American Journal of Construction and Building Materials
2022; 6(1): 1-10
http://www.sciencepublishinggroup.com/j/ajcbm
doi: 10.11648/j.ajcbm.20220601.11
ISSN: 2640-0022 (Print); ISSN: 2640-0057 (Online)

Sustainable Building Materials Selection Awareness: The Case of Ethiopian Architectural and Engineering Offices

Abdulkerim Kiflu[1], Nebyou Yonas[2, *]

[1]College of Architecture and Civil Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia

[2]Urban Design, Ethiopian Institute of Architecture, Building Construction and City Development (EIABC), Addis Ababa University (AAU), Addis Ababa, Ethiopia

Email address:

kifluabdulkerim@gmail.com (A. Kiflu), nebyou.yonas@eiabc.edu.et (N. Yonas)

[*]Corresponding author

To cite this article:

Abdulkerim Kiflu, Nebyou Yonas. Sustainable Building Materials Selection Awareness: The Case of Ethiopian Architectural and Engineering Offices. *American Journal of Construction and Building Materials*. Vol. 6, No. 1, 2022, pp. 1-10. doi: 10.11648/j.ajcbm.20220601.11

Received: February 21, 2022; **Accepted**: March 18, 2022; **Published**: March 23, 2022

Abstract: The construction industry is regarded as one of the pivotal aspects of achieving the objectives of sustainable development in communities. In this regard, the choice of building materials is one of the pivotal challenges in order to improve program performance with respect to sustainable development needles, and the use of sustainable building materials is an effective step towards achieving sustainable construction. Selection of sustainable building materials represents an important strategy in the design and construction of buildings. One of the central challenges is the mindfulness of designers or architects and the recognizable proof of building materials based on the concepts and standards of sustainability. One of the study's limitations is that it excludes other stakeholders, such as the client, who may have an influence on material selection. Another drawback is that since elements are used to organize materials and components, thus the study based solely on product performance within each constituent group. On the other hand, this study excluded several items. For example, "products" such as lighting, water fixtures, HVAC, and electrical fixtures are not included. Therefore, the purpose of this paper is to know whether the consultants have awareness or not on sustainable building materials. The study result shows that 50.7% have awareness, while the other 49.3% do not have awareness on the sustainable building materials.

Keywords: Sustainable Building Material, Ecological Dimension, Economical Dimension, Social Dimension

1. Introduction

In the previous decades, the world witnessed tremendous focus on environmental dilemmas such as global warming, resource depletion, energy, air and water pollution, waste, population growth, and globalization. These issues fall under the purview of sustainability arguments, emphasizing the need for sustainability integration in the ways we live, act, use resources, and build. In assembly of human needs, sustainable architecture represents the interrelationship between natural, cultural, social, and economic resources to create the most efficient relationships between humans and their environments [1]. It has been substantiated that the immoderate consumption of natural resources surpasses their replacement time. This situation is no longer sustainable in terms of maintaining a balance between the desires of human activities and their adaptation to the environment in order to ensure future enjoyment requirements for future generations. Since the construction, industry is accountable for the exploitation of 50% of the world's natural resources [2, 3].

The building materials can affect human health if the architects select good building materials it can play a major role in offering a healthy indoor environment and promoting well-being for all, at all levels. On the contrary, hazardous materials (e.g. asbestos, formaldehyde, polychlorinated biphenyls (PCBs), mercury, and lead-based paint) have been found in several building materials (e.g. insulation, cement, coatings, roofing and flooring materials) and they have the potential to damage health and cause serious diseases, reduce growth, and could create what is known as a "sick building syndrome" [4-6].

Designers do not only design for function and use, but also for practice. In architecture, the materials that shape an environment will mainly influence the user’s insight into that

environment. Choosing materials for an architectural project is not only about meeting technical requirements; the material's appearance and sensory behavior play an important role while designing. While selecting a material, the architect reflects on performance-related features, such as the material's durability, but also looks into aspects that concern the user experience or sensory stimulation, such as the material's color or texture. Moreover, the architect might have a certain atmosphere in mind that will be reflected through the feelings the materials evoke, as a "formal" feeling.

Observation on the architectural products in Ethiopia showed that the problem of the designer in the selection of sustainable building materials are gets fixated on a particular family of materials and/or manufacturing; a material/manufacturing process has been used historically for the given application; The use of printed and visual presentation resources for building material information; focuses on aesthetics criteria and the unit cost of the building materials; the information for accessing building materials is presented in a disorganized way; based on trusting experience rather than using a numerical approach; in addition, due to the lack of formal and availability of measurement criteria.

Traditionally the practice showed that, the material selection process is done at the final design stage. At this stage, the design is generally fully worked out and some part or component drawings have already been created. It also means that critical issues related to materials and manufacturing processes are often not identified until this phase, forcing the designer to make compromises to overcome these critical issues. The later in the design process the designer uncovers such issues, especially those critical to the success of the design, the less flexibility the designer has to accommodate and incorporate the required changes into the design. The consequence is the acceptance of a modified design, which may be non-optimal because of compromises driven by delivery dates, lead times, and associated costs. In the author's opinion, the final design stage is too late to go back and redesign the structure.

2. Literature Review

Sustainable building materials typically thought of as natural materials that provide certain benefits to users, such as low maintenance, energy efficiency, improved occupant health and comfort, and increased productivity, while being less harmful to the environment. However, according to [7] natural materials are not necessarily sustainable materials, such as asbestos, radon, and turpentine. They are natural materials, but they are harmful to the built and natural environment in various forms and ways. Therefore, materials that are ecologically friendly or environmentally responsible are referred to as sustainable building [8, 7]. Accordingly, sustainable building materials dominate with materials that are from renewable sources rather than from nonrenewable sources. They must also be environmentally friendly throughout their whole life cycle and utilize less energy in the production process. These materials must not emit pollutants or other emissions that are harmful to human health or comfort during their entire life cycle.

So generally characteristics of sustainable building materials are:

1) Typically thought of as natural materials.
2) Needs low maintenance.
3) Low energy efficiency.
4) Improved occupant health, comfort and increased productivity.
5) Ecologically friendly or environmentally responsible.
6) Renewable sources.
7) Less pollutant to the environment in the production process.

Several strategies for material selection problems have been developed, some of which are applicable not only to material selection but also to any design selection procedure. Although no one method is accepted as the standard approach, there are a wide variety of normally used strategies [9].

1) Selection with computer-aided databases;
2) Performance indices or table;
3) Decision matrices;
4) Selection with expert systems;
5) Value analysis (particularly for materials substitution);
6) Failure analysis;
7) Cost–benefit analysis [9].

Generally, in Ethiopia, the methodology of architectural design has three phases: pre-design, preliminary design, and detail design.

The pre-design includes compiling contextual information, defining the topic, applying evaluation and quintessential judgments, and formulating strategies of action. Successively, the design phase is developed according to the content and complexity of the topic and information gathering that is represented in graphics, illustrations, sketches, and three-dimensional images. The pre-design phase, additionally known as the programming phase, is a systematic assessment of the interrelated values, goals, facts, and wants of a client's family and the surrounding community. A well-conceived program leads to high-quality design. Programming is when you'll meet with your architect to talk about all of your wishes and desires for your new home. During programming, your architect will acquire facts about your construction site or existing home (if you are remodeling). At this time, the proprietor and architect will begin to structure a cohesive relationship and a shared notion for the last building. The first steps to a property development in this phase, the owner and architect set up and analyze a set of prerequisites and research that will establish the framework and requirements for the building development. This includes site analysis, zoning, budgeting, and programming use requirements. The architectural concerns in the pre-design stage are: Project Goals, Site Selection, Site Analysis, Title Search, Zoning Analysis, Existing Building Assessment, Programming, Budgeting, Pro Forma, and Project Team Selection.

Secondly, the preliminary design includes the specific development of the emplacement and occupation diagram, locations of functions, morphology, and materiality of the schematic design (a spatial suggestion that brings together

main project characteristics as design ideas and programmatic areas). The accepted locations for functions within the building are considered and graphically represented in diagram form. Simple plans and elevations are produced to signify relationships among spaces and the basic envelope shape. Material options start to become part of the discussion, and a target budget is set for the overall project. The initial concept is defined based on the contents, restrictions, and requirements formulated in the pre-design phase. The architects create a work format to define what will be completed and when. An average layout strategy is chosen. At this stage, we decide the characteristics of the functional, formal, and structural components, unified in aesthetic languages that supply identification and character to the spatial proposal. At this moment, the graphical representation is more defined and incorporates specific dimensional data in scales tailored to the stage of detail for every urban or architectural proposition. The spatial proposal consists of approaches to set out the task and ordinary specs for the building, structural system, envelope form, and roof forms. An early conceptual format indicates the general layout roughly to scale, while an aerial point of view design locates the project on site, and showing property lines.

Finally, final design is the process of developing the design so that it is dimensionally correct and coordinated, describing all the main components of the building and how they fit together. Not all drawings produced during this stage will necessarily be detailed drawings. In the final design phase, final considerations are made concerning the layout and dimension of interior spaces. Materials and finishing materials, water fixtures, electrical equipment, and artificial lights are selected. This section is nevertheless very essential for the implementation of sustainability because these techniques will have an amazing impact on acoustic comfort, indoor air quality, power efficiency, and durability of the building. Moreover, water fixtures' desires will have an effect on potable water conservation [10]. The purpose of the detailed design stage is to develop the initial schematic design into more detailed building documentation that addresses specific building and regulatory requirements in preparation for later construction documentation. This stage is used to detail and develop the design.

As a result, architects' material choice contemplations are recognized and organized into four categories: context, manufacturing, material aspects, and experience. The angles that are considered while selecting material are physical viewpoints, appearance, subjective, cultural context, physical context, time, and fee [11].

Transform the informal into the formal. In Transactions on Ecology and the Environment, ecosystems and considering that the architectural design method complements at least three phases: pre-design, preliminary design, and detail design. Each of these phases is implemented by a decision-making process that involves analysis, synthesis, evaluation, and decision.

3. Methodology

A questionnaire is an instrument that is typically used for quantitative data gathering. It outlines a series of questions relating to the sustainable building materials and requires the research subjects to choose or provide responses that reflect their knowledge and experiences. There are different types of questions that can be contained in a questionnaire, including close-ended questions, and fixed alternatives. Therefore, based on the data given by the Ethiopian [12], there are 199 consulting architects' offices registered, so based on the sample size formula,

Necessary sample size = (z-score) 2*StdDev*(1- StdDev)/ (margin of errors) 2. [13] Therefore Population size= 199, Confidence Level=90%, Margin of Error=10%.

Based on online calculation method on [14]. 51 offices will be selected for questionaries' randomly.

4. Result and Discussions

From among these, 51 offices were chosen as a sample size. As a result, it is concerned with the outcomes of the data collection and analysis. The following is the order in which the results are presented: First, Assessing current architects' and designers' sustainable building material selections. Second, Identifying gaps or barriers in the selection of sustainable building materials among architects.

4.1. Assessing Current Consulting Architectural Offices on the Selection of Sustainable Building Materials

To assess the current consulting architectural offices on the selection of sustainable building materials, it is better to know or ask about their awareness of maintainability, health or comfortability, process of manufacturing, locality, natural or artificial, indoor and outdoor impact, distance, weight, energy consumption, and creativity of building materials.

4.1.1. Maintainability

No matter how sustainable a building may have been in its design and construction, it can only remain so if it is operated responsibly and maintained properly. Sustainable operations and maintenance practices focus primarily on the actions of building occupants and encompass safety, health and safety, comfort, and productivity, with an understanding of the need for subsequent generations to reuse and recycle building components.

The chart below depicts the building materials serviced, repaired, or replaced throughout the life cycle of the building by 68% of consulting architectural offices in Ethiopia, but the maintainability of building materials not considered by 32%. To the maximum extent possible, during the design and construction processes, select materials that will be easy to maintain.

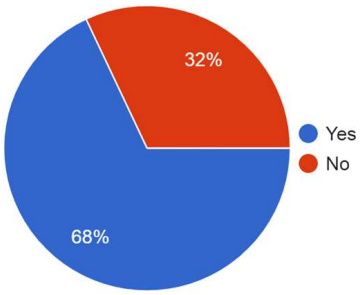

Figure 1. *Maintainability.*

4.1.2. Healthy

Indoor environments now have a significant impact on users' health, well-being, and performance. Building materials are obviously major factors in defining indoor air quality, with serious negative impacts on human health, comfort, and productivity. Pollutant-containing materials can have negative consequences throughout their life cycle, impacting employees during production, building occupants during usage, and generating pollution during recycling and terminal treatment. It is the architect's responsibility to choose a healthy building material for the occupants. It is also necessary to understand how architects choose materials, whether based on experience, material ingredients, manufacturing processes, or social needs.

The chart below shows that personal experience, nearly half of the offices (44.9%) know whether the building material is healthy or unhealthy based on personal experience, while 18.4% know based on the material's constituent. 14.3% are based on inspecting manufacturing processes, while 6.1% are based on societal necessity. 2% by consulting product catalogues and specifications, 2% by testing building materials, and 2% by reading and personal experience. Personal experience and production specifications account for 2%, non-destructive testing methods account for 2%, product catalog and lab test results account for 2%, testing certification accounts for 2%, and company catalog accounts for 2%. By gathering information and assistance from material engineers, 2%, it is better to select materials based on material content or constituent because the other cannot be fully reliable, so 18.4% of offices had a good understanding of it.

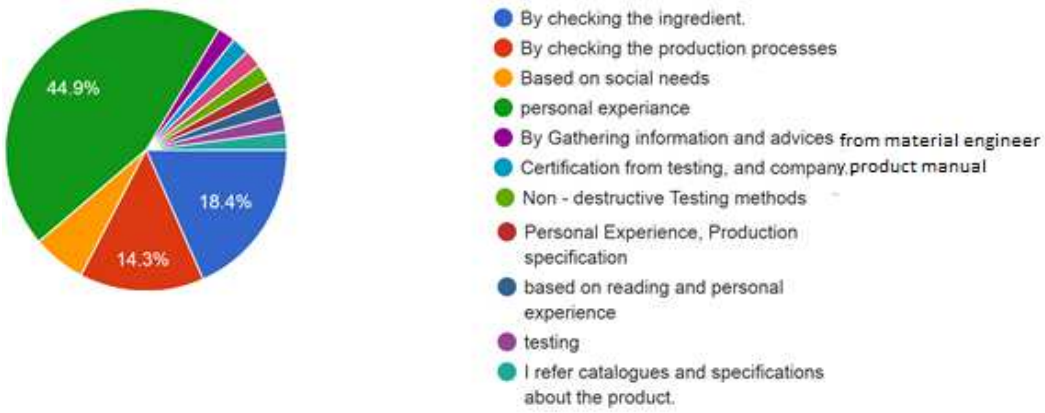

Figure 2. *Healthy.*

4.1.3. Manufacturing Processes

Sustainable building materials should be ecologically sound and reduce environmental hazards without producing pollutants or other emissions that affect human health and comfort over their entire life cycle. Sustainable building materials are better considered during the manufacturing process of sustainable building materials. This includes resource conservation, energy conservation, waste minimization, durability, and water conservation. Flexibility, Recyclability, Weight, Mass, Constructability, Modular designs with standardized materials Cleaning, maintenance, and repair ease, recycling potential, demolition ease, reusing building materials or components, and so forth. Aesthetics, life-cycle cost, and so on.

Investigating where and how the material is manufactured is one of the final approaches to finding sustainable building materials. Choosing suppliers that also practice environmentally friendly processes means that your materials have an environmentally friendly life cycle. Many companies use their environmental practices to differentiate themselves from their competition and advertise their green initiatives.

Resource-friendly manufacturing can include green manufacturing buildings, using renewable energy sources, choosing toxic-free materials, and disposing of the manufacturing byproducts in an environmentally friendly way. The chart below shows that 68.6% of consulting architectural offices examine the manufacturing process while selecting a building material, while the remaining 31.4% do not.

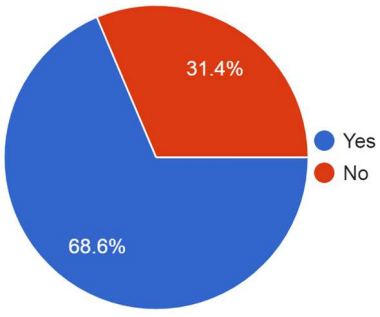

Figure 3. *Manufacturing processes.*

4.1.4. Locally Produced Building Materials

On the basis of sustainability, locally produced building materials have the following advantages: Low transportation costs, availability, labor supply, and compatibility with social, religious, cultural, environmental, and climate change.

Local building materials can reduce the construction cost to its barest minimum by about 60% [15] allowing low-income individuals to get access to decent housing at a reasonable price with local technology while contributing to the reduction of poverty and building a resilient local community (which reduces the local individuals' exposure and vulnerability to extreme external environmental disasters [16].

There are plenty of vernacular building materials in Ethiopia. Stone masonry, wood, basalt, earth, and straw mortar thatch, limestone, mud, bamboo, grass, false banana, barley and wheat straw, ropes, woven mats, animal skins, plastics, animal dung, ashes, palm fibre, palm mats, pumice, etc.

The ability of sustainable buildings to handle environmental concerns in a positive way is becoming more generally acknowledged. In this regard, vernacular building materials provide easy solutions to long-term problems. It incorporates significant environmentally favorable features, such as low-energy techniques for human comfort. Therefore, lessons learned from vernacular architecture can help in designing environmentally friendly built environments.

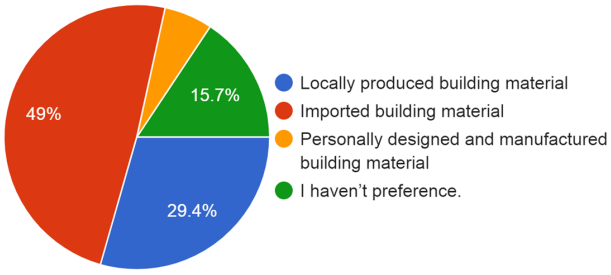

Figure 4. *Locally produced building materials.*

The chart below indicates that nearly half of the offices (49%) prefer imported building materials, while 29.4% prefer locally produced building materials, 5.7% prefer personally-designed and manufactured building materials, and 15.74% had no choice. 68.6% of offices examine the manufacturing process while selecting a building material, while the remaining 31.4% do not. From a sustainability point of view, it is better to select locally produced building materials. So 29.4% of respondents were correct.

4.1.5. Natural Building Materials

Buildings that employ more natural materials have the potential to improve the health and well-being of individuals who live, work, and play in and around them without the environmental damage that comes with the manufacturing of traditional building materials. Natural materials found in nature that can be utilized directly for a specific architectural function or that require human intervention (such as processing) to make them usable. We can use natural materials more effectively and efficiently to create a more pleasurable, healthier, and sustainable urban environment. Plant-based materials like bamboo and timber are renewable and widely available. The raw materials for these materials are grown and harvested rather than mined and reformed, which sets them apart from more traditional building materials like steel, concrete, and plastic. This mismatch results in a wide spectrum of material features that humans have only lately begun to understand and utilize on a larger scale.

The chart below directs that more than half of the respondents (58%) choose natural and newly manufactured materials, whereas 26% prefer artificial and newly created materials, 14% natural and reused materials, and 2% artificial and reused materials. Natural building materials are commonly used in sustainable buildings, have low energy consumption and maintenance costs, and are easily removed and recycled. From a sustainability standpoint, it is preferable to choose natural and reused building materials, which account for 14% of the total.

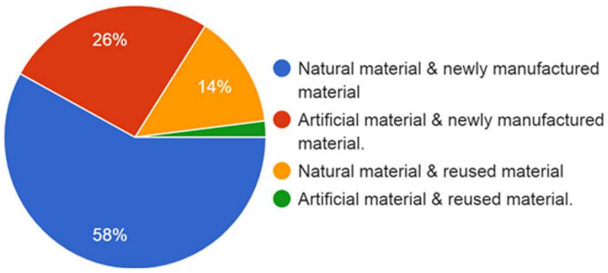

Figure 5. *Natural building material.*

4.1.6. Indoor and Outdoor Environment

The building envelope and urban public space are the two primary components of any city (roads, public squares, parks, etc.). Each component is made up of different materials. Building materials are at the heart of building engineering. It determines some of the city's and structures' most distinguished characteristics. Buildings and urban space construction materials have a significant impact on urban temperatures and heat storage. The use of artificial surfaces, which can absorb and store large amounts of heat throughout the day, raises the air temperature in the city. When building materials are exposed to the sun's heating of the air near the surface, their ability to absorb, store, and radiate radiant energy is affected, which has an impact on the urban microclimate. Indoor air quality is directly linked to human health. Building materials are one of the sources of indoor pollution.

The chart below directs that almost all (92%) of Ethiopian consulting architectural offices examine the impact of building materials on indoor and outdoor dwellers, but the remaining 7.8% do not.

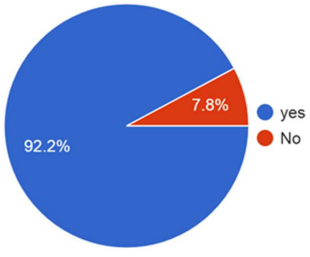

Figure 6. *Indoor and outdoor environment.*

4.1.7. Modular Building Material

The use of modular building materials or factory-controlled manufacturing is also a greener process that generates less waste, reduces on-site disturbances, and allows for tighter control of the entire process. There is less material waste and greater use of recycling of building materials, and with relocatable buildings, they can be dismantled and relocated or refurbished for a new or secondary use [17]. The chart below leads that based on the size and weight of building materials, most (74%) offices prefer modular and light-weight building materials, 12% non-modular and light-weight, 10% modular and weighty, and the other 4% non-modular and weighty building materials. From a sustainability standpoint, it is preferable to choose modular and light-weight building materials since 74% have a clear understanding of it.

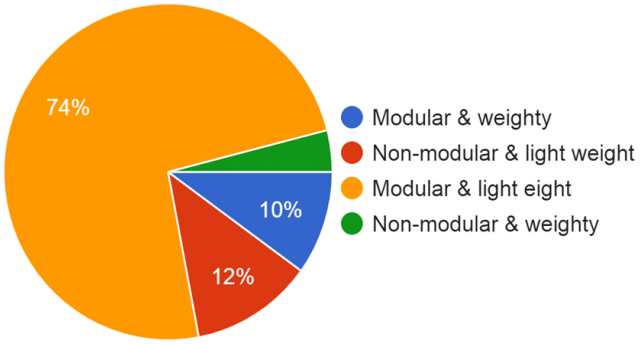

Figure 7. *Modular building material.*

4.1.8. Distance of Building Material to the Site

The distance between the source of the building material and the site should be considered when choosing a sustainable building material because a long distance from the site increases transportation costs, time management costs, and the need for new construction techniques, etc. The chart below illustrates that most (84.3%) of the consulting offices consider the distance of the building material source, but the other 15.7% do not.

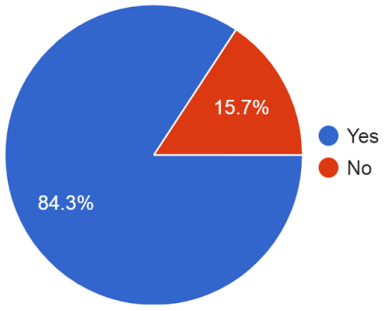

Figure 8. *Distance of building material to the site.*

4.1.9. Energy

Selecting materials with low embodied energy will help to limit energy consumed via mining, processing, manufacturing, and transporting the materials. Embodied energy is the energy consumed through all of the processes associated with the manufacturing of a material, from the mining and processing of natural resources to manufacturing, transport, and product delivery.

The chart below clarifies that in terms of energy consumption, most consulting architectural offices (88%) prefer low energy consumption and renewable energy sources, 6% prefer high energy consumption and renewable energy sources, 4% prefer low energy consumption and nonrenewable energy sources, and 2% prefer high energy consumption and nonrenewable energy sources. From a sustainability aspect, it is desirable to choose low energy consumption and renewable energy sources, which 88% of respondents correctly.

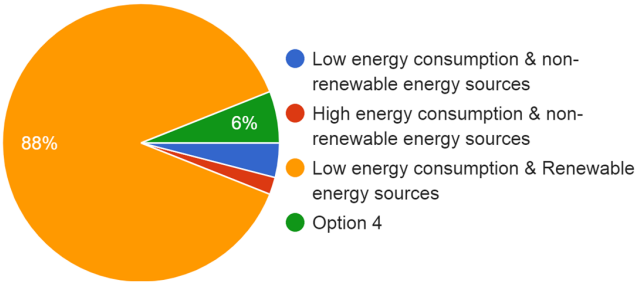

Figure 9. *Energy.*

4.1.10. New Material Production (Creativity)

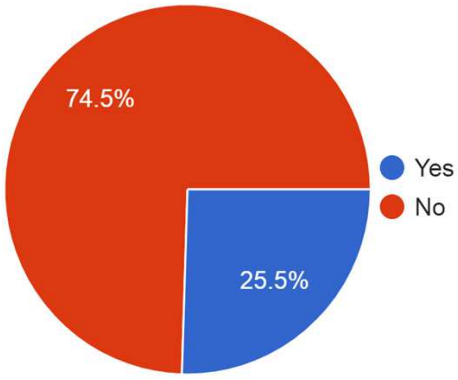

Figure 10. *New material production (creativity).*

The chart below explain that most (74.5%) of the consulting architectural offices in Ethiopia tried to create or manufacture their own building materials, while the others did not.

Table 1. *Show general response on the assessment of current consulting architectural offices on the selection of sustainable building materials.*

No	Assessing parameters	% of gain	% of loss	Total
1	Maintainability	68%	32%	100%
2	Healthy	18.4%	81.6%	100%
3	Manufacturing processes	68.6%	31.4%	100%
4	Locally produced building materials	29.4%	70.6%	100%

No	Assessing parameters	% of gain	% of loss	Total
5	Natural building material	14%	86%	100%
6	Indoor and outdoor environment	92%	8%	100%
7	Modular building material	74%	26%	100%
8	Distance of building material to the site	84.3	15.7%	100%
9	Energy	88%)	12%	100%
10	New material production (creativity)	74.5%	25.5%	100%
11	Sub tot/10	61.12%	38.88%	100%

From the above table, the analysis show that when we evaluate current consulting architectural offices on the selection of sustainable building materials, they have a good understanding of things like producing new materials, energy, transportation, indoor and outdoor environments, manufacturing processes, and maintainability of building materials, which is 61%. However, when it comes to topics like choosing natural, locally produced, healthy building materials, 39% of offices are unaware.

4.2. Identifying Gaps or Barriers Between Consulting Architectural Offices on Selection of Sustainable Building Material

To identify gaps or barriers between consulting architectural offices on the selection of sustainable building materials, it is better to know or ask about their awareness of material information, performance of the material, design stage, and material selection method.

4.2.1. Material Information

Nowadays, increasing varieties of materials are accessible for the buildings that architects design. Material selection problems are primarily based on material properties and design requirements, where the material properties are attached to those of the physical structure and the relevant structural properties of the component. To pick among this large number of materials, the architect has to take into account numerous design criteria like context, manufacturing, material aspects, and experience. In general, each material selection process is hired to fulfill a simple need, identifying the best material for a specific structure. In order to identify what the "best" material can be, it is important to understand what aspects are at play while architects are choosing materials. Moreover, to facilitate a constructive material selection process, the architects are in need of the proper information on materials (to guide them in taking decisions).

The chart below enlighten that, nearly half of the offices (47.1%) get their building material information from personal experience, 29.4% from the manufacturer, and 15.7% from newspapers and magazines. It is preferable to choose building materials based on manufacturer specifications because they describe how the materials are made, and since one building material has distinct constituents, the other cannot be completely reliable or provide complete information about the material, which only 29.4% of offices understood.

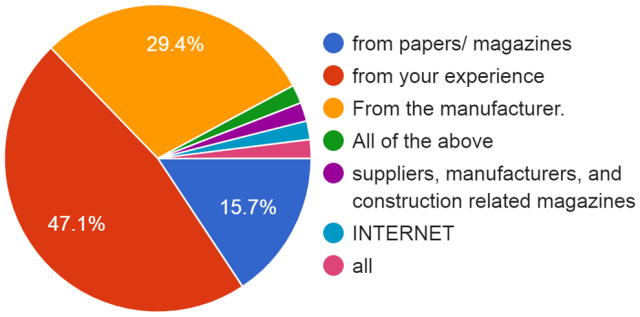

Figure 11. *Material information.*

4.2.2. Performance of the Material

Designers consider not only function and use, but also practice. The materials that shape an environment will have the most impact on the user's perception of that environment in architecture. When it comes to selecting materials for an architectural project, it's not only about satisfying technical specifications; the material's look and sensory behavior are also factors to consider. When choosing a material, the architect considers performance qualities such as the material's durability as well as aspects that affect the user experience or sensory stimulation, such as the material's color or texture. Furthermore, the architect may have a specific mood in mind, which will be reflected in the feelings evoked by the materials, such as a "formal" sense.

In our nation, Ethiopia, the designer's challenge in selecting sustainable building materials is that they become obsessed with a certain family of materials and/or production (concrete, aluminum, glass, etc.). When a product has evolved over time and a material or manufacturing process has been historically used for the given application, the use of printed and visual presentation resources for building material information focuses on aesthetics criteria and the unit cost of the building materials. Information for accessing building materials is presented in a disorganized manner, based on trusting experience rather than scientific evidence.

The chart below clarify that 34% of offices prioritize building material performance; 18% prioritize materials that have historically been used for the specific application; 18% prioritize material aesthetics; and 14% prioritize building material unit cost. It is preferable to choose building materials based on performance. It is the most reliable measurement tool among the others, which is a 34% office selection mechanism.

Figure 12. *Performance of the material.*

4.2.3. Design Stage

Traditionally, material selections are made at the end of the design phase. The design is usually complete at this point, and some part or component drawings have already been prepared. It also means that key concerns with materials and manufacturing methods are frequently overlooked until this stage, forcing the designer to make sacrifices in order to overcome them. The later in the design process that such concerns are discovered, particularly those that are crucial to the design's success, the less flexibility the designer has to accept and incorporate the required changes into the design. As a result, a modified design is accepted, which may be suboptimal due to compromises caused by delivery dates, lead times, and associated costs. From the author's perspective, it is too late to go back and rework the structure at the detail design stage.

However, from the chart below, we can see that there is a change that shifts from the final design stage to the preliminary design stage. 52.9% of offices prefer to choose building materials at the preliminary design stage, which is good for the sustainability of the building material because it allows for flexibility in changing the design, saving time and associated costs; 23.5% of offices prefer to choose building materials at the final design stage; 19.6% of offices prefer to choose building materials at the predesign stage; and 2 (3.9%) do not. The most recommended design stage for choosing building materials is the predesign stage because it integrates with the concept of the project and has the advantage of more flexibility in changing the design and the material. It also saves time and minimizes the cost of the design, so 19.6% of the respondents had a good understanding of the design stage for selecting the material. As we always say, materials are the food of architecture. That is why when we think about a project, we should also think about building materials.

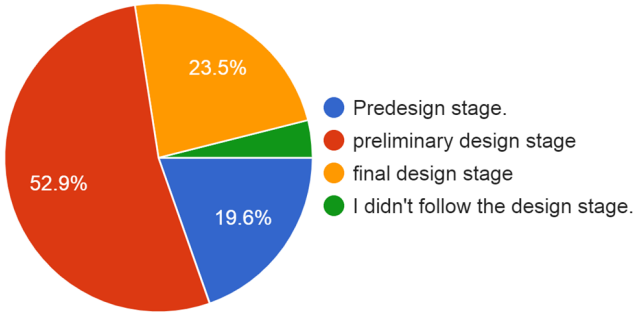

Figure 13. *Design stage.*

4.2.4. Material Selection Method

Several strategies for material selection problems have been developed, some of which are applicable not only to material selection but also to any design selection procedure. Although no one method is accepted as the standard approach, there are a wide variety of normally used strategies [9] selection with computer-aided databases; performance indices or tables; decision matrices; selection with expert systems; value analysis (particularly for materials substitution); failure analysis; and cost–benefit analysis [9].

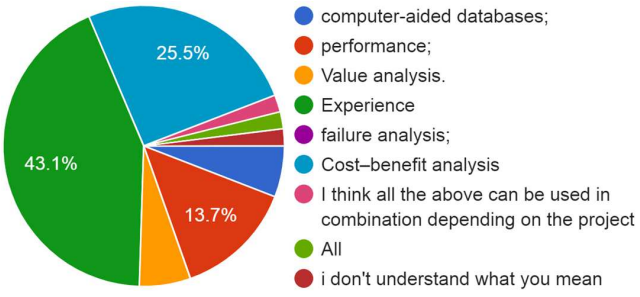

Figure 14. *Material selection method.*

Table 2. *Identifying gaps or barriers between consulting architectural offices on selection of sustainable building material.*

No	parameters	Item of parameters	%	Gain	loss
1	Material information	from papers/ magazines	15.7%	29%	71%
		from your experience	47.1%		
		From the manufacturer.	29.4%		
		others	7.8%		

No	parameters	Item of parameters	%	Gain	loss
2	Performance of the material	Material that has been used historically for the given application. Example column by concrete.	18%	34%	66%
		Aesthetics of the material.	18%		
		Unit cost of the building materials.	14%		
		Performance.	34%		
		other	16%		
3	Design stage	Predesign stage.	19.6%	19.6%	80.4%
		preliminary design stage	52.9		
		final design stage	23.5%		
		I didn't follow the design stage.	3.9%		
4	Total	Total number of gain/loss/300		27.5%	72.5%
5	Material selection method	computer-aided databases;	5.9%		
		performance;	13.7%		
		Value analysis.	5.9%		
		Experience	43.1%		
		failure analysis;	0%		
		Cost–benefit analysis	25.5%		
		other	5.9%		

The chart below explain that most prevalent material selection strategy in most architectural projects, according to the majority of offices, is based on experience (43.1%), 25.5 percent on cost-benefit analysis, 13.7 percent on performance, 5.9 percent on value analysis, and 5.9 percent on computer-aided design.

Based on the table above, 72.5% of consulting architectural offices do not have a good understanding of the selection of sustainable building materials based on material information, material performance, and design stage, while the remaining 27.5% do. There are no defined guidelines for material selection methods, so each office can use whichever method they want.

5. Conclusion

Table 3. *The awareness of the consulting architectural offices in Ethiopia.*

No	Assessing parameters	% of gain	% of loss	Total
1	Maintainability	68%	32%	100%
2	Healthy	18.4%	81.6%	100%
3	Manufacturing processes	68.6%	31.4%	100%
4	Locally produced building materials	29.4%	70.6%	100%
5	Natural building material	14%	86%	100%
6	Indoor and outdoor environment	92%	8%	100%
7	Modular building material	74%	26%	100%
8	Distance of building material to the site	84.3	15.7%	100%
9	Energy	88%)	12%	100%
10	New material production (creativity)	74.5%	25.5%	100%
11	Material information	29.4%	70.6%	100%
12	Performance of the material	34%	66%	100%
13	Design stage	19.6	80.4%	100%
14	performance	13.7%	83.3%	100%
	Sub tot/13	50.564	49.221	100%

From the above table, it is clear that the awareness of consulting architectural offices in Ethiopia on sustainable building materials is nearly half of them (50.7%) have a good understanding of the sustainable building material characteristics like maintainability, manufacturing processes, indoor and outdoor environment, modular building materials, distance of building material to the site, and new material production, but the other 49.3% do not have a good understanding of the sustainable building material characteristics like performance, design stage, performance of the material, material information, natural building materials, locally produced building materials, and the health of sustainable building materials. A sustainable building material selection framework is needed.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

[1] Salman M. Sustainable house… Futuristic approach for sustainable architecture. In: Proceedings of Housing Symposium II. Riyadh: Al-Riyadh Development Authority. PP; 2004.

[2] Anink, D., Mak, J., & Boonstra, C. (2004). Handbook of sustainable building. London: James & James.

[3] Edwards, B.; Hyett, P. (2004). Guía Básica de la Sostenibilidad (Basic Guide to Sustainability); Editorial Gustavo Gili: Barcelona, Spain, 2004.

[4] Kim, J., & Yu, C. (2014). Hazardous materials in buildings. Indoor and Built Environment, 23 (1), 44-61. doi: 10.1177/1420326x14524073.

[5] Passarelli, G. (2009). Sick building syndrome: An overview to raise awareness. Journal of Building Appraisal, 5 (1), 55-66. doi: 10.1057/jba.2009.20.

[6] World Health Institute-WHO (2016). WHO | Improved building materials. Retrieved December 12, 2018, fromhttps://www.who.int/sustainable-development/housing/strategies/building-materials/en/.

[7] Franzoni, E. (2011). Materials Selection for Green Buildings: which Tools for Engineers and Architects? Procedia Engineering, 21, 883-890. doi: 10.1016/j.proeng.2011.11.2090.

[8] Spiegel, R. & Meadows, D. (1999) Green building materials: a guide to product selection and specification, John Wiley & Sons Inc., New York.

[9] Dieter, G. E. (2000) Engineering Design, a Materials and Processing Approach, McGraw-Hill, New York.

[10] O. (2015). WATER CONSERVATION ASPECTS OF GREEN BUILDINGS. International Journal of Research in Engineering and Technology, 04 (25), 75-79. doi: 10.15623/ijret.2015.0425012.

[11] Feria, M., & Amado, M. (2019). Architectural Design: Sustainability in the Decision-Making Process. Buildings, 9 (5), 135. doi: 10.3390/buildings9050135.

[12] Membership List. (2022). Retrieved 21 March 2022, from http://e-ceaa.org/membership/membership-list/.

[13] How to Determine the Correct Survey Sample Size. (2021). Retrieved 16 August 2021, from https://www.qualtrics.com/experience-management/research/determine-sample-size/.

[14] Sample Size Calculator (Use in 60 Seconds) // Qualtrics. (2021). Retrieved 16 August 2021, from https://www.qualtrics.com/blog/calculating-sample-size/.

[15] Ugochukwu, I., & Chioma, M. (2015). Local Building Materials: Affordable Strategy for Housing the Urban Poor in Nigeria. Procedia Engineering, 118, 42-49. doi: 10.1016/j.proeng.2015.08.402.

[16] Celentano, G., Escamilla, E., Göswein, V., & Habert, G. (2019). A matter of speed: The impact of material choice in post-disaster reconstruction. International Journal of Disaster Risk Reduction, 34, 34-44. doi: 10.1016/j.ijdrr.2018.10.026.

[17] What is Modular Construction? The Complete Guide - Ramtech Building Systems. (2021). Retrieved 1 December 2021, from https://www.ramtechmodular.com/modular-construction-info/.