0.78	3.13	0.80	86.96	√
	Community connectivity	18	72.00	3.48	1.02	3.48	0.77	91.30	√
	Landscape connectivity	15	60.00	3.28	0.78	3.26	0.74	91.30	√
	Material availability	19	76.00	3.32	0.88	3.35	0.76	91.30	√
	Near basic services	13	52.00	3.68	0.97	3.70	0.91	91.30	√
	Urbanized location	18	72.00	3.12	1.03	3.00	0.83	78.26	√
	Mixed-use location	**13**	**52.00**	**2.92**	**1.02**	**2.83**	**0.87**	**x**	**x**
	Desirable location	**15**	**60.00**	**3.20**	**0.80**	**2.78**	**0.59**	**x**	**x**
Sustainable Site Design	**Ecological preservation**	**18**	**72.00**	**3.28**	**0.83**	**2.91**	**0.41**	**x**	**x**
	Smart outdoor lighting	13	52.00	3.58	1.11	3.74	0.79	95.65	√
	Clustering home design	23	92.00	3.56	1.13	3.61	0.57	100.00	√
	Passive solar design	16	64.00	3.88	0.86	4.13	0.45	100.00	√
	Surface-water design	16	64.00	3.52	1.02	3.52	0.50	100.00	√
	Irrigation system design	17	68.00	3.28	0.92	3.09	0.72	86.96	√
	Lower UHI effect design	19	76.00	3.64	1.09	4.04	0.55	100.00	√
	Site protection design	16	64.00	3.60	0.80	3.74	0.74	95.65	√
	Low emission design	21	84.00	3.56	0.85	3.61	0.71	95.65	√
	Compact building design	12	48.00	3.44	0.94	3.26	0.61	91.30	√
	Sustainable landscape design	13	52.00	3.48	1.02	3.35	0.48	100.00	√
Resource Conservation Plan	Land use conservation	21	84.00	3.36	0.74	3.39	0.64	100.00	√
	Material conservation	20	80.00	3.96	0.60	4.04	0.55	100.00	√
	Water conservation	23	92.00	3.76	0.86	3.83	0.56	100.00	√
	Energy conservation	24	96.00	4.12	0.95	4.39	0.64	100.00	√
Building Cost Reduction Plan	Material cost saving	21	84.00	3.60	0.89	3.74	0.61	100.00	√
	Energy cost saving	22	88.00	3.84	0.92	4.13	0.54	100.00	√
	Productive worth	21	84.00	3.40	0.89	3.43	0.65	95.65	√
	Design cost saving	21	84.00	3.28	0.96	3.26	0.85	82.61	√
	Initial cost reduction	19	76.00	3.68	0.79	3.65	0.70	95.65	√
	Operation cost reduction	14	56.00	3.64	0.84	3.65	0.70	95.65	√
	Maintenance cost reduction	12	48.00	3.64	0.97	3.57	0.65	91.30	√
	Retrofitting cost planning	**13**	**52.00**	**3.04**	**1.04**	**2.70**	**0.80**	**x**	**x**

Table 1. *Cont.*

Category	General Consensus	Delphi Round One		Delphi Round Two		Delphi Round Three		Delphi Consensus	
	Validated Criteria	**N**	**%**	**x̄**	**σ**	**x̄**	**σ**	**%**	**C**
Sustainable Building Space Design	Efficient building shape	18	72.00	3.60	1.10	3.74	0.67	95.65	√
	Lower building footprint	**16**	**64.00**	**3.16**	**0.88**	**2.87**	**0.45**	**x**	**x**
	Space utilization strategy	15	60.00	3.48	0.81	3.26	0.61	91.30	√
	Elimination of corridors	**13**	**52.00**	**2.76**	**0.99**	**2.17**	**0.70**	**x**	**x**
	Creating common spaces	18	72.00	3.56	0.98	3.26	0.74	86.96	√
	Multifunctional spaces	19	76.00	3.67	0.80	3.43	0.82	86.96	√
	Unnecessary item removal	**17**	**68.00**	**3.24**	**0.99**	**2.74**	**0.53**	**x**	**x**
Indoor Environmental Management	Indoor light control	21	84.00	4.16	0.88	4.26	0.67	95.65	√
	Thermal management	15	60.00	3.48	0.90	3.52	0.65	95.65	√
	Ventilation management	19	76.00	4.00	0.85	3.91	0.65	95.65	√
	Humidity control planning	18	72.00	3.40	0.94	3.09	0.65	86.96	√
	Indoor carbon reduction	**11**	**44.00**	**3.08**	**0.93**	**2.70**	**0.69**	**x**	**x**
	Noise pollution control	17	68.00	3.20	0.85	3.09	0.50	91.30	√
	Odor pollution control	13	52.00	3.44	0.94	3.09	0.58	95.65	√
	Value aesthetic decisions	14	56.00	3.52	0.98	3.35	0.81	86.96	√
	Hazardous risk mitigation	18	72.00	3.40	1.10	3.30	0.86	91.30	√
	Emitting pollutant prevention	20	80.00	3.40	1.02	3.52	0.88	95.65	√
Sustainable Water Management	Plumbing system management	18	72.00	3.28	0.92	3.22	0.59	91.30	√
	Dual plumbing installation plan	**17**	**68.00**	**3.16**	**0.97**	**2.87**	**0.74**	**x**	**x**
	Rainwater storage management	14	56.00	3.28	1.11	3.26	0.67	95.65	√
	Proper pressure reduction plan	**12**	**48.00**	**3.28**	**0.72**	**2.91**	**0.58**	**x**	**x**
	Water recirculation management	16	64.00	3.32	1.01	3.13	0.61	100.00	√
Sustainable Energy Management	Renewable energy plan	23	92.00	4.16	0.73	4.30	0.69	100.00	√
	Effective daylighting design	21	84.00	3.76	0.76	3.96	0.62	100.00	√
	Natural ventilation design	23	92.00	3.88	0.95	4.22	0.51	100.00	√
	Energy optimization plan	21	84.00	3.80	1.06	3.96	0.81	95.65	√
	Insulation use management	19	76.00	3.32	0.84	3.17	0.56	95.65	√
	Material choice-based design	**17**	**68.00**	**3.28**	**0.87**	**2.87**	**0.80**	**x**	**x**
Material Use Planning and Conditions	No material pollution	19	76.00	3.68	0.79	3.70	0.62	100.00	√
	No chemical pollution	15	60.00	3.48	0.90	3.22	0.83	86.96	√
	Local material promotion	18	72.00	3.52	0.94	3.78	0.51	100.00	√
	Energy-efficient materials	16	64.00	3.76	1.03	3.91	0.58	100.00	√
	Efficient embodied energy	17	68.00	3.36	0.93	3.26	0.67	91.30	√
	Material durability	15	60.00	4.04	0.77	4.00	0.83	95.65	√
	Integrated maintainability	17	68.00	3.48	0.81	3.39	0.82	91.30	√
	Material waste control	19	76.00	3.72	0.96	3.70	0.62	95.65	√
	Recycled material use	21	84.00	3.56	0.70	3.57	0.77	95.65	√

Note: "N" refers to 'number of panelists provided that criteria' "x̄" refers to 'average/mean value'; "σ" refers to 'standard deviation'; "C" refers to 'consensus'; "√" refers to 'reached consensus'; "x" refers to 'not reach consensus'.

In the category of sustainable site selection, the Delphi consensus method reduced three criteria from the general consensus-based valid criteria. These criteria "retrofitting building, mixed-use location, and desirable location" are currently over the capacities of sustainable building assessments in Cambodia. Based on the Cambodian sustainable construction industry [51] and on the comparison of the five green building criteria rating systems [50], these criteria were also not taken into account. In the categories of sustainable site design and building cost reduction plan, the Delphi consensus method reduced one criterion, for each category, from the general consensus-based valid criteria. It is not really necessary to include "ecological preservation" and "retrofitting cost planning" in the criteria for sustainable building assessments in Cambodia. Furthermore, in the category of sustainable building space design, the Delphi consensus method also reduced three criteria from the general consensus-based valid criteria. These criteria, namely, "lower building footprint", "elimination of corridors", and "unnecessary item removal" are not effective and necessary for currently promoting sustainable building assessments in Cambodia; these criteria were even not considered in the green building criteria of the five rating systems.

In the categories of indoor environmental management and sustainable energy management, the Delphi consensus method reduced one criterion, for each category, from the general consensus-based valid criteria. These criteria "indoor carbon reduction and material choice-based design" are currently over the capacities of sustainable building assessments in Cambodia. Based on the comparison of the green building criteria of the five internationally recognized rating systems [50] and on the study on sustainable construction industry in Cambodia [51], these criteria were also not shown to be necessary. Furthermore, in the category of sustainable water management, the Delphi consensus method also reduced two criteria from the general consensus-based valid criteria. These criteria "dual plumbing installation plan" and "proper pressure reduction plan" are also considered over the capacities of the current sustainable building assessments in Cambodia.

The above comparative results and discussion showed that seventeen of the valid criteria obtained from the general consensus method were not consistently necessary for the current sustainable building assessment in Cambodia. This revealed that data validation of the reviewed sustainable building criteria by using a Delphi consensus method is more significant than by using a general consensus method.

Based on the results of this experiment (H2 = Delphi consensus method is more significant to use for data validation in order to obtain accurate information), we see that even though the sustainable building criteria were validated by the same respondents in the group meetings using the general consensus method, seventeen of these criteria were still reduced in the survey using the Delphi consensus method. In this case, individual respondents assumed that the improved sustainable building criteria they validated during the group meetings were important. However, after seeing all the levels of the importance of the criteria (mean value) obtained from Delphi round two, the respondents changed their opinions and judgments accordingly. Delphi methods generally provide an opportunity for individual respondents to reassess the concerned criteria based on statistical evidence (mean value) [23]. Furthermore, this experiment showed that the Delphi consensus method and its characteristics are quite significant for validating the gathered data on sustainable building criteria. It incorporated the 5-point Likert-type scale to assess the concerned criteria, whose scales from 1 to 5 represented not important, less important, important, very important, and extremely important, respectively. Thus, if compared to the general consensus method, it is better to apply for supporting decision making. Moreover, it provides a good condition for individual respondents to assess the criteria confidentially—no one knows the opinions and judgments of anyone else regarding the concerned criteria. This condition allows all respondents to make the decisions without influencing or following by other respondents. More importantly, it provides statical evidence (mean value), which are reported to the respondents to make the final decision in Delphi round three. Therefore, the assessment based on statistical evidence reaches a good level of accuracy. Three-round Delphi is considered more useful and effective because the assessments are based on the statical evidence “the level of error is small” and the respondents become familiar with all the criteria “the judgment is more accurate” [21].

5. Conclusions

With the aim to find out whether or not data validation by using the Delphi consensus method is more significant than by using the general consensus method, this study initially collected and reviewed the data of sustainable building criteria, accordingly with a problem statement on sustainable building criteria development in Cambodia, which means the experiment was conducted in a necessary and suitable condition. Afterward, this study, firstly, validated these data by using a general consensus method and, secondly, by a Delphi consensus method. Finally, this study made a comparison of data validation between both consensus methods. The results showed that seventeen of the valid sustainable building criteria obtained from the general consensus method and reduced by the Delphi consensus method were found to be inconsistent for sustainable building assessments in Cambodia. Therefore, this study concludes that using the Delphi consensus method is more significant in validating the gathered and reviewed data. This study contributes to the selection and application of consensus methods in validating data, information, or criteria, especially in engineering fields. Although this study found that the Delphi consensus is more significant than the general consensus method in validating sustainable building criteria, the verified levels of importance could not be used to prioritize the valid criteria because these levels of importance resulted from a 5-point Likert-type scale, not a pairwise-comparison scale. Hence, a future study could use a pairwise-comparison method to prioritize these criteria in Cambodia. The analytic network process (ANP) [52], analytic hierarchy process (AHP) [53], and modified AHP approach [54] are significant pairwise-comparison methods for prioritization by analyzing relative weights or importance. Systematizing the criterial indications by using participatory system dynamics modelling with experts in Cambodia is also a significant method [55] to understand the connection of all criteria to each other, especially the effect of one criterion to another criterion.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data7020018/s1, Table S1: Data Collection on Sustainable Building Criteria.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A Delphi Consensus Analysis

Table A1. Results of Delphi Consensus Analysis.

Category	Criteria	Mean	SD	Percentage of Participants Agreed on Criteria as						
				1	2	3	4	5	1–2	3–5
	Sustainability brainstorming	3.96	0.62	0.00	4.35	13.04	65.22	17.39	4.35	95.65
	Sustainability goal setting	3.61	0.57	0.00	0.00	43.48	52.17	4.35	0.00	100.00

Table A1. *Cont.*

Category	Criteria	Mean	SD	Percentage of Participants Agreed on Criteria as						
				1	2	3	4	5	1–2	3–5
Sustainable Project Orientation	Sustainable project briefing	3.39	0.71	0.00	8.70	47.83	39.13	4.35	8.70	91.30
	Sustainable project baseline	3.09	0.50	0.00	8.70	73.91	17.39	0.00	8.70	91.30
	Code of behaviors	**2.61**	**0.97**	**13.04**	**30.43**	**43.48**	**8.70**	**4.35**	**43.48**	**56.52**
	Management rule orientation	3.57	0.71	0.00	8.70	30.43	56.52	4.35	8.70	91.30
	Key dimension integration	**2.91**	**0.58**	**0.00**	**21.74**	**65.22**	**13.04**	**0.00**	**21.74**	**78.26**
	Stakeholder orientation	3.35	0.56	0.00	4.35	56.52	39.13	0.00	4.35	95.65
	Project cost intimation	3.83	0.87	4.35	4.35	8.70	69.57	13.04	8.70	91.30
	Incentive support provision	3.13	0.74	0.00	13.04	69.57	8.70	8.70	13.04	86.96
	Available material briefing	3.30	0.62	0.00	0.00	78.26	13.04	8.70	0.00	100.00
Sustainable Project Planning	Early engagement	3.65	0.63	0.00	0.00	43.48	47.83	8.70	0.00	100.00
	Design charrette	3.61	0.71	0.00	4.35	39.13	47.83	8.70	4.35	95.65
	Working together	3.57	0.77	4.35	4.35	21.74	69.57	0.00	8.70	91.30
	Inclusive documentation	3.61	0.64	0.00	4.35	34.78	56.52	4.35	4.35	95.65
	Commissioning process	3.13	0.61	0.00	8.70	73.91	13.04	4.35	8.70	91.30
	Whole-building design	3.52	0.58	0.00	4.35	39.13	56.52	0.00	4.35	95.65
	Perspective reflection	**2.83**	**0.48**	**0.00**	**21.74**	**73.91**	**4.35**	**0.00**	**21.74**	**78.26**
	End-user reflection	3.09	0.72	4.35	8.70	60.87	26.09	0.00	13.04	86.96
Sustainable Team Formation	Sustainability qualification	4.00	0.51	0.00	0.00	13.04	73.91	13.04	0.00	100.00
	Competence qualification	4.17	0.64	0.00	0.00	13.04	56.52	30.43	0.00	100.00
	Individual qualification	3.96	0.46	0.00	0.00	13.04	78.26	8.70	0.00	100.00
	Integrated project team	3.61	0.57	0.00	4.35	30.43	65.22	0.00	4.35	95.65
	Sustainability missions	3.70	0.55	0.00	0.00	34.78	60.87	4.35	0.00	100.00
	Sustainability bureau	3.09	0.83	4.35	13.04	56.52	21.74	4.35	17.39	82.61
	Collaborative session	**2.74**	**0.61**	**0.00**	**34.78**	**56.52**	**8.70**	**0.00**	**34.78**	**65.22**
	Progress meetings	3.65	0.63	0.00	4.35	30.43	60.87	4.35	4.35	95.65
Potential Stakeholder Involvement	Lenders and investors	3.70	0.69	0.00	4.35	30.43	56.52	8.70	4.35	95.65
	Construction managers	4.35	0.56	0.00	0.00	4.35	56.52	39.13	0.00	100.00
	Sustainability coordinators	3.91	0.50	0.00	0.00	17.39	73.91	8.70	0.00	100.00
	Facility managers	3.70	0.55	0.00	0.00	34.78	60.87	4.35	0.00	100.00
	Local stakeholders	3.70	0.62	0.00	0.00	39.13	52.17	8.70	0.00	100.00
	After-design stakeholders	3.48	0.58	0.00	4.35	43.48	52.17	0.00	4.35	95.65
	Civil engineers	4.74	0.53	0.00	0.00	4.35	17.39	78.26	0.00	100.00
	Mechanical engineers	4.30	0.75	0.00	0.00	17.39	34.78	47.83	0.00	100.00
	Electrical engineers	4.17	0.87	0.00	0.00	30.43	21.74	47.83	0.00	100.00
	Plumbing engineers	4.04	0.81	0.00	4.35	17.39	47.83	30.43	4.35	95.65
	Design professionals	4.30	0.62	0.00	0.00	8.70	52.17	39.13	0.00	100.00
	Interior designers	4.13	0.68	0.00	4.35	4.35	65.22	26.09	4.35	95.65
	Landscape architects	3.91	0.65	0.00	4.35	13.04	69.57	13.04	4.35	95.65
	In-house employees	**2.96**	**0.55**	**4.35**	**17.39**	**60.87**	**13.04**	**4.35**	**21.74**	**78.26**
	Market representatives	3.09	0.65	0.00	13.04	69.57	13.04	4.35	13.04	86.96

Table A1. *Cont.*

Category	Criteria	Mean	SD	Percentage of Participants Agreed on Criteria as						
				1	2	3	4	5	1–2	3–5
Sustainable Site Selection	Environmental goals	3.78	0.59	0.00	0.00	30.43	60.87	8.70	0.00	100.00
	Retrofitting building	**2.96**	**0.86**	**8.70**	**17.39**	**52.17**	**13.04**	**8.70**	**26.09**	**73.91**
	Brownfield location	3.17	0.87	4.35	13.04	47.83	30.43	4.35	17.39	82.61
	Energy-saving location	3.96	0.81	0.00	8.70	8.70	60.87	21.74	8.70	91.30
	Geographic accessibility	3.52	0.58	0.00	0.00	52.17	43.48	4.35	0.00	100.00
	Environmental impacts	3.87	0.80	4.35	0.00	13.04	69.57	13.04	4.35	95.65
	Livable infrastructures	3.13	0.80	4.35	8.70	60.87	21.74	4.35	13.04	86.96
	Community connectivity	3.48	0.77	0.00	8.70	43.48	39.13	8.70	8.70	91.30
	Landscape connectivity	3.26	0.74	0.00	8.70	65.22	17.39	8.70	8.70	91.30
	Material availability	3.35	0.76	0.00	8.70	56.52	26.09	8.70	8.70	91.30
	Near basic services	3.70	0.91	4.35	4.35	21.74	56.52	13.04	8.70	91.30
	Urbanized location	3.00	0.83	4.35	17.39	56.52	17.39	4.35	21.74	78.26
	Mixed-use location	**2.83**	**0.87**	**0.00**	**39.13**	**47.83**	**4.35**	**8.70**	**39.13**	**60.87**
	Desirable location	**2.78**	**0.59**	**4.35**	**17.39**	**73.91**	**4.35**	**0.00**	**21.74**	**78.26**
Sustainable Site Design	**Ecological preservation**	**2.91**	**0.41**	**0.00**	**13.04**	**82.61**	**4.35**	**0.00**	**13.04**	**86.96**
	Smart outdoor lighting	3.74	0.79	0.00	4.35	30.43	52.17	13.04	4.35	95.65
	Clustering home design	3.61	0.57	0.00	0.00	43.48	52.17	4.35	0.00	100.00
	Passive solar design	4.13	0.45	0.00	0.00	4.35	78.26	17.39	0.00	100.00
	Surface-water design	3.52	0.50	0.00	0.00	47.83	52.17	0.00	0.00	100.00
	Irrigation system design	3.09	0.72	4.35	8.70	60.87	26.09	0.00	13.04	86.96
	Lower UHI effect design	4.04	0.55	0.00	0.00	13.04	69.57	17.39	0.00	100.00
	Site protection design	3.74	0.74	0.00	4.35	30.43	52.17	13.04	4.35	95.65
	Low emission design	3.61	0.71	0.00	4.35	39.13	47.83	8.70	4.35	95.65
	Compact building design	3.26	0.61	0.00	8.70	56.52	34.78	0.00	8.70	91.30
	Sustainable landscape design	3.35	0.48	0.00	0.00	65.22	34.78	0.00	0.00	100.00
Resource Conservation Plan	Land use conservation	3.39	0.64	0.00	0.00	69.57	21.74	8.70	0.00	100.00
	Material conservation	4.04	0.55	0.00	0.00	13.04	69.57	17.39	0.00	100.00
	Water conservation	3.83	0.56	0.00	0.00	26.09	65.22	8.70	0.00	100.00
	Energy conservation	4.39	0.64	0.00	0.00	8.70	43.48	47.83	0.00	100.00
Building Cost Reduction Plan	Material cost saving	3.74	0.61	0.00	0.00	34.78	56.52	8.70	0.00	100.00
	Energy cost saving	4.13	0.54	0.00	0.00	8.70	69.57	21.74	0.00	100.00
	Productive worth	3.43	0.65	0.00	4.35	52.17	39.13	4.35	4.35	95.65
	Design cost saving	3.26	0.85	0.00	17.39	47.83	26.09	8.70	17.39	82.61
	Initial cost reduction	3.65	0.70	0.00	4.35	34.78	52.17	8.70	4.35	95.65
	Operation cost reduction	3.65	0.70	0.00	4.35	34.78	52.17	8.70	4.35	95.65
	Maintenance cost reduction	3.57	0.65	0.00	8.70	34.78	47.83	8.70	8.70	91.30
	Retrofitting cost planning	**2.70**	**0.80**	**8.70**	**21.74**	**65.22**	**0.00**	**4.35**	**30.43**	**69.57**

Table A1. *Cont.*

Category	Criteria	Mean	SD	Percentage of Participants Agreed on Criteria as						
				1	2	3	4	5	1–2	3–5
Sustainable Building Space Design	Efficient building shape	3.74	0.67	0.00	4.35	26.09	60.87	8.70	4.35	95.65
	Lower building footprint	**2.87**	**0.45**	**0.00**	**17.39**	**78.26**	**4.35**	**0.00**	**17.39**	**82.61**
	Space utilization strategy	3.26	0.61	0.00	8.70	65.22	17.39	8.70	8.70	91.30
	Elimination of corridors	**2.17**	**0.70**	**13.04**	**60.87**	**21.74**	**4.35**	**0.00**	**73.91**	**26.09**
	Creating common spaces	3.26	0.74	0.00	13.04	52.17	30.43	4.35	13.04	86.96
	Multifunctional spaces	3.43	0.82	4.35	8.70	26.09	60.87	0.00	13.04	86.96
	Unnecessary item removal	**2.74**	**0.53**	**0.00**	**30.43**	**65.22**	**4.35**	**0.00**	**30.43**	**69.57**
Indoor Environmental Management	Indoor light control	4.26	0.67	0.00	4.35	8.70	43.48	43.48	4.35	95.65
	Thermal management	3.52	0.65	0.00	4.35	43.48	47.83	4.35	4.35	95.65
	Ventilation management	3.91	0.65	0.00	4.35	13.04	69.57	13.04	4.35	95.65
	Humidity control planning	3.09	0.65	0.00	13.04	69.57	13.04	4.35	13.04	86.96
	Indoor carbon reduction	**2.70**	**0.69**	**8.70**	**17.39**	**69.57**	**4.35**	**0.00**	**26.09**	**73.91**
	Noise pollution control	3.09	0.50	0.00	8.70	73.91	17.39	0.00	8.70	91.30
	Odor pollution control	3.09	0.58	4.35	0.00	78.26	17.39	0.00	4.35	95.65
	Value aesthetic decisions	3.35	0.81	4.35	8.70	34.78	52.17	0.00	13.04	86.96
	Hazardous risk mitigation	3.30	0.86	4.35	4.35	56.52	26.09	8.70	8.70	91.30
	Emitting pollutant prevention	3.52	0.88	4.35	0.00	47.83	34.78	13.04	4.35	95.65
Sustainable Water Management	Plumbing system management	3.22	0.59	0.00	8.70	60.87	30.43	0.00	8.70	91.30
	Dual plumbing installation plan	**2.87**	**0.74**	**4.35**	**21.74**	**56.52**	**17.39**	**0.00**	**26.09**	**73.91**
	Rainwater storage management	3.26	0.67	0.00	4.35	73.91	13.04	8.70	4.35	95.65
	Proper pressure reduction plan	**2.91**	**0.58**	**0.00**	**21.74**	**65.22**	**13.04**	**0.00**	**21.74**	**78.26**
	Water recirculation management	3.13	0.61	0.00	0.00	69.57	30.43	0.00	0.00	100.00
Sustainable Energy Management	Renewable energy plan	4.30	0.69	0.00	0.00	13.04	43.48	43.48	0.00	100.00
	Effective daylighting design	3.96	0.62	0.00	0.00	21.74	60.87	17.39	0.00	100.00
	Natural ventilation design	4.22	0.51	0.00	0.00	4.35	69.57	26.09	0.00	100.00
	Energy optimization plan	3.96	0.81	0.00	4.35	21.74	47.83	26.09	4.35	95.65
	Insulation use management	3.17	0.56	0.00	4.35	78.26	13.04	4.35	4.35	95.65
	Material choice-based design	**2.87**	**0.80**	**8.70**	**13.04**	**60.87**	**17.39**	**0.00**	**21.74**	**78.26**
Material Use Planning and Conditions	No material pollution	3.70	0.62	0.00	0.00	39.13	52.17	8.70	0.00	100.00
	No chemical pollution	3.22	0.83	4.35	8.70	52.17	30.43	4.35	13.04	86.96
	Local material promotion	3.78	0.51	0.00	0.00	26.09	69.57	4.35	0.00	100.00
	Energy-efficient materials	3.91	0.58	0.00	0.00	21.74	65.22	13.04	0.00	100.00
	Efficient embodied energy	3.26	0.67	0.00	8.70	60.87	26.09	4.35	8.70	91.30
	Material durability	4.00	0.83	4.35	0.00	8.70	65.22	21.74	4.35	95.65
	Integrated maintainability	3.39	0.82	0.00	8.70	56.52	21.74	13.04	8.70	91.30
	Material waste control	3.70	0.62	4.35	0.00	34.78	56.52	4.35	4.35	95.65
	Recycled material use	3.57	0.77	0.00	4.35	26.09	65.22	4.35	4.35	95.65

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