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# Analysis of Factors Affecting the Selection of Low-Cost Green Building Materials in Housing Construction

Ibuchim Cyril Ogunkah[1], Junli Yang[1]

[1]School of Architecture and The Built Environment, University of Westminster, London, UK

**Abstract:** This paper is informed by a study conducted to determine how the understanding of the principles of best practices associated with the impacts of low-cost green building materials could be improved to fulfill the objective of their greater use in mainstream housing. The aim of this paper is to address one of the main objectives of this study: to identify the key influential factors that will aid designers in the informed selection of low-cost green building materials and components for sustainable low-cost green housing projects. The findings and results derived through an extensive literature review and a preliminary study with leading experts emphasised the need for appropriate informed data for use in the material selection decision-making process. Solution proposed in this study contributed to the simplification of this task by conducting further surveys with experts who represent various fields in the housing construction industry and research institutions in nigeria, to examine views and current thinking from leading researchers in the field, and obtain relevant data on issues specific to the critical factors affecting the choice of low cost green building materials. The methodology adopted in undertaking this research was the mixed method approach involving a detailed review of the relevant literature, networking with domain experts and practitioners, knowledge-mining interviews and industry-wide surveys with design and building professionals in nigeria. A total of 210 out of 480 questionnaires were returned for analysis. A variety of statistical methods within the statistical package for the social scientist (spss v.20) were used to analyse the data collected and identify the key influential factors. The identification hence helped to develop a methodological framework for depicting the ranked factors for sustainable low-cost green housing. The information gathered from the analysis with inputs elicited from domain experts and extensive literature review will be used to further develop a multi-criteria material selection decision support system (msdss), and later to be refined with feedbacks obtained from selected expert builder and developer companies. The rationale of this paper is inevitably built on the ground that the identified factors; site-related issues, cost effectiveness, environmental impacts, socio-cultural impacts, sensorial effects, and technical performance-giving that the value $p < 0.05$, are crucial in ensuring the design of sustainable low-cost green housing in nigeria.

**Keywords:** Decision Support System (DSS); Factors; Housing; Construction; Low-Cost Green Building Materials

## 1. INTRODUCTION

The housing construction industry is one of the most important industries that underpin the economic development of any nation [1]. It is by virtue of its size, one of the largest users of energy, material resources, and water, and also a formidable polluter of the environment [2, 3]. The Report Emissions for Greenhouse Gases in the United States [4], estimates that around half of all non-renewable resources mankind consumes are used in housing construction, making it one of the least sustainable industries in the world. Recent estimates suggest that building materials consumption in the Nigerian housing construction industry for example, constitutes about 40-80% of the total input in housing construction, and that 10-30% of the total energy consumption is embodied in building construction materials, i.e. energy used for the extraction, production, and transportation of the materials [5, 6]. The United States Department of Energy (USDOE) [4] further indicates that housing construction constitutes a major impact on the built environment in its consumption of energy, both directly from the embodied energy in the materials that it uses, and indirectly from building energy in use. Due to the nature of construction activities that change the natural landscape, it is now impossible to perform construction activities without assessing their impacts on the environment [7].

As construction practitioners in the developed world have begun to pay attention to controlling and correcting the environmental damage associated with housing construction activities, the selection of building materials has attracted scrutiny [8]. Efforts have been made by studying the extent to which design and building professionals are aware of the implications of their design decisions, in using the available material information and techniques to make appropriate choices [9, 10]. This is largely the reason why sustainable building materials come into view.

Ibuchim Cyril Ogunkah (Correspondence)

cyrilguchi@ymail.com

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However, with the advent of modern manufacturing processes, the list of materials available to builders today is far longer than at any other time in the history of construction [11].

With the introduction of cement and concrete, steel, aluminium and products from the chemical industry, and the cost of energy required in their production, the demand for low-cost green building materials and components has increased dramatically as they possess features that can help to mitigate climate change, reduce production and construction material cost, lower operating energy, and reduce maintenance cost. Ofori [12] argued that the selection of environmentally responsible building materials and components has definite implications on the performance of the building. Zhou et al. [13] however, remarked that the extent, to which design and building professionals are aware of the implications of their design decisions when using the available material information and techniques to make appropriate choices, largely depends on a wide range of factors and variables.

With so many different products and materials, both individually and as assembled building components currently available in the market, selecting the most suitable building materials and components can be a very complex process [13, 14]. Ding [3] notes that this increases the workload and responsibilities of the specifiers who have to evaluate and select the building materials from a range of possibilities, and thus, often results in material failure, and underperformance of the building due to wrong choices. He further notes that a number of factors that should be considered when selecting construction materials are often ignored, adding that failure to properly consider the various factors involved when selecting materials at the early design stages could have serious consequences in terms of additional costs, and overall performance of the building [15].

While the choice and environmental suitability of building materials are commonly influenced by factors such as cost, availability and appearance, Castro-Lacouture et al. [16] suggest that there are quite an inordinate number of factors that are being acknowledged by construction practitioners. However, when multiple factors are to be satisfied in a material selection problem, complexities often arise with regards to criteria conflicts and/or the importance of each criterion- hence constitutes a critical challenge to the designer.

This paper therefore, aims to identify, analyse, and classify the key influential factors that will aid designers in the informed selection of low-cost green building materials and components for sustainable low-cost green housing projects. It presents a framework, based on a literature study and the analysis of in-depth interviews, in which the different factors or variables affecting the material selection process are identified and organized in their respective categories, to provide the ability to formulate and systematically compare different material alternatives against large sets of design criteria. To refine this framework and make it available for design and building professionals during the material selection process, a group of practicing architects, engineers, material specifiers, and a host of building professionals-who influence material choice decisions in the Nigerian housing construction industry, were selected for the survey. This study presents a discussion on how the participants of the surveyed questionnaire identified, classified and commented on the factors that influence their decisions while selecting materials for low-cost green housing projects. The evaluation of the collected data, and the discussion from the interviews, permitted the formulation of comments and resulted in the development of a conceptual model for a Multi-Criteria Material Selection Decision Support System (MSDSS), useful during the design and selection process of low-cost green building materials and components.

The following section is devoted to reviewing the nature of the various categories of potential factors or variables that influence the selection of low-cost green building materials in order to establish the methodological framework for the assessment model. It examines a holistic set of these criteria by reviewing state of the art studies concerned with highlighting criteria affecting the selection of sustainable building materials and products in the building industry.

## 2. Factors Affecting the Selection of Sustainable Building Materials: A Review

The material selection process is a complex process that is influenced and determined by numerous preconditions, decisions and considerations [17]. This means that material selection is not about choosing the strongest, cheapest, or most obvious materials available [17], but considering a wide range of variables that affect the choice of materials during the design and selection processes. In view of the importance attached to the selection of materials in construction projects, several research studies on factors that can affect the decision-making and selection processes have been carried out [18, 19, 20].

For example, Ashby and Johnson [21] introduced 'aesthetic attributes' in the material properties list for product designers when describing material aspects such as the transparency, warmth, or softness. He claimed that within the field of product design, several studies focus on the definition or description of sensorial, expressive or emotive qualities of products, with little or no reference to the impacts of such aspects in the selection process. Wastiels & Wouters [17] however, maintain that their model is far more difficult to apply in the selection of building materials for housing construction, than in civil engineering projects.

Furthermore, six critical factors: visible benefits, safe, efficient, satisfying to use, durable and serviceable were identified as vital for selecting sustainable products for large public projects in Cagan and Vogel [22]. Other studies [18] maintain that the importance of safety and health of the end-users at times surpass cost and durability in housing construction projects. They maintain that overemphasis on cost of material can have profound implications on occupants well being.

Chan and Tong [18] conducted a comprehensive literature review and established a theoretical framework for factors that contribute to the safety and health of the end-users using grey relational analysis approach. He identified durability, functions and quality of the product as crucial in the selection of composite materials. Despite the fact that the research represents a theoretical framework, it represents one of the pioneer works in the context of polymer composites in engineering structures, doubting its usefulness in residential housing construction. Their study tends to be more mechanically driven with perceived efficiency gain. Moreover, the study fails to prioritize the relative importance of the factors identified.

Van Kesteren, Stappers, and Kandachar [23] present a material selection consideration model for product design, where product-personality, use, function, material characteristics, shape, and manufacturing processes are represented as the elements that are considered by the industrial designer during the material selection process. Wastiels & Wouters [24] however doubt the validity of the model in the selection of sustainable building materials for architectural design and construction. They noted that architecture is not only concerned with a larger scale, as the interaction with the user is different for architecture and product design.

Ljungberg [25] identified specific factors such as environmental impacts, economic impacts, customer requirements, highly satisfying to the user, safe to use, low reparable and highly prolonged, and market demand for assessing different sustainable construction products. Meanwhile, in the context of material selection no mention is made about the objective and subjective measures.

Similarly, low-emitting contaminants, rapid renewable periods, socially and creatively awarding, low consuming, low reparable and highly prolonged, easy to build with, and safe to use were perceived as critical in large-scale construction project in Glavic and Lukman [20]. It was however discovered that the factors identified were too limited to determine their significance in sustainable material selection.

Mora [26] proposed a material selection model and material data sheets that provide extensive information on the technical aspects of materials, useful for specifying a material's technical performance. He maintains that undermining the issue of technical performance in housing construction projects has resulted in the colossal waste of material resources and underperformance of housing construction projects. The material source/model, however, lack the considerations or descriptions to evaluate the sensorial and intangible aspects that are important to architects. Wastiels & Wouters [24] argue that restricting the selection of building materials to a limited range of factors could impede the discovery of sustainability properties inherent in materials themselves.

In a previous study, Wastiels et al. [27], conducted in-depth interviews that revealed how the choice for a particular material influences a project and how it contributes to create a certain expression for the building or space. A framework was presented based on the analysis of the data. In the presented framework, no pronouncement was made upon how considerations from these different categories influence each other.

In addition, employing modeling of the critical factors; high recycled content, low-emitting contaminants, safe to use, and harm of contaminants free, were the factors identified as crucial in housing construction projects in Zhou et al. [28]. They identify "safe to use" as one of the four most important factors that can be applied in housing construction sector when selecting building materials. They opine that these factors play an integral and pivotal role in material selection and suggest that designers need to be well informed about these factors. Heijungs et al. [29] however considers quality in housing construction to be concerned with what the client requires. He therefore, asserts that quality and client's satisfaction at the design stage depends on the designers' ability to identify factors that relate to client's requirements.

In the context of housing construction projects, Heijungs et al. [29] suggested another set of factors namely occupants' satisfaction, the aesthetic of facades, landscape quality in the planning and design stage, with no reference to objective measures. Florez' et al. [30] argue that the best results in the choice and quality of materials in low-cost green housing construction projects are achieved when both the objective and subjective measures are combined to ensure that the right materials and techniques are employed. This finding tends to imply that the quality and level of performance that will be achieved in material or product will depend upon the consideration of both objective and subjective variables.

In addition, Florez' et al. [30] study demonstrated how decision making may be enhanced by considering subjective as well as objective factors in the decision making process. Their study proposed a sustainability instrument that assesses subjective characteristics in order to improve the current decision- making process. In the context of material selection no mention is made about the proposal of a decision support system.

Although an increasing amount of books have attributed attention to the critical factors that influence the selection of sustainable building materials [25, 26, 27, 28, 29, 30], Wastiels et al. [27] argue that their interest is limited to an occasional description of the phenomena without providing a clear and comprehensive overview that might be useful to designers. This paper hence underscores the need for a more structured description of the various attributes that influence the choice of materials in order to ease the architect or designer's material selection process in the selection of low-cost green building materials. To achieve this, this study aims to identify, organize, map and classify, the different factors considered during the material selection process in a more comprehensive way, in order to provide this information to architects for use during their material selection process and to allow a less ambiguous discussion of these aspects amongst architects and with their clients.

To identify the key selection factors or variables that formed the basis for the development of the prototype multi-criteria decision support system (DSS), suitable clusters of research approaches were considered in the research exercise as discussed in the following section.

## 3. RESEARCH METHODOLOGY

The material selection process for residential housing development is a complex undertaking and it depends on a number of factors that can be categorized as spatial (such as geographical and geotechnical characteristics of the region; proximity to site, and location) and economic-related factors (such as cost of material and labour) [27, 30]. The methodological background adopted to identify these factors or variables in this study was built on the mixed-method approach (consisting of both qualitative and quantitative research methods).

To develop preliminary ideas on issues specific to the research theme within the context of identifying decision-making factors associated with the selection of low-cost green building materials and components in the housing construction industry, this study reviewed relevant literature through synthesis and analysis of recently published data, using a range of information collection tools such as; books, and peer-reviewed journals from libraries and internet-based sources.

In-person interviews were also conducted to further clarify and elaborate on less detailed issues associated with the factors affecting the informed selection of low-cost green building materials in the housing construction industry. The in-depth interviews consisted of 15 participants, involving a sample of practicing architects, engineers, material specifiers, and a host of building professionals-who influence material choice decisions in the Nigerian housing construction industry. This approach was used to examine other potential factors for the proposed MSDSS model for the assessment and evaluation of low-cost green building materials.

Consequently, a quantitative questionnaire was developed as the result of the analysis of the results from the literature review and interviews, providing essential triangulation of data gathered through reviews, and interviews. In order to elicit the ''key influential'' factors, a semi-structured questionnaire survey was conducted among the executives of some selected building firms, with over 10 years of experience. The inclusion of qualitative open-ended questions provided respondents a chance to clarify issues. The targeted respondents were randomly drawn from the construction profession who have or had participated in an undertaking or completed sustainable or green building projects; to avoid bias and uneven sample sizes amongst different professional groups [31]. The sampling frame used in this survey was drawn primarily from the directory of the Building Design and Construction Consultants (BDCC), Building Professionals Registration Council Board Register of Nigeria (BPRCBN), and the directory of various top ranking universities in Nigeria offering building and construction related courses. To facilitate the response rate, snowball sampling was also adopted, where the approached respondents were asked to distribute the questionnaire to their colleagues and partners [32]. They were asked to rank order from a list of factors (compiled from existing literature on the topic and after initial consultation with some of the executives) based on their judgment and experience. The executives were also asked to indicate desired features they would like to have in a DSS for material selection.

The analysis of the questionnaire survey provided a list of ‘‘key influential” factors having significant impacts on the process of selecting low-cost green materials for residential green housing projects. Therefore, it was decided to use a commercial SPSS (v.20) software package. There were two reasons for choosing the commercial software package: (i) these software are developed and tested by professionals, so they are reliable, accurate and user- friendly; (ii) they provide easy interface for data transfer in different modes, thus can be integrated with any other software application.

Using a progressive approach of data collection, a total of 480 questionnaires were distributed and 210 completed questionnaires were received, representing a response rate of 44%. The data collection exercise was conducted over a three-month period from November 2012 until mid of March 2013. The response rate was accepted as the normal ranges between 20-30% were found in most of the construction industry related research [33, 34]. Prior to distribution, the questionnaire was pre-tested for comprehensibility by consulting five academics at two universities [32]. A number of changes were suggested and implemented. The next section presents the results of the analysis from the surveyed questionnaire, and compares them to the previous framework. In combination with the discussion of the presented framework, a refined model of considerations concerning low-cost green materials in construction is presented as a result.

## 3. DATA ANALYSIS AND RESULT DISCUSSIONS

### 3.1 Introduction

This section presents a careful investigation of the structural patterns exhibited in the data collected. It describes the analyses and discussions of information gathered from the survey of building and design professionals in Nigeria, with regard to comments made on practices relating to the informed selection of low-cost green building materials, and how such practices influence their design decisions at the early design stages of building projects. It also discusses responses from all the respondents taken during interviews and surveys, which were examined, compiled and evaluated to answer the research question: how can the understanding of the principles of best practices associated with the impacts of low-cost green building materials be improved, to fulfill the objective of their greater use in mainstream housing? The completed questionnaires were first tested for reliability and internal consistency using Cronbach’s Alpha. The Cronbach’s value accounted for 0.789, which is above the threshold value of 0.7 [35]. Having satisfied the reliability test, the relative important index of the variable was calculated.

The process was performed using the Statistical Package for the Social Science (SPSS), version 20. From the analysis, the top three factors from various categories were life expectancy (0.952), resistance to fire (0.919), and maintenance cost (0.912). It was worth a note that the factors were the technical-related and economic/cost-related factors. Out of 60 initially identified factors, only the top fifty-five ranked factors were used in establishing the methodological framework. As for the effective monitoring and control of the project, previous studies such as [28], [29] and [30] supported the assumption that the factors greatly influence the performance of a housing construction project.

As far as possible, data were tabulated and displayed through tables, charts, and graphs, with the aim of identifying and discerning any patterns that provided the best interpretation of the results of the study. The size of the response across available response categories is indicated in both percentage (%) and raw numeric terms. For ease of reference, the questions were numbered through various sections and the numerals were used in the text to refer to specific statements attributed to each of the questions (see appendix A). Uncompleted responses from respondents, who opted not to complete the survey till the end, were excluded. A general description of the results and the demographic study are given in section 3.2. Further explanations and discussions on the results are given in various sections. The rest of this chapter has been written under the following headings: (3.2) Analysis of Demographic Data; (3.2.1) Designation of respondents; (3.2.2) Experience in environmental awareness and design practices; (3.2.3) Areas of project interest; (3.2.4) Phase of material choice; (3.2.5) Decision making in low-cost green building material selection – stakeholder influence, source of information, drivers and obstacles limiting their greater industry acceptance; (3.2.6) Material assessment methods and obstacles to usage; (3.3.1) Identification of key decision factors or variables for material selection; (3.3.2) Factors importance rating; (3.3) Factor analysis; (3.4) Consideration of potential means of facilitating the wider-scale use of low-cost green materials in the building design and housing construction industry; (4) Presentation of proposed Material Selection Decision Support Model (MSDSS) model; (5) General findings of the study; and (6) Conclusions and further works.

While the sample groups cannot be proven to be representative of the entire design and building professionals in Nigeria, the limited number of registered and accredited building professionals in the Nigerian housing construction industry proved that the number of respondents of this survey was quite reasonable to conduct a full analysis of the study. The study identified the key influential factors or variables that formed the basis for the development of the prototype multi-criteria decision support system (DSS), for the evaluation and selection of low-cost green building materials and components. These analyses are undertaken as a prelude to the development of the material selection decision system (MSDSS). Summary of the findings and a general discussion of this study exercise are given in sections 5 and 6.

### 3.2 General Analysis of the Demographic Study

Relevant data relating to personal views associated with the informed selection low-cost green building materials was obtained from leading experts in the field of housing construction in Nigeria, following the closure of the main survey launched between November 2012 and mid March 2013. Participants' responses and results summaries of the survey were automatically generated by the syncforce survey tool and stored in SPSS v.20. To establish the evidence base for this research, and provide an emerging markets perspective and insights to responsible material selection decision-making process, as an area of growing industry relevance, a combined research approach consisting of qualitative personal interviews supported by a quantitative online survey was conducted. Interviews were conducted with senior decision-makers across 10 organisations with a further 210 individuals participating in the online survey.

The main survey attracted 480 interested participants with 210 eligible respondents, who have relevant knowledge on issues specific to the use of low cost green building materials, and representing various fields in both the housing construction industry and research institutions in Nigeria. These activities were undertaken across the five areas of geographic interest due to different geographies, and variations in the technical nature of participant's roles. This means the project evidence base has been informed by feedback from over 200 individual participants leading to views of separate data items across the issues of interest. The project was interested in how informed-decision making changes between conventional and low-cost green building material choices, and how designers' choices influence life-cycle cost, energy use and performance of low-cost green housing projects. The results of the survey are summarized below.

#### 3.2.1 Designation of Respondents

The question as to how best you describe your self, revealed the participants' respective job affiliations. This question allowed the respondents to choose from 5 available categories including architect, builder, engineer, quantity surveyors and urban designers. Hair et al. [36] noted that it is important to consider not only the statistical significance and size of the sample population, but also the quality and practical significance of the results. They noted that unequal or uneven sample sizes amongst different professional groups could also influence the results. In order not to bias results, the random sampling method was introduced to achieve sampling equivalence amongst various building professionals both in higher institutions and practicing building design and construction firms. To facilitate the response rate, snowball sampling was also adopted, where the approached respondents were asked to distribute the questionnaire to their colleagues and partners.

This was achieved by deploying roughly equal numbers of questionnaires to individual professional associations resulting in a ratio of 1.48, very much in range with Hair's et al [36] 1.5. The aim was to ensure a sample size that would be statistically adequate to achieve even response rate and valid data.

Remarkably, under the "Other" option, a number (7%) of other professionals within the housing sector also provided complete responses. The 'Other' category included sustainability consultants, academics, research consultants, program/software developers and other specialist consultants. The summary report showed that 20% of the architects were accredited members of the Nigerian Institute of Architects (NIA) with surprisingly, almost the same proportion as the members of the Nigerian Institute of Builders (NIB) who had slightly more (22%) than would have been expected. On the other hand, more than a quarter of engineers (16%) were ASHRAE Professional Engineers (PE) of the Nigerian Institute of Civil Engineers, with a higher representation from the Society of Construction Industry Arbitrators of

Nigeria. 22% of the respondents were accredited professionals of the Nigerian Institute of Quantity Surveyors, and (13%) of the Nigerian Institute of Urban Designers. However, the encouraging finding here is that on average the size of each group was balanced, and so allowed the study to reasonably compare views of respective professionals. Table 1 and Figure1 show the number of respondents grouped under each professional category.

**Table 1: Job Affiliation**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Architect | 43 | 20.0 | 20.0 | 20.0 |
| | Builder | 47 | 22.0 | 22.0 | 42.0 |
| | Engineer | 33 | 16.0 | 16.0 | 58.0 |
| | Quantity Surveyor | 46 | 22.0 | 22.0 | 80.0 |
| | Urban Designer | 27 | 13.0 | 13.0 | 93.0 |
| | Other | 14 | 7.0 | 7.0 | 100.0 |
| | Total | 210 | 100.0 | 100.0 | |

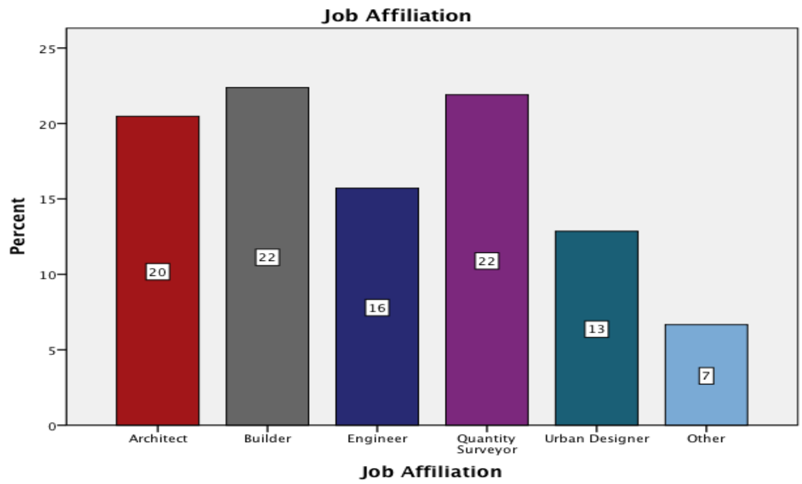



**Fig.1: Respondents' designations, affiliations and certifications.**

### 3.2.2 Experience of Respondents

The second question revealed the participants' level of experience in the field of low-cost green housing construction. To successfully implement green development goals in housing design and construction, Zhou et al. (2008) note that the knowledge and experience of building and design professionals is indispensable. From the survey results, 95% of the respondents had sufficient to excellent knowledge relating to low-cost green development, especially in the selection of low-cost green building materials. The analysis of the study indicated that 15% of the respondents who participated in the study had between 1 and 5 years of experience in low-cost green housing construction, 26% had industry experience ranging between 6 and 10 years, 36% had at least 11-15 years of experience, while 18% had over 20 years of experience working on low-cost green housing projects. 4% reported an insufficient knowledge and 1% undecided. An explanation for the 1% and 4% suggests that there is a possibility that the respondents who fell under those categories may not have handled housing projects in which green development concept was part of the project criteria.

The encouraging finding is that the majority of respondents who participated in the survey had reasonable experience in low-cost green housing construction, which further showed that more than half of the respondents were sufficiently experienced to provide data that were reliable and credible. This showed that responses were received from representatives of relevant professional groups from throughout the construction value chain, and from people who influence material choice decisions and who have experience in green building rating schemes. Knowledge on materials sustainability was however, found to vary significantly between participants due to different geographies, areas of interest and variations in the technical nature of participant's roles. The results of the survey on their knowledge and experience are shown below in table 2 and figure 2.

**Table 2.** Summary of responses by experience, demonstrated by their participation in green projects

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 [No Experience] | 10 | 4.0 | 4.0 | 4.0 |
| | 1-5 [Less Experienced] | 32 | 15.0 | 15.0 | 19.0 |
| | 6-10 [Fairly Experienced] | 54 | 26.0 | 26.0 | 45.0 |
| | 11-15 [Very Experienced] | 75 | 36.0 | 36.0 | 81.0 |
| | 15 and Above [Highly Experienced] | 38 | 18.0 | 18.0 | 99.0 |
| | Other | 1 | 1.0 | 1.0 | 100.0 |
| | Total | 210 | 100.0 | 100.0 | |

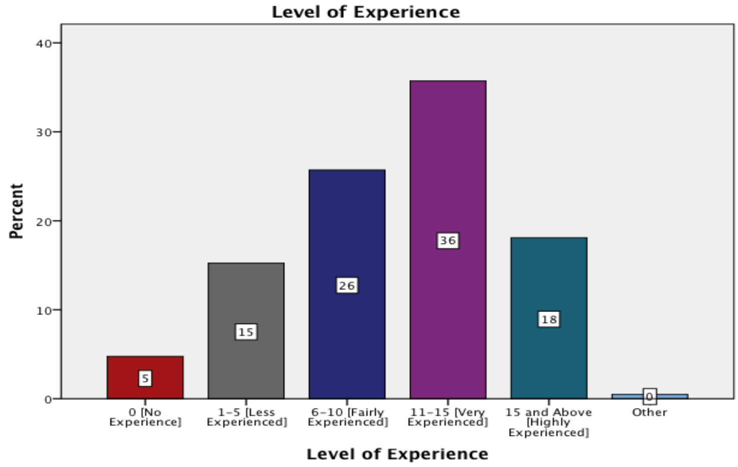



**Fig. 2**. Summary of respondent's level of experience in low-cost green developments

### 3.2.3 Areas of Project Interest

The results in figure 3 shows the frequency by which respondents influence decisions on material choice. It indicated that most of the respondents are concerned with the design aspects of low-cost green residential housing projects. Within the combined valid response, "all aspects of housing design" (36%) was the leading area of low-cost green housing project specialty reported by respondents, with "design and build" (23%) making a significant proportion of the responses. 21% of the respondents agreed that the "material specification" aspects of the building project was their most important area of interest, 14% considered construction aspect of the building project as the most crucial aspect of the project, while 6% came in the "other" category of specialisation. The larger numbers of residential design respondents further reflect the intended focus of the research, which is on low-cost green residential housing design.

**Table 3. Participants' area of interest**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Design | 48 | 23.0 | 23.0 | 23.0 |
| | Construction | 30 | 14.0 | 14.0 | 37.0 |
| | Material Specification | 44 | 21.0 | 21.0 | 58.0 |
| | All Aspects | 76 | 36.0 | 36.0 | 94.0 |
| | Other | 12 | 6.0 | 6.0 | 100.0 |
| | Total | 210 | 100.0 | 100.0 | |

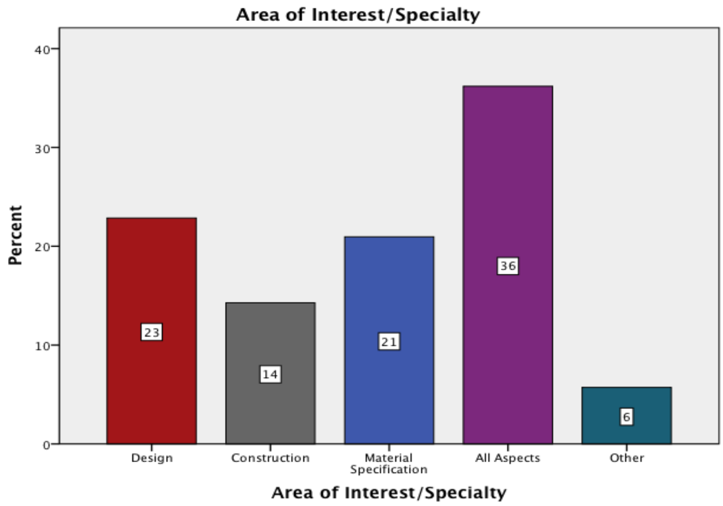



**Fig. 3.** Area of low-cost green housing project interest

### 3.2.4 Views on Decisions Regarding the Phase of Material Choice

In the follow up question, respondents were asked to indicate the phase for which they thought best to make decisions on the choice of materials for housing projects. Analysis of the returned questionnaire showed that planning and decision-making requirements were found to be significant, particularly for the choice of low-cost green materials, as 60% of respondents considered the choice of materials at these phases. Of the other lots, 23% noted the design development phase, 9% of them went for construction, while as little as 1% and 3% went for operation and final design stages. 2% made up the "other" option. The views obtained through this survey tend to be more representative of respondents who are more particular about the cost, social and environmental implications of materials at the decision-making, planning and preliminary design stages of the project; as changes to the overall building performance, visual appearance or energy cost can be difficult after this point.

**Table 4. Phase of Material Selection**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Planning and Decision-Making | 125 | 60.0 | 60.0 | 60.0 |
| | Design Development | 49 | 23.0 | 23.0 | 83.0 |
| | Final Design | 7 | 3.0 | 3.0 | 86.0 |
| | Construction | 23 | 11.0 | 11.0 | 97.0 |
| | Operation | 1 | 1.0 | 1.0 | 98.0 |
| | Other | 5 | 2.0 | 2.0 | 100.0 |
| | Total | 210 | 100.0 | 100.0 | |

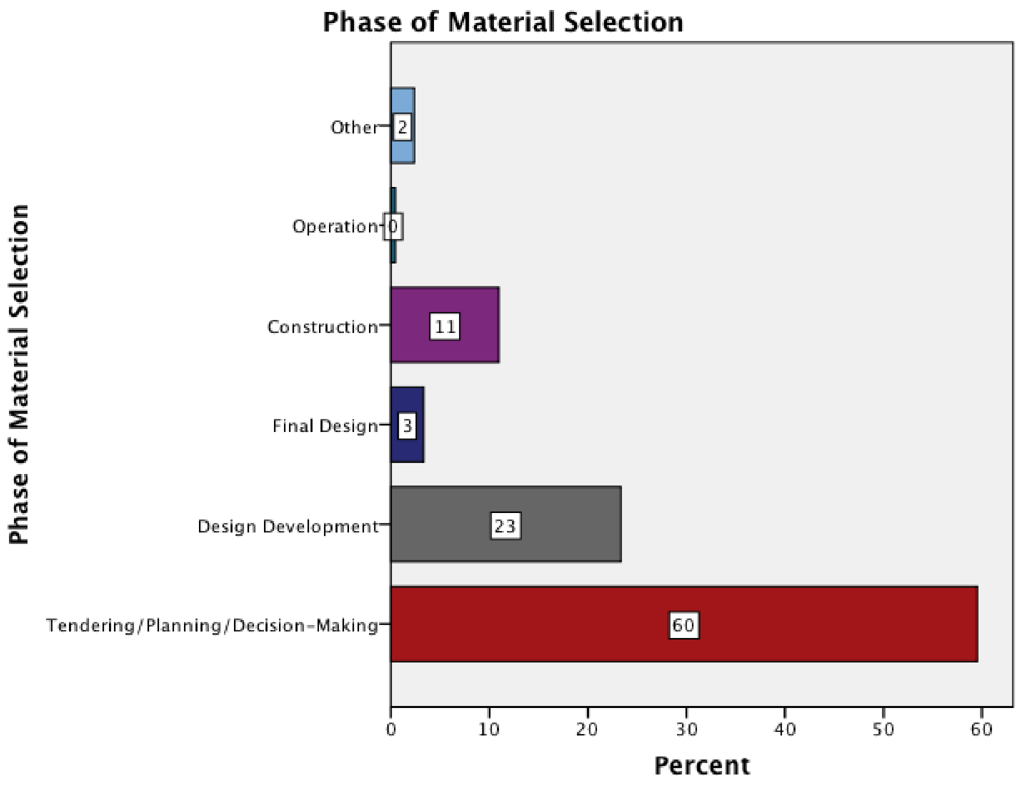



**Fig. 4.** Phase of material selection

### 3.2.5 Obstacles in the Use of Low-Cost Green Building Materials

An attempt was made to identify obstacles perceived by design and building professionals as they sought to use low-cost green building materials in their design and building projects. In order to detect disciplinary differences and conduct the inter-group comparison among professionals, all categories were binned into five main groups.

Participants that did not fall into any of the 5 categories were grouped under the 'other' option. Using the 5-point likert scale from "strongly disagree" (=1) to "strongly agree" (=5), respondents were asked to rank the extent to which they agreed on the following factors as obstacles that significantly deter them from using Low-Cost Green Building Materials (LCGBM) in housing design projects. Kendall's procedure states that if the test statistic W is 1, then all the survey respondents have been unanimous, and each respondent has assigned the same order to the list of concerns. If W is 0, then there is no overall trend of agreement among the respondents, and their responses may be regarded as essentially random.

To check whether or not intermediate values obtained for W indicated a greater or lesser degree of unanimity among the various professional groups, and to verify that the degree of agreement or disagreement did not occur by chance, the significance of W was tested, resulting in the null hypothesis being in relatively perfect disagreement. The Kendall's coefficient of concordance (W) value obtained was 0.226, which was significant at 95% confidence level.

The analysis implied that the W was significant with Asymp.Significant value of 0.00 and as such the null hypothesis was not supported and thus, rejected. Test statistics was further applied to the rankings in order to test the significance of the findings (as shown in table 5.5). The result of the analysis showed a greater degree of agreement in opinions among the various responses, so that there were no relatively significant differences in agreement between the number of 'K' dependent variables and the population from which these samples were drawn. The analysis was interpreted to indicate a significant degree of agreement among various design and building professionals as to the ranking of the perceived obstacles.

**Table 5**: **Test statistics for obstacles affecting the use of low-cost green materials**

| | |
|---|---|
| N | 135 |
| Kendall's W[a] | 0.226 |
| Chi-Square | 396.655 |
| df | 13 |
| Asymp. Sig. | 0.000 |

a. Kendall's Coefficient of Concordance

The biggest concern in specifying low-cost green building materials, of the ten potential factors listed in table 6 and as displayed in figures 5 and 6, was client's preference, with a relative index of (RI =0.795). This was closely followed by the contractual agreement with (RI = 0.775); lack of access to adequate and sustainable material information to compare material alternatives (RI= 0.772); nature of the building project (RI =0.699); Unwillingness to change from conventional materials (RI = 0.683); with limited availability of materials (RI=0.479) and maintenance concern (0.480) trailing in the last positions as the least influential obstacles.

The ranking of client's preference as the most recognised obstacle to the wider scale use of low-cost green materials is not surprising as clients greatest financial obligation for selecting ideal and cost effective building products is frequently their central concern, as costs must be monitored and controlled, whether from the point of view of the owner, or the designer. Remarkably, within the "Architects category", "Aesthetically less pleasing" was clearly identified as the most critical factor inhibiting greater industry acceptance of local materials, thus, corroborating Seyfang [37] and Malanca's [38] observation(s) about their reluctance in using such materials in their design projects. Summary discussions of the top three obstacles are presented in sections 3.2.5.1-3.2.5.3.

**Table 6.** Perceived obstacles inhibiting the wide-scale use of low-cost green materials in the housing industry

| Obstacles | Architect [1] | | Builder [2] | | Engineer [3] | | Quantity Surveyor [4] | | Urban Designer [5] | | Other [6] | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RI | Rank | RI | Rank | RI | Rank | RI | Rank | RI | Rank | RI | Rank | RI | Rank |
| **Clients' Preference** | 0.600 | 9 | 0.786 | 2 | 0.986 | 1 | 0.852 | 1 | 0.956 | 1 | 0.943 | 1 | 0.795 | 1 |
| **Contractual Agreement** | 0.815 | 2 | 0.800 | 1 | 0.725 | 5 | 0.719 | 3 | 0.733 | 2 | 0.800 | 2 | 0.775 | 2 |
| **Limited Accessibility to Relevant Information** | 0.755 | 3 | 0.779 | 3 | 0.863 | 2 | 0.778 | 2 | 0.689 | 3 | 0.743 | 3 | 0.772 | 3 |
| **Nature of the Project Design** | 0.730 | 4 | 0.676 | 5 | 0.625 | 7 | 0.711 | 4 | 0.733 | 2 | 0.700 | 4 | 0.699 | 4 |
| **Unwillingness to Change** | 0.680 | 6 | 0.683 | 4 | 0.825 | 3 | 0.644 | 6 | 0.533 | 8 | 0.700 | 4 | 0.683 | 5 |
| **Lack of Familiarity with Techniques** | 0.700 | 5 | 0.593 | 7 | 0.788 | 4 | 0.659 | 5 | 0.622 | 5 | 0.514 | 9 | 0.655 | 6 |
| **Unreliability of Suppliers** | 0.605 | 8 | 0.634 | 6 | 0.700 | 6 | 0.615 | 7 | 0.444 | 10 | 0.743 | 3 | 0.628 | 7 |
| **Aesthetically Less Pleasing** | 0.950 | 1 | 0.538 | 12 | 0.525 | 11 | 0.437 | 13 | 0.378 | 11 | 0.486 | 10 | 0.622 | 8 |
| **Low Flexibility for Substitutes** | 0.595 | 10 | 0.572 | 8 | 0.588 | 9 | 0.600 | 8 | 0.511 | 9 | 0.614 | 6 | 0.587 | 9 |
| **Uncertainty in the Project Outcome** | 0.565 | 13 | 0.517 | 11 | 0.613 | 8 | 0.578 | 10 | 0.556 | 6 | 0.671 | 5 | 0.572 | 10 |
| **Building Code Restriction** | 0.580 | 11 | 0.531 | 10 | 0.563 | 10 | 0.593 | 9 | 0.555 | 7 | 0.586 | 8 | 0.569 | 11 |
| **Perception that Materials are of Low Status** | 0.635 | 7 | 0.517 | 11 | 0.513 | 12 | 0.526 | 11 | 0.533 | 8 | 0.600 | 7 | 0.563 | 12 |
| **Limited Availability of Materials** | 0.575 | 12 | 0.545 | 9 | 0.338 | 13 | 0.593 | 9 | 0.667 | 4 | 0.371 | 11 | 0.529 | 13 |
| **Maintenance Concern** | 0.560 | 14 | 0.386 | 13 | 0.525 | 11 | 0.504 | 12 | 0.511 | 9 | 0.329 | 12 | 0.480 | 14 |

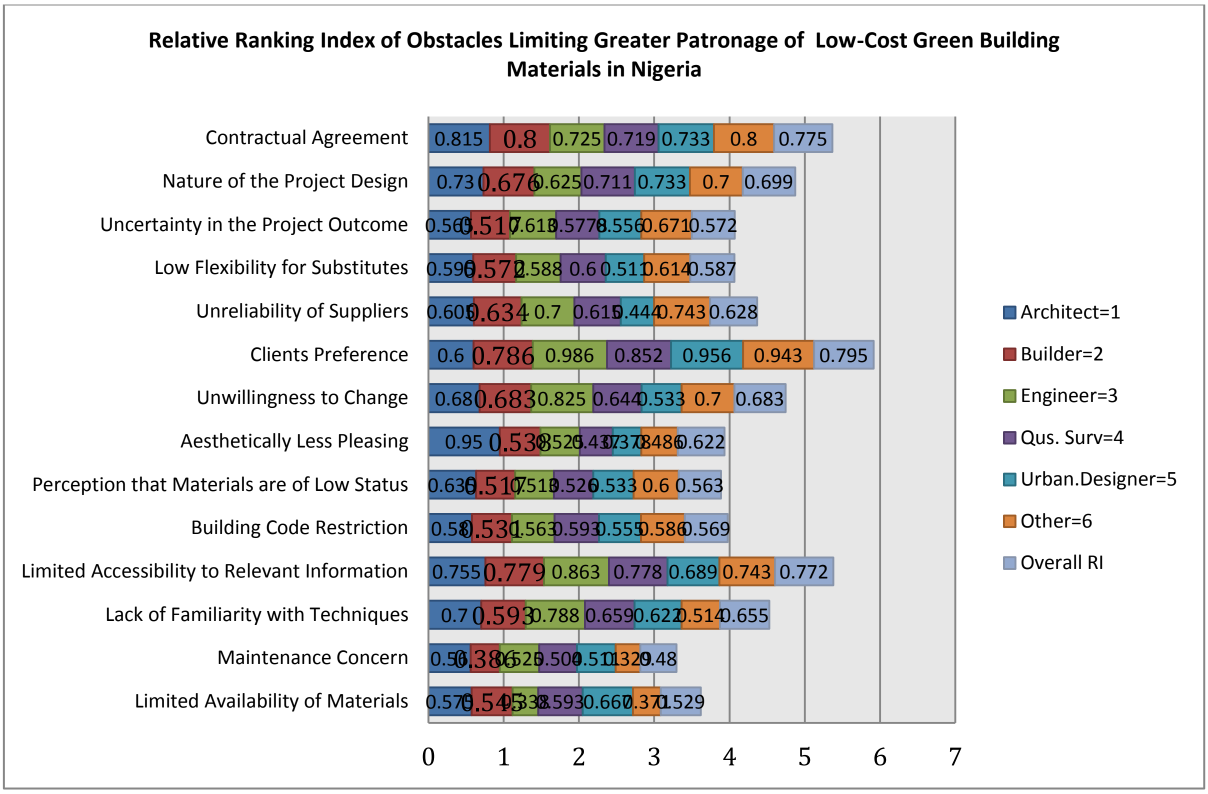



**Fig. 5. "Relative mean rank" of the perceived obstacles limiting greater use of low-cost green materials**

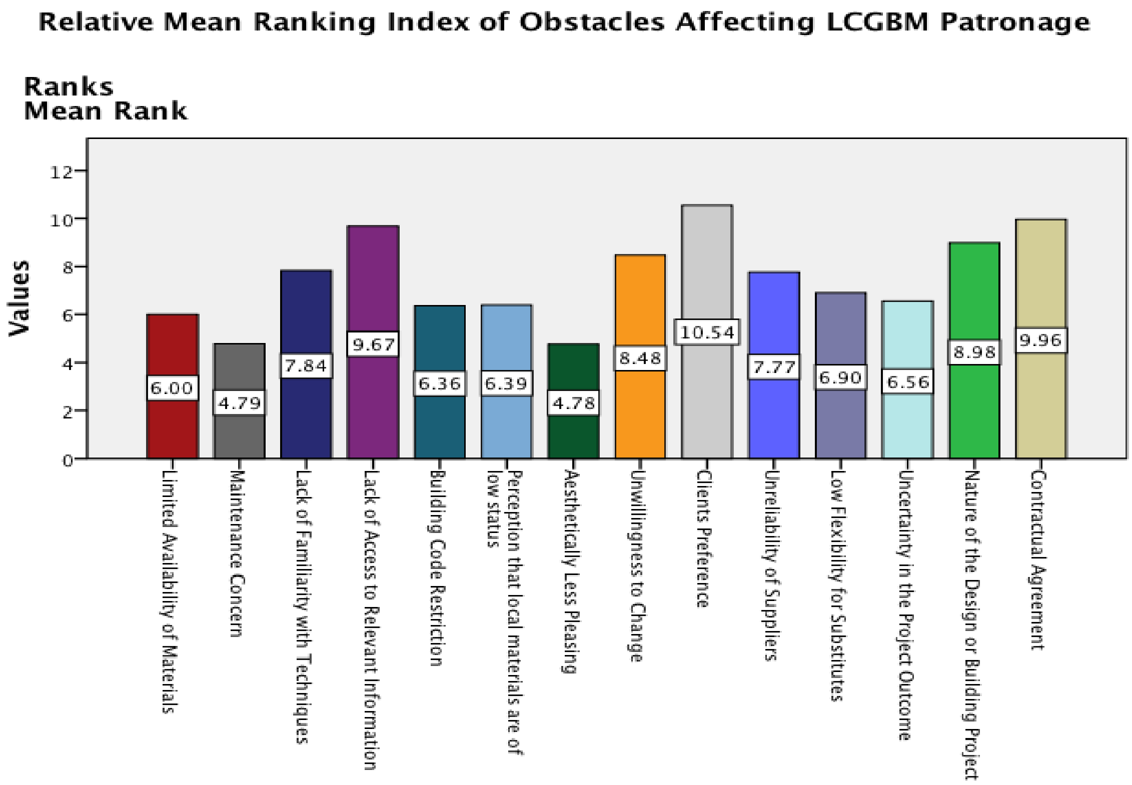



**Fig. 6.** Mean rank of the perceived obstacles limiting greater use of low-cost green material

#### 3.2.5.1 Client's preference

In an attempt to identify the potential factors that hinder the steady use of low-cost green materials in housing projects, respondents were asked to score their level of agreement with a list of potential factors as perceived obstacles that affect their use of such materials using a 5-point Likert scale (where '1= strongly disagree' to '5 = strongly agree'). Feedback demonstrated that client's preference had the most significant influence on the decision of which materials to use, since clients and investors regularly have significant influence on material choices due to the terms they impose on a project through budget and brief. This is not entirely surprising given that materials are increasingly sought by clients, who normally are anxious to minimise the running costs associated with residential housing construction, though unaware of the consequences of their decisions in the choice of materials [39, 40]. Some participants noted that the degree to which they use building materials largely depends on clients' perception, as they are made to believe that buildings designed with locally-sourced products are not permanent and has to be re-worked, maintained or out rightly re-built more often than it is with buildings constructed with conventional building materials.

The significance of this factor was well phrased by one interviewee: "The choice of building materials is governed by the economic power of the client, and therefore his preference of choice". He suggested that scientific research into best practices relevant to the use of these materials by various research stations might likely enhance durability, construction, and thus greater patronage. He added that clients' influence is understandable as they are legally responsible for the project, and carry the initial risks for the costs of the project. This thus, suggests that an awareness campaign that will help both clients and building professionals to be more specific in their choices of low-cost green construction materials, and thus, patronise their use in housing projects. This does not necessarily demonstrate a preference of usage by each group of professionals, but rather represents a potential for using materials that suits and incorporates clients expectations.

#### 3.2.5.2 Contractual agreement

Contractual agreement was rated as the second most prominent factor that affects the effective use of low-cost green building materials in housing projects. This is also not surprising, as the issue of the impacts of the contractual agreement on the choice of materials has been repeatedly highlighted in various literatures [39, 40].

Ofori [1] noted that despite the many strong advantages of standard form construction contracts, they are not flexible to fit all projects, and circumstances. He added that once the contract agreement is defined, its limit has a major influence on subsequent decisions for both the design structure and material choices. Even though they are an appropriate starting point for housing projects, he suggests that the contract terms may need to be re-modified to fit specific circumstances that are likely to occur in the event of construction, and therefore accept alternative building construction techniques and materials.

In considering whether or not a construction contract will affect respondents' choices in the use of low-cost green building materials, a similar study by Chinyio (40), showed that the contractual agreement was the most influential in deciding the choice of materials due to the expenses involved in altering prior terms and conditions contained in the Joint Contract Tribunal. The research study by Hammond & Jones [41] asserted that successful use of low-cost green building materials requires all members of the team to buy in to the idea and the process during the contract agreement stage. They remarked that it is crucial that the contract document fully considers their implications during tendering to ensure that warranties will be provided, risk pricing is minimised and lead times for sourcing such materials could be factored in.

#### 3.2.5.3 Lack of access to adequate material information

The identification of lack of information was noted as the third biggest obstacle to specifying low-cost green building products and materials in light of the current proliferation of documentary resources relating to the informed selection of such materials. The issue of accessing up-to-date information through different steps of the housing construction process, what the sources are and how they are obtained is one of the most discussed topics in the field of construction. The respondents reported that many sustainability principles and green housing development goals associated with the use of low-cost green building materials in housing construction have fallen by the wayside due to the absence of readily available information.

### 3.2.6 Building Assessment Tools for Low-Cost Green Materials

This part of the survey included questions that explored the sources of information and assessment tools building professionals use when assessing low-cost green building materials for housing projects. Van Kesteren [42] noted that selecting materials could be a problem-solving activity, given the high influx of new products of different qualities entering into the market. He added that this increases the workload and responsibilities of the specifiers who have to evaluate and select the building materials needed, as this demands a large and constant flow of adequate information. To investigate whether or not respondents were familiar with any source of information or tools used in evaluating and selecting low-cost green building materials, they were asked to indicate yes or no to the use of available tools and identify their sources of information, and how they obtained them. As shown in table 7, approximately 6% of the respondents "within job affiliation" confirmed knowledge of such tools, followed by approximately 1% of the sample population confirming the usage of other likely sources. However, a large proportion of the respondents with an approximate value of (93%) "within job affiliation" noted that they had no knowledge of any of such tools. Some of the sources mentioned include; The Guide by UN-Habitat, Going Green Guide for Sustainable Housing in Developing Countries, Literature, Online information, National Building Instructions, Maurice ile Durable, and the African Green Building Council.

One of the respondents noted that low-cost green building material information exists generally in paper form (e.g. brochures and catalogues). He added that paper-based information becomes quickly obsolete, as their updates do not keep pace with the speed with which new building materials appear on the market. He further argued that paper-based information are quickly being replaced by the information that serves the users by taking advantage of online web-based tools.

More importantly, the study revealed that design professionals lack the knowledge of best practices associated with the use of low-cost green building materials and therefore, require constant information and informed knowledge that guide them in their choice of materials [37]. The result of this question hence, suggests the importance and urgency of introducing a decision support system for evaluating decision trade-offs associated with the informed selection of low-cost green materials and components, since the quality and reliability of the information are as important as its accessibility, and should be accessed easily and timely. The findings also suggest that the accuracy of the model should be adaptive and adjustable to the user type and design phase to correspond to the different needs of the user. A summary of the result is presented in figure 7 and table 7.

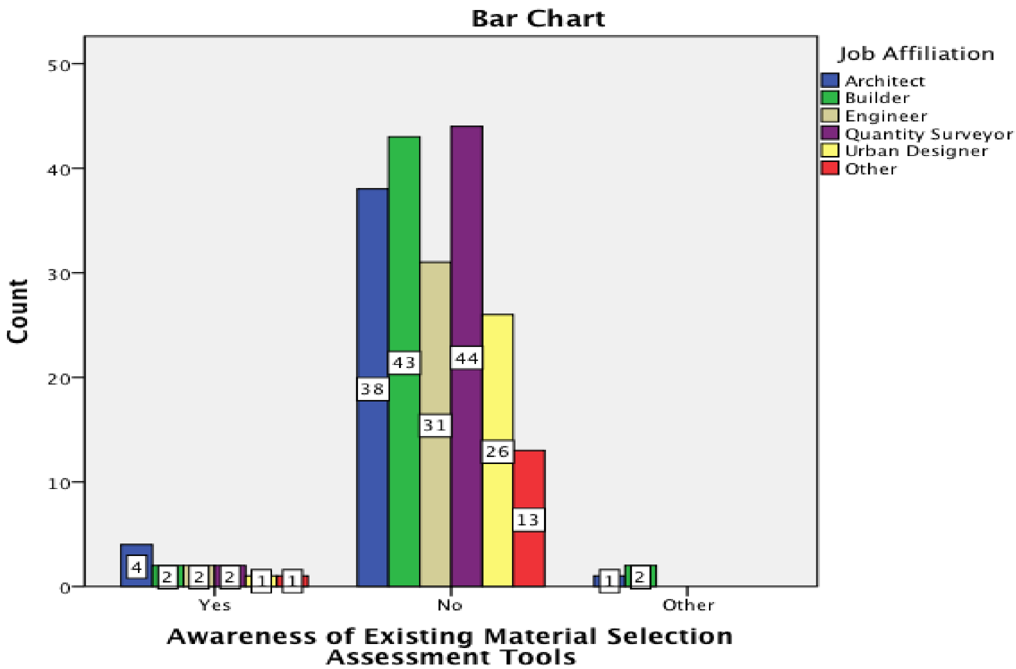



**Fig.7.** A graphical report on the available tools for evaluating low-cost green material

### 3.3 Decision Factors for Selecting Low-Cost Green Building Materials

One of the ultimate objectives of this research was to identify, define and classify the key decision selection factors set to assist design team members in their selection of low-cost green building materials during early design stages of housing projects. A wide scope literature review in section 1.2 including findings from the preliminary survey revealed that there was no comprehensive list of assessment factors developed specifically for assessing low-cost green building material selection process in housing design and construction.

As a result, a main survey consisting of a list of material-selection factors - (gleaned from the results of in-depth literature review, preliminary study and in-person interviews) was conducted to identify the key decision factors that would influence designers decisions in their choice of materials; to meet society's socio-economic goals and account for the cultural, political, and environmental impacts of low-cost green housing projects. Overall a total of 60 factors were identified and selected for low-cost green building material assessment, with 6 variables in socio-cultural criteria category, 18 variables in technical category, 10 variables in environmental category, 5 variables in economic/cost category, 12 variables in general/site category, and 12 variables in sensorial category (as shown in table 9). These were to be used as the basis to assess the building material options to know whether or not the material selection process is moving towards or away from green development goals. Foxon et al. [43] however, proposed that every comprehensive list of decision factors or variables must be able to meet the following requirements:

(1) Comprehensiveness: According to Foxon et al [43], the factors chosen should cover at most the six (6) categories of site, economic, environmental, socio-cultural, sensorial, and technical, in order to ensure that account is being taken of progress towards green development objectives. They noted that the factors chosen should have the ability to demonstrate movement towards green development goals.

(2) Applicability: Another point noted is that the identified factors or variables chosen should be applicable across the range of options under consideration. This is needed to ensure the comparability of the options.

(3) Transparency: Thirdly, the factors should be chosen in a transparent way, to understand the criteria used, and be able to propose any other criteria for consideration.

(4) Practicability: Finally, the set of factors chosen must form a practicable set for the purposes of the decision to be assessed. Considering the green development requirement goals for projects, a list of assessment factors was developed (see table 9).

Based on the list of the derived factors in table 8, a questionnaire survey was designed to investigate the perspective of building and design professionals in Nigeria, on the importance of the factors in selecting low-cost green building materials. Respondents were thus asked to rate the level of importance of the derived factors on a scale of 1–5, where 1 is ‘least important’, 2 ‘fairly important’, 3 ‘important’, 4 ‘very important’, and 5 ‘extremely important’. To ensure a better understanding of the factors and variables, the definition of each factor or variable was clarified and guidance on completion was given in the questionnaire. At the same time, respondents were encouraged to provide supplementary factors or variables that they consider to influence building material selection but were not listed in the provided questionnaire (refer to Appendix A for questionnaire details).

Several studies [45] have suggested that researchers check the underlying assumptions that apply to the data gathered before proceeding with any relevant statistical procedure. Orme & Buehler [44] noted that making any conclusion about the normality of the data as to whether or not a particular data follows a normal distribution (i.e., requires parametric statistical procedures) or non-normal distribution (i.e., requires non-parametric procedures) is a decision that must be considered to avoid violating the normality of the assumption. They noted that understanding the type of data gathered is very important in letting the analyst or researcher know the appropriate method for analysing the data collected, as failure to do so may result in conclusions that are unlikely to be valid.

Since most of the responses were based on both ratings measured on Likert scale, and open-ended responses, data obtained for this research conformed to both the ordinal and nominal scales. Given that the data would draw on views of experts with different perspectives, the possibility of a low response rate, and that the information gathered would contain both quantitative and qualitative data, there was a tendency that the sample distribution may be skewed [46]. Although the residuals of the dependent variables did not breach the normality assumptions, which normally would have required the use of parametric statistical approach, it was however, decided that the use of non-parametric statistical method would be appropriate for the data analysis considering that the study could likely create unpredictable distortions.

However, to address this uncertainty, check that any of the ‘assumptions’ incurred on individual tests were not violated, and provide conclusive evidence of what the underlying assumption held, a normality test (following the principles of the Kolmogorov-Smirnov and Shapiro-Wilk) was undertaken to assess whether or not the sample came from a population with a normal distribution. The Kolmogorov-Smirnov test, and Shapiro-Wilk test were adopted because of their simplicity, and to compensate for their individual weaknesses. The performances of the tests were evaluated under various spectrums of the sample distribution and size as shown in table 8.

**Table 8. Tests of normality results for sampling distribution**

| Tests of Normality | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Job Affiliation | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| Level of Experience | Architect | .198 | 43 | .000 | .914 | 43 | .003 |
| | Builder | .221 | 47 | .000 | .872 | 47 | .000 |
| | Engineer | .326 | 33 | .000 | .824 | 33 | .000 |
| | Quantity Surveyor | .271 | 46 | .000 | .878 | 46 | .000 |
| | Urban Designer | .232 | 27 | .001 | .797 | 27 | .000 |
| | Other | .214 | 14 | .003 | .895 | 14 | .006 |

a. Lilliefors Significance Correction

**Source**: analysis of surveyed data, 2013

The above table presents the results from two well-known tests of normality, namely the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test. Orme & Buehler [44] have argued that the Shapiro-Wilk Test is one of the most sensitive and appropriate tests for determining the assumptions of normality given that it can handle small sample sizes (< 50 samples), and sample sizes as large as 2000. For this reason, the Shapiro-Wilk test was considered the most relevant numerical means of assessing normality for the sample distribution.

Given that the result analysis of the P, Significant values for a confidence interval of 95% for both tests were < 0.05 as shown in the table 8, there was enough evidence to reject the claims or hypothesis that the sampled population was of a normal distribution. Therefore, this study applied the nonparametric tests to the data given that: 1] The data came from a non-normally distributed population; and 2] Non-parametric tests do not rely on whether or not the underlying data is to have any specific distribution [46].

The Statistical Package for the Social Sciences (SPSS V-20) and Microsoft Excel for Windows application software package were used for these processes. Section 3.3.1 confirms how the factors identified in table 9 were ranked, and grouped based on respondents' preferences, wishes and needs. The data has been analysed using the various forms of non-parametric techniques as justified and discussed above.

### 3.3.1 Development of the Framework for the Key Material Selection Factors

To identify the key influential factors needed to be incorporated in the material selection decision support system, respondents were asked to rate the validity of a range of sub-factors under each category of the parent groups on the frequency with which they are relevant in the selection of low-cost green building materials using a 5- point Likert scale (where "1= least important" to "5 =extremely important") as shown in Appendix A. Respondents were also asked to add and rate the relative importance of any other relevant factors not included in the list. The study results (in table 12) showed that a large number of factors or variables influence low-cost green material choice in housing construction, with cost and socio-cultural factors/variables remaining the overarching priorities, unlike in the preliminary study involving leading researchers in the developed regions, where environmental factors were rather considered as the most essential element in the material selection process.

The analysis in table 10 indicated that "Economic/Cost (RI=0.918)" and "Technical (RI=0.916)" factors were found to have the strongest influence on material choice(s). These were followed by "Socio-Cultural (RI=0.912)", "Environmental (RI=0.890)", "General/Site (RI=0.838)" and "Sensorial (RI=0.830)". Within the "Economic/Cost" category, key factors such as maintenance cost (RI=0.912) and "Labour/Installation cost" (RI=0.898) were commonly found to have more influence in the project's budget.

Surprisingly, result analysis based on the views from the participants indicated that factors such as "Capital cost (RI=0.891)" and "Material embodied energy cost

(RI=0.876)" were found to have the least impact on material choices. However, Sensorial and Site criteria were largely deemed to be less significant by many respondents, although clearly relevant within the material selection process. The Technical and Environmental aspects were also found to be prominent including recyclability and odour, as well as safety and health of end-users. In addition, the health implications of materials (particularly from an in-use perspective) emerged as a theme that many participants were concerned about. Issues such as end of life and resistance to scratch in the technical category are less comprehensively dealt with in the green building rating schemes and came up less frequently as a priority factor.

### 3.3.2 Factors Importance Rating

To ensure that the rating scale (1–5) for measuring the factors or variables yielded the same results, a reliability analysis using the internal consistency method was first conducted. Cronbach's alpha was calculated to test the internal consistency reliability of the generated scale examined (see table 11). The Cronbach's rule states that the closer alpha value for each factor is to 1, the greater the internal consistency reliability of the factor/criteria in the scale. Cronbach's formula is given as:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Here N is equal to the number of items, c-bar is the average inter-item covariance among the items and v-bar equals the average variance. (Note that a reliability coefficient of 0.70 or higher is considered "acceptable" in most social science research situations.)

**Table 10. Item Statistics**

| | Relative Index (RI) | Rank | Std. Deviation | N |
|---|---|---|---|---|
| F3: Economic or Cost Factors (C) | 0.918 | 1 | 1.340 | 210 |
| F5: Technical Factors (T) | 0.916 | 2 | 1.429 | 210 |
| F4: Socio-Cultural Factors (SC) | 0.912 | 3 | 1.385 | 210 |
| F2: Environmental and Health Factors (EH) | 0.890 | 4 | 1.331 | 210 |
| F1: General and Site Factors (GS) | 0.838 | 5 | 1.518 | 210 |
| F6: Sensorial Factors (SN) | 0.830 | 6 | 2.146 | 210 |

The value for Cronbach's alpha was estimated at 0.781, which was well above Cronbach's specification of 0.7, and thus, provided evidence for composite reliability. Therefore, the results shown in Tables 10 and 11 proved that all the six factors presented adequate reliability scores. This indicated that the six factors (i.e. GS-Site variables; EH-Environmental; EC-Economic; SC-Socio-Cultural; T-Technical; and SN-Sensorial extracted from the factor analysis could be used as a multidimensional measure for internal and external forces affecting designers' decisions relating to material-selection practices.

Cronbach's alpha values for sensorial, site, environmental, technical, economic, and socio-cultural criteria came up as 0.830, 0.838, 0.890, 0.916, 0.918, and 0.912, respectively. Given that the resultant alpha values for each factor category was greater than 0.7, there was strong evidence to show that all reliability coefficients of all the factors were acceptable, and internally consistent.

**Table 11.** Reliability Statistics

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|---|---|
| 0.781 | 0.789 | 6 |

In order to identify the relative importance of the sub-categorical factors or variables based on the survey data, ranking analysis was performed. The Relative index analysis was used to rank the sub-factors according to their relative importance as shown in table 14.

Five important levels were transformed from Relative Index values: Highly Significant Level (H) (0.8≤RI≤1), High–Medium Level (H–M) (0.6≤RI<0.8), Medium Level (M) (0.4≤RI<0.6), Medium–Low Level (M–L) (0.2≤RI<0.4), and Low Level (L) (0≤RI<0.2). Recognizing that the derived factors and variables were likely to be inter-related through an underlying structure of primary factors, and to obtain a concise list of decision factors under these circumstances, considering that the nature of the factor to be extracted was unknown, an exploratory factor analysis- was undertaken using the maximum likelihood approach as the factor analysis extraction method.

Exploratory or common factor analysis is an effective statistical method used to describe variability among observed variables in terms of fewer unobserved variables (latent variables) called “Latent factors” [36]. In other words, it reduces variables with similar characteristics together into a smaller set of correlated or uncorrelated dimensions factors, which are capable of explaining the observed variance in the larger number of variables [35, 36]. Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to examine the sampling adequacy, ensuring that factor analysis was going to be appropriate (see table 15). Afterwards, the maximum likelihood factor analysis method was also used to drive the minimum number of factors and explain the maximum portion of variance in the original variable. It was chosen to extract the latent factors based on the criterion that the associated eigenvalue should be greater than 1 [35, 36].

However, Kline [35] argued that with a sample size of at least 100 participants or above, loadings of 0.30 or higher could be considered significant, or at least salient (see discussion in Kline, [36], pp. 52-53). This meant that variables with factor loadings of 0.30 or higher were considered significant, while variables that loaded near 0 were clearly considered as unimportant. However, given that a broad consensus of recent studies in the literature [47] confirmed that the Eigen value of 1 was among the least accurate methods for selecting the number of factors to retain, + 0.30 — was classified as the minimum consideration level and statistically significant factor loading for the selected factors in this study, since attaining a value of 0.8 or greater was unlikely to occur in real data [48].

To interpret the relationship between the observed variables and to identify the latent factors more easily given the sample size of 210, the most ideal and more robust rotation method, “direct oblimin rotation” was selected since oblique rotation produced results nearly identical to the orthogonal rotation when using the same extraction method, as evident in tables 12 and 13 [47, 48].

However, to ascertain whether or not “direct oblimin” was the ideal rotation method, or a more accurate, and perhaps more reproducible solution for simplifying and clarifying the data structure, factor analyses- using both “varimax” and “oblique” rotation methods (as shown in tables 12 and 13), were conducted to check whether or not the correlation matrix produced results of values that were truly uncorrelated ($+0.1 \leq X < +0.3$) or significantly correlated ($+0.3 \leq X \leq 1$). Kline [35] argued that the choice of rotation (whether orthogonal or oblique) could make little difference, particularly where the factors are markedly correlated (as demonstrated in tables 12 and 13). The results of the analysis (shown in tables 12 and 13) indicated that the correlations for both varimax and oblique rotations exceeded +0.32, showing a 10% overlap in variance among factors, which was enough to warrant oblique rotation.

Therefore, based on the result of the analysis, and given that oblique rotation will easily reproduce an orthogonal solution but not vice versa (Costello & Osborne, 2005), the oblique rotation was recommend as ideal for this research. Table 14 shows the ranking results for each sub-factor under each factor category derived using the relative index analysis equation in section 3.3.2. The value of KMO came up to be 0.862, which is well above Kaiser’s (1974) specification of 0.5. Therefore, the results shown in table 14 proved that all the fifty-five (55) factors were adequate to undertake any material selection process. The final ranked results of the relative index factor analysis are shown below.

**Table 12.** Correlation Matrix Using “Varimax/Orthogonal” Rotation

| | | GS1 | GS2 | GS3 | GS4 | GS5 | GS6 | GS7 | GS8 | GS9 | GS10 | GS11 | GS12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correlation | GS1 | 1.000 | .622 | .244 | .292 | .295 | .372 | .310 | .409 | .397 | .372 | .289 | .321 |
| | GS2 | .622 | 1.000 | .446 | .486 | .449 | .497 | .537 | .464 | .487 | .465 | .282 | .389 |
| | GS3 | .244 | .446 | 1.000 | .523 | .436 | .325 | .310 | .399 | .346 | .299 | .286 | .312 |
| | GS4 | .292 | .486 | .523 | 1.000 | .714 | .559 | .559 | .494 | .488 | .393 | .435 | .458 |
| | GS5 | .295 | .449 | .436 | .714 | 1.000 | .578 | .621 | .608 | .659 | .420 | .566 | .527 |
| | GS6 | .372 | .497 | .325 | .559 | .578 | 1.000 | .641 | .531 | .586 | .480 | .529 | .561 |
| | GS7 | .310 | .537 | .310 | .559 | .621 | .641 | 1.000 | .549 | .615 | .581 | .434 | .529 |
| | GS8 | .409 | .464 | .399 | .494 | .608 | .531 | .549 | 1.000 | .579 | .443 | .605 | .577 |
| | GS9 | .397 | .487 | .346 | .488 | .659 | .586 | .615 | .579 | 1.000 | .604 | .526 | .535 |
| | GS10 | .372 | .465 | .299 | .393 | .420 | .480 | .581 | .443 | .604 | 1.000 | .501 | .470 |
| | GS11 | .289 | .282 | .286 | .435 | .566 | .529 | .434 | .605 | .526 | .501 | 1.000 | .786 |
| | GS12 | .321 | .389 | .312 | .458 | .527 | .561 | .529 | .577 | .535 | .470 | .786 | 1.000 |

**Table 13. Correlation Matrix Using "Direct Oblimin/Oblique" Rotation**

| | | GS1 | GS2 | GS3 | GS4 | GS5 | GS6 | GS7 | GS8 | GS9 | GS10 | GS11 | GS12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Correlation | GS1 | 1.000 | .622 | .244 | .292 | .295 | .372 | .310 | .409 | .397 | .372 | .289 | .321 |
| | GS2 | .622 | 1.000 | .446 | .486 | .449 | .497 | .537 | .464 | .487 | .465 | .282 | .389 |
| | GS3 | .244 | .446 | 1.000 | .523 | .436 | .325 | .310 | .399 | .346 | .299 | .286 | .312 |
| | GS4 | .292 | .486 | .523 | 1.000 | .714 | .559 | .559 | .494 | .488 | .393 | .435 | .458 |
| | GS5 | .295 | .449 | .436 | .714 | 1.000 | .578 | .621 | .608 | .659 | .420 | .566 | .527 |
| | GS6 | .372 | .497 | .325 | .559 | .578 | 1.000 | .641 | .531 | .586 | .480 | .529 | .561 |
| | GS7 | .310 | .537 | .310 | .559 | .621 | .641 | 1.000 | .549 | .615 | .581 | .434 | .529 |
| | GS8 | .409 | .464 | .399 | .494 | .608 | .531 | .549 | 1.000 | .579 | .443 | .605 | .577 |
| | GS9 | .397 | .487 | .346 | .488 | .659 | .586 | .615 | .579 | 1.000 | .604 | .526 | .535 |
| | GS10 | .372 | .465 | .299 | .393 | .420 | .480 | .581 | .443 | .604 | 1.000 | .501 | .470 |
| | GS11 | .289 | .282 | .286 | .435 | .566 | .529 | .434 | .605 | .526 | .501 | 1.000 | .786 |
| | GS12 | .321 | .389 | .312 | .458 | .527 | .561 | .529 | .577 | .535 | .470 | .786 | 1.000 |

From the results of the analysis shown in table 14, forty factors were identified under the "Highly significant" level for evaluating low-cost green building materials with an RI value ranging from 0.952 to 0.806, with "life expectancy (T15)" topping the list of this group and "Thickness of material" occupying the least position. Fifteen factors where grouped under the "High-Medium" level.

"Life Expectancy" was ranked as the first priority in the technical category with an RI value of 0.952, and it was also the highest among all factors and was highlighted at "High" importance level. "Resistance to fire" was also rated high in importance among the selection factors. "Maintenance Cost" was ranked third in importance. It was clear from this research that there is a perception of ambiguity surrounding the long-term maintenance of low-cost green building materials. This is not entirely any surprise given that maintenance free buildings are increasingly sought after by clients, anxious to minimise the running costs associated with buildings. "Life-cycle cost" has been, and will continue to be, major concerns for building designers, as well as important traditional performance measure. Among the top 20 ranking factors, it was observed that only one factor from the environmental category out of the list was ranked high among the selection factors. This again suggests that environmental issues within the context of the developing countries are not strongly considered despite the high environmental awareness exhibited by design and building professionals in developed regions.

**Table 14. Ranked decision factors for low-cost green building material selection**

| Material selection factors/variables | Valid percentage of score (%) | | | | | Relative Index Scores | Ranking by Category | Overall Ranking | Importance Level |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | | | |
| **GENERAL/SITE FACTORS** | | | | | | | | | |
| GS2-Material Availability | 1.6 | 2.9 | 17.9 | 50.5 | 27.0 | 0.795 | 1 | 35 | H-M |
| GS1-Geographic Location of Building Site | 2.1 | 2.6 | 19.3 | 51.2 | 24.3 | 0.773 | 2 | 38 | H-M |
| GS10-Building and Space Usage | 0.8 | 5.5 | 21.4 | 52.2 | 20.1 | 0.764 | 3 | 39 | H-M |
| GS9-Knowledge Base in Construction | 1.1 | 7.4 | 33.2 | 42.1 | 16.3 | 0.731 | 4 | 41 | H-M |
| GS6- Natural Disasters Common to the Site | 1.4 | 11.3 | 27.7 | 39.5 | 20.1 | 0.726 | 5 | 42 | H-M |
| GS7-The Type of Building Material(s) | 1.8 | 8.2 | 36.3 | 37.0 | 16.7 | 0.712 | 6 | 43 | H-M |
| GS4-Building Regulation and Certification for Use | 2.7 | 10.8 | 33.5 | 36.1 | 16.9 | 0.709 | 7 | 44 | H-M |
| GS5-Design Concept | 0.8 | 15.2 | 35.5 | 13.1 | 15.4 | 0.702 | 8 | 45 | H-M |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GS12-Spatial Scale: Building Size and Mass | 4.5 | 17.8 | 30.3 | 28.4 | 19.0 | 0.675 | 9 | 47 | H-M |
| GS8-Project Site Geometry/Setting/Condition | 1.4 | 17.5 | 38.1 | 33.3 | 9.7 | 0.663 | 10 | 46 | H-M |
| GS3-Distance | 5.6 | 17.9 | 32.1 | 31.3 | 13.1 | 0.653 | 11 | 47 | H-M |
| GS11-Building Orientation | 4.6 | 21.9 | 29.5 | 28.4 | 15.6 | 0.652 | 12 | 48 | H-M |
| **ENVIRONMENTAL/HEALTH FACTORS** | | | | | | | | | |
| EH3-Safety and Health of End-users | 0.5 | 2.5 | 3.1 | 46.2 | 47.1 | 0.876 | 1 | 17 | H |
| EH6-The Climatic Condition of the Region | 0.3 | 2.0 | 5.3 | 49.2 | 42.6 | 0.860 | 2 | 23 | H |
| EH7-Material Environmental Impact | 0.7 | 2.6 | 6.0 | 49.0 | 41.1 | 0.850 | 3 | 27 | H |
| EH2-Level of Carbon Emissions and Toxicity | 0.3 | 4.9 | 5.6 | 49.2 | 39.5 | 0.849 | 4 | 28 | H |
| EH4-Habitat Disruption: Ozone Depletion Potential | 1.6 | 1.8 | 9.6 | 52.0 | 34.4 | 0.830 | 5 | 30 | H |
| EH1-Environmental Statutory Compliance | 2.1 | 6.3 | 9.7 | 42.7 | 38.7 | 0.820 | 6 | 32 | H |
| EH5-The Amount of Pesticide Treatment Required | 3.0 | 2.9 | 8.2 | 52.5 | 32.9 | 0.813 | 7 | 33 | H |
| **ECONOMIC/COST FACTORS** | | | | | | | | | |
| C4-Maintenance or Replacement Cost | 0.5 | 1.8 | 5.9 | 20.2 | 71.6 | 0.912 | 1 | 3 | H |
| C5-Labour or Installation Cost | 0.5 | 2.0 | 5.2 | 27.3 | 64.9 | 0.898 | 2 | 8 | H |
| C1-Life Cycle Cost | 4.5 | 3.0 | 26.1 | 66.4 | 99.6 | 0.897 | 3 | 9 | H |
| C3-Capital Cost (Economic Status of the Client) | 0.8 | 3.6 | 7.1 | 22.0 | 66.5 | 0.891 | 4 | 10 | H |
| C2-Material Embodied Energy Cost | 0.5 | 5.6 | 4.0 | 25.4 | 64.5 | 0.876 | 5 | 17 | H |
| **SOCIO-CULTURAL FACTORS** | | | | | | | | | |
| SC5-Local Knowledge of the Custom | 0.5 | 3.7 | 5.5 | 32.0 | 57.8 | 0.884 | 1 | 13 | H |
| SC1-Material Compatibility with Traditions | 1.0 | 4.5 | 2.7 | 33.9 | 57.4 | 0.879 | 2 | 16 | H |
| SC6-Compatibility with Client's Preference | 0.4 | 2.9 | 3.7 | 36.2 | 56.2 | 0.876 | 3 | 17 | H |
| SC2-Material Compatibility with Regional Settings | 0.5 | 2.5 | 6.4 | 32.7 | 57.4 | 0.875 | 4 | 18 | H |
| SC3-Cultural Restriction(s) on Usury | 1.0 | 3.3 | 10.8 | 31.1 | 53.3 | 0.851 | 5 | 26 | H |
| SC4-Family Structure: Size of Family Unit | 3.0 | 21.0 | 15.7 | 19.8 | 39.9 | 0.737 | 6 | 40 | H-M |
| **TECHNICAL FACTORS** | | | | | | | | | |
| T15-Life Expectancy | 1.1 | 0.3 | 4.2 | 26.9 | 66.8 | 0.952 | 1 | 1 | H |
| T7-Resistance to Fire | 0.3 | 1.2 | 4.8 | 28.8 | 64.9 | 0.919 | 2 | 2 | H |
| T9-Resistance to Moisture | 0.5 | 1.5 | 3.6 | 24.7 | 69.7 | 0.911 | 3 | 4 | H |
| T11-Resistance to Weather | 0.3 | 1.0 | 4.8 | 25.0 | 69.0 | 0.911 | 3 | 4 | H |
| T5-Availability of the Technical Skills | 0.5 | 1.5 | 4.5 | 28.4 | 65.0 | 0.905 | 4 | 5 | H |
| T8-Resistance to Heat | 0.3 | 1.2 | 4.8 | 28.8 | 64.9 | 0.904 | 5 | 6 | H |
| T13-Resistance to Decay | 0.3 | 1.5 | 5.7 | 25.7 | 66.8 | 0.902 | 6 | 7 | H |
| T3-Level of Maintenance Requirement | 0.5 | 1.8 | 4.2 | 30.6 | 62.8 | 0.897 | 7 | 9 | H |
| T6-Ease and Speed of Method fixing | 0.5 | 2.2 | 7.5 | 29.4 | 60.4 | 0.883 | 8 | 14 | H |
| T4-Ability to Tolerate Expansion and Contraction | 8.3 | 2.0 | 6.7 | 32.9 | 50.0 | 0.882 | 9 | 15 | H |
| T1-Recyclability and Reusability | 2.2 | 2.2 | 5.2 | 31.4 | 59.0 | 0.868 | 10 | 20 | H |
| T12-Resistance to Chemicals | 0.1 | 1.9 | 13.1 | 27.9 | 57.0 | 0.865 | 11 | 21 | H |
| T2-Ease to Remove and Reaffix | 0.7 | 2.2 | 6.8 | 36.5 | 53.8 | 0.864 | 12 | 22 | H |
| T14-Weight and Mass of the Material | 0.3 | 2.6 | 12.4 | 29.2 | 55.5 | 0.856 | 13 | 24 | H |
| T10-Resistance to Scratch | 1.1 | 3.1 | 11.6 | 27.0 | 57.1 | 0.852 | 14 | 25 | H |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **SENSORIAL FACTORS** | | | | | | | | | |
| SN4-Temperature | 0.4 | 0.4 | 3.1 | 44.8 | 51.0 | 0.887 | 1 | 11 | H |
| SN6-Odour | 0.4 | 1.2 | 5.6 | 37.7 | 54.8 | 0.886 | 2 | 12 | H |
| SN10-Lighting Effect | 1.4 | 8.9 | 17.5 | 33.5 | 37.8 | 0.886 | 2 | 12 | H |
| SN5-Acoustics | 0.7 | 0.5 | 5.6 | 42.2 | 50.7 | 0.876 | 3 | 17 | H |
| SN1-Aesthetics or Visual density | 0.3 | 1.4 | 6.0 | 46.0 | 46.0 | 0.870 | 4 | 19 | H |
| SN2-Texture | 3.1 | 10.0 | 45.2 | 41.4 | 0.3 | 0.839 | 5 | 29 | H |
| SN3-Colour | 0.3 | 3.0 | 12.2 | 46.0 | 38.2 | 0.823 | 6 | 31 | H |
| SN7-Thickness/Thinness | 1.5 | 8.9 | 13.3 | 35.5 | 40.6 | 0.806 | 7 | 34 | H |
| SN9-Hardness | 1.5 | 8.9 | 18.9 | 30.6 | 39.9 | 0.790 | 8 | 36 | H-M |
| SN8-Glossiness/Fineness | 2.6 | 9.2 | 18.7 | 33.1 | 36.2 | 0.774 | 9 | 37 | H-M |

**Source:** Analysis of surveyed data, 2013

**Table 15. Kaiser-Meyer-Olkin and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.862 |
| | Approx. Chi-Square | 42121.213 |
| Bartlett's Test of Sphericity | df | 1485 |
| | Sig. | 0.000 |

This finding also corroborates the initial observations of various studies [37, 38] repeatedly highlighted in the background and literature studies. They suggest that the problems within the developing regions are characterised by mainly social and economic issues, unlike the developed regions where the scale of social issues and lack of access to basic resources are simply not much of a problem as it is in the developing world

From table 14, a total of 15 factors, consisting of 12 site factors, 1 socio-cultural factor, and 2 sensorial factors, were recorded to have "High–Medium" importance levels. Although these 15 variables were in the same importance level category, the "building orientation" factor within the "general/site category" (average RI=0.652) was considered to be the least important variable compared to the factor "Glossiness" under the "sensorial category" (with an average RI=0.774), and "material availability" still under the "general/site category" (with an average RI=0.795). However, it should be noted that site factor account for 75% in the "High-Medium" importance level. The result is an example of evidence pointing to the trend that environmental and perhaps site issues are no longer considered as the most important factors for material selection in housing projects, especially within the context of the less developed regions.

Some factors in the three categories were ranked relatively higher in the "High– Medium" level. For example, "material availability (GS1)" was rated as first in the general/site subcategory, and ranked as thirty-fifth in the overall ranking with an RI value of 0.795. An interesting observation from the results shown in table 5.10 is that none of the criteria fell under the medium and other lower importance level. This clearly shows how important the factors are to building designers in evaluating low-cost green building materials. All factors were rated with "High" or "High– Medium" importance levels. However factors such as Compatibility with other materials, Skills availability, and UV resistance fell with in the medium-low level. The findings of the analysis asserted that the criteria with medium or low RI does not mean they are not important for selecting materials, but rather created an opportunity to highlight the relative importance of the key criteria from their vantage points. The following shows a framework consisting of the key factors in their order of importance:

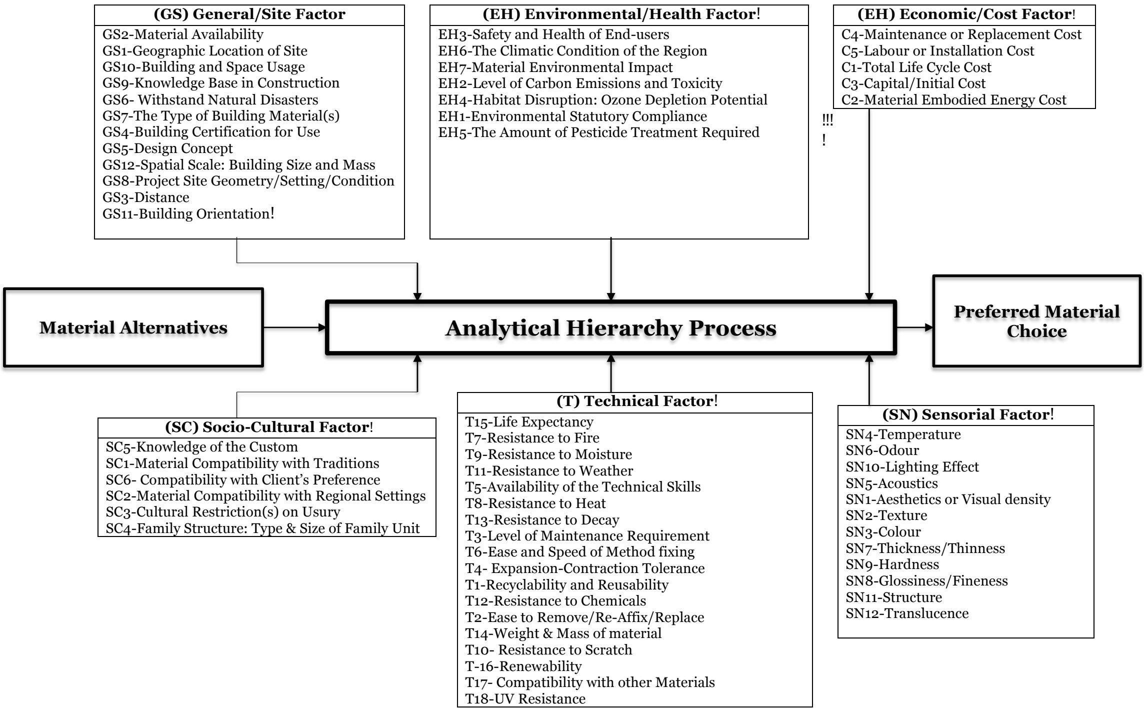



**Fig. 8.** Methodological framework for the analysed-ranked factors

### 3.3.3 Factor analysis for Sub-Categorical Factors

Given that the reliability test proved to be consistent in the measuring instrument as proven by Cronbach's alpha score of 0.781 (in table 11)**,** a factor analysis was performed using SPSS v.20 to: 1] obtain a concise list of the key influential factors needed to aid design and building professionals in making fully informed decisions when making choices from a range of possibilities at the design stage, 2] determine the optimal dimensions of the materials that were retainable, 3] extract significant factor loadings of each variable and 4] identify the latent factors within each category. According to Hutcheson & Sofroniou [49], a KMO value is regarded as ideal if it falls within the range of 0.7 and above. They argued that values closer to 1 indicate that patterns of correlation are relatively compact and therefore, should yield reliable factors that are able to assess low-cost green building materials and components. They recommended that values between 0.5 and 0.7 are mediocre, values between 0.7 and 0.8 are good, values between 0.8 and 0.9 are excellent and values above 0.9 are superb. They further argued that for factor analysis to produce efficient results there must be strong and close relationships between variables, and the test analysis must exhibit a significant value of $p<0.05$. The following sections present the results of the factor analysis for the various categories of the material-selection factors.

#### 3.3.3.1 General/site category

For the "General/Site" category, the analysis results showed a Kaiser– Meyer–Olkin's (KMO) measure of sampling adequacy score of 0.883 (much larger than 0.5), falling into the range of 0.8-0.9. Therefore, the value of 0.883 suggests that the sample was very much acceptable for factor analysis, as recommended by Hutcheson & Sofroniou [49].

The Bartlett Test of Sphericity was 1468.871 and the associated significance level of 0.000 ($p<0.001$), indicated that the test was highly significant and that the population correlation matrix was not an identity matrix. Both tests showed that the obtained data in the general/site category supported the use of factor analysis, which was grouped into smaller sets of underlying factors. Using maximum likelihood analysis, the factor analysis extracted two latent factors under genera/site category, namely Factor GS11: building orientation; and Factor GS12: Spatial scale with their respective Eigen values greater than 1.0. Combined, the two variables accounted for 55.6% of the total variance. The rotated factor-loading matrix results based on the direct oblimin rotation for the two latent factors are shown in Table 16,

**Table 16.** Factor loadings for general-site factors after direct oblimin rotation

| Observed general/site variable | Latent general/site factors | |
|---|---|---|
| | 1 | 2 |
| GS11: Building Orientation | 0.997 | |
| GS12 Spatial Scale: Building Size and Mass | 0.623 | |
| GS7: The Type of Building Material(s) | | 0.816 |
| GS2: Material Availability | | 0.809 |
| GS4: Building Regulation and Certification for Use | | 0.721 |
| GS9: Knowledge Base in Construction | | 0.699 |
| GS5: Design Concept | | 0.683 |
| GS6: The Type(s) of Natural Disasters Common to the Site | | 0.666 |
| GS8: Project Site Geometry/Setting/Condition | | 0.538 |
| GS3: Distance | | 0.533 |
| GS10: Building and Space Usage | | 0.530 |
| GS1: Geographic Location of Building Site | | 0.518 |
| Eigenvalues | 3.766 | 2.904 |
| Percentage of variance (%) | 31.379 | 24.203 |
| Cumulative of variance (%) | 31.379 | 55.582 |

The factor matrix as shown in table 16 identifies the relationship between the observed variables and the latent factors. The higher the absolute value of the loading, the more the latent factor contributes to the observed variable. Small factor loadings with absolute values less than 0.3 were suppressed to help simplify table 16. Further interpretation(s), conceptualised the two latent factors under the general/site category as: "building site analysis factors" since they both, relate to the site dimension. Similar factor analyses were also performed to identify the underlying structures for other factor categories as discussed in the following sections.

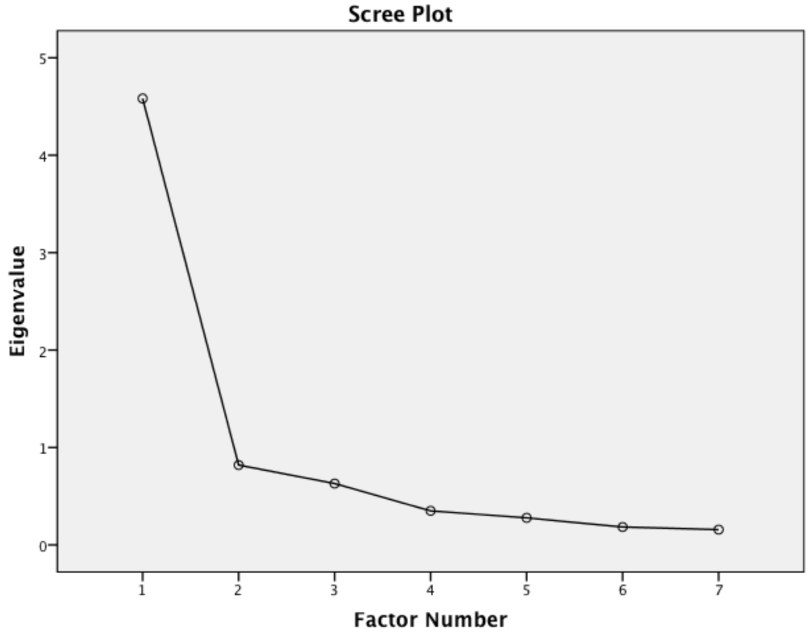
**3.3.3.2 Environmental/health category**

The analysis performed on the Environmental/Health category produced a KMO measure of sampling adequacy test score of (0.867) and Bartlett's Sphericity of (1027.062), with an associated significant score of (p=0.000). The results indicated that factor analysis was also appropriate for this category. However, only one factor under environmental/health category was extracted from the factor analysis using both the scree plot diagram (figure 9) and the total variance (table 17). The percentage of variance attributable to each factor and the cumulative variance values is shown in Table 17. From table 17, it can be seen that only one factor accounted for 60.2% of the total variance

**Table 17**. Factor loadings for environmental/health factors after direct oblimin rotation

| Observed environmental/health variable | Latent environmental/health factors | |
|---|---|---|
| | 1 | 2 |
| EH4: Habitat Disruption: Ozone Depletion Potential | 0.851 | |
| EH7: Material Environmental Impact | 0.836 | |
| EH3: Safety and Health of End-users | 0.829 | |
| EH6: The Climatic Condition of the Region | 0.801 | |
| EH2: Level of Carbon Emissions and Toxicity | 0.787 | |
| EH5: The Amount of Pesticide Treatment Required | 0.736 | |
| EH1: Environmental Statutory Compliance | 0.549 | |
| Eigenvalues | 4.215 | - |
| Percentage of variance (%) | 60.217 | - |
| Cumulative of variance (%) | 60.217 | - |

**Fig. 9.** Scree Plot for environmental/health factors




### 3.3.3.3 Economic/cost category

In the economic/cost category, the results for the factor analysis showed that the KMO measure was 0.794 and the Bartlett's test (p=0.000) was also significant, which indicated that the factor analysis was also appropriate in identifying the underlying structure of the economic category. This means that the test is highly significant and that the population correlation matrix was not an identity matrix. The results of the analysis are presented in table 18. Just one factor named Factor C4: Maintenance and replacement cost was extracted, explaining 61.1% of the total variance.

**Table 18:** Factor loadings for economic/cost factors after direct oblimin rotation

| Observed economic/cost variable | Latent economic/cost factors | |
|---|---|---|
| | 1 | 2 |
| C4: Maintenance or Replacement Cost | 0.938 | |
| C5: Labour or Installation Cost | 0.861 | |
| C3: Capital Cost (Economic Status of the Client) | 0.793 | |
| C1: Life Cycle Cost | 0.714 | |
| C2: Material Embodied Energy Cost | 0.544 | |
| Eigenvalues | 3.054 | - |
| Percentage of variance (%) | 61.078 | - |
| Cumulative of variance | 61.078 | - |

### 3.3.3.4 Socio-cultural category

Similarly, the results for the exploratory or common factor analysis in the social category produced a KMO measure of 0.831 and a Bartlett's test of Sphericity value of 626.700, indicating that the test is highly significant and that the population correlation matrix was not an identity matrix. A significant value of (p=0.000) indicated that factor analysis was also suitable in identifying the underlying structure of the factors within the socio-cultural category. However, just as in the cases of the previous categories using both the scree plot diagram and the total variance table in Appendix H, only one factor (factor 6: material compatibility with regional settings) was extracted, explaining 51.5% of the total variance of the six socio-cultural criteria The results of the analysis is presented in table 19.

**Table 19.** Factor loadings for socio-cultural factors after direct oblimin rotation

| Observed socio-cultural variable | Latent socio-cultural factor |
|---|---|
| | 1 |
| SC2: Material Compatibility with Regional Settings | 0.913 |
| SC3: Cultural Restriction(s) on Usury | 0.833 |
| SC1: Material Compatibility with Cultural Traditions | 0.826 |
| SC6: Material Compatibility with Cultural Traditions | 0.695 |
| SC5: Local Knowledge of the Custom & Lifestyle | 0.505 |
| SC4: Family Structure: Type & Size of Family Unit | 0.378 |
| Eigenvalues | 3.090 |
| Percentage of variance (%) | 51.498 |
| Cumulative of variance (%) | 51.498 |

### 3.3.3.5 Technical category

For the technical category, the results for the factor analysis showed a KMO measure of 0.902 and the Bartlett's test of Sphericity value of 2848.547, with significant p value=0.000, indicating that the test was highly significant and that the population correlation matrix was not an identity matrix. This indicated that the factor analysis was also appropriate in identifying the underlying structure of the technical category. Three factors under technical category, namely Factor T9: Resistance to moisture; Factor T11: Resistance to weather; and Factor T7: Resistance to fire were extracted from the factor analysis, explaining 67.8% of the total variance after rotation. The three group of factors 1, 2 & 3 were conceptualised as “Performance”, “Efficiency”, & “Specialty”. The results of the analysis are presented in table 20.

**Table 20.** Factor loadings for technical factors after direct oblimin rotation

| Observed technical variable | Latent technical factor | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| T9: Resistance to Moisture | 0.946 | | |
| T11: Resistance to Weather | 0.856 | | |
| T7: Resistance to Fire | 0.851 | | |
| T8: Resistance to Heat | 0.812 | | |
| T5: Availability of the Technical Skills | 0.655 | | |
| T3: Level of Maintenance Requirement | 0.589 | | |
| T15: Life Expectancy | 0.530 | | . |
| T12: Resistance to Chemicals | | 0.875 | |
| T10: Resistance to Scratch | | 0.741 | |
| T14: Weight and Mass of the Material | | 0.528 | |
| T13: Resistance to Decay | | 0.487 | |
| T2: Ease to Remove and Reaffix | | | 0.779 |
| T4: Ability to Tolerate Expansion and Contraction | | | 0.462 |
| T6: Ease and Speed of Method fixing | | | 0.456 |
| T1: Recyclability and Reusability | | | 0.448 |
| Eigenvalues | 8.561 | 0.877 | 0.737 |
| Percentage of variance (%) | 57.073 | 5.849 | 4.916 |
| Cumulative of variance (%) | 57.073 | 62.921 | 67.837 |

### 3.3.3.6 Sensorial Category

In the sensorial category, the results for the exploratory factor analysis showed that the KMO measure was 0.891 and the Bartlett's test of Sphericity score of 1705.393, with a significant value of (p=0.000), which revealed that the factor analysis was also appropriate in identifying the underlying structure of the sensorial category. In this category, two factors named Factor SN4: Temperature and Factor SN6: Odour were extracted, both accounting for 66.19% of the total variance. Thus, SN5, SN4, SN6, SN2, SN3, and SN1, constituted the first factor group. The study conceptualised this factor group as “Receptive/Emotive” and SN9, SN8, SN7, and SN10 constituted the second factor and this was conceptualized as “Intrinsic/Sensitivity qualities of product”. Along with rotated factor-loading matrix, the percentage of variance attributable to each factor and the cumulative variance values are shown in table 21. From the table, it can be seen that the two factors accounted for 66.1% of the total variance.

**Table 21.** Factor loadings for sensorial factors after direct oblimin rotation

| Observed sensorial variable | Latent sensorial factor | |
|---|---|---|
| | 1 | 2 |
| SN5: Acoustics | 1.017 | |
| SN4: Temperature | 0.965 | |
| SN6: Odour | 0.775 | . |
| SN2: Texture | 0.596 | |
| SN3: Colour | 0.453 | . |
| SN1: Aesthetics or Visual density | 0.442 | |
| SN9: Hardness | | 0.935 |
| SN8: Glossiness/Fineness | | 0.891 |
| SN7: Thickness/Thinness | | 0.801 |
| SN10: Lighting Effect | | 0.223 |
| Eigenvalues | 5.834 | 0.785 |
| Percentage of variance (%) | 58.336 | 7.853 |
| Cumulative of variance (%) | 58.336 | 66.189 |

In summary, a total of ten latent factors resulting from the overall analysis were extracted to present the underlying structure of the variables used for selecting low-cost green building material for building projects, at the design stage. Two factors were identified under the general/site category; one factor under the environmental/health category; one factor each for both the economic and socio-cultural categories; three factors for the Technical dimension, and two factors for the sensorial group. However, as Kline [35] argued, factors with loadings of 0.30 or higher were considered significant, or at least salient in this study, so that the model constituted of all those variables that had factor loadings greater than or equal to 0.3 after rotation.

### 3.4 General Knowledge on Low-Cost Green materials

The final survey questions required participants to comment on what could be done to facilitate the wider-scale use of low-cost green materials in the housing industry, and precautionary measures that should be undertaken to encourage greater industry acceptance of such materials in mainstream housing. The second question of the final set of questions bordered on issues associated with the integration of the proposed material selection decision support tool in design practice, aiming to give participants the opportunity to share or clarify their opinions regarding the proposed MSDSS model. The following sections present full analyses of respondents' view(s) of the final set of questions.

#### 3.4.1 Measures in Promoting Greater Use of Low-Cost Green Building Materials

The study identified some potential measures that could be adhered to, or undertaken to encourage greater industry acceptance of low-cost green building materials. Respondents were provided with a list of potential measures that could be undertaken to encourage greater use of low-cost green materials and components. They were asked to rank on a 10-point scale from (1) "least relevant" to (10) "extremely relevant", the level of relevance of each measure as it will affect, influence or facilitate greater patronage of such materials in the Nigerian housing industry. The aim of this question was to identify the significant measures that could be adopted to encourage greater use of low-cost green building materials in the Nigerian housing construction sector.

The importance accorded to "Provision of readily available information specific to the informed selection of low-cost green materials" was rated highest with a relative index of (RI=0.929). This was followed by "Subsidising low-cost green building materials and components" with a relative index score of (RI=0.888). "Government's adequate funding of research to boost production and wide-scale use" ranked third with a relative index of (RI=0.874). "Setting up workshops to spread awareness to building professionals & clients of their potential economic, environmental and health benefits" placed fourth on the list (RI=0.857), while "Strong mainstreaming initiatives, and effective implementation of policies that encourage their wider scale use" trailing the fifth position with a relative index of (RI=0.839): all making the top five of the potential measures as shown in table 22. Figure 11 and 12 compares the different preferences of all measures. Summary of the top three potential measures are discussed in the following order in sections 3.4.1.1- 3.4.1.3.

**Table 22.** Potential measures that could influence greater use of low-cost green materials

| Measures | Relative Index (RI) | Rank |
|---|---|---|
| M1: Provision of Adequate Information on Low-Cost Green Materials | 0.929 | 1 |
| M10: Adequate Research Funding | 0.888 | 2 |
| M2: Subsidising Low-Cost Green Building Materials | 0.874 | 3 |
| M5: Setting up Workshops to Sensitise Building Professionals & Clients | 0.857 | 4 |
| M6: Effective Implementation of Policies | 0.839 | 5 |
| M7: Stringent Measures for Corruption in the Construction Industry | 0.787 | 6 |
| M9: Import Restriction of Foreign Building Materials | 0.751 | 7 |
| M4: Stringent Building Regulation Standards | 0.741 | 8 |
| M8: Diversification of Production Technology | 0.591 | 9 |
| M3: Use of Highly Mechanised Production System | 0.515 | 10 |

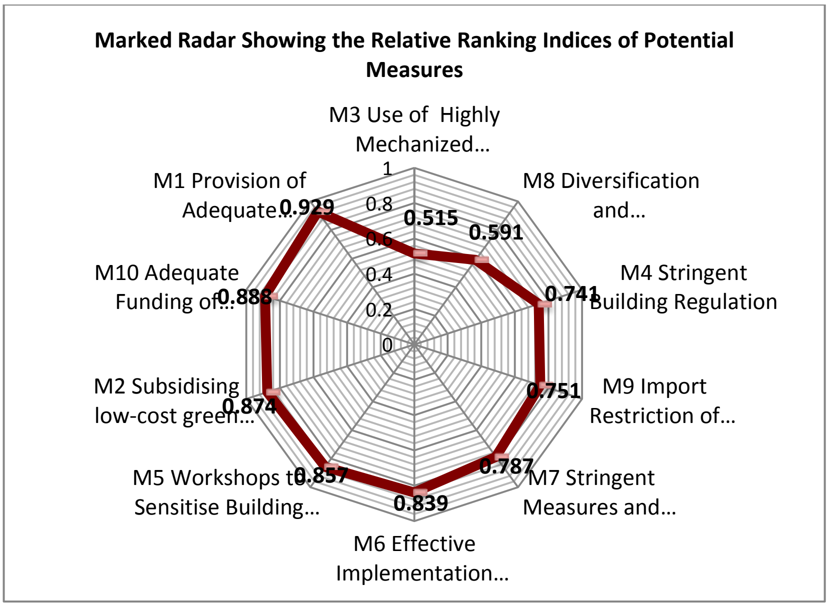



**Fig. 11.** Radar Graph showing potential measures that affect the wider-scale use of low-cost green materials

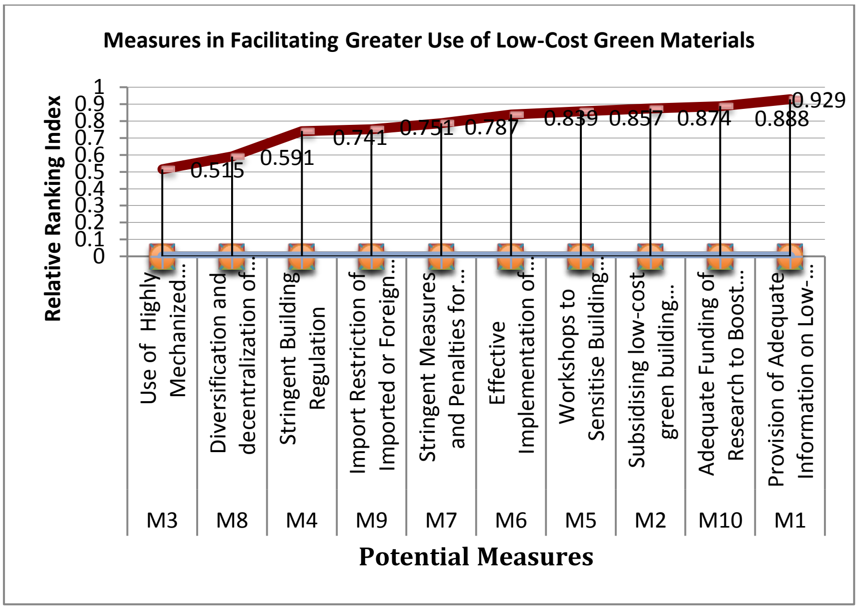



**Fig. 12.** Potential measures that influence the wider-scale use of low-cost green materials

#### 3.4.1.1 Provision of well-informed information on low-cost green materials

The survey question invited participants to rank on a 10-point scale from (1) “least relevant” to (10) “extremely relevant”, a list of potential suggestive measures that could be undertaken to overcome the low-patronage of low-cost green materials in the Nigerian housing sector. A consensus of the respondents agreed that provision of readily available information specific to the informed selection of low-cost green materials was the most important measure of the ten factors presented in the questionnaire, suggesting that information should be sufficient to educate as well as inform the user on issues specific to the use of such materials (see table 22).

The findings of the study indicated that many existing evaluating methods and selection models are perceived to be either lacking in comprehensiveness on best practices relating to the use of low-cost green building materials or possess information that are difficult to understand. It further revealed that the lack of inclusion of factors reflecting green development advantages or disadvantages of different building material options means designers have relatively little or no reason for choosing a material over another. The result implies that the factor (provision of adequate information) have significant effect on the frequency of use of low-cost green materials. It suggests that if the quality and availability of information on the impacts of the materials are responsible for the preference in patronage giving to them by stakeholders then, the preference can be attributed to designers' perception of the adequacy and quality of the available information associated with the properties of such products.

Studies such as Nwafor [5] and Nwokoro [50] have argued that provision of adequate information relating to the informed selection of low-cost green building materials could be a means of encouraging organizations and industries to implement green practices. With such information available, they added that design and building professionals are able to understand the environmental impacts of their design decisions; be conscious of the socio-cultural, economic, and environmental implications of their design decisions as they relate to the selection of such materials; as well as consider their life cycle environmental impacts. They noted that in situations where access to information on low-cost green building material are constrained, designers do often carry on with conventional materials they are familiar with, therefore paying little or no attention to the adverse effects of their decisions. The results obtained from this analysis are consistent with previous empirical findings by Nwafor [5] and Nwokoro [50] who stated that regulatory pressures on the use of such materials are associated with both the availability of sustainable information that could aid informed decision-making, and firms’ decisions to implement green construction practices.

More importantly, they remarked that most architects lack the knowledge of good practice associated with the use of low-cost green building materials, and therefore, require constant information and educational knowledge that guide them in their choice of such materials. They noted that the importance given to availability of readily accessible information suggests an increase in the awareness of environmental, social and economic benefits associated with the use of low-cost green materials. They suggested that what is required now is a better investigation of the strategic framework of well-informed data, within which design and building professionals could realistically assess a range of alternatives. The extant analysis across the country therefore, suggests a need to consider, at the very heart, the importance of and need for a support system that is capable of aiding more informed decision-making in the use of low-cost green building materials and components – an aspect which Nwafor [5] argues, is unfortunately downplayed in the Nigerian housing construction sector, and in much of the existing literature.

#### 3.4.1.2 Government’s adequate funding of research

As clearly observed in table 22, low-cost green interventions in the construction industry through research funded by the government is a barrier for developers, as plenty of proven choice of alternative and massively abundant low-cost green building materials and products are yet to be tapped. The findings of the survey supports Oluwakiyesi’s [6] view, which acknowledged that the long delays in implementing research schemes have also affected housing developers looking to introduce new and cost effective building materials and technology. He noted that the research incentives introduced in by the government in 2007 to encourage the production capacity of low-cost green building materials, to promote the development of affordable low-cost green housing are still very much the means by which studies [5, 50] believe the government could encourage the greater industry acceptance and wider-scale use of low-cost green materials and components in the Nigerian housing sector.

In their respective studies, Ajanlekoko [51], Aluko [52], and Akinlusi [53] however, noted that currently, the Nigerian housing sector does not have a physical development plan that supports longitudinal research on low-cost green products, and promotes the need for the development of a low-cost green developments. They further suggested that Appropriate Building Material and Technology programmes mandated to enforce research schemes might help to educate the government on the viability and effectiveness of funding research on alternative low-cost green construction materials. They noted that the Ministry of Housing could potentially explore a variety of low-cost green material options that are yet to be tapped, through this means.

#### 3.4.1.3 Subsidising low-cost green building materials and components

Another important measure, ranking third on the table is subsidising low-cost green building materials and components. The social acceptability of alternative low-cost green building materials and components particularly centres on the rate at which they are subsidised [51, 52, 53]. A review of Nigeria's housing finance markets by Nwafor [5] revealed that Nigeria has been exploring the possibility of adopting a low-cost green building materials subsidy scheme modeled after South Africa as one of the strategies of meeting the huge housing demand in the country. In his observations around the fast growing urban areas in Nigeria, he noted that builders and developers in the studied regions face a number of barriers that prevent them from being able to deliver affordable housing in the housing construction sector, some of which were the relatively high cost of building materials and restrictive regulations that limit the use of alternative cheaper low-cost green building materials. He argued that even the building code and enforcement in Nigeria is only erratic, foreign and unsystematic, and thus, requires competent and broad formulation to subsidise all types of construction materials, including locally-sourced and recycled building products.

In their study of the Indigenous building materials firms in Nigeria, Oruwari et al. [54] further suggest that subsidizing low-cost green materials could create an enabling environment, particularly for the low-income groups, through partnerships and participation by all key actors. They added that this initiative has been known to be responsible for reducing housing cost in other developing regions [51, 52]. Nubi [55] noted that full subsidies and credit guarantee programmes as well as the promotion of alternative construction materials could deliver cheaper housing. In his recommendations, he added that subsidising low-cost green materials to private developers could be one of government's ways of facilitating the provision of affordable housing, considering that the provision of housing is currently being undertaken by private sectors.

## 4. THE MATERIAL SELECTION DECISION SUPPORT SYSTEM (MSDSS)

The MSDSS framework presented in this section provides an overview of the perspectives or features available to the architect while selecting low-cost green building materials. It consists of a variety of databases that can aid architects or designers in meeting their design intentions through well-considered material choices. Moreover, it helps to understand and explain the seemingly simple but often complex, refined, and meaningful material decisions, and facilitates the communication with clients and manufacturers. The methodological framework consisting of the ranked factors as represented in figure 8 was the result of a literature study in combination with the analysis of in-depth interviews with architects. Six domains describing the material impact in a design and material selection process were identified: site-related issues, cost effectiveness, environmental impacts, socio-cultural impacts, sensorial effects, and technical performance. The results from the interviews and surveyed questionnaire are discussed in the following section, to elicit valuable information with which to perfect the MSDSS model where necessary.

### 4.1 Views on the Proposed Decision Support System

The last question for this part of the questionnaire was a combination of both closed and open- ended questions aimed at giving participants the opportunity to share their general views regarding the proposed MSDSS model. The final question "What other features should be improved in the development of the decision support system", showed contradictory priorities for each group of design and building professionals.

Scoring a record high of 30% as respondents first preference, besides the system being able to perform the entire task enlisted, is the confidence to create real low-cost green design that considers the social, economic and environmental implications of the various material alternatives with the information provided in the system. This choice is in line with Zhou et al's [28] study in which they confirm that many design and building professionals doubt the ability of decision support systems to create real green designs based on the information in the database [28]. The second priority (with a percentage score of 25%) was the ability of the system to provide accurate and reality like results followed by (15%) the ability to provide validated performance measures. The ability to calibrate the uncertainty (10%) and the high resolution of decision support model (5%) were the least important criteria.

On the other hand, the majority of the respondents, when asked to indicate the desired features they would like to have in a MSDSS for low-cost green material selection, also agreed that accurate and reality like results was another most important feature concerning tools accuracy. Another important criterion (15%) was the ability to provide validated performance measures to support effective design decision trade-offs in the choice of such materials at the early stages.

In this context, accuracy of material assessment results was not as important to some respondents as much as understanding the relative effect on material performance due to changes in design decision of material alternatives. This finding also suggested that the accuracy of the decision support model should be adaptive and adjustable to the user type and design phases to correspond to the different needs of the designer as well as other potential users. Other suggestions expected of the system concentrated more on the operability of the system which include: Allowing debugging; Error-checking to ensure models are correct; User friendliness; Easy searchable material selection inputs database; Ability to add/remove material selection features with ease; Ability to make custom reports; Ability to easily navigate all components with ease; Assisting decision making process through guidance; Comprehensive "USER INSTRUCTIONS" menu explaining what the tool is doing; Being able to understand the selection process through the lens of non experts; Must be built on an underlying database to aid in benchmarking; Ability to perform trade-off analysis to compare different material options; Clarity on the algorithms used to perform the simulations and their limitations; and, Having a huge amount of customizability in terms of output.

This question also revealed another important finding, showing contradictory priorities for each group. Architects, designers, and Specifiers first preference was the confidence to create real low-cost green/sustainable design. They suggested developing tools that correspond to all design stages allowing the flexibility to provide basic information on material alternatives during pre- design phases.

Most respondents within the Architect, Designers and Specifiers group argued that the lack of detailed knowledge in low-cost green material performance might be the fundamental reason for their low-patronage in mainstream housing. They mentioned that the fragmented housing delivery process in Nigeria has resulted in little progress in the augmentation of simulation and decision support tools that address material performance during the conceptual design stage. They suggested that much more effort is needed to get material selection support tools into mainstream housing, and maximize the tools usage in the design process.

On the other hand, engineers and model developers had different views. There was an agreement between engineers and software programmers. Engineers ranked the accuracy of tools and ability to simulate complex design elements in the first place. The second most important criterion was the friendliness of interface concerning usability and information management followed by the ability of the tool to integrate intelligent design knowledge-base to assist designer in decision making with a very small difference, when selecting materials at the design phase. There is no doubt that engineers and programmers require adaptive and friendly interfaces and are looking for tools that can assist the decision taking whether for code compliance or optimization issues. They clearly identified the quality control of simulation input as another important feature concerning low-cost green material information management for the decision support system interface. This is not surprising since the issue of attaining quality assurance of simulation input has been repeatedly highlighted in various literatures [25, 26, 27]

However, architects, designers and material specifiers prioritised the ability to create comparative reports for multiple material alternatives above the input quality control. This means that the issue of assigning meaningful and accurate input data is not as much of a priority to designers as much as the results of the comparative relative effect on material performance analysis amongst various material alternatives. Perhaps, an explanation to that might be that architects, designers and material specifiers are more involved with material selection optimization and material impacts during early design decision-making stages, than the quality control of the simulation input, even though it is also relevant. The result analysis of the surveyed questionnaire and interviews thus helped to develop a more robust empirical framework for depicting the factors for the selection of low-cost green building materials for sustainable low-cost green housing projects as shown in fig. 13.

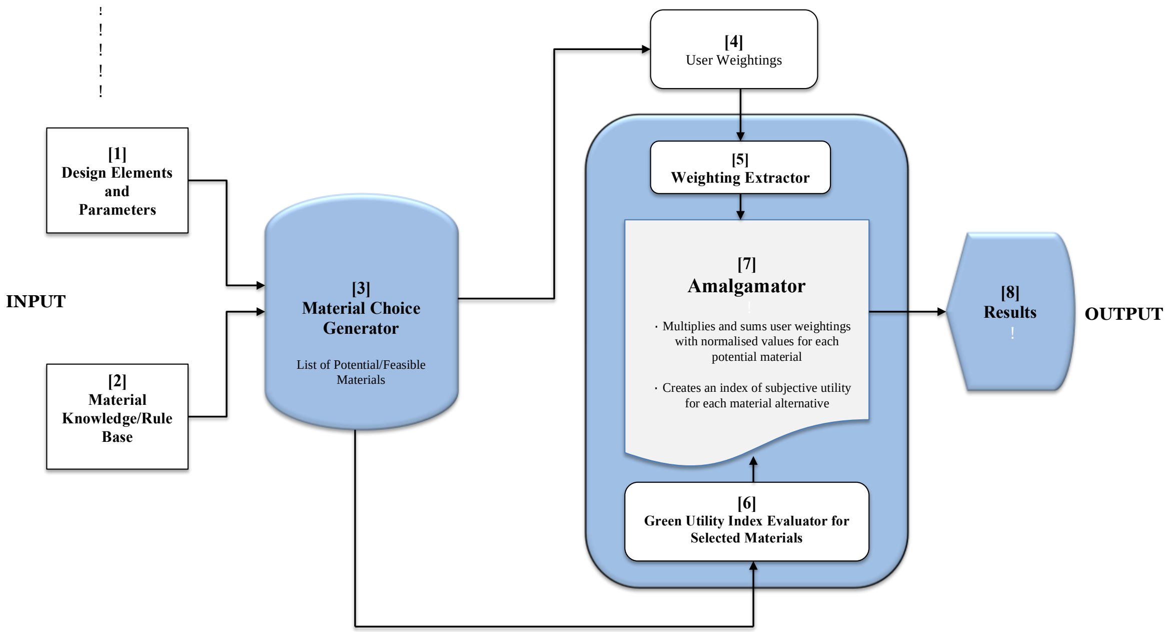



**Fig. 13.** Refined MSDSS model for the selection of low-cost green materials

**Table 3.** Individual functions of the various features/components of the MSDSS model

| Proposed Features of the MSDSS Model | Functions of the Various Features |
|---|---|
| **1. Design Elements and Parameters** | This feature provides users with a range of building design elements and their respective parameters |
| **2. Material Rule Base** | This feature articulates the listing of individual materials in prescribed sequences, gradually eliminating candidate materials based on their inability to meet stated material selection heuristics/rules. |
| **3. Material Choice Generator** | This feature contains the material/component database, which generates the set of all possible material alternatives that are available for selection. |
| **4. User's Weightings** | Sets preferred weighting value for all attributes to compare with. |
| **5. Weighting Extractor** | This feature queries the user to obtain weightings for the factors, based on the user's preference of value on a scale of 1-9. |
| **6. Material Index Evaluator** | The material index evaluator calculates values of the selected factors or variables for each feasible material choice. |
| **7. Amalgamator** | Here the user's weightings are amalgamated (i.e. multiplied and summed) with the factor values or weightings for each potential material, resulting in a relative ranking of the feasible materials for each element. |
| **8. Results** | - This component provides the ability to view the processed data, and to generate reports. It allows the MSDSS model User Interface to communicate with the user; and also connects all the reports and queries that are generated in the Monitoring databases to the corresponding project files. |

## 5. RESEARCH FINDINGS: SUMMARY

This paper has presented the results and analyses of the questionnaire survey involving design and building professionals in Nigeria. The questionnaire was aimed at ascertaining current practices in low-cost green design and housing construction in the Nigerian housing industry, particularly in the context of decision-making associated with the informed selection of low-cost green building materials. The survey questionnaires were distributed to 480 building and design professionals across Nigeria, receiving an overall response rate of 44%, quite beyond the ideal response rate of 20 – 30%, which is believed to be the norm in construction surveys (Takim et al., 2004), due to the poor and conservative response rate common with housing construction industries. The respondents were mostly design and building professionals from research institutions and small to medium scale housing construction organizations, with considerable experience in building material selection. The analyses of the surveyed questionnaire have highlighted drivers and obstacles that influence the use and implementation of low-cost green building materials and components in the Nigerian housing sector, and identified principal green development decision factors and variables for modeling decision making material selection process.

Various statistical tests including frequencies, relative indices, Kendall's Concordance, Chi-square tests and factor analysis were used to analyse the surveyed data. While there were slight variations between the findings of the main study conducted in Nigeria, and that of the preliminary study undertaken in few developed regions, the results and findings of both studies showed similar observations. From the main analyses, a number of observations were made.

- The main study confirmed that the majority of design and building professionals in the Nigerian housing construction industry appear to have low level of awareness and ill-informed knowledge of the adverse socio-economic and environmental impacts of construction materials and how their design decisions contribute to this;
- Many existing decision support systems in the developed countries do not as yet, seem to have the appropriate performance thresholds that are able to relate to matters associated with the informed selection of building materials that are commonly used for housing projects in Nigeria;
- Many design and building professionals in the Nigerian housing sector still do not have a clear idea of the issues, requirements, constraints and opportunities specific to the use of low-cost green building materials and components, despite their years of experience in housing construction;
- The Nigerian housing construction industry's contribution to green development goals, particularly in terms of providing adequate green housing and developing sophisticated decision support models based on low-cost green material alternatives- needed to help designers in choosing the most appropriate green products, is still at its infancy;
- Good practice in the informed selection of low-cost green building materials are still rare and isolated in Nigeria, compared to other developing countries such as South Africa Brazil, and Egypt;
- The result analysis showed that the quality performance of conventional materials is not significantly higher than the quality performance of indigenous products;
- This result showed that if the adequacy and availability of information associated with the impacts of low-cost green products are responsible for the preference in patronage giving to them by designers and clients then, the preference can be attributed to designers and clients' perception of the quality of available data for the materials used for housing projects;
- Unlike the preliminary study where environmental factors were considered the most important of all others in the developed regions, the majority of building professionals in Nigeria and perhaps other developing countries still regard cost and socio-cultural factors as conventional project priorities when selecting low-cost green building materials and components;
- The findings of the study identified six dimensions of green assessment criteria assisting building designers in selecting appropriate low-cost green building materials and components namely: site-related issues, cost effectiveness, environmental impacts, socio-cultural impacts, sensorial effects, and technical performance;
- This result suggests that low-cost green building products would perform far better than conventional materials provided the key factors are properly considered;
- This result indicates that conventional products are significantly different from indigenous materials in the cost of maintaining projects executed;
- The results of the survey revealed that the clients in Nigeria do have the greatest involvement and influence in building design and material selection. The influence of clients defines the overall context within which materials selections are made vital for whether or not green development goals are implemented in a project, thereby constituting a pragmatic 'starting point' for design decision-making;
- Respondents also acknowledged that their lack of detailed understanding of green design concept and lack of informed information regarding the use of low-cost green building material makes it difficult in making optimal decisions and educating their clients;
- The current data on best practices associated with the informed selection of low-cost green building materials are normally stored in non-

operational databases, making it impossible for design decision makers or builders to easily access valuable information in usable forms and formats;

- The study revealed that a majority of the existing databases on best practices associated with the use of low-cost green materials and their formats are based on the concept of online transaction processing; and thus, not designed to efficiently and directly provide such information to design decision makers.
- There is little compelling evidence of technical research on any readily available decision support system adequate in providing information specific to the informed selection of low-cost green materials in the Nigerian housing industry;

Given the significance of the proposed MSDSS model, further works are therefore needed to fully develop the model.

## 6. Conclusion

The results from the analysis of the surveyed questionnaire and interviews have provided an overview of the factors and variables that need to be addressed by design and building professionals, to improve the material selection and evaluation processes. It identified 55 out of 60 key influential factors that would be used to assess the selection of low-cost green material alternatives. The above survey results further confirmed the inherent apparent limitations associated with the use of low-cost green materials including designers' lack of detailed knowledge, and their reticence in the use of such materials. The results and findings of the analysis are a clear indication that stakeholders and building professionals within Nigeria's built environment are fairly familiar with most green-building concepts and best practices associated with the informed selection of low-cost green building materials and components. The results of the study revealed that provision of information associated with such materials is the most important yardstick for their patronage by designers. The implication of these findings is that designers' perception of the quality of information remains the ground for sustaining the preference given to conventional materials.

Considering the findings of the overall analyses, and the potential benefits of low-cost green residential developments in recent years, the research survey has shown that there is a dire need for a simple and efficient decision support framework to aid designers in their choice of materials. The objectives of this paper were to identify and organize the factors considered by design and building professionals during the material selection process in order to offer a descriptive model associated with the informed selection of materials for residential housing projects. Based on the comparison of the framework suggested by the interviewees and survey participants a modified MSDSS model for analysing decisions on material selection considerations in architecture was presented (figure 13). The content of each of these categories was further described briefly but extensively. The ultimate objective of the model is to facilitate low-cost green material selection and assessment at the various project levels of both the design and building decision-making processes in the Nigerian housing sector, since current material assessment tools are undermined by usage issues such as; lack of familiarity, absence of appropriate informed information relating to the use of such materials, incompatibility, context specificity, and lack of clear and simple assessment procedures as identified in the reviewed literature and findings from the surveyed questionnaire. Based on the contextual background study, the findings of the literature review, and the results of the main survey conducted in Nigeria, this research therefore, offered a favourable condition to develop a Material Selection Decision Support System (MSDSS). The aim of the proposed model is to improve the sharing of informed knowledge associated with the use of low-cost green materials, to assist design and building professionals during material selection at the various stages of the design process. The model was developed considering the views and suggestions of the respondents.

### 6.1 Contributions to Research and Industry

Insights into the methodology employed to address the research objectives represent part of the original contribution to knowledge made by this study. By suggesting an alternative means of integrating the available resources associated with the informed selection of low-cost green building materials, it is hoped that the model will help decision makers to further refine their material selection criteria hence, encourage effective decision-making. The outcome of this study could aid top executives within the housing sector to consider low-cost green materials as part of the existing regulatory frameworks of the Construction Standards Institute (CSI) for capital projects. By so doing, such an approach may create a potential market for local manufacturing and processing of such materials in large quantities.

### 6.2 Further Works

The next stage of this exercise is dedicated to making the most substantial contribution to the study by addressing the research question posed in section 3.1. To address the research problem and gap identified in this study, the next phase is to demonstrate the design and development of the proposed material selection decision support system. It presents a methodology and computational process that will address the existing problem of selecting appropriate low-cost green building materials in the design of low-cost green housing projects in Nigeria. To validate the proposed model, this research intends to run further case studies ideally using 'live' building design projects.

## AUTHORS' CONTRIBUTIONS

'Author A' managed the literature searches, designed the study, performed the statistical analysis, wrote the protocol, and wrote the first and final drafts of the manuscript. 'Author B' supervised the analyses of the study. All authors read and approved the final manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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