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Research Article

Development and validation of a survey instrument for measuring barriers to green building adoption using quantitative methods

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ABSTRACT

In order to measure the perception of green building stakeholders regarding the low adoption rate of green buildings, a survey instrument was designed by carefully identifying the barrier items from the existing literature using the systematic literature review method. Now there was a need to further develop and validate the items in the survey instrument before using it for the survey. This study aims to develop and validate a survey instrument to capture the opinions and perceptions of green building stakeholders regarding the barriers hampering the adoption of green buildings. The survey instrument was first screened by a three-member panel of subject-matter experts. Then the judgmental evidence was collected from an eight-member panel of judges using quantitative methods like Content Validity Ratio and Content Validity Index to develop and validate the survey instrument. Kappa score was calculated for individual items in the final version of the survey instrument to remove any possibility of chance agreement among the judges. The final revised version of the survey instrument showed high content validity of individual items (0.875 to 1.00). The scale-level content validity score using the average method was 0.956, which suggests that the survey instrument has excellent content validity. The Kappa score calculated for each item was found to be excellent (0.871 to 1.00), which indicates that the judges agreed upon the relevance of items in the scale, and this agreement was not by chance. This study is novel as it is the first to explain in detail the process and methodology used for the development and validation of the survey instrument employing quantitative techniques. The methodology employed in this research can be used by researchers to explain in detail the development and validation of the survey instrument to enhance the reliability of their research outcomes.

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INTRODUCTION

In order to diminish the impact of buildings on the environment, active measures have been initiated under sustainable development strategies globally [1]. Green buildings (GBs) have been termed a sustainable solution to increasing the urban built environments by negating

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the deteriorating impact on the natural environment [2,3]. The Indian Green Building Council defines green buildings as the process of creating buildings that are environment-friendly, water and energy efficient, effectively handle solid and water waste, are sustainable throughout their life cycle, and prioritize the health and comfort of the occupants [4]. According to the Canadian Green Building Council, they reduce the use of energy and water, cut waste, reduce carbon emissions, have an impact on the environment, encourage environment-friendly innovations, and are more economical to operate [5]. Similar definitions of green buildings have been given by various green building rating and certification agencies and other stakeholders. All these definitions outline the reduced impact of GBs on the environment in terms of natural resource consumption and waste generation throughout their lifecycle and post-demolition. Although the benefits of green buildings are immense and their environmental benefits with respect to conventional buildings have been proven by previous studies [3], the adoption rate of green buildings has been a cause of concern [6]. So, the literature was examined to identify the impediments to green building adoption. It was found that many studies in the past two decades have studied and identified the barriers/impediments/challenges/obstacles to the adoption of green buildings.

Several studies across the globe have analysed the barriers to GB adoption. One of the earliest studies conducted in the US undertaken by Hendricks and Calkins on adoption barriers to green building technologies and identified high cost in the long-term, short-term, and maintenance as the top three barriers [7]. Another study in the UK found that lack of importance, false perceptions of costs, and lack of expertise were the top barriers [8]. The study conducted by Richardson & Lynes concluded that long payback time, higher capital cost, and lack of communication were the main impediments to GB adoption [9]. Another study by Zhang et al. in Hong Kong found that poor promotion, absence of incentives, higher maintenance costs, lack of awareness, and design and construction technical issues were the top five barriers [10]. Hwang & Ng studied the barriers to green construction in Singapore and concluded that longer time periods, lack of subcontractors, unreliable and costly green materials and equipment, lack of cooperation, and lack of coordination among the stakeholders are the top five barriers [11].

A study investigated the barriers in India and found the cost of GB, lack of incentives, and the unorganized nature of the Indian construction industry as the top three barriers, followed by unclear information on the payback period and long-term savings of GBs, lack of choices, and lack of trained labour as the next group of critical barriers, while lack of a green movement and lack of reliable GB technology were identified as the moderate barriers [12]. Lack of literature, lack of technical standards, lack of training, and lack of skilled labour were the top barriers to adoption of green buildings in higher education in Brazil [13]. Economic unfeasibility, inadequate awareness, unwilling stakeholders, inadequate policy and regulation, inoperability, risk and uncertainty, and inefficient project management were identified as the top barriers to the adoption of sustainable construction in China [14]. A study investigated the impediments to green building practices adoption in Pakistan and found that unawareness about green building practices, unsupportive government, missing green building codes and regulations, inefficient enforcement of existing laws and legislation, and lack of training/education were the top five barriers [15]. A study in Ghana concluded that green building technologies are costlier, which acts as the top barrier to their adoption, followed by lack of incentives from the government, unavailability of schemes like bank loans for finance, lack of suppliers for GBTs, and unavailability of institutes for R&D as the other top five barriers [16]. A study in Cambodia investigated the barriers to adoption of sustainable construction practices in Cambodia and found that costlier sustainable construction practices, unavailability of incentives from the government, lack of priority due to economic constraints, lack of regulations for green procurement methods, and unavailability of sustainable construction professionals and designers [17]. A study in Bangladesh identified a lack of incentives to owners, an increase in maintenance costs, regular maintenance, a lack of incentives to developers, and a lack of owner/client interest as the top five barriers [18]. A study in Malaysia found government support to be the most influential group of barriers influencing GB adoption, whereas lack of resources with the company, inadequate knowledge and information about green buildings, and lack of financial schemes were the other critical barrier groups [19]. A study investigated and compared the barriers to the adoption of sustainable practices in the US, India, and Afghanistan and found that unavailability of training and education is the top barrier, followed by unavailability of information and lack of definition of sustainable construction as the top three barriers [20]. Lack of knowledge had been identified as the top obstacle to adoption of green building materials in Mauritius [21]. A study in Egypt examined the barriers to adoption of value management practices for sustainable buildings in China and found lack of experts to be the top barrier, followed by bad coordination among the stakeholders, inadequate facilitation, difficulty in decision-making, and lack of knowledge as the top five barriers [22]. Simpeh et.al. considered 34 variables while investigating the barriers to adoption of GB in South Africa and found inadequate cost data, limited knowledge sharing, inadequate information, lack of relevant GB research, and lack of incentives to be the top five barriers [23]. A study was conducted by Akcay in Turkey to find the barriers to the adoption of green building projects [2]. He considered seventeen barriers and identified the high cost of construction as the topmost barrier, followed by paucity of green building projects, lack of GB materials, lack of material suppliers for GBs, and insufficient market demand as the top five barriers, respectively.

From the available literature, it can be inferred that several barriers hinder the adoption of green buildings (GBs) [24]. The studies on barriers to GB adoption in India are limited [25-29], and only two studies [12,30] could fulfill the criteria to be reviewed for identification of barriers in the present study. The barriers to GB adoption have been identified from the above-mentioned studies. These barriers were used as items for the development of scale in the survey instrument.

In order to properly assess and evaluate the GB adoption barriers, all the previous studies have used a survey instrument in the form of a questionnaire that can measure the inherent construct, i.e., barriers to GB adoption [31]. For studies measuring a construct, it is important to get the validity of the instrument designed to measure the construct [32]. Earlier studies on green building adoption conducted in countries like the United States, the United Kingdom, and Ireland [7,8,33] failed to report any method used for the validation of the survey instrument. Hwang & Tan [34] examined the obstacles to green project management in Singapore, Hopkins [35] studied the barriers to the adoption of green buildings on campuses in Canadian universities, and Azeem et al. [15] conducted a survey in Pakistan on barriers inhibiting the adoption of green buildings, but all of them failed to report the use of any scientific method to ascertain the validity of the survey instrument. Hwang & Ng [11] studied the challenges to green construction in China, Chan et al. [36] conducted a survey of global experts to determine the criticality of green building adoption barriers, Ayarkwa et al. [37] studied the barriers to green building adoption in Ghana, and Akcay et al. [2] studied the barriers to green building projects in Turkey. All these studies reported a pilot survey being conducted before the survey but do not mention the results of the validity test of the survey instrument. After a detailed examination of all the above-mentioned studies and several others, two inferences can be deduced as follows:

1. The researchers studying green building adoption barriers do not conduct a validity test on the survey instrument deployed for the survey
2. They conduct a pilot survey but do not report its results in detail.

In the first case scenario, the results obtained from such a survey that uses a survey instrument with no validity test may be considered invalid and cannot be relied upon. In the later, the absence of validity test details of the survey instrument renders the survey results doubtful. Inherently, in both cases the reliability of the test result is rendered ambiguous. The policy measures framed based on such results may fail to overcome the green building adoption barriers, resulting in low adoption rates of green buildings. This also opens up a gap in the literature that needs to be addressed.

From the discussion in the previous section, it is clear that all the earlier studies in the field of green building adoption barriers-related research have evaluated the green building adoption barriers using some form of the survey instrument. But none of them explained the detailed methodology and process used for the development and validation of the survey instrument. Although some studies do report a one- or two-step process of a pilot survey, they fail to give the detailed methodology of the validity test conducted, if any. They also fail to mention the validity score of individual items in the scale or the overall scale validity score. Hence, this research aims to develop and validate a self-administered survey instrument that is able to adequately represent all the domains of the construct, i.e., barriers to green building adoption in India.

This study is novel as it is the first to explain the detailed process and methodology used for the development and validation of the survey instrument employing quantitative methods in the field of green building adoption barriers-related research. It also reports the validity score of each item in the scale and the overall validity of the survey scale.

MATERIAL AND METHODS

Methods

The survey instrument was developed in two stages as suggested by several authors [38,39] and done in previous studies [32,40-42]. Stage One comprised instrument design and layout using standard practices prescribed in the literature. Barrier items were identified from the systematic literature review. The instrument design and layout comprised content identification, data collection, survey instrument construction, and layout of the content [42]. Stage Two comprised content validation of the survey scale using qualitative and quantitative methods.

This study focuses on Stage Two of instrument development. The survey instrument was first evaluated by a three-member panel of subject-matter experts (SMEs). Then the survey instrument was validated using quantitative techniques. The content validity ratio (CVR) method was employed to determine the essential items in the scale Lawshe [43] followed by the content validity index (I-CVI) method, which ascertained the relevance of items in the scale [44,45]. The scale-level validity is calculated using two methods. First is the universal agreement method (S-CVI/UA), which considers only the items rated relevant by all judges, and second is the average method (S-CVI/Ave), which takes into account all the ratings received by individual items to calculate the scale level validity [32,42,46]. The Kappa score for individual items in the scale was calculated to determine the possibility of chance agreement among the judges.

Determining The Content Validity of The Survey Instrument

Validity is a measure of the ability of the new survey instrument to comprehensively cover all the domains of the construct it is designed to measure [39]. The perception shall be measured by the rating of several barrier items (statements) by the respondents of the survey [32]. The validity of the survey instrument is determined to achieve the following objectives:

1. The items in the survey instrument are understood by the respondents in the way the researcher wants them to understand [47].
2. The survey instrument covers all the aspects of the construct it aims to measure [40].
3. The answers received from the survey are the answers that the researcher wanted to receive from the respondents [47].
4. The items in the survey instrument are relevant, and the irrelevant items are deleted from the survey [48].

The objectives of survey instrument validity were achieved using qualitative and quantitative methods in the following steps:

Step 1: Screening by subject-matter experts

Step 2: Collection of judgmental evidence

Step 1: Screening By Subject-Matter Experts

The first version of the survey instrument was submitted for screening to a three-member panel of subject-matter experts. As suggested by Davis [49], one of the members was an expert in survey instrument design, and the other two were experts in the construct to be measured, i.e., "barriers to green building adoption." The details of the panel are given in Table 1. The experts gave several suggestions to be incorporated in the survey instrument.

The expert No. 1 was from the field of social science with more than 30 years of experience in survey instrument design and layout. The questionnaire expert was requested to give his suggestions regarding the layout, wordings of the barrier statements, sequential order, and overall presentation of the survey instrument. The suggestions given by the expert are as follows:

1. To use a 3-point Likert scale for the essentiality test and a 4-point Likert scale for the relevance test of the barrier items in the survey scale instead of a 5-point Likert scale.
2. To add "any other, please specify" or "none" as the last option in the multiple check-box option category. Space was given for filling in the "any other" option.
3. Another suggestion was to add the option of "other" in multiple-choice options and "provide space below."

Expert No. 2 was from the field of architecture and had experience in teaching and research related to green buildings. He was asked to examine the comprehensiveness of the survey scale in covering each and every dimension of the construct and give comments on the absolute necessity of the information to be collected by the survey instrument for completion of the survey. The suggestions given by the green building expert are the following:

1. To categorize the barrier items for "ease of perception and comprehension of the respondents."
2. To add an option of "Type of green building experience" under the "Experience" category in the survey instrument.

Expert No. 3 was a GB professional working in the field of design and certification of green buildings. He gave several valuable inputs about the GB barriers. He also suggested adding "Other" and "None" options under the "Professional Membership" category in the multiple-choice options and providing space below for adding any other membership besides the listed options.

Step 2: Collection of Judgmental Evidence (Content Validity)

Content validity tests ascertain that the items in the survey instrument are able to comprehensibly measure all the domains of the construct, and they are done using quantitative techniques [39]. Content validity needs to be measured using a variety of approaches, as a single test is not sufficient. Documenting the content validity of the instrument used for the survey also ensures that the results are more accurate [50]. This study adopted the Content Validity Ratio (CVR) and the Content Validity Index (CVI) methods to ensure that the items in the survey instrument cover all the domains of the construct and are essential and relevant for the construct to be measured. An eight-member judges panel was used to collect judgmental evidence in four subsequent rounds of evaluation as recommended by Lynn [45] and advocated by some other authors [32,44]. The details of the judges are given in Table 2.

The information for judges about the survey scale, the definition of the construct to be measured, and the use of the scale to rate the barrier items in the survey scale is given in Table 3.

Based on the rating by the judges, the score for the items is calculated. The CVR varies between -1 and 1, where a value closer to 1 is considered more appropriate [42]. In order for an item to be considered essential, it should receive a CVR score of 0.75 from an eight-judge panel of experts [43]. The score of individual items in the survey

Table 1. Details of Subject Matter Experts for first evaluation of the survey instrument

S. No.	Domain Expert	Field of expertise	Relevant GB experience	Exp. (in years)
1	Professor	Survey instrument design	Instrument Design	33
2	Associate Professor	Building Planning and Design	Green Building Research	10
3	Architect	GB Design and certification	Design and certification of GBs	12

Table 2. Details of the eight-judge panel for CVR and CVI evaluation of barrier items in the survey scale Content Validity Ratio (CVR)

S. No.	Domain Expert	Field of expertise	Type of GB Exp.	GB Exp. (in years)
1	Architect	Building Planning and Design	GB Design and Certification	10_15
2	Architect	Building Planning and Design	GB Design and Certification	5_10
3	Architect	Building Planning and Design	GB Design and Certification	5_10
4	Engineer	Construction Management	GB Construction	15_20
5	Engineer	HVAC consultant	HVAC design	5_10
6	Engineer	Electrical Layouts	Energy auditor	10_15
7	Engineer	HVAC consultant	HVAC design	5_10
8	Professor	Building Planning and Design	GB Research	15_20

Table 3. Introductory note for the judges for rating the essentiality of the barrier items on a 3-point Likert scale

Respected Sir/Madam,
You are approached to act as a judge based on your experience/acquaintance in/with the green building construction industry/ academia/research. You are requested to assess the barrier items listed in the scale developed to measure the construct, i.e., GB adoption barriers, following due scientific process. Barriers are factors that act as obstacles/roadblocks to the adoption of green buildings (GBs). You are to assess and rate each item using the following scale: 1 = not essential; 2 = useful but not essential; 3 = very essential.

scale was determined using the formula CVR = (Ne-N/2)/(N/2) [43], wherein Ne is the number that indicates the agreement among the judges on an item being essential and N is the number that represents the total number of judges [42].

Content Validity Index (CVI)

This study employed another quantitative technique known as the Content Validity Index (CVI) method. This method was employed by various previous studies and highly recommended by experts for validating the content of a new survey instrument [38,45]. Item-level CVI (I-CVI) is based on the level of agreement of the judges about the relevance of an item. Items receiving a rating of 3 or 4 on a 4-point scale are only considered relevant [45], while items with a rating of 1 or 2 are considered irrelevant [44]. Item-level CVI, or the I-CVI, is dependent on the agreement of the judges on the relevance of individual items in the survey scale. The number of judges that consider an item to be relevant is taken as the numerator, while the total number of judges acts as the denominator [32]. The I-CVI score thus obtained is checked against the range of values to consider if the item is to be retained in the scale, revised, or deleted. The I-CVI score range values are dependent on the number of judges in the assessment panel. For an eight-judge panel, various authors have suggested scores for an item to be considered relevant. An I-CVI score of more than 0.78 is considered good. According to Davis, an item should obtain an I-CVI score of at least 0.8 to be considered relevant. Such an item is to be retained in the survey scale as it is considered relevant by a significant number of judges [49]. According to Polit and Beck [44], items with an I-CVI score between 0.70 and 0.79 are to be considered for revision, while items that obtain an I-CVI score of less than 0.70 are to be eliminated from the survey scale and not be considered any further in the survey. It means that such items are no longer relevant enough to be retained in the survey scale. From the above discussion, it can be deduced that all experts agree that an item receiving an I-CVI score of 0.8 or more is to be considered relevant.

After examining the validity of individual items in the survey scale, the validity of the scale in its entirety was also checked. The scale is validated based on the I-CVI scores of the items in the scale. Two methods have been used to calculate the scale level CVI (S-CVI). First is the universal agreement (UA) method. This method is very rigid as it only takes into account the items considered valid unanimously by all the judges. All other items that receive an I-CVI score of less than 1.0 are not considered for calculation of scale validity.

Second is the average method used for checking the validity of the comprehensive scale. This method considers the I-CVI score of all the items in the scale, no matter how high or low. The total of all the I-CVI scores is taken in the numerator, and the total number of items in the scale is taken as the denominator. The score so arrived at is naturally higher as compared to the universal agreement method.

The content validity survey was accompanied by a cover letter explaining the survey scale, the definition of the

Table 4. Introductory note for the judges for rating the relevance of the barrier items on a 4-point Likert scale

Information for Judges
The scale is developed to measure the construct, i.e., GB adoption barriers, following due scientific process. Barriers are factors that act as obstacles/roadblocks to the adoption of green buildings (GBs). You are selected as a judge to assess the listed barriers for GB adoption and rate each item based on your previous experience/acquaintance in/with the green building construction industry/academia/research. The following scale should be used to rate the barrier items: 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = very relevant.

construct to be measured, and the use of the scale to rate the barrier items in the survey scale, as given in Table 4.

Kappa Statistics

As the possibility of chance agreement among the judges is not taken into account by the CVI method, the validity of the survey scale using this method may be exaggerated [44,45]. So, some authors suggest that the Kappa score of the items in a scale should be calculated along with CVI to supplement I-CVI scores [42,51]. Kappa calculation ensures that the agreement among the judges is beyond chance. Many studies have used the Kappa score as a supplement to CVI [32,42]. The Kappa score varies from 0 to 1. A value of Kappa below 0.4 is considered to be poor, while 0.74 to 1 is considered excellent [42]. The Kappa score is expressed as K value. It indicates how much the judges agree on the relevance of the items in the scale [32].

RESULTS AND DISCUSSION

The results of the various methods used to validate the survey instrument are discussed in this section.

Results of The Survey Instrument Screening (Versions One and Two)

In the first evaluation of the survey instrument, the suggestions given by Expert No. 1 were incorporated. The 5-point Likert scale was replaced by a 3-point scale for testing the essentiality of the items and a 4-point scale for testing the relevance of the items in the survey instrument. "None" was added as the last option in the multiple-choice

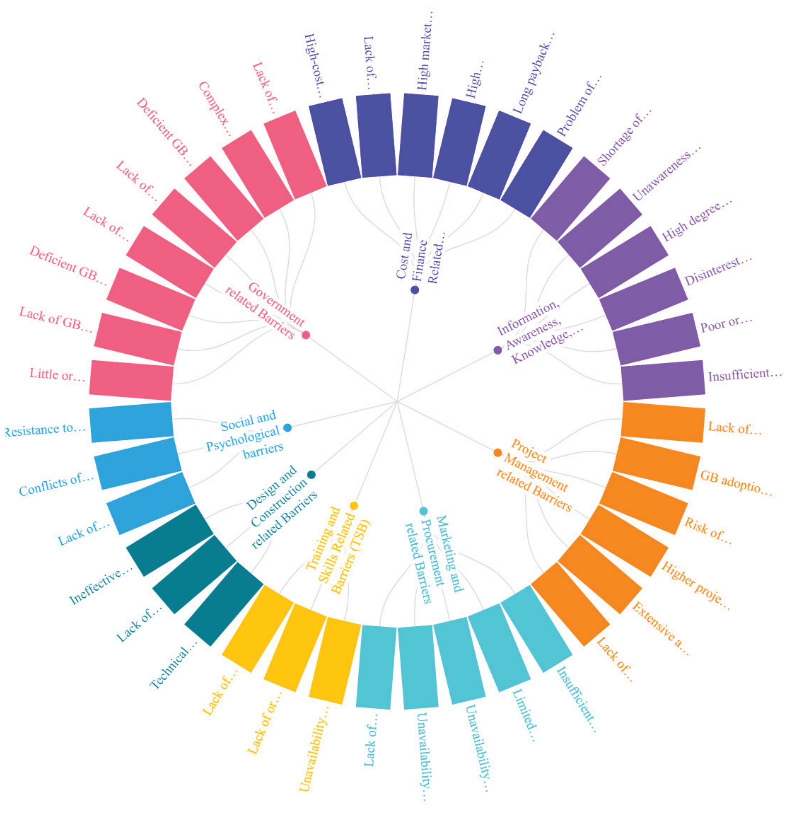

Figure 1. The 40 barrier items under eight categories after evaluation by three-member committee.

option under the question related to professional membership. It was decided to add the prominent categories in the multiple-choice option and add "other" at the end of the list of options. Space was given for filling in the "Other" option.

As per the suggestions of Expert No. 2 and for ease of respondents [52], the survey instrument was revised by dividing the barrier items into eight categories based on the previous studies, which are as follows: 1) Cost and finance-related barriers [19,53,54], 2) Information, Awareness, Knowledge, Education, and Training related Barriers [19,55,56], 3) Government-related Barriers [19,24,57], 4) Project Management related Barriers [34, 53], 5) Training and Skills related Barriers [53,54], 6) Design and C onstruction related Barriers [34,53,57], 7) Social and Psychological Barriers [58-60], and 8) Marketing & Procurement related Barriers [57,60].

Another suggestion was to add a category of "type of GB experience" under the "Experience" category. As suggested by Expert No. 3, the "Other" option was added under the "Professional Membership" category, and space was provided below for adding any other membership besides the listed options. The experts were satisfied with the coverage of items under each category. So, the second version of the survey instrument had 40 barrier items under 8 categories as represented in Figure 1.

Content Validity Results

The content validity results have been calculated for the second version (40 items under 8 categories) of the survey instrument.

CVR Results (Version Three And Four)

The CVR score determines the essential and non-essential items on a survey scale. The CVR was calculated based on evaluation of items by an eight-judge panel. According to Lawshe [43], for an eight-judge panel, items in a scale that achieve a CVR score of 0.75 or more should be retained in the scale, while items with a CVR score of less than 0.75 are to be considered non-essential. The CVR score of 1.0 was obtained by only 02 items in the survey scale. Another set of 17 barriers scored 0.75, whereas 8 items scored 0.5 based on the ratings by the judges. The remaining 13 items in the survey scale with a 0.25 score were eliminated from the survey scale. The details of the CVR results after round one evaluation are represented in Figure 2.

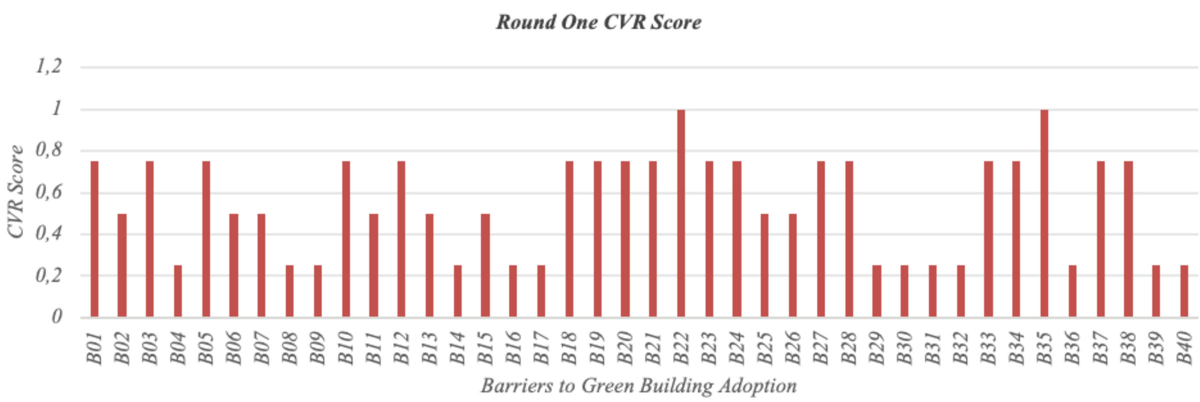

Figure 2. Results of round one of essentiality evaluation.

Table 5. A sample of CVR results based on the responses of the eight-judge panel received in Round One of the essentiality evaluations

Barrier codes	NE	CVR	Interpretation
Government related barriers			
B13	6	0.5	Revision
B14	5	0.25	Eliminated
B15	6	0.5	Revision
B16	5	0.25	Eliminated
B17	6	0.5	Eliminated
B18	7	0.75	Retained
B19	7	0.75	Retained
B20	7	0.75	Retained

A sample of the CVR result after round one of essentiality evaluation is given in Table 5. After the first round of CVR results, 19 items with a CVR value of 0.75 and above were retained. The items with CVR = 0.5 were discussed with the judges, and eight of them were revised and kept in the third version of the survey instrument. The barrier item "lack of affordability or financial schemes for GB construction" was revised to "lack of affordability for

GB construction," "problem of split incentives (e.g., the rentee gets the benefit for green investment by the owner)" was revised to "problem of split incentives between the owner and the rentee," and "shortage of GBTs & GBMs databases and information among the stakeholders" was revised to "lack of accessibility to GBTs & GBMs databases and information," "poor or insufficient knowledge and expertise among construction professional and practitioners of GBTs and choices offered by GBMs" was revised to "lack of awareness and knowledge among construction professional and practitioners about GBTs and GBMs," "little or insufficient government incentives and rebates for green building construction" was revised to "lack of or insufficient government incentives and rebates for green building construction," "deficient Green Building rating systems and labelling programs" was revised to "deficient green building rating and certification systems," "extensive and rigid requirements involved in green building certification" was revised to "extensive documentation involved in green building certification," and "lack of support to green building businesses and practices due to unorganized construction industry" was revised to "lack of support to green building businesses and practices". All 3 barrier items in the "Design and Construction" category were eliminated.

So, the third version of the survey instrument contained a total of 19 retained and 8 revised barrier items and 7 categories from the second version of the survey instrument. The second round of CVR evaluation was carried out using the third version of the survey instrument with 27 barrier items under 7 barrier categories. A total of 2 items had CVR=1.0; 21 items had CVR=0.75. In this round, 04 of the revised barrier items from the previous round were retained, with each of them receiving a CVR of 0.75, while 04 items received a CVR of 0.5 and were eliminated. The details of the CVR results after round two evaluation are represented in Figure 3.

The details of revised barrier items retained in round two are given in Table 6. The fourth version of the survey instrument contained 23 items and seven categories.

I-CVI Results (Version Fifth and Sixth)

After eliminating the non-essential items from the scale, the index of content validity was determined for the fourth version of the survey scale. A sample calculation of the I-CVI rating of barrier items in the project management category is given in Table 7. The judges considered a total of nineteen items to be relevant with an item score greater than 0.8. Another set of 02 barrier items achieved a score of 0.75, while 02 items could not meet the threshold of 0.70

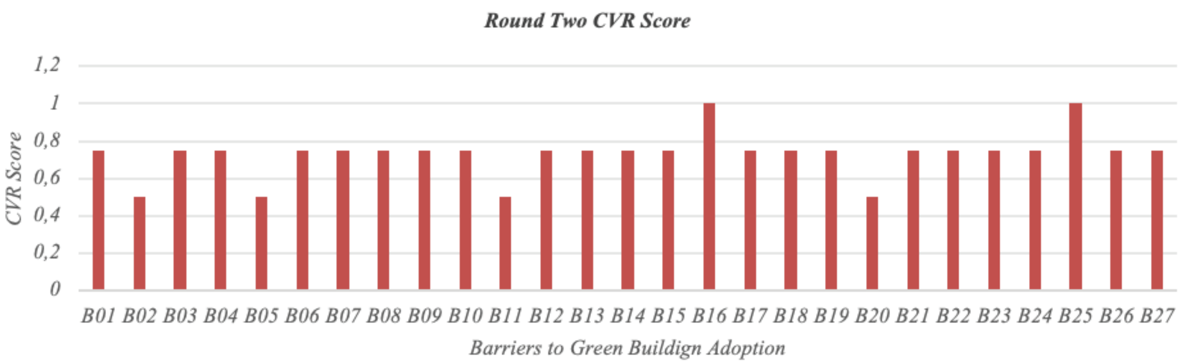

Figure 3. Results of round two of essentiality evaluation.

Table 6. A sample of CVR results based on the responses of the eight-judge panel received in Round Two of essentiality evaluation

Barrier Codes	Round One score	Interpretation	Round Two Score	Interpretation
B06	0.5	Revision	0.75	Retained
B10	0.5	Revision	0.75	Retained
B17	0.5	Revision	0.75	Retained
B19	0.5	Revision	0.75	Retained

Table 7. A sample of I-CVI results after round one of relevance rating by the judges

Barrier Codes	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7	Exp 8	I-CVI
Project Management related Barriers									
B11	1	1	1	1	1	1	1	1	1
B12	1	1	1	1	1	1	1	1	1
B13	1	1	1	1	1	1	1	1	1
B14	1	1	1	1	1	1	0	1	0.875
B15	0	1	1	0	1	1	1	0	0.625

and ended up achieving a CVI score of 0.625. These were deleted from the survey scale.

The details of the CVI score of barrier items after round one of relevance evaluation by the judges are represented in Figure 4. All the items on the scale had a score of more than 0.625. The judges were consulted about the items that achieved an item score of 0.75. These barrier items were rewritten after consultation with the judges. The fifth version of the survey instrument was developed, containing 21 barrier items and 7 categories.

Another round of I-CVI evaluation was conducted using the fifth version of the survey instrument, containing 19 retained items and 2 revised barrier items. A total of thirteen barriers achieved an I-CVI score of 1.00, and 7 items achieved an I-CVI score of 0.875. One of the revised barrier items achieved an I-CVI score of 0.875. It was deemed appropriate and retained in the survey instrument. Another revised barrier item remained at its previous score of 0.75. It was decided to delete this item from the survey scale. A sample of I-CVI results for one of the categories is given in Table 8.

The details of the CVI round two of relevance evaluation by the judges are represented in Figure 5. After the second round of evaluation by the eight-judge panel, 20 items were retained in the scale. The sixth version of the survey instrument was developed, containing 20 barrier items under 7 barrier categories.

S-CVI Results

After ascertaining the validity of individual items in the scale, the scale level validity was calculated. Using the universal agreement method, the scale level validity of the whole scale was found to be 0.65. This method only considered the 13 items that achieved an individual item score of

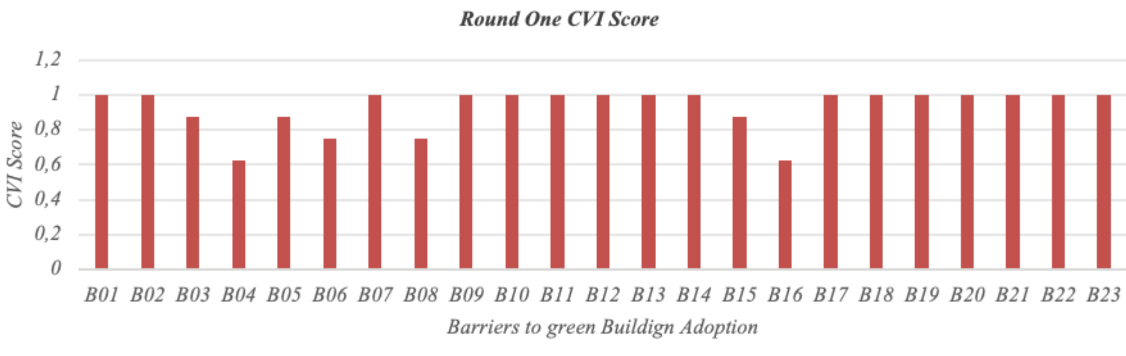

Figure 4. Results of round one of relevance evaluation.

Table 8. A sample of I-CVI results after round two of relevance rating by the judges

Barrier Codes	I-CVI Score	Interpretation	Final Decision
Government related Barriers			
B07	0.75	Revision	Retained
B08	0.875	Appropriate	Retained
B09	1	Appropriate	Retained
B10	1	Appropriate	Retained

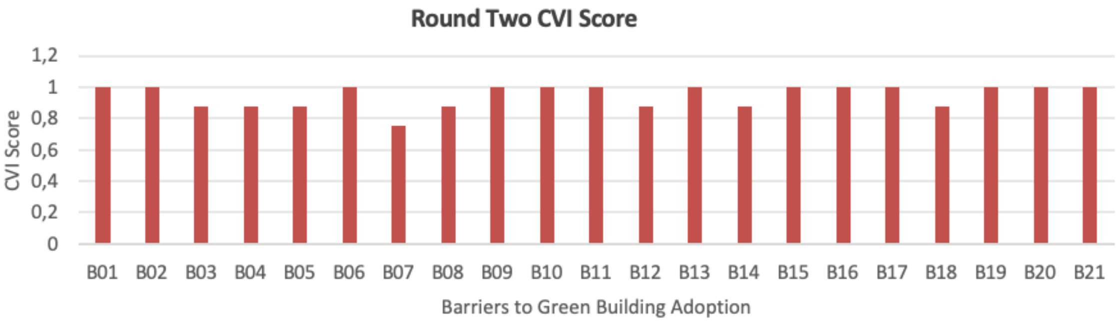

Figure 5. Results of round two of relevance evaluation.

Table 9. Results of I-CVI, Pc, and K values of barrier items retained after evaluation by an eight-judge panel along with the S-CVI values using the average method and the universal agreement method

Barrier codes	I-CVI	Pc	K	Interpretation
Cost and Finance related Barriers				
B01	1	0.003906	1	Excellent
B02	1	0.003906	1	Excellent
B03	0.875	0.03125	0.871	Excellent
Information, Awareness, Knowledge, Education and Training related Barriers				
B04	0.875	0.03125	0.871	Excellent
B05	0.875	0.03125	0.871	Excellent
B06	1	0.003906	1	
Government related Barriers				
B07	0.875	0.03125	0.871	Excellent
B08	1	0.003906	1	Excellent
B09	1	0.003906	1	Excellent
Project Management related Barriers				
B10	1	0.003906	1	Excellent
B11	0.875	0.03125	0.871	Excellent
B12	1	0.003906	1	Excellent
B13	0.875	0.03125	0.871	Excellent
Training and Skills Related Barriers				
B14	1	0.00390625	1	Excellent
B15	1	0.00390625	1	Excellent
Social and Psychological barriers				
B16	1	0.00390625	1	Excellent
B17	0.875	0.03125	0.871	Excellent
B18	1	0.00390625	1	Excellent
Marketing and Procurement related Barriers				
B19	1	0.00390625	1	Excellent
B20	1	0.00390625	1	Excellent
Overall S-CVI using Average method		S-CVI/Ave	0.956	Excellent
Overall S-CVI using Universal Agreement method		S-CVI/UA	0.65	Poor

1.0 and were agreed upon by all the judges to be relevant. The sum of scores of these items, i.e., 13, was taken as the numerator, while the total number of items in the scale, i.e., 20, was the denominator. The scale level CVI using the average method was also determined, and it was found to be 0.956, which is excellent. The sum of scores of individual items in the survey scale was 19.125. This value was taken as the numerator, while the total number of items in the scale, i.e., 20, was the denominator.

According to previous studies [44,45] the universal agreement method, being stringent in its approach to calculating the scale validity, uses a lower threshold for validity, i.e., 0.80, whereas the average method mandates a minimum S-CVI value of 0.90 or more to be called excellent [61].

KAPPA Score

The K value was calculated for the remaining twenty-one items. The K value for all 20 barrier items ranged from 0.875 to 1.0, which is excellent. The details of the Kappa values along with I-CVI values of all barrier items are given in Table 9. The result of the Kappa statistics indicates that a greater number of experts agreed upon the barrier items in the survey scale, and this agreement among the judges is beyond chance. All the judges have delinquently rated all the items in the survey scale, and this agreement is not simple guesswork by the judges.

This study focused on the development of a survey instrument and the validation of its content. Judgemental evidence was collected in two steps. In Step One, the survey instrument was evaluated by a three-member panel of subject-matter experts. As suggested by the experts, the barrier items were categorized as prescribed in the literature, and some additional questions were added. Such categorization had been done in earlier studies in this area of research [11,15,36,62]. Minor adjustments were also made in the wordings of some questions. In Step Two, judgmental evidence was collected using quantitative techniques for validation of the survey scale content. The content validity ratio (CVR) was calculated using two rounds of judgmental evidence by an eight-judge panel, which determined the essentiality of the items in the survey scale. An aggregate of 40 barrier items was evaluated in Round One, wherein 23 items were judged to be essential. After discussion with the judges, 8 items were revised and included in Round Two. In Round Two, 27 items were retained in the scale and used for calculating item-level CVI. Zamanzadeh et al. [32] also adopted this methodology of revising the items after consultation with the judges and going for a second round of evaluation.

In Round One of CVI judgement by an eight-judge panel, 19 items were considered relevant, while 2 items were revised after consultation with the judges and retained in the scale for further evaluation. In Round Two, 20 barrier items scored above 0.78, which is considered the minimum value for an item to be retained in the scale without any change. So, 20 barrier items were retained in the survey scale after four rounds of judgmental evidence. Similar methodology was also adopted by previous researchers [32,42,61].

The universal agreement method was used to determine the scale-level validity, and it was found to be 0.65, which is considered to be low and indicates the survey scale has items which are not agreed upon by all the experts. Rodrigues et al. (2017), while validating a survey instrument for nurses, had a similar score (S-CVI/UA = 0.63) using the universal agreement method. He attributed the low score to a lack of clarity of the items in the survey scale. So, it can be safely inferred that there is a need for further refining the items in the survey scale with respect to wording and language. Although the universal agreement method may be considered more appropriate to determine the scale level validity, as it only considers items that have received agreement from all the judges in the panel, the likelihood of chance agreement among all the judges gradually declines with the increase in the number of judges in the panel [44]. So, according to Lynn [45], for a greater number of judges, i.e., more than five, it is desirable to go for the average method to calculate the scale level validity. Wang & Sahid [61] validated a questionnaire measuring three dimensions of entrepreneurial behavior in China and seconded Polit & Beck's [44] opinion that the universal agreement method is more stringent. He also opined that the average method is more appropriate for calculating the scale-level validity of the survey instrument as the number of judges increases (n=8 in the present case). The scale-level validity calculated using the average method was 0.956, which is excellent and acceptable, as it relies on validation of each item by the judges rather than the agreement of judges [44]. With this score of scale validity, it can be inferred that the items in the scale are appropriate and relevant to measure the construct, i.e., barriers to GB adoption.

After carefully examining the results of scale-level validity derived using both methods, it can be inferred that the universal agreement method may be underestimating the content validity of the scale and the average method may be overestimating it. The difference in validity achieved by the two methods can be attributed to the fact that the average method always has a higher number in the numerator if the judges do not agree on all the items in the scale [44]. It can be safely inferred that the actual scale level validity may lie somewhere in between the values calculated by both the methods [42].

The research work comes up with a valid survey instrument that can be used by researchers for identifying the critical barriers to green building adoption. As the survey instrument is developed and validated and the whole process and methodology are explained in detail, surveys conducted using this instrument shall yield better research outcomes.

It also opens up the possibility for further refinement of the survey instrument. Several qualitative methods can be used, like the focus group discussions, and cognitive interviews. Such steps are taken up by researchers to further refine the instrument, if desired.

There is a further need to develop more such validated survey instruments for green building adoption-related research. The scope of this research work mandated the use of green building professionals and researchers as judges for validating the survey instrument. The validated survey instrument can be calibrated for other stakeholders like green building owners and end-users as well. Moreover, more survey instruments need to be developed and validated, focusing on specific barrier categories identified in this research work, like finance-related barriers, government-related barriers, project management-related barriers, etc. A survey instrument developed and validated using quantitative or qualitative techniques helps in improving the reliability of the research outcomes. It is important that these steps are reported in detail with the results at each step to yield better results and remove ambiguity from the research work.

Every research has its limitations. It is imperative for the researcher to point out the limitations of the study. This study used experts from academia and industry to validate the barrier items in the scale. It did not take into account the opinions of owners/clients of green buildings. So, the survey scale lacks generalizability. The survey scale needs to be recalibrated in order to use it for other stakeholders. Secondly, the study used an eight-judge panel. Future studies can broaden the panel base to incorporate a greater number of judges in the study. Although utmost care has been taken to record and report the results of the discussion and feedback from the experts, there is always a chance of using a self-reported measure. All practical measures have been taken to design and develop the survey instrument in an unbiased manner, but still subjective biases cannot be ruled out. Multiple rounds of consultation have been undertaken to reduce such biases.

CONCLUSION

This research explained in detail the different quantitative methods used for survey instrument validation, which is a first in the field of green building adoption barriers-related research. After a screening by a three-member committee of subject-matter experts, the instrument underwent two rounds of evaluation by an eight-judge panel to determine the essentiality of items (content validity ratio method), followed by two rounds of evaluation to determine the relevance of items (content validity index method) in the survey scale. Each item in the survey scale scored a high level of content validity (0.875 to 1.00). To determine the validity of the survey scale, the average method was used, which gave an excellent validity score of 0.956. Employing the universal agreement method, the scale-level validity was found to be poor, with a score of only 0.65. But it is not very important, as the number of chance agreements drastically goes down with the increase in the number of judges. The results of the content validity, although satisfactory, hint at the necessity of further refinement of the survey instrument using qualitative techniques. The Kappa score was also calculated for individual items in the final version of the survey instrument, and each item had an excellent score (0.871 to 1.00). The existing research works on green building adoption fail to report the step of survey instrument validation in detail. This is an important step that is presently not being covered. The methodology used in this research work and the results of this research work are novel, as they fill an important research gap in the existing literature. Henceforth, the researchers in the field of green building adoption can report this step of instrument validation in detail so that the validity of the survey instrument can be judged and the research outcomes become more reliable. Further, the survey instrument developed and validated in this research work can be used by future researchers in toto or as a base to develop a more accurate survey instrument. The methodology employed in this research can be used to develop and validate the survey instruments in any field of study employing questionnaire-based surveys as a research method.

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