ANALYSIS OF INTEGRATING SUSTAINABLEECO-FRIENDLY MATERIALS ON THE PERFORMANCE OF CONVENTIONAL BUILDING PROJECTS DELIVERY

(A STUDY OF PORT HARCOURT METROPOLIS, RIVERS STATE).

BY

ODUALI, NHEOMACHI FAITH

Reg No: 20204251848

SUBMITTED TO POST GRADUATE SCHOOL,

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF SCIENCE (MSC) IN PROJECT MANAGEMENT TECHNOLOGY.

JUNE, 2025

CERTIFICATION

The Board of Examiner certifies that the research titled Analysis of Integrating Sustainable Eco-friendly Materials on Conventional Building Projects Delivery in Port Harcourt Metropolis Rivers State" was carried out by ODUALI, NHEOMACHI FAITH (reg. no. 20204251848) in partial fulfillment of the requirements for the award of the degree of Masters of Science (M.Sc) in Project Management Technology in the Department of Project Management Technology of the Federal University of Technology, Owerri. Nigeria.

....	22/07/2025
Prof. E.C. Ubani (Project Supervisor)	Date
....	23/7/25
Dr. G.C. Enyinna (Co-Supervisor)	Date
....	23/7/25
Dr. G.C. Enyinna (Head of Department)	Date
....	29/7/25
Prof. K. A. Okorocha, (Dean of SLIT)	Date
....	....
Prof. (Mrs) J. N. Nwosu (Dean of PGs)	Date
....	28/05/2025
External Examiner	Date

DEDICATION

I dedicate this research to God Almighty for His infinite mercy, guidance and wisdom. This research is also dedicated to my loving husband Engr. Oduali S.D. Ikedi who took all the pains to make sure I attain this level of education.

ACKNOWLEDGEMENTS

My greatest thanks goes to the Almighty God for His loving kindness upon my life and the opportunity to pass through the process of learning in Federal University of Technology Owerri. My profound gratitude also goes to my supervisor, Prof. Ubani Emmanuel C. for hispieces of advice, tutoring and support to ensure that this research was successful, I also want to appreciate the Dean of SLIT, Prof. K.A. Okorocha and the H.O.D of P.M.T., Dr G.C. Enyinna, for impacting in me with their encouragement and support.

Also, I say thank you to all the staff both academic and non-academic of SLIT in the persons of Dr. C.I. Anyanwu, Prof. C.C Nwachukwu, Dr. S.O. Okpighe, Dr. I.I. Echeme, Dr. Amade Benedict and Dr. (Mrs.) U.U. Moneke.

I will not forget to thank my loving husband Engr. Oduali S.D. Ikedi, my parents, Mr. and Mrs. Samuel Obinna Njoku, Arc Henry Eze Onu, Mr. Njoku Uzochi Robert, Mrs Charity Rex, Engr, Chineme Oduali, Mr. Andrew Echesi and Engr Meshack Chalokwu whose constant encouragement and support saw me through this level and to all who have in one way or the other contributed to the success of my academics.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This study investigated the effects of integrating sustainable eco-friendly materials on the performance of conventional building project delivery, aiming to addressenvironmental degradation issues. The research focused on the Port Harcourt metropolis in Rivers State, involving key stakeholders in the construction industry, including Architects, Builders, Quantity Surveyors, and Structural Engineers, as respondents. Data collection utilized a Likert scale questionnaire, resulting in 82 out of 103 questionnaires being used for analysis. Key findings revealed various barriers of integrating sustainable eco-friendly building materials. Government-related barriers ranked highest in hindering the integration of sustainable eco-friendly building materials, with the RSI values for all barriers ranging from 0.95 to 0.78. The study also assessed the correlation between conventional building project delivery (CBP) andsustainableeco-friendly materials, including Earthen Materials (EM), Renewable Resources (RR), Recycled Materials (RM) and Other Sustainable Options (OS). The correlation co-efficient were as follows: 0.87 for RR andCBP, 0.82 for EM and CBP, 0.78 for RM and CBP, and 0.046 for OS and CBP. Additionally, correlations between CBP and benefits of integrating sustainable material were assessed: Pearson correlation coefficient of 0.823 was obtained forEnvironmental benefits (EB) and CBP, 0.778 forEconomic Benefit (ECB) and CBP and 0.206 forSocial Benefit (SB) and CBP. The Relative Importance Index (RII) ranged from 0.98 to 0.37, with the highest importance attributed to educating building owners about the future benefits of sustainable building. Statistical Package for Social Sciences (SPSS v.25) was used for data analysis which employed descriptive statistics, such as: simple percentages and bar charts. In conclusion, this study identified government-related barriers as the primary impediment to the adoption of sustainable/green building projects in Port Harcourt. This study recommends the need for government intervention and policy changes to encourage sustainable construction practices in the Port Harcourt building/construction industry.

KEY WORDS:
Sustainable, Conventional, Materials, Projects, Integration, Delivery

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The world's population is always growing, and this has raised awareness of the need to preserve the earth's bountiful resources for future housing requirements.

The constant growth of the population of Nigeria is resulting in the increase in demand for housing and energy which is one of the major causes of degradation and depletion of the earth's resources. With greater quality, energy efficiency, and the use of recycled and recyclable materials for construction, sustainable construction aims to meet the housing needs of the expanding population and increase building lifespan and occupant health.

Materials are crucial for the construction of buildings. The mechanical strength of the building is a result of the materials' chemical, physical, and mechanical characteristics as well as an appropriate building design. The choice and use of environmentally friendly or sustainable materials should be the first step in the design of sustainable or green buildings. According to Environmental Protection Agency (EPA)for materials to be sustainable it means that they can stand the test of time without having an adverse effect on the environment, have a minimal negative impact on natural resources, and are safe for people and the environment to use.

Sustainable construction, according to the Environmental Protection Agency, is the process of designing buildings and employing resource and environmentally-conscious methods at every stage of a building's lifecycle, including design, construction, operation, maintenance, renovation, and deconstruction.

Without taking into account resource conservation, energy efficiency, land preservation, storm water runoff reduction, and pollution reduction, the building construction industry in developing countries continues to use the conventional method of construction, which is primarily associated with bricks/blocks, mortar, and concrete as major materials for the end product of the conventional building. (Chukwu et al. 2019). The activity of developing and utilizing healthier and more resource-efficient models for construction, reconstruction operation, maintenance, and demolition is known as sustainable or green building. Among other design considerations for improved sustainable performance, sustainable building construction incorporates energy-saving strategies such as low emissivity glass, green roof technology, solar energy cells, energy-efficient air conditioning systems, sun shading devices,building space planning and orientation. (Qian et al. 2015). Sustainable or green building focuses on the interaction between the structure and the environment, limiting negative effects on the environment, health risks, energy use, and natural resource consumption. (mayhoub et al. 2020). According to Prutha Patel, (2021) because of the increase in population, the adoption of sustainable structures is required and the construction industry places high priority on the construction of sustainable buildings. He is also of the opinion that due to the huge urbanization activities, lots of environmental issues are originating in the sense that the recent advanced technology and facilities consume more energy which directly or indirectly impact on the environment. The building construction industry also consume enormous amounts of energy and raw materials, as well as releases a significant amount of carbon dioxide into the atmosphere, all of which have a negative impact on human health and cause climate change. The only way to lessen the impact of pollution is for the building sector to shift toward sustainable building practices (Patel et al, 2021).

Nduka and Ogunsanmi (2015) study on the Adoptability of Green Building Practices in Construction Projects in Nigeria states that to ensure awareness and knowledge of the practice, professional organizations should teach and educate their members on green or sustainable concepts. Professionals must participate in training programs, seminars, and conferences to advance their understanding of sustainable design, the availability of sustainable building materials, and construction processes and procedures. Adopting a green or sustainable design concept aims to minimize energy consumption, operating and maintenance costs, boost occupant productivity and comfort, minimize waste and pollution, and increase building and component durability and adaptability. The emphasis on green or sustainable concept should be adopted at the design, planning, and construction stages of the project.

Encouraging the construction of sustainable buildings and making sure that they are designed with sustainability in mind is important. There is little public awareness of sustainable building practices, particularly in Rivers State. This may be due to; lack of institutional structures supporting sustainable or green buildings, insufficient funding to support green construction, limited professional capacity to integrate sustainable buildings into construction, and lack of government support for initiating sustainable construction and the use of sustainable materials for construction purposes.

However, according to Kaanchan and Mahendraa (2017), the level of adoption of sustainable construction techniques is still low due to the complexity of sustainability and the fragmentation of the construction industry. This research is aimed at evaluating the level of awareness of sustainable construction and also promoting sustainable building in Rivers state by integrating sustainable eco – friendly building materials for building construction purposes.

1.2 Problem Statement

The increase in the use of conventional building materials (cement, asbestos, paint, vanishes) has led to the deterioration of theenvironment and depletion of the earth's natural resources (Odeyale&Adekunle, 2008). Although, in Port Harcourt, a few housing developments have been discovered to have some elements of sustainable eco-friendly material(solar installation and water conservation systems) embedded in their design, there is no known evidence of buildingscompletely built with sustainable eco-friendly materialsas Building Professionals (Architects, Structural Engineers, Quantity Surveyors and Builders) along with their clients opt to use the conventional building materials for building projects.

Rivers State is one of the states in Nigeria with increasing population. According to the statistics from the last census in 2006, Rivers State was the 6th most populous state in Nigeria with the population of over 5million people living in the State. The high population of the State, has led to the corresponding highdemand for housing. Construction of these houses involves several activities that are not friendly to the environment. This is in line with the opinion of Usman et.al.,(2014)that 65% of the waste disposed in our landfills, 70% energy consumption, 30% of the greenhouse gas emission, and about 80% of raw material consumption are as a result of housing and its construction activities.Rivers State has massive urban dwellers which makes it densely populated, leading in ongoing building growth on virgin grounds without regard for green principles. The State is currently decongesting its cities through real estate development. Due to above reason, the state government some time ago introduced a new layout in Rivers State known as 'Greater Port Harcourt'. However, no consideration was made to sustainability in design, construction, or material to be used. One could picture what would happen to Rivers State and other States in Nigerianin the near future if no measures to promote sustainable building construction are pursued.

Due to the negative impact on the environment resulting from the construction, operation and maintenance of conventional buildings, it is important for the construction industry especially in Rivers State to deviate its focus from conventional buildings to sustainable buildingsby integrating sustainable eco-friendly building materialsin order to achievezerogreenhouse gasemission, pollution reduction, energy efficiency and material conservation.

1.3Objectives of the Study

The aim of the study is to analyse the effects of sustainable eco-friendly building materials on the performance level of conventional building projects deliveryin Port Harcourt metropolis, Rivers State.

The specific objectives of the study are as follows:

I. Identification of the barriers of integrating sustainable eco-friendly building materials into construction of building projects in Rivers State.

II. Evaluation of the opinions of stakeholders on the influenceof sustainable eco-friendlybuilding materials (SEBM) on the performance of conventional building projects (CBP) in Rivers State.

III. Correlation ofthe benefits of integrating SEBMand the performance level of CBP.

IV. To proffer solutions to the barriers of integratingsustainable eco-friendly building materials in Rivers State.

1.4 Research Questions

1. What are the barriers of integrating sustainable eco-friendly building materials in Rivers State?

2. To what extent can the use of SEBM influence the performance of conventional building projects (CBP) in Rivers State?
3. What are the levels of correlation between environmental, economic and social (EES) benefits of integrating SEBM and performance level of CBP?
4. What are the solutions to the barriers of integrating sustainable eco-friendly building materials in Rivers State?

1.5 Research Hypotheses

In order to achieve the objectives of this study, the following hypotheses are postulated and are to be tested in this study:

HO_1: There is no significant correlation between the integration of SEBM and performance level of CBP.

HO_2: There is no significant correlation between environmental, economic and social benefits respectively with performance level of CBP.

HO_3: There is no significant difference among the opinions of construction professionals on the use of SEBM in the CBP delivery in Port Harcourt metropolis Rivers State.

1.6Scope of the Study

The scope of the study includes content scope, time scope and analytical scope.

1.6.1.Content Scope

The study focuses on evaluating the effects of sustainable eco-friendly building materials on the performance level of conventional building projects delivery using Rivers State as the geographical scope as toevaluating the barriers of integrating sustainable eco – friendly building materials for building projects, evaluating how the use of sustainable building materials can enhance the performance of conventional building projects, and also to proffer solutions to constraining factors limiting the use of sustainable building materials. The performance parameters are project budget, schedules, quality and durability, green environment and risk containment, while sustainable material are natural material (straw bales, bamboo, timber, solar energy etc), earth material (stone, bricks, cob, lime and mud), industrial waste (empty plastic bottles, worn out tires, fly ash, cow dung and rice husk).

1.6.2. Time Scope

The study was carried out as it is a compulsory requirement for the award of masters of Science (MSc). The duration of this study was for the period of 6 months to enable the researcher meet the target date for submission and approval of the research work.

1.6.3. Analytical Scope

The study shall be limited to the construction industry in Port Harcourt metropolis. For the sake of this study, Port Harcourt metropolis include Port Harcourt city and Obio-Akpor LGAs respectively, Rivers State, Nigeriabecause there will be easy access to information in this area by the researcher.

The target respondents for this study will be the principal actors in the construction industry namely; the Architects, Structural Engineers, Quantity Surveyors, Builders, and the Contractor.

1.7Justification for the Study

In many developed and some developing countries, the construction industry is establishing sustainability ethics based on the ideas of resource efficiency, health and productivity. According to Dania (2007), Nigerians are not sufficiently aware of or interested in sustainable building practices and the usage of sustainable materials. However,according to Alabi (2012), Aje (2016), and Baron and Donath (2016), many emerging countries have poor levels of sustainability, and claims regarding the poor nature of sustainability in construction projects undertaken in most developing nations have been made recently; and the Nigerian construction industry is not exempted (Aje, 2016; Baron & Donath, 2016 Alabi, 2012; Al-Saleb& Taleb, 2010;). A number of studies have been published about the challenges associated with green building (GB) in third world (developing) nations (Aigbavboa et al., 2017; Alsanad, 2015; Ametepey et al., 2015;

Ayarkwa et al., 2017; Djokoto et al., 2014). However, researches on sustainable building and its material adoption emerging from Nigeria are more centered on sustainable or green building knowledge issues (Ekung et al., 2016). This encompasses perspective, awareness, and sustainable facility management (Aluko 1997; Magaji, 2015; Nduka &Sotunbo 2014), as well as renewable energy and energy efficiency (Ahmed & Gidado, 2008; Bugaje 2006).Sustainable or green building materials, however, has to be taken into account as a crucial justification in the field of green architecture with regard to environmental sustainability in urban as well as rural communities across the country.

The benefit of this study is to achieve environmental sustainability by integrating sustainableeco-friendly materials for building projects in Port Harcourt Rivers State, highlightinghow the use of sustainable eco-friendly building materials can enhance the performance of conventional building projects, examining the barriers to integrating the use of sustainable building materials for building projects in Port Harcourt Rivers State,and proffering possible solutions and recommendations to constraining factors limiting the use of sustainable building materials in Port Harcourt,Rivers State.

CHAPTER TWO

LITERATURE REVIEW

2.1Conceptual Review

Materials are essential components of building construction, building materials significantly impact the environment and building users. For a building to be tagged sustainable or green it must be constructed with sustainable or green building materials. Greenhouse gases (GHG) are the main causes of global warming, and buildings are a significant source of GHG emissions (Geng, X. et al., 2017). According to the EPA, buildings use 41% of the world's energy and produce 40% of the greenhouse gas emissions (Yudelson, J., 2017). Concerns about the sustainability of buildings have emerged in the building sector. Reducing GHG emissions through sustainable building development would be extremely beneficial. According to the WECD (1987), sustainable development is defined as growth that meets current demands while preserving future generations' ability to meet their own needs.However, according to the INDIA CSR (2023), a green or sustainable building is a structure that minimizes its environmental impact while improving the well-being and comfort of its occupants this is of the same opinion with (WECD, 1987).There is a need to build using sustainable ways since what we build now will shape the built environment of tomorrow and influence future generations' ability to meet their requirements (Dickie and Howard, 2018). Green buildings are built to meet environmental standards and improve operational efficiency, hence reducing the negative influence on the environment. Green buildings also consider the comfort level of their occupants.

Sustainability refers to having little to no negative impact on people or the environment, whether it be through the use of materials, energy, or practices. This is of the same opinion with (Thomas, 2019), who said that the concept of sustainable or "green" buildings envisions a novel approach to conserving water, energy, and material resources throughout the building's construction and maintenance, which can lessen or even eliminate the negative environmental effects of structures.Sustainability is a wide, complicated term that has become a major focus in the architecture and construction industries. The concept of sustainability entails improving the quality of life, allowing people to live in a healthy environment with improved social, economic, and environmental conditions (Akadiri et al, 2012).Sustainable construction involves incorporating various environmentally friendly concepts and practices to minimize the impact of building projects on the planet. Below are some key concepts in sustainable construction:

a. Energy efficiency
b. Passive design
c. Water efficiency
d. Material efficiency
e. Waste reduction
f. Improved indoor air quality.

2.1.1 Energy Efficiency

Energy efficiency is a fundamental concept in green or sustainable construction, focusing on reducing energy consumption and minimizing the environmental impact of buildings. According to the U.S. Environmental Protection Agency (EPA), energy efficient buildings use less energy for heating, cooling, lighting, and other functions without compromising comfort or performance. This approach not only helps mitigate climate change but also lowers operational costs for building owners and occupants. In any functioning society, managing energy usage is a need because it is one of the most significant environmental challenges. The biggest consumers of energy are buildings. At every stage of a building project, from design and construction through operation and final demolition, buildings need energy and other resources. According to Lenzen and Treloar (2012), the type and quantity of energy used throughout a building material's life cycle, from the manufacturing process to the disposal of building materials, can have a variety of long-term effects on how greenhouse gases (GHGs) enter the atmosphere. Their consumption can be significantly reduced by increasing efficiency, which is a powerful way to reduce greenhouse gas emissions and limit the depletion of nonrenewable energy sources.

The primary objective of energy conservation, according to Akadiri et al. (2012), is to decrease the consumption of fossil fuels while increasing the usage of renewable energy sources. Energy efficiency strategies in sustainable construction include proper insulation in walls, ceilings and floors, high-performance windows, efficient HVAC systems, and the use of energy efficient appliances and lighting. Awnings, porches, and trees should be positioned, along with windows and walls, to maximize solar gain in the winter while providing summertime shade for windows and roofs. Moreover, strategically placed windows (daylighting) can increase natural light and reduce the demand for artificial lighting during the day. By implementing energy efficient practices and technologies, sustainable construction aims to create buildings that consume less energy, lower greenhouse gas emissions and contribute to more sustainable future.

2.1.2Passive Design

Passive architecture involves designing windows, walls, and floors to gather, retain, bounce back, and disperse solar energy. This energy is harnessed as warmth during winter and repelled during summer months. (*Wikipedia).*

Passive design is a pivotal concept in green construction that involves designing buildings to take maximum advantage of natural resources, climate conditions, and building materials in order to reduce the need for mechanical heating, cooling, and lighting. According to the American Institute of Architects (AIA), passive design strategies harness the natural elements to create comfortable indoor environments while minimizing energy consumption. Passive design principles include optimizing building orientation, incorporating effective insulation, maximizing natural daylight, and promoting natural ventilation. By strategically placing windows, using thermal mass materials, and employing shading devices. Passive design reduces the reliance on active heating and cooling systems, resulting in both energy savings and improved indoor comfort.The Passive House Institute, an international standard for energy efficient construction, focuses on achieving extremely low energy consumption through passive design strategies. This concept aligns with the broader goals of green construction, emphasizing sustainability and reduced environmental impact.

2.1.3Material Efficiency

Buildings use a variety of materials at various phases, and the choice of material will impact the performance and life cycle of the structure as a whole. Building materials for eco-friendly or sustainable structures are sourced from natural, renewable resources managed and harvested sustainably. Alternatively, they're locally procured to cut down on transportation energy expenses or reclaimed from nearby sites, minimizing environmental impact.(Abeysundara et al, 2019). Wood sourced from forests certified to third-party standards, rapidly renewable plants such as bamboo and straw,recycled metal, sheeps wool, cork, hermpcrete, ferrocks, and others are all regarded to be sustainable building materials. According to Akadri et al (2012) to achieve material efficiency, tactics for conserving resources include designing to minimize waste, selecting durable materials, opting for natural and locally available resources, planning for pollution prevention, and choosing non-toxic or less harmful materials.

2.1.4Water Efficiency

Water efficiency is a crucial concept in sustainable construction that focuses on minimizing water consumption and optimizing water use within buildings. According to the U.S. Green Building Council (USGBC), water efficiency aims to reduce the strain on local water supplies and waste water systems, while also decreasing the energy required for water treatment and distribution. In order to construct sustainably, it's crucial to reduce water usage and safeguard water quality. In many regions, the demand on the supply aquifer exceeds its capacity to replace itself, which is a serious problem for water consumption (Dweiri, 2022). Facilities should rely more on water that is collected, used, purified, and reused as much as is feasible. Water efficiency strategies in green construction include using low-flow fixtures, rainwater harvesting systems, graywater recycling, and drought resistant landscaping. The USGBC's Leadership in Energy and Environmental Design (LEED) certification program recognizes the importance of water efficiency by awarding points for water saving measures in building designs. Through the adoption of water-saving technologies and methods, sustainable construction not only preserves a valuable resource but also promotes environmental sustainabilityand reduces the overall ecological footprint of buildings.

According to Akadiri et al. (2012), the following will help to minimize water usage;

a. Creating dual plumbing systems to recycle water for toilet flushing can protect and preserve water throughout a building's lifespan. Incorporating water-saving fixtures such as ultra-low flush toilets and urinals, low-flow showerheads, sensor-activated sinks, and efficient dishwashers and washing machines helps reduce wastewater.
b. Collecting rainwater for irrigation will greatly reduce the consumption of treated water, rain water can also be used for some household applications.
c. Re-circulation systems for centralized hot water distribution can also help reduce it by saving water that consumers generally spend while waiting for warm water to flow from a warm water faucet.

2.1.5 Waste Reduction

Waste reduction is a fundamental concept in green construction that aims to minimize the generation of construction and demolition waste while optimizing the ruse and recycling of materials. According to the U.S. Environmental Protection Agency (EPA), construction and demolition debris constitute a significant portion of waste in the United States, and waste reduction strategies can lead to both environmental and economic benefits. Sustainable construction incorporates waste reduction by implementing practices such as deconstruction (careful dismantling of structures to salvage materials), recycling of materials like concrete, metals and wood, and incorporating recycled content into new construction materials. The Leadership in Energy and Environmental Design (LEED) certification program by the U.S. Green Building Council (USGBC) emphasizes waste reduction as one of its key criteria for sustainable building practices. By minimizing waste and maximizing material reuse, sustainable construction contributes to a more sustainable built environment and reduces the strain on landfills and natural.

2.1.6Indoor Air Quality (IAQ)

Indoor air quality (IAQ) is a critical concept in green construction that focuses on creating healthy and comfortable indoor environments by minimizing pollutants and ensuring proper ventilation. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) describes indoor air quality (IAQ) as air that doesn't contain harmful levels of known contaminants, as assessed by relevant authorities, and which satisfies a significant majority (80% or more) of occupants without causing dissatisfaction.Green buildings can sustainably improve indoor air quality by using high-quality insulation, ventilation systems, and building materials (Blade, 2023).

Sustainable or green construction emphasizes IAQ by using low-VOC (volatile organic compound) materials, proper ventilation systems, and effective air filtration.The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification program recognizes IAQ as an essential component of healthy and sustainable building design. Indoor air quality is a core principle of green construction, highlighting the importance of healthy living spaces and the well-being of building occupants. By prioritizing IAQ, green construction aims to create indoor environments that promote occupant health, productivity and well-being while minimizing the potential negative health effects associated with poor air quality.

Using non-toxic products and resources will enhance indoor air quality and lower the prevalence of asthma, allergies, and sick building syndrome, according to (Gopal Mishra, 2019). These materials are moisture resistant to fend off mold, spores, and other germs and are emission free. They also contain little to no volatile organic chemicals.

Indoor air quality is managed through ventilation systems and materials that control humidity and allow for proper airflow within the building.

Akadiri et al., (2012) in their research on ‘Design of A Sustainable Building: A ConceptualFramework for Implementing Sustainability in the Building Sector’, stated that in order for a building to be considered sustainable or green, it must be able to satisfy the following objectives:

a. Resource conservation
b. Cost efficiency, and
c. Design for human adaptation.

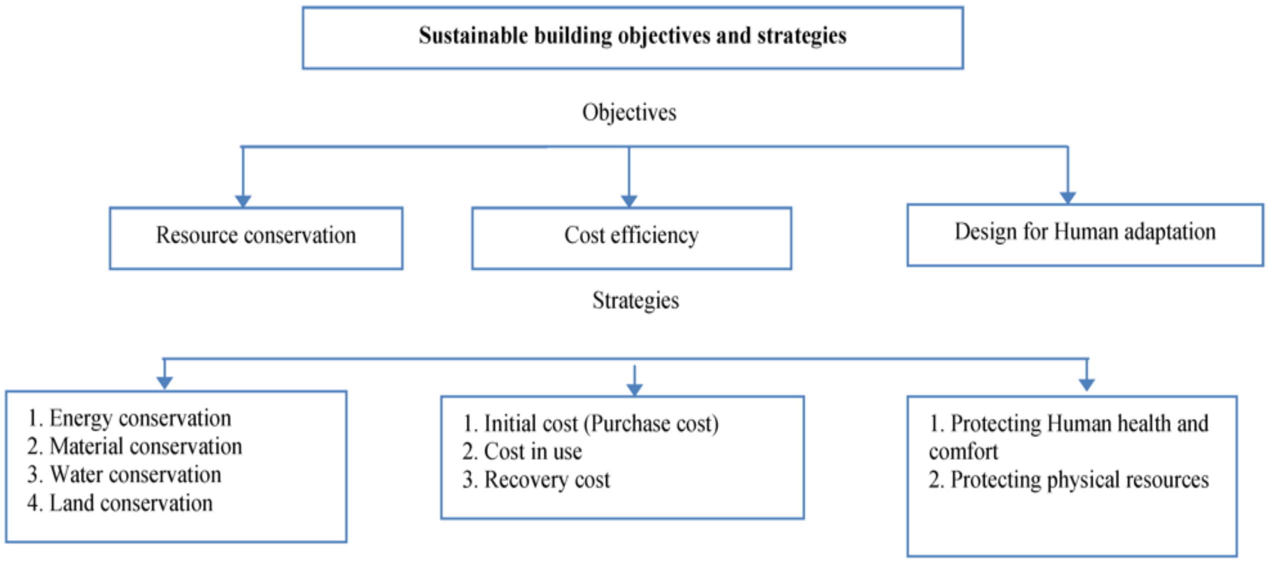


Figure 2.1Framework for implementing sustainability in building construction (Akadiri et al., (2012).

2.1.7Resource Conservation

Resource conservation requires achieving more with less. The best way to use natural resources is to manage them in a way thatfuture generations can continue to rely on them while the present generation still receives the most benefit from the resources for their needs today. (Halliday 2018) observed that because some resources are becoming incredibly scarce, care should be taken in using the stocks that are still available. He demanded that rare resources be replaced by less rare or renewable ones.According to Graham (2023), the building industry is a significant consumer of natural resources, therefore many of the attempts taken to design ecologically sustainable structures are concentrated on improving resource utilization. The concepts of solar passive design, which aim to limit the use of non-renewable resources, the consumption of energy generation, life cycle design, and design for the building were some of the examples he provided.Resources are consumed more efficiently when waste is reduced during the construction of buildings and possibilities are provided for recycling and reusing building materials, from figure 1 above, the strategies for achieving resource conservation includes; conservation of Energy, material, water and land. Akadiri et al,(2012) in their study further stated the methods that will be used in other to achieve the conservation of the resources.

2.1.8Cost Efficiency

The aim of sustainability in building construction is to optimize efficiency and reduce expenses. Various indicators suggest that numerous businesses, both in public and private sectors, base their decisions on building investments solely on initial construction costs, often overlooking expenses related to operation and maintenance throughout the building's lifespan.

The initial cost of developing a sustainable or ecologically friendly structure is the aspect that receives the most criticism. Modern technologies, new appliances, and photovoltaic systems typically cost more money. The Environmental Protection Agency (EPA) claims that while most sustainable or green buildings are more expensive than conventional structures, they produce ten times as much over the course of their lifetime.

2.1.9Design for Human Adaptation

One of the primary objectives of sustainable construction is to establish a pleasant and healthful environment conducive to human activities. A building should offer the necessary facilities for work, residence, education, healthcare, manufacturing, and other functions, in line with its intended design. Additionally, it must ensure the safety and comfort of its occupants by being structurally sound, fire-resistant, and non-hazardous to both inhabitants and the surrounding environment. Buildings must not put an extra burden on the environment or pose a risk to it, such as through excessive energy use. According to Akadiri et al, (2012) to promote and enhance human adaption, the building should be designed in such a way that can be able to:

a. Protect health and comfort of occupants and,
b. Protect physical resources.

2.1.9a ProtectingHealth and Comfort of Occupants

A healthy building acknowledges that occupant comfort and health demands come first. Several architects and building designers have prioritized style and form-making over environmental sustainability and the enjoyment of people living in and around built environments.

A product may be efficient and effective, but Sev (2019) argues that it is not sustainable if it does not improve productivity and the comfort of its users.Akadri et al. (2012)

intheirarticle on "design for sustainable building," addressed some techniques essential to improving the coexistence of the environment, buildings, and their occupants, which includes:

a. Thermal comfort
b. Acoustic comfort
c. Daylighting
d. Natural ventilation
e. Functionality
f. Aesthetics

2.1.9b Protecting Physical Resources

One of the most significant aspects of sustainable design and construction is the protection of natural resources. Design elements that contain resilience against both natural and man-made disasters, such as fire incidents, earthquakes, flooding, and criminal attacks, must be taken into account. Hazard mitigation planning, according to Akadri et al. (2012), is the process of figuring out how to decrease or eliminate the loss of life and property damage. The techniques to accomplish these tasks include the following;

a. Design for Fire Protection
b. Resist Natural Hazards
c. Design for crime prevention

2.1.10Sustainable Eco-friendly Building Materials

Building materials refer to a blend of naturally sourced or artificially produced minerals or compositions employed in constructing structures. These materials encompass a variety of substances like concrete, sand, granite, gravel, fabricated steel, foundational steel, sandcrete blocks, fired bricks, cement blocks, roofing materials, among others.(Opara, 1999).The three main principles of construction materials are resources, contamination, and execution (Berge, 2010). Any building material uses resources when it is being produced, which includes all of the raw materials and energies used from the time of extraction to the time of removal. As was said above, contamination refers to any harmful emissions that result from the production of the material, products used to clean and maintain the material, off-gassing from materials during their lifetime, and final burning or landfilling.A sustainable or environmentally friendly material is one that is both eco-friendly and possesses traits such as renewability, biodegradability, and recyclability. As outlined by Attmann (2019), these materials fall into three main categories: nanomaterials (such as nano-carbon tubing), biomaterials (organic materials like polyurethane, carbon, and straw), and smart materials (including carbon fiber).However, Baumann, &Bragd, (2012) assessed that the disarray regarding the meaning of green materials is still present. The three R's (re-use, recycle, and reduce) should be considered while picking the best building materials, according to (Kelly and Hunter, 2019). Building materials that are typically considered to be "green" include things like bamboo, due to its rapid growth, straw, responsibly harvested wood from well-managed forests, biological blocks, dimension stone, reused stone, recycled metal, and similar non-toxic, renewable, recyclable, and/or reusable materials.(Shittu, 2014). Enhancing safety and wellness is important not only from a human perspective to reduce receivers' anxiety, but also as a means of ensuring the success and sustainability of the buildings, as well as their advancement over a longer and better term. When we plan or carry out a development project, we should keep in mind a strong concern for nature protection. We should take into account how circuits of matter and energy change, which becomes necessary and only practical if we fully embrace and take into account ecological enactment on the unique preservation of nature (Cazacu, 2015). Development's negative impact on the environment is mostly manifested in excessive energy consumption and CO2 emissions, which result in global warming, water pollution, the production of solid waste, noise, and dust (Georgescu, 2015). Reusing building materials is becoming more popular as a way to reduce the environmental impact of the construction industry (Sarvesh & Chouhan, 2013). Despite the fact that projects are carried out on a few different levels and are wisely examined based on the financial results, the actual environmental implications are rarely taken into consideration (Sarvesh & Chouhan, 2013). The environmental impact of a building as a whole will be significantly reduced by recycling these materials (Sarvesh & Chouhan, 2013). For energy efficiency, sustainability, and durability, green buildings use materials that are currently available (Akshay et al, 2015). Utilizing lime in construction aids in sequestering carbon rather than releasing it, thereby mitigating adverse environmental impacts. Lime serves as a sustainable building material, reducing indoor temperatures by 5°C to 4°C compared to concrete during plastering.(Ashish, 2012). Green construction materials reduce climatic effects to create effective, sustainable structures and, in addition, lower pollution levels that contribute to resource depletion, greenhouse gas emissions, soil contamination, ozone depletion, and health risks. There is a trend to use green building materials as a result for a better tomorrow and a healthy existence for future generations (Gupta, 2016). By integrating these materials into construction projects, green structural materials and products help protect dwindling non-sustainable resources and lessen the environmental impacts associated with the extraction, transportation, handling, manufacturing, installation, recycling, reuse, and disposal of source materials in the construction industry (Geeta et al., 2014). Research indicates that native materials including stone, grasses, mud, cow dung, bamboo, leaves, and reeds, among others, were employed in constructing diverse structures in Nigeria. Despite the fact that these materials are easily accessible in large quantities, their use has decreased as a result of people's preference for imported building materials, which are produced carelessly and at a higher cost as a result of this (Odeyale& Adekunle, 2008). Living in brick, stone, or timber structures is thought to indicate extreme poverty, which has led to a dislike of these green building materials. Our desire for civilized structures without considering our history has also done little to help us view things critically or advance our domestic building materials rather than looking for materials from abroad (Odeyale& Adekunle, 2008). In Nigeria, there are abundant supplies of laterite, clay, lime, stone, timber, agro-industrial waste, glass sand, and bitumen in their normal or regular states, which helps to meet the demand for using these green building materials for construction purposes (Kayode & Olusegun, 2013). According to investigations, these materials have been found to be useful in the building construction sector (Kayode & Olusegun, 2013). It was emphasized that the difficulty in providing low-income people with housing through their own efforts was due to the higher cost of the building materials, which can be traced to high rates of imported materials used for development that have drawn in much expense in comparison to the indigenous building materials (Kayode & Olusegun, 2013). If the government provided genuine information and comfort to the Nigerian residents, a variety of alternative building materials may meet their needs and those of the imported materials (Kayode & Olusegun, 2013). According to Amal and Halil (2017), the majority of buildings in Northern Nigeria are still constructed using sustainable, traditional materials and methods like bamboo and wood. By using an easier construction process, less expensive transportation, and fewer economic demands, green building materials, also known as sustainable traditional building materials, reduce the cost of the overall construction. Sustainable, renewable, affordable, and widely accessible green building materials will improve energy efficiency, promote sustainability, and lower construction costs when used in modern building approaches (Amal & Halil, 2017). The advancement and adoption of modernization and innovation to comply with contemporary building standards and lifestyle requirements present a challenge to the viability of green building materials. However, the growing awareness of green building practices enables the utilization of such materials by leveraging locally available resources that align with the specific needs and conditions of the locality, offering an affordable solution (Amal & Halil, 2017).

Building materials are one of the main resources needed to construct a building from the foundation to the finishing level. The cost of construction is directly related to the type of building materials employed to erect the project. Using sustainable or green building materials such as recycled materials, sustainable wood, and low emitting materials is very advantageous in the long run because they do not harm the environment during their manufacturing, usage, or disposal and are easily recyclable (Blade, 2023). Green home construction dramatically lowers carbon emissions and uses less energy, which results in lower energy costs.In contrast to a normal construction, a green building requires particular systems and materials to adapt sustainability (Sheth, 2016). Ecologically sustainable materials should be chosen, according to the Green Building Rating for Integrated Habitat Assessment (GRIHA).Environmentally friendly materials typically incorporate a substantial amount of recycled content, utilize rapidly renewable resources, and exhibit low emission potential.Sustainable eco-friendly materials that are used for building construction purposes can be grouped into four categories which includes;

a. Renewable resources.

b. Recycled materials.

c. Earthen materials

d. Other sustainable options.

Renewable resources includes but not limited to the following;

i. Bamboo

ii. Straw bales

iii. Timber

iv. Solar shingles

Bamboo: Bamboo, a type of plant, can regenerate within approximately 3–5 years. When not subjected to chemical processing, it is entirely biodegradable, possesses antimicrobial properties, and is environmentallyfriendly. Its axially flowing fibers are what give it its tremendous strength (Giovanni, 2021). Bamboo is one of the building materials that is becoming more and more popular. For example, in addition to its traditional uses as scaffolding and support, bamboo is now being proposed as a replacement for steel reinforcement in short beams and columns.

Straw Bales: Straw bales serve as highly effective insulation material, similar to wool, commonly installed in ceilings, attics, and walls to maintain consistent temperatures. Straw, being a renewable resource, can be harvested and replanted with minimal environmental impact. Additionally, farmers often supply straw material by repurposing it from burning off after harvest. Sarath (2012) suggests that repurposing this waste byproduct into compressed ceiling and wall panels ensures the preservation of its carbon content in an eco-friendly manner, preventing the release of embodied carbon into the environment upon destruction, thereby reducing carbon emissions. From material acquisition to energy efficiency, straw bale stands as a sustainable building material utilized in eco-friendly construction, frequently compressed and crafted into insulated cladding panels for homes.

Timber: Timber is a renewable sustainable building material, it has a low carbon footprint compared to many other building materials (Peuhkuri et al, 2019). He is of the opinion that trees naturally absorb carbon dioxide from the atmosphere as they grow, the carbon absorbed remains stored in the timber even after it is harvested and used in construction, helping to mitigate the impacts of greenhouse gas emissions.

Solar energy: Solar energy systems such as solar panels, are often considered sustainable building materials due to their ability to harness renewable energy from the sun. (Renewable Energy World, 2021). With advancing technology and increasingly appealing designs, solar panels are becoming more prevalent on roofs and in yards. Homes can opt for solar panel tiles or mounted structures to decrease their dependence on nonrenewable energy sources.In conclusion, solar energy is a sustainable building material that offers several environmental and economic benefits. It is renewable, cost-saving, and has ability to increase resilience to power outages.

Recycled materials include but not limited to the following:

i. Reclaimed wood
ii. Recycled plastic
iii. Recycled steel
iv. Fly ash
v. Demolition waste

Reclaimed wood: This is an environmentally sustainable building material that offers several advantages over newly harvested timber. It is sourced from old buildings, bridges, warehouses, and other structures. Using reclaimed wood helps reduce the demand for new timber, which can help preserve forests and biodiversity (Smith, 2019). Using reclaimed wood can help reduce waste. Rather than sending old timber to landfills, it is repurposed for use in new construction projects. This helps conserve landfill space and reduce the environmental impact of waste disposal (Johnson, 2020).

Recycled plastic: According to Barbulianno, (2020) plastic items can take up to 1000 years to decompose, whereas the plastic bags we use every day take 10–20 years and plastic bottles take 450 years. It's time to begin cleaning up our planet and reusing all the plastic that we have let to float freely in our parks, oceans, and residences. Barbulianno (2020) claims that recycled plastic reduces greenhouse gas emissions by 95% when compared to concrete blocks. Recycled plastic is a strong, long-lasting material that is excellent at retaining sound.

Recycled steel: This is produced from scrap steel, which can include old cars, appliances and demolished buildings. Using recycled steel in construction helps to reduce the need for virgin steel production, which is energy intensive and contributes to greenhouse gas emissions (Steel Recycling Institute, 2020). According to the Steel Recycling Institute, recycling steel can save up to 74% of the energy required to produce steel from raw materials. By using recycled steel in construction projects, builders can help conserve natural resources, reduce energy consumption, and minimize waste.

Fly Ash: According to Marcelle, (2023). Fly ash is a byproduct of coal combustion made up of the tiny fragments of fuel that have been burned and are expelled with the flue gases from coal-fired boilers. Fly ash is a versatile substance that may be used for a variety of tasks. Depending on the conditions in the area, it can be utilized in various ways for different products. In concrete, fly ash is used to substitute Portland cement to a maximum of 30% by mass, while larger percentages may be utilized in some circumstances. In certain cases, fly ash improves the durability, chemical resistance, and final strength of concrete.Fly ash has the potential to substitute a portion of the cement and sand in concrete, enhancing the workability of fresh concrete, reducing heat during hydration, improving impermeability, and bolstering resistance to sulfate attack. Fly ash in concrete can be used when its properties lie in certain limits as of concrete but classification by particle size and control of the unburned coal greatly enhances the beneficial effects of the fly ash.

Demolition waste: this refers to the materials that are generated from the demolition of buildings and structures, including concrete, wood metals, and other materials. Instead of sending these materials to the landfills, they can be recycled and reused in construction projects, which helps conserve natural resources and reduce waste by reducing the demand for virgin materials (U.S. Environmental Protection Agency, 2021).

Earthen materials includes but not limited to the following;

i. Rammed earth

ii. Cob

iii. Stone

iv. Bricks

v. Lime

Rammed earth: This is a sustainable building material that is made by compacting a mixture of earth, gravel, sand and clay between forms to create solid walls. Rammed earth construction offers several environment benefit. Its low environmental impact, durability thermal mass properties, and non-toxic nature make it an attractive option for sustainable construction (Varges, 2019). Rammed earth walls have a long lifespan and are durable, requiring minimal maintenance over time.

Cob: Clay, sand, straw, and water are combined to create a cob, cob is a material that is malleable and flexible enough to allow for the creation of intricate and lovely structures. It is as durable as concrete after drying. Cob store and transfer heat, it is completely natural, locally sourced, renewable, and non-toxic (Rima, 2019). He is also of the opinion that due to the impermeable nature of walls and the constant discharge of gases from artificial paints, plasters, and other building materials, conventional buildings are plagued with indoor air pollution but because cob is a permeable material that breathes via its tiny pores to keep the air clear and fresh, cob houses do not have these issues. They are also damp-free.

Living in a cob house could dramatically enhance your quality of life if you have indoor allergies since it gets rid of the chemicals that might be the cause. Because of its capacity to absorb sunlight and warm the structure throughout the day, as well as its ability to cool and reflect this into a hot, humid building throughout the summer, a cob house does not require supplementary heating or cooling (Kuru, 2017).

Stone: Stone is a naturally occurring substance in the earth that may be used for both construction and home furnishings like countertops and titles, according to Klemm (2016). When utilized in construction projects, stone produces little to no waste and is both long-lasting and low-maintenance. It often doesn't require factory manufacture because it is a naturally occurring material, reducing CO2 emissions.

Bricks: Brick made from earth-derived clay and water is a natural material that is entirely recyclable and environmentally friendly. When disposed of in a landfill, it does not emit any harmful chemicals. Clay bricks are energy-efficient, helping to keep homes cooler in the summer and retain warmth for extended periods during the winter. (Torsten, 2021).

Lime: According to Eco House Store, Lime mortar is made from a mixture of lime, sand, and water. These resources are inexpensive to use in building because they are plentiful and widely accessible. Lime mortar is a more environmentally friendly option than cement mortar, which is manufactured of Portland cement. Due to the use of fossil fuels in its production, Portland cement greatly increases carbon dioxide emissions. Lime mortar, on the other hand, is formed of organic resources and has a smaller carbon footprint. Additionally, lime mortar production uses a lot less energy than current cement production, which entails high temperatures (1300°C–1450°C) and large atmospheric carbon dioxide emissions. Lime production, on the other hand, typically requires lower temperatures (between 954°C and 1066 °C) and is therefore more environmentally friendly.

Other sustainable options includes but not limited to the following;

i. Cork
ii. Sheep wool
iii. Hempcrete
iv. Rice husk
v. Cow dung

Cork: Cork, derived from the cork oak tree, stands out as an exceptionally sustainable and environmentally friendly material. It boasts resilience against moisture and liquids, along with the ability to dampen vibrations effectively. Moreover, it excels in noise absorption, rendering it ideal for insulation purposes. Its impressive shock-absorbing capabilities make it suitable for sub-flooring, while its inherent fire resistance, particularly when untreated, and enhances its value as a thermal insulator that doesn't emit harmful gases when burned. And even more, being nearly impervious, this material does not absorb water or rot (Knapic et al, 2016).

Sheep's Wool: Sheep's wool stands as a wholly natural and eco-friendly material, capable of rapid regeneration. Renowned for its use in crafting warm blankets and sweaters, wool's fibers form countless small air pockets that effectively trap air, making it an outstanding choice for home insulation. Its energy-saving properties and easy accessibility further underscore its excellence.(Bosia et al, 2015).

Hermpcrete: Hempcrete comprises a blend of sand, hemp fibers, and lime, commonly utilized in construction and insulation. Notably lightweight and easy to handle, hempcrete blocks are made from hemp, a rapidly renewable resource, making them environmentally friendly (Biehl, 2019). Once dried, hempcrete exhibits no fracture lines due to its permeable, non-shrinking nature. While not as robust as concrete, it offers resistance to pests and fire, along with effective insulation properties. Designed as a non-load-bearing glued masonry product, hemp blocks are versatile and appreciated by professionals for various construction and renovation projects, including healthy and natural insulating envelopes, partition walls, and counter-partitions. (Megan, 2021).

Rice Husk: Rice husk ash (RHA) serves two main purposes in concrete construction. Firstly, it can substitute Portland cement, effectively reducing concrete production costs. Secondly, it functions as an additive for producing high-strength concrete. It's essential to highlight that the form of RHA used in concrete is amorphous rather than crystalline, which makes it suitable for pozzolanic activity. Apart from its applications in ceramic glaze and roofing shingles, RHA finds diverse uses in construction such as in high-performance concrete, insulation, green concrete, bathroom floors, industrial flooring, waterproofing, and rehabilitation projects.

Cow Dung: Cow dung is a residual resource derived from cows, comprising undigested remnants of their consumed food that are expelled through excretion (Gupta, 2016).It is a biodegradable resource that is beneficial to us in a number of ways. Pallvika (2016) asserts that cow excrement is rich in several minerals, including salt, potassium, magnesium, and others. India has used it for thousands of years in a variety of fields. Cow dung serves a variety of purposes, including insect repellant, biogas production, building material, and rich fertilizer. Minerals including potassium, magnesium, and phosphorus, which serve as good binders, are abundant in cow dung. Additionally, it makes the soil's texture better and aids with moisture retention. In India's rural dwellings, a paste made of cow dung and mud is occasionally placed to the walls and floors to create a water-resistant coating that prevents heat from entering the residence. The fibers in the dung also aid in producing a fine and smooth floor surface, as well as preventing floor cracking and improving plaster's insulating capabilities. It is also an eco-friendly, health-friendly, and mosquito repellent. It possesses anti-thermal and anti-radioactive qualities that provide a barrier for protection from dangerous radiations (magudeaswaran 2018). The combination of cow dung, water, mud, and air, according to Barman research, released serotonin, a hormone also known as a happy hormone and responsible for fostering a positive environment.

2.1.15Characteristics of Sustainable Eco-friendly Building Materials

According to GRIHA, for building material to be termed sustainable it must have these two characteristics;

a. Rapidly renewable
b. Easily recyclable or reusable.

According to the U.S. Green Building Council (USGBC), rapidly renewable materials are those that can regenerate themselves in 10 years or less. This covers goods derived from plants that are harvested every 10 years or less. According to USGBC, adopting fast renewable content aims to decrease the quantity and caliber of goods made from derivatives of fossil fuels. Among the fast renewable materials used in building construction are hempcrete, tember, bamboo, cork, straw bales, sheep's wool, rammed earth, and reclaimedwood. Used or outdated materials that can be recycled are known as recyclable materials. Reduced garbage in landfills is a requirement for sustainable or green buildings. Recycling materials like metals, glass, paper, and plastic makes this possible (Sheth, 2016). The Environmental Protection Agency (EPA) lists the following as the advantages of recycling and reusing building materials:

a. Reduces greenhouse gas emissions that contribute to climate change.
b. Mitigates pollution by minimizing the necessity for harvesting fresh raw materials.
c. Conserves energy.
d. Preserves the environment for succeeding generations.
e. Decreases the volume of waste requiring recycling or disposal in landfills and incinerators.

2.1.16Importance of Using Sustainable Eco-friendly Building Materials

Waste reduction, pollution prevention, recyclability, and embodied energy reduction are all factors in the production of sustainable building materials (Usman et al., 2018). He also believes that there are alternatives for waste management, energy efficiency, conservation, nontoxic, longer life, and building operations that result in building materials that are biodegradable, recyclable, and reused. According to Ben-Alon et al. (2019), using sustainable building materials can save material costs, carbon emissions, transportation expenses, and employment prospects. Abimaje et al. (2019) assert that environmentally friendly, cost-effective, versatile, and long-lasting sustainable building materials are necessary. Building materials that are environmentally friendly, like wood, store up to 250 kg/m3 of carbon dioxide (CO_2) while releasing just 15 kg/m3 into the atmosphere. Steel, concrete, and aluminum, in contrast, do not store carbon dioxide while releasing, respectively, 5320 kg/m3, 120 kg/m3, and 2 2000 kg/m3 into the atmosphere. The embodied energy and carbon of cob are much lower than those of the other traditional materials, according to the environmental effects of cob as an alternative building material from a life cycle perspective. As a result, its use can slow down global warming (Ben-Alon et al., 2019). Additionally, the Environmental Protection Agency (EPA) listed some advantages of using sustainable building materials, such as preserving resources to lessen negative environmental effects, enhancing environmental quality, and accruing savings through increased productivity and waste reduction.

2.2 Theoretical Review

This is based on the theories and principles that already exist in this area of study in other to increase understanding of the study.

2.2.1 Triple Bottom Line Theory

The Triple Bottom Line (TBL) theory is an accounting framework that considers three key dimensions of sustainability: economic, social, and environmental. It was introduced by John Elkington (1997) and aims to measure an organization's performance not only in terms of profit (the economic bottom line) but also in terms of its impact on people (the social bottom line) and the planet (the environmental bottom line). Key Principles of the Triple Bottom Line Theory include:

Economic: Assessing financial performance and profitability, taking into account the long-term financial viability of the organization.

Social: Evaluating the social and ethical impact of the organization, including its relationships with employees, communities, and stakeholders.

Environmental: Measuring the environmental footprint of the organization, such as its resource use, emissions, and efforts towards sustainability.

The figure below shows the principles of the Triple bottom line theory.

Figure 2.2: Cannibals with Forks: The Triple Bottom Line of 21st Century Business(Elkington, J. 1997).

2.2.2. Cradle to Cradle Design Theory

The Cradle to Cradle (C2C) design theory, developed by McDonough and Braungart (2002), presents a holistic and innovative approach to designing products and systems that aim to have a positive impact on the environment and human health. Unlike the traditional "cradle to grave" linear model of production and consumption, where products eventually become waste, the C2C model envisions a continuous cycle of materials and resources.Principles of Cradle-to-Cradle Design Theory include:

Waste Equals Food: In nature, waste from one process becomes a resource for another. Similarly, C2C design seeks to create products that can be safely and effectively reused, recycled, or composted at the end of their life cycle, with no negative impact on the environment.

Use of Renewable Energy:the theory encourages the use of renewable energy sources in the production and operation of products, reducing the reliance on fossil fuels and minimizing greenhouse gas emissions.

Diversity of Materials:C2C design emphasizes the use of a variety of materials that can be easily disassembled and recycled. This avoids the creation of monstrous hybrids, where materials are difficult to separate and recycled

Design for Positive Impact:C2C design goes beyond minimizing negative impacts and aims to create products and systems that have a positive impact on society and the environment.

Product and Material Health: the materials used in products should be assessed for their potential impact on human health and the environment. Harmful substances are eliminated, and the focus in on using materials that are safe and noon-toxic.

2.2.3Some Examples of Sustainable or Green Buildings around the World

2.2.3a. Pixel Building (Melbourne, Australia)

The Pixel building, inaugurated in 2010, stands out as Australia's pioneer carbon-neutral office complex. It operates independently by generating its own power and water on-site. Its innovative design incorporates vibrant panels for shading and optimizing daylight, wastewater processing supports, a rainwater-collecting roof, and vertical wind turbines to conserve energy.

2.2.3b. One Central Park (Sydney, Australia)

One Central Park, a residential complex unveiled in 2014, was designed by Ateliers Jean Nouvel and PTW Architects. The structure is adorned with a diverse array of 250 Australian plant species and flowers, as reported by archdaily.com. Apart from their aesthetic appeal, these greenery elements provide cooling shade and make a strong visual statement. Additionally, the building boasts a remarkable design feat in the form of a suspended cantilever, housing the most luxurious penthouses of the taller tower. Skyscraper.com highlights its exceptional energy efficiency, consuming 25% less energy compared to conventional buildings of similar size.

2.2.3c. Shanghai Tower (Shanghai, China)

The Shanghai Tower, inaugurated in 2015, stands as the world's second tallest building, soaring to a height of 2,073 feet. Renowned not only for its architectural grandeur but also for its sustainability, the tower boasts innovative features. Encircling the structure is a transparent secondary layer that forms a barrier of trapped air, facilitating natural ventilation and thus lowering energy consumption. Additionally, 270 wind turbines integrated into the facade harness wind power to illuminate the exterior lights. With its platinum LEED certification, the tower sets a high standard for environmental efficiency, consuming notably less power than its counterparts in the skyscraper realm.

2.2.4Principle of Material Selection

Any effort to develop buildings with great performance requires the use of durable, appealing, and eco-friendly building materials (Umar et al, 2014). Additionally, he believes that using natural and healthy materials enhances residents' wellness and fosters a sense of connection to the abundance of the natural world. Many building materials deplete natural resources, produce pollutants, and destroy habitat, all of which have a significant negative impact on the environment. This will take place throughout the phases of raw material extraction and procurement, production and manufacture, and transportation (Patel et al, 2021). Also, some building materials expose workers and building occupants to toxic and dangerous compounds, which could be harmful to their health. Hence, identifying and choosing ecologically preferable materials for use in construction activities at the prebuilding phase presents a chance to limit such environmental and human health implications (Umar et al, 2014). Yet, according to Akadri et al. (2012), the process of resource conservation and selection of non-toxic materials generally results in the selection of environmentally desirable materials with minimum environmental impacts. The Environmental Protection Agency (EPA) asserts that the production of construction materials carries detrimental effects on the environment, as they consume energy, deplete natural resources, and emit pollutants into the air, water, and soil. These materials, containing such elements, can also pose risks to human health directly or through the release of volatile compounds into the atmosphere. Therefore, it's advisable to base material choices on a comprehensive evaluation of the environmental impacts associated with the entire product or material. While conducting a thorough environmental life-cycle assessment for every building procurement decision may not always be feasible, adopting a life cycle perspective can help assess available information regarding the environmental performance of items, aiding consumers in making informed choices.

2.2.5Life Cycle Assessment (LCA)

A life cycle assessment (LCA) serves as a systematic analytical method for gauging the environmental impact of a building. By examining the entire spectrum of impacts associated with each stage of a process from inception to disposal (referred to as cradle-to-grave), including raw material extraction, processing, manufacturing, distribution, utilization, maintenance, and eventual disposal or recycling, LCA helps to prevent a narrow focus on environmental, social, and economic concerns. The impacts considered encompass various factors such as embodied energy, global warming potential, resource consumption, air and water pollution, and waste generation [Taleai, 2008]. Despite its widespread acknowledgment as the optimal approach for assessing the environmental impacts of buildings, LCA has yet to become a consistent requirement within green building rating systems and codes. This is noteworthy as embodied energy and other life cycle impacts play a pivotal role in the design of environmentally sustainable buildings.

2.2.6Green Building Rating System

Green building rating systems are a collection of tools and rating scales that are used to evaluate the sustainability and environmental impact of a building or construction project (EPA). To help organizations offer outstanding environmental performance with relation to their building stock, a number of standards, approaches, and tools have been established. They include, but are not limited to the following:

i. **LEED:**

The Leadership in Energy and Environmental Design (LEED) accreditation stands as a prominent green building standard within the United States. Managed by the U.S. Green Building Council, this system for rating buildings undergoes verification either on-site or through a third-party assessment. Diverse building types, ranging from new constructions to existing structures, residences, and communities, are eligible to apply for this certification program. LEED certification is categorized into four levels: certified, silver, gold, and platinum. The evaluation criteria encompass nine key areas, including location and transportation, sustainable site development, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation, regional priority, and integrative processes. Attaining LEED certification necessitates a building's efficient use of resources and maintenance of a healthy environment for all occupants throughout its lifecycle.

ii. **WELL:**

The International WELL Building Institute (IWBI) administers the WELL certification program for buildings. Primarily, WELL emphasizes elements of building design that impact the health and well-being of occupants. Air quality, water quality, nutrition, lighting, physical activity opportunities, thermal comfort, noise levels, material choices, mental well-being support, community engagement, and innovation constitute the eleven concepts utilized by WELL to assess a building. Prior to obtaining WELL certification, buildings must meet certain conditions or requirements outlined within this green building system. Similar to LEED, WELL certification is applicable to various building types and building areas.

iii. **Fitwel:**Fitwel prioritizes the health and welfare of building residents as well as the local community, similar to WELL. Fitwel does not, however, require any prior knowledge to complete this green building certification program. Fitwel is a versatile program that can be utilized in a range of building styles and locations, just as the other stated tools. Location, access to the building, outdoor areas, entrances, stairs, the indoor environment, workplaces, shared spaces, water supply, cafeterias and prepared food sections, vending machines and snack bars, and emergency protocols are the main concerns of Fitwel.

2.2.7Environmental Laws and Regulations on Construction in Nigeria

To protect the environment in Nigeria, the Federal Government of Nigeria has issued a number of laws and regulations. The National Environmental Standards and Regulations Enforcement Agency 2007 (NESREA Act), National Policy on the Environment (NPE) 1989, and Environmental Impact Assessment Act of 1992 (EIA Act) constitute the current legislation governing the built environment in Nigeria. Oversight and enforcement of environmental regulations fall under the purview of Nigeria's Federal Ministry of Environment (FME). The FME has issued numerous guidelines for administering the FEPA and EIA Acts, as well as protocols for reviewing environmental impact assessment reports (EIA Reports). The primary objectives of regulatory agencies include preventing environmental damage, controlling potentially hazardous activities, and prosecuting intentional environmental harm, if it occurs. Additionally, the environmental agencies adopt a collaborative approach by engaging in dialogue with individuals and communities at risk of environmental damage. As part of the FME's EIA approval process, a system of public hearings is employed, inviting interested members of the public to participate in these hearings.The Rivers State Ministry of Environment (RSMENV), which was founded in 2003, handles environmental issues in Rivers State. Its duties include developing, carrying out, and assessing policies for the state's ecological and environmental projects.

2.3Empirical Review

Every nation's environment, economy, education, political climate, and social life are heavily influenced by housing (Alaghbari et al. 2011). Building materials are one of the main resources needed in the construction of a building from the foundation to the finishing level; as a result, the cost of construction is dependent on the kind of materials employed in the building's erection.

Pulselli et al.'s (2007) research titled "Sustainable resource utilization in the production of building materials" reveals that buildings exert a substantial environmental footprint. They consume approximately 40% of the natural resources extracted in industrialized nations and contribute to 30% of greenhouse gas emissions through their operational activities. Additionally, an extra 18% of emissions are indirectly generated by the exploitation and transportation of building materials. The study employed both primary and secondary data sources. The research study used a questionnaire as a key for primary data collection.

Wang et al. (2005) in their study on ‘Applying multi-objective genetic algorithms in green building design optimization’Life cycle analysis methodologywas employedto evaluate design alternatives for both economic and environmental criteriafound that buildings consume almost 70% of electricity, 12% of potable water, and produce between 45% and 65% of the waste disposed in our landfills.

Furthermore, according to Yu's (2008) study on environmentally sustainable acoustics in urban residential areas, building construction uses 25% of the raw wood and 40% of the raw stone, gravel, and sand that are utilized annually around the world. From the standpoint of environmental impact, the building industry significantly affects the entire environment.In this study (Yu, 2008),questionnaire surveys were applied in the urban residential areas with a number of representative questions from which primary data were obtained.

Heakkinen and Belloni (2011)conducted researchto assess the obstacles hindering the adoption of sustainable building materials (SBM) in the construction sector of a developing nation. Utilizing a meticulously designed quantitative questionnaire, data were collected from key stakeholders in the construction industry, the snowball sampling technique and electronic distribution of questionnaires was used. Various statistical analyses such as frequencies, percentiles, relative importance index, Kruskal-Wallis H test, Kendall's coefficient of concordance, and exploratory factor analysis were employed to analyze the gathered data. The research findings demonstrated a correlation between awareness of green building materials, knowledge about sustainable construction, and the actual adoption of sustainable practices.Form the result, implementation of green building is hampered by the fact that the majority of stakeholders are either unaware of or lack information about green or sustainable construction materials. The attainment of sustainability is hampered by a number of factors, including a lack of understanding of the sustainability concept, a lack of client awareness of the advantages of sustainable building materials, and inadequate education in sustainable design. Additionally, the adoption of new approaches is required by the use of sustainable building materials for construction projects and other technologies, and the present pool of industry specialists lacks the necessary expertise. A few significant barriers to the effective use of sustainable building materials include the paucity of environmentally friendly construction materials, the absence of model demonstration projects, a persistent labor and skill deficit, and a lack of technical assistance (Ofori and Kien, 2004). Some of the barriers preventing the adoption and accomplishment of sustainability include the gross lack of knowledge of sustainability principles among industrial designers and professionals (Rydin et al., 2006) and the scarcity of locally produced sustainable building materials (Osaily, 2010). Green construction, also known as sustainable building, has emerged as a new building philosophy that encourages the use of more environmentally friendly materials, the adoption of measures to conserve resources and reduce waste production, as well as the enhancement of indoor environmental quality (Wang et al, 2005). Environmental, financial, economic, and social benefits could result from this. The installation of high-efficiency lighting and insulation systems, as well as an appropriate material selection procedure that takes into account factors such as daylight roof reflection, can reduce the operating and maintenance expenses of sustainable or green buildings, for example (Ross et al, 2006).The key benefits of sustainable buildings connected to improvements in indoor environmental quality, however, are the decrease in health costs and the rise in staff productivity, according to Moeck and Yoon's study on green buildings and possible electric light energy savings from 2004.

Darko and Chan (2018) Researched on“Strategies to promote green building technologies adoption in developing countries: The case of Ghana’’,they conducted an empirical survey using a questionnaire, involving 43 professionals with experience in green building. Analysis of the data revealed that increasing media exposure, providing educational and training programs on green building technologies (GBTs) for key stakeholders, establishing an institutional framework for effective implementation of GBTs, and offering financial incentives and market-based rewards were identified as the primary strategies to encourage GBTs adoption. Moreover, a comparison of the results suggested that the preferred strategies for promoting GBTs adoption in Ghana, a developing country, differed significantly from those in the United States, a developed nation. Additionally, factor analysis revealed that the strategies could be categorized into groups such as government regulations and standards, awareness campaigns, education and information dissemination efforts, and awards and recognition programs. The study contributes theoretically to the literature on green building by enhancing understanding of the critical strategies to promote the adoption of GBTs from the perspective of a developing country.

Green or sustainable building is the activity of developing and utilizing healthier and more resource-efficient methods of construction, renovation, operation, maintenance, and destruction, according to the EPA as quoted in Qian et al. (2015). The adoption of green or sustainable building practices was initially hindered by high costs, according to Hoffman and Henn's (2008) study on "Overcoming the social and psychological barriers to green building," but literature has since reported advancements and cost advantages in favor of green or sustainable building over time. They added that green or sustainable buildings go above and beyond with their layout, finishes, and appliances; they substitute out more polluting products for less polluting ones, incorporate features, or change design parameters to take advantage of building system synergies, which reduce operating costs for water, wastewater, and energy (hard cost benefits) and enhance occupant performance (soft cost benefits) by 6-26%. In numerous developing nations, conventional approaches persist in the design, location selection, building, operation, and maintenance processes, as well as in managing construction and demolition waste. This is primarily because these countries lack the capacity for employing eco-friendly technologies that facilitate environmentally friendly or sustainable construction practices.(Okafor, 2016). The practice of constructing structures in Nigeria, a developing nation, undermines international efforts to build sustainably and pays little or no regard to the numerous sustainable or green building methods that have already been studied and accepted in the majority of industrialized nations (Darko et al, 2018).

Fehling et al. (2016) claimed in their study on "Ultra-High Performance Concrete and High-Performance Building Materials" that the harmless features of green building materials, which are manufactured from recycled materials, are a result of their concentration on renewable resources. According to Lockrey et al. (2018), who endorse this viewpoint, sustainable buildings share the qualities of being both energy and water efficient since they are constructed with sustainable construction materials. A concrete house would normally consume a couple of times more energy, according to Morel et al. (2001), who examined the energy consumption of stone vs concrete. They also pointed out that transporting concrete requires considerably more energy than transporting stone. Several researchers have since emphasized stone as a superior substitute for concrete, wood, and steel. Especially when the materials' resilience, upkeep, energy requirements, and environmental effects are taken into account. Yet, Bartlett and Howard (2008) discussed how there is a widespread misunderstanding that building green costs 5% to 15% more than building conventionally. They go on to say that cost advisors in the construction sector vastly underestimate potential cost reductions while grossly overestimating the central cost of green building. Nalewaik (2008), who also asserts that green buildings benefit from lifespan cost reductions and that some components of such design methodologies are more cost-efficient, supports this point of view. The popular perception of green buildings can then be determined to be related with greater expenses throughout their lifetime. The concept of green materials was discussed by Gharehbaghi and Rahmani

(2018) in relation to recycled materials, specifically concrete, metal, and to some extent, wood. Although crushed materials form the bulk of recycled concrete, it can also serve as dry aggregate for various purposes, including incorporation into new mixtures.Nevertheless, recycled metal typically consists of scraped aluminum, copper, steel, brass, iron, and so forth. Recycled metal and concrete can both drastically lower the overall cost of materials (Gharehbaghi et al, 2018).Moreover, recycled wood might be treated again and used as an alternative building material. Hence, recycling and reusing concrete, metal, and wood would ultimately reduce material waste and, more significantly, have a smaller negative impact on the environment (Pritchard and Pitts, 2006).Sakaray et al,(2012) undertook a feasibility assessment on moso bamboo as a reinforcing material for concrete, determining that bamboo could replace steel in concrete applications. In a separate study, Nayak et al. (2013) examined the impact of substituting steel reinforcement with bamboo. One finding highlighted that bamboo reinforcement is three times more cost-effective than steel reinforcement. Rehman et al. (2011) conducted experiments on bamboo-reinforced concrete beams,and one of the conclusions wrote that bamboo is a potential reinforcing material in concrete. Naveena et al (2017) conducted a research on the strength and durability properties of fly ash aggregates concrete. One of the conclusion wrote that up to 100% replacement of fly ash aggregate can be utilized in the production of concrete.

Yarramaka (2012) examined the impact of fly ash substitution on the strength characteristics of cement mortar. One finding indicated that initially, and for all fly ash ratios, the strength decreased compared to regular mortar. However, after 28 days and beyond, mortars containing fly ash exhibited a 15% increase in strength, surpassing that of regular mortar.

2.5 Research Gap

Sheth (2016) conducted research on sustainable building materials used in green building without a putting into consideration how the use of sustainable building materials can enhance the performance of the conventional building projects. Marut and Igwe (2020) also carried out research on a review of alternative building materials for sustainable construction towards sustainable development which was aimed at studying and knowing the alternative building materialsthat can be used for construction. Prutha and Anant (2021) conducted research on use of sustainable green materials in construction of green buildings for sustainable development the study was targeted on the cost implication of using sustainable building materials. Bunga (2020) conducted research on material conservation as part of environmental sustainability in architecture, he only focused on material conservation as a feature of sustainable or green building. Erik (2019) conducted research on analysis of sustainable building materials, their possibilities and challenges. Several studies have been carried out on sustainable building and sustainable building materials with their focus on the awareness and practice of green building, challenges of green building, analysis of sustainable building materials e.t.c. without a putting into consideration how the use of sustainable eco-friendly building materials can enhance the performance of the conventional building projects. It is important for the construction industry especially in Rivers State to deviate its focus from conventional buildings to sustainable buildings by integrating sustainable eco-friendly building materials in order to achieve zero greenhouse gas emission, pollution reduction, energy efficiency, material conservation e.t.c.

Therefore, this study emphasizes this gap by focusing more on the integration of sustainable eco-friendly building materials in the building construction process in the Port Harcourt metropolis, Rivers State, Nigeria.

CHAPTER THREE

METHODOLOGY

This chapter outlines the research procedure employed for this study. A research methodology refers to the systematic and scientific approach adopted to present results of a study to the research audience. An attempt is made by the researcher to present the method used in the study.

3.1Research Design

Research designs are viewed as a comprehensive strategy chosen by researchers to integrate various components of a study logically, aiming to address a research problem effectively. In this particular study, the researcher utilized the survey research design, given the nature of the research which involved sampling opinions and viewpoints of stakeholders. As Singleton and Straits (2009) suggest, survey research can employ quantitative approaches (such as utilizing questionnaires with numerical rating scales), qualitative approaches (such as employing open-ended questions), or a combination of both (known as mixed methods).

3.2 Nature and Sources of Data

Primary and secondary data was used to generate information for the study. Primary data were collected using questionnaire approach.

Primary Sources: this is a source through which firsthand information was gathered, the method employed under the primary source of data collection for this research includes: interview, a structured questionnaire, rating scale.

Secondary Data Sources: these are sources through which second hand information that are relevant to the research were collected. These sources include textbooks, journals, newspapers, internets, published and unpublished government records and related research project.

3.3 Population of the Study

According to Udoyen (2019), a study population refers to a collection of elements or individuals, each possessing common characteristics such as location, gender, age, or specific interests. The key aspect of a study population is its homogeneity, comprising individuals or elements with similar descriptions.

This study was carried out to ascertain theeffects of integrating sustainable eco-friendly materials on conventional building projects delivery in Port Harcourt metropolis, Rivers State, Nigeria. The study involved key stakeholders in the construction industry; which are the Architects, Builders, Quantity Surveyors, and Structural Engineers in some selected construction companies in Port Harcourt, Rivers State as the respondents. The questionnaire was distributed to twenty-four (24) Architects, thirteen (13) Builders, thirty-seven (37) Quantity surveyors and twenty-nine (29) Structural Engineers making it a total of one hundred and three (103) respondents.

3.4Sample Size and Sample Techniques

A study sample is simply a systematic selected part of a population that infers its result on the characteristics in like similitude (Udoyen, 2019). According to Nwana (2005), sampling techniques are procedures adopted tosystematically select the chosen sample in a specified away under controls. A judgmental and area sampling technique was adopted in this study and the Taro Yamani (1976) formular, at 0.05 was used in getting the sample size of eighty two (82) as shown below:

$$n = \frac{\mathbf{N}}{1XN(e^2)}$$

Where

N= -Population

1= Constant

N=Total population

e^2 = Level of significance $(0.05)^2$

Therefore:

$$\frac{103}{1+103(0.05)^2} = 82$$

3.6 Research Instrument and Administration

The research instrument used in this study is the questionnaire. The questionnaire was structured into two parts: the first part gathered demographic or personal information about the respondents, while the second part, aligned with the study objectives, aimed to address the research questions. Respondents were instructed to indicate their answers by marking the appropriate column.The questionnaire was personally administered by the researcher.

3.7 Method of Data Analysis

The responses wereanalyzed using relative severity index (RSI), correlation analysis and relative importance index (RII) which provided answers to the research questions. A computer software called Statistical Package for Social Sciences (SPSS v.25) was used to analysis data. Descriptive statistical tool such as simple percentages and bar chart were used to present the data.

The questionnaire was scaled using Likert scale(five points rating scale). The five points rating scale will be given values as follows:

SA = Strongly Agree 5

A = Agree 4

SWA = Somewhat Agree 3

D = Disagree 2

SD = Strongly Disagree 1

The hypothesis test was conducted using Pearson's correlation analysis.

3.8 Operationalization of variables.

SEBM – Sustainable eco-friendly building materials

CBP – Conventional building projects

RR – Renewable resources

OS – Other sustainable options

EM – Earthen materials

RM - Recycled materials.

SB – Social benefit

EB – Environmental benefit

ECB – Economic benefit

3.9 Validity of the Study

Validity, as discussed here, pertains to the extent to which an instrument accurately measures its intended targets. An instrument is deemed valid when it effectively aligns with the research objectives. The researcher developed the questionnaire for the study and presented it to the project supervisor. The supervisor, leveraging his intellectual expertise, meticulously evaluated the relevance of the questionnaire's contents and statements, ensuring its validity for the study through critical, analytical, and logical examination.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

This chapter delves into the analysis of data gathered through fieldwork surveys, offering a thorough examination of primary data through the use of tables and charts. The overarching goal of this data analysis is to provide insights that address the research questions, thereby contributing to the fulfillment of research objectives and testing of hypotheses. The process involves condensing the dataset into a concise summary and presenting it in a manner conducive to drawing meaningful conclusions. As noted by Castellan (2010), data analysis is an ongoing, inductive process characterized by sorting, sifting, and careful examination of the data.

4.1.1: Demographic Information of Respondents: this section presents the demographic information of the respondents in tables as it is derived from the returned questionnaires.

Table 4.1: Distributed and recovered questionnaire among stakeholders.

Stakeholders	Architects	Builders	Quantity surveyors	structural engineers	Total
No. Distributed	24	13	37	29	103
No. Received	17	12	32	21	82
Percentage	70.83%	92.31%	86.49%	72.41%	79.61%

Source: Researcher's Fieldwork, 2023

Percentage = No. received X 100/No. distributed.

One hundred and three (103) questionnaires were randomly administered to Architects, Builders, Quantity Surveyors and Structural Engineers (Twenty-four to Architects, Thirteen to Builders, Thirty-seven to Quantity Surveyors and Twenty-nine to Structural Engineers). As at the time of compiling this report, a total of eighty- two usable responses were received, representing 79.61% effective response rate.

Table 4.2: Education attainments of respondents

Education Attainment	**No. of Responses**	**% of Response**
OND/NCE	5	6.25
HND/B.Sc	58	70.73
M.Sc	17	20.73
Ph.D	2	2.44
Total	82	100

Source:Researcher's Fieldwork, 2023

Table 4.2 shows the education attainments of the respondents. Five (5) respondents representing 6.25% are OND/NCE holders, fifty eight (58) respondents representing 70.73% are HND/B.Sc holders, seventeen (17) respondents representing 20.73 are M.Sc holders while two (2) respondent representing 2.44% are Ph.D holders.

Table 4.3: Work experience of respondents

Years of experience	No. of Responses	% of Response
Less than 5years	11	13.41
5 - 15years	23	28.05
16 - 25years	34	41.46
More than 25years	14	17.07
Total	82	100

Source:Researcher's Fieldwork, 2023

Table 4.3 shows the work experience of respondents. Eleven (11) respondents representing 13.41% has less than 5 years' work experience, twenty three (23) respondents representing 28.05% has 5 -15 years' work experience, thirty four (34) respondents representing 41.46% has 16 -25 years' work experience while fourteen (14) respondents representing 17.07% has more than 25 years' work experience.

Table 4.4: Respondents' Role in Construction

Role	No. of Responses	% of Response
Client	22	26.83
Consultant	17	20.73
Contractor	43	52.44
Total	82	100

Source:Researcher's Fieldwork, 2023

Table 4.4 shows the respondents role in construction. Twenty two (22) respondents representing 26.83% are Clients, seventeen (17) respondent representing 20.73% are Consultant while forty three (43) respondents representing 52.44% are Contractors.

4.1.2: Research question 1: What are barriers of integrating sustainable eco-friendly Building Materials in Rivers State?

Table 4.5: Barriers of integrating sustainable eco-friendly building materials.

Barriers of integrating Sustainable Eco-friendly Building materials	**RSI**
Government Related Barriers	0.95
Knowledge related barriers	0.91
Human related barriers	0.88
Cost & Risk related barriers	0.8
Market related barriers	0.78

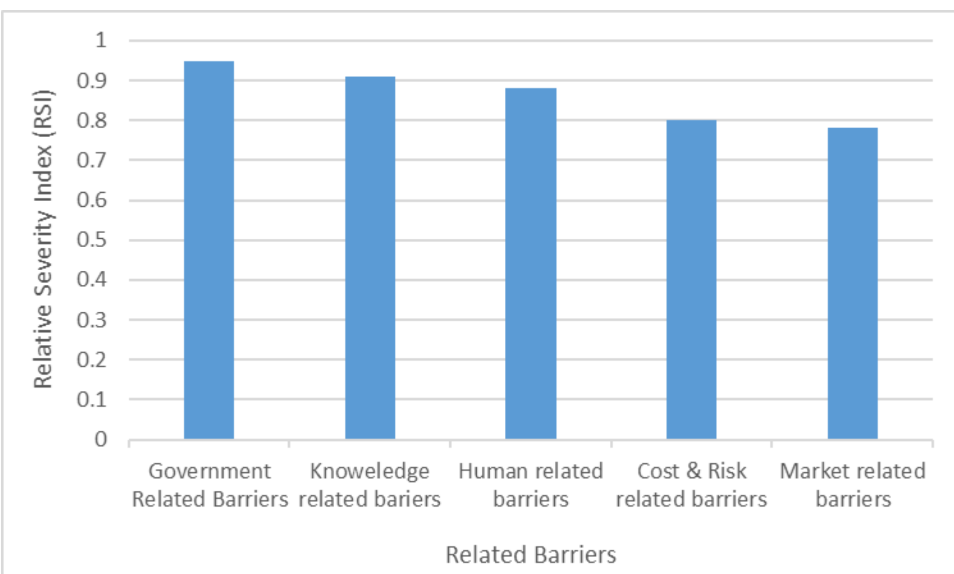


Figure: 4.1: Barriers of integrating Sustainable eco-friendly building materials

Table 4.5 and Figure 4.1, shows the barriers of integrating sustainable eco-friendly building materials in Port Harcourt. The relative severity index (RSI) was employed to rank each barriers according to the level of severity. The RSI values obtained ranged from 0.95 – 0.78 with the highest and lowest value going for Government Related Barriers and Market related barriers respectively.

4.1.3: Research question 2: To what extent can the use ofSustainable Eco-friendly Building Materials (SEBM) influence the Performance of Conventional Building Projects (CBP) in Rivers State.

Table 4.6: Correlation between SEBM (RR, OS, EM and RM) and CBP

	Statistical Test	RR	OS	EM	RM	CBP
RR	Pearson correlation	1				
	Sig. (2-tailed)					
	N	82				
OS	Pearson correlation	0.096	1			
	Sig. (2-tailed)	0.392				
	N	82	82			
EM	Pearson correlation	0.823	0.052	1		
	Sig. (2-tailed)	0	0.64			
	N	82	82	82		
RM	Pearson correlation	0.782	0.062	0.762	1	
	Sig. (2-tailed)	0.72	0.486	0.356		
	N	82	82	82	82	
CBP	Pearson correlation	0.87	0.046	0.82	0.78	1
	Sig. (2-tailed)	0.003	0.683	0	0.003	
	N	82	82	82	82	82

From Table 4.6, Pearson correlation between dependent variable (CBP) and independent variables (RR, OS, EM and RM) was carried out. The relationship between each independent variable and dependent variable showed correlation of 0.87 for CBP and RR, 0.82 for CBP and EM, 0.78 for CBP and RM finally, 0.046 for CBP and OS. The order of relationship with the dependent using the Pearson correlation as shown in Table 4.6 is RR > EM > RM > OS.

On the other hand, the relationship between independent variables showed correlation of 0.823 for RR and EM, 0.096 for RR and OS, 0.782 for RR and RM and 0.052 for OS and EM. The order according to the strength of correlation is RR & EM > RR & RM >RR & OS> OS&EM.

4.1.4: Research question 3: What are the levels of correlation between environmental, economic and social benefits of integrating SEBM and the Performance level of Conventional Building Projects (CBP).

Table 4.7: Correlation between SEBM and CBP

	Statistical Test	SEBM	CBP
SEBM	Pearson correlation	1	
	Sig. (2-tailed)		
	N	82	
CBP	Pearson correlation	0.86	1
	Sig. (2-tailed)	0.003	
	N	82	82

From Table 4.7, Pearson correlation between dependent variable (CBP) and independent variable (SEBM) was carried out. The relationship between the independent variable and dependent variable showed correlation of 0.86.

Table 4.8: Correlation between EB, ECB and SB and CBP

	Statistical Test	SB	EB	ECB	CBP
SB	Pearson correlation Sig. (2-tailed) N	1 82			
EB	Pearson correlation Sig. (2-tailed) N	0.758 0 82	1 82		
ECB	Pearson correlation Sig. (2-tailed) N	0.576 0.001 82	0.432 0.005 82	1 82	
CBP	Pearson correlation Sig. (2-tailed) N	0.206 0.063 82	0.823 0 82	0.778 0 82	1 82

From Table 4.8, Pearson correlation between dependent variable (CBP) and independent variable (EB, ECB and SB) was carried out. The relationship between each independent variable and dependent variable showed correlation of 0.823 for CBP and EB, 0.778 for CBP and ECB and 0.206 for CBP and SB. The order of relationship with the dependent using the Pearson correlation as shown in Table 4.8 is EB > ECB > SB.

On the other hand, the relationship between independent variables showed correlation of 0.758 for SB and EB, 0.576 for SB and EC and 0.432 for EB and ECB. The order according to the strength of correlation is SB & EB >SB & ECB >EB & ECB.

4.1.5: Research question 4: What are the solutions to the barriers of integrating sustainable eco-friendly building materials in Rivers State?

Table 4.9: Solutions to Barriers of Integrating Sustainable Eco-friendly Building Materials in Rivers State.

Key	Possible solution	RII
Q1	Educating building owners on the future benefits of sustainable building	0.98
Q2	Intensive promotion of sustainable or green building by the government, via: Radio, televisions and social media.	0.97
Q3	Establishment of enticements to inspire invention in sustainable construction by the Government	0.93
Q4	Use of resources from more sustainable source	0.92
Q5	Provision of adequate training centers with adequate funding of research and development to enhance sustainable development	0.89
Q6	Provision of sustainable materials selection criteria	0.79
Q7	Utility of technologies that license the reprocessing of the building components and deconstruction	0.73
Q8	Promotion of sustainable construction by the building industry	0.6
Q9	Employ natural resource management strategy	0.52
Q10	Regular inspection and monitoring of works with set rules and legislation	0.46
Q11	Appraisal of building code and establishment of sustainable building code	0.37

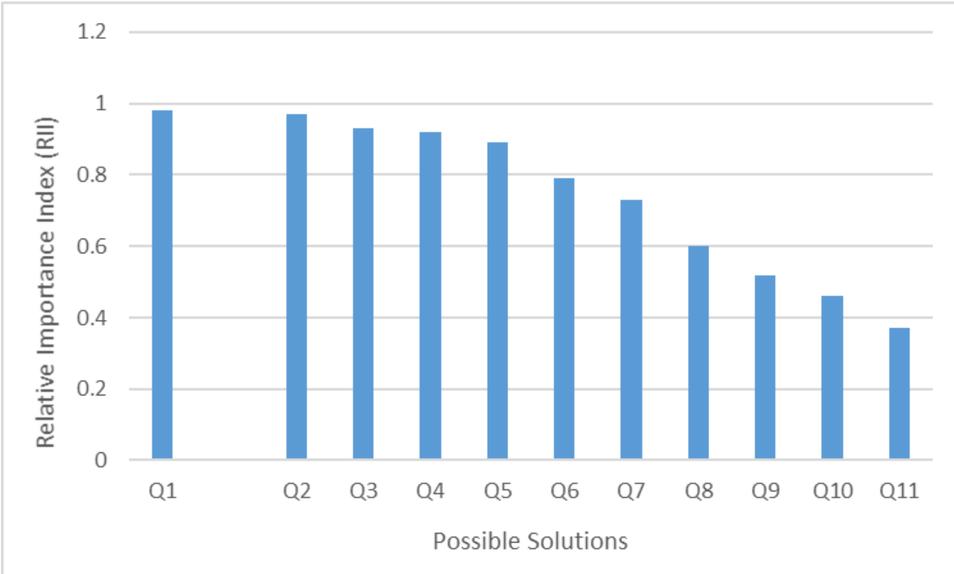


Figure: 4.2: Solutions to Barriers of Integrating Sustainable Eco-friendly Building Materials

Table 4.9 and Figure 4.2, shows the solutions to barriers of integrating sustainable eco-friendly building materials in Port Harcourt. The relative importance index (RII) was employed to rank each solution according to the level of importance. The RII values obtained ranged from 0.98 – 0.37 with the highest and lowest value going for Educating building owners on the future benefits of sustainable building and Appraisal of building code and establishment of sustainable building code.

4.1.6: Test of Hypothesis

HO_1: There is no significant correlation between the integration of SEBM and performance level of CBP.

Table 4.6 at 5% level of significance showed the correlation between the integration of SEBM (Renewable resources, Recyclable materials, earthen material and other sustainable options) and performance level of CBP. Renewable resources (RR) and performance level of CBP showed p value of 0.003. Other sustainable options (OS) and performance level of CBP showed p value of 0.683, Recycled materials (RM) performance level of CBP showed p value of 0.003 while earthen material (EM) and performance level of CBP showed p value of 0.000.

The results obtained showed significant correlation between the integration of RR, EM, RM and CBP respectively. While that of OS and CBP showed no significant correlation.

HO_2: There is no significant correlation between environmental, economic and social benefits respectively with performance level of CBP.

From Table 4.8 and at 5% level of significance, the correlation between the Environmental Benefits (EB) of integrating SEBM and performance level of CBP showed p value of 0.000. Economic Benefit (ECB) and performance level of CBP showed p value of 0.000, while Social Benefit (SB) and performance level of CBP showed p value of 0.63.

The results obtained showed significant correlation between EB, ECB and performance level of CBP, while that of SB and performance level of CBP showed no significant correlation.

HO_3: There is no significant difference among the opinions of construction professionals on the use of SEBM in the CBP delivery in Port Harcourt metropolis Rivers State.

Table 4.10: Significant difference among the opinions of construction professionals on the use of SEBM in the CBP delivery in Port Harcourt.

Stakeholders	**Architect (AR)**	**Builder (BD)**	**Quantity Surveyor (QS)**	**Structural Engineer (SE)**
P value (p)	0.000	0.003	0.001	0.000
Alpha value (α)	0.05	0.05	0.05	0.05

From Table 4.10, the p-values for Architects, Builders, Quantity surveyors and Structural engineers are 0.000, 0.003, 0.001 and 0.000 respectively. Showing that there is significant difference among the opinions of the construction professionals.

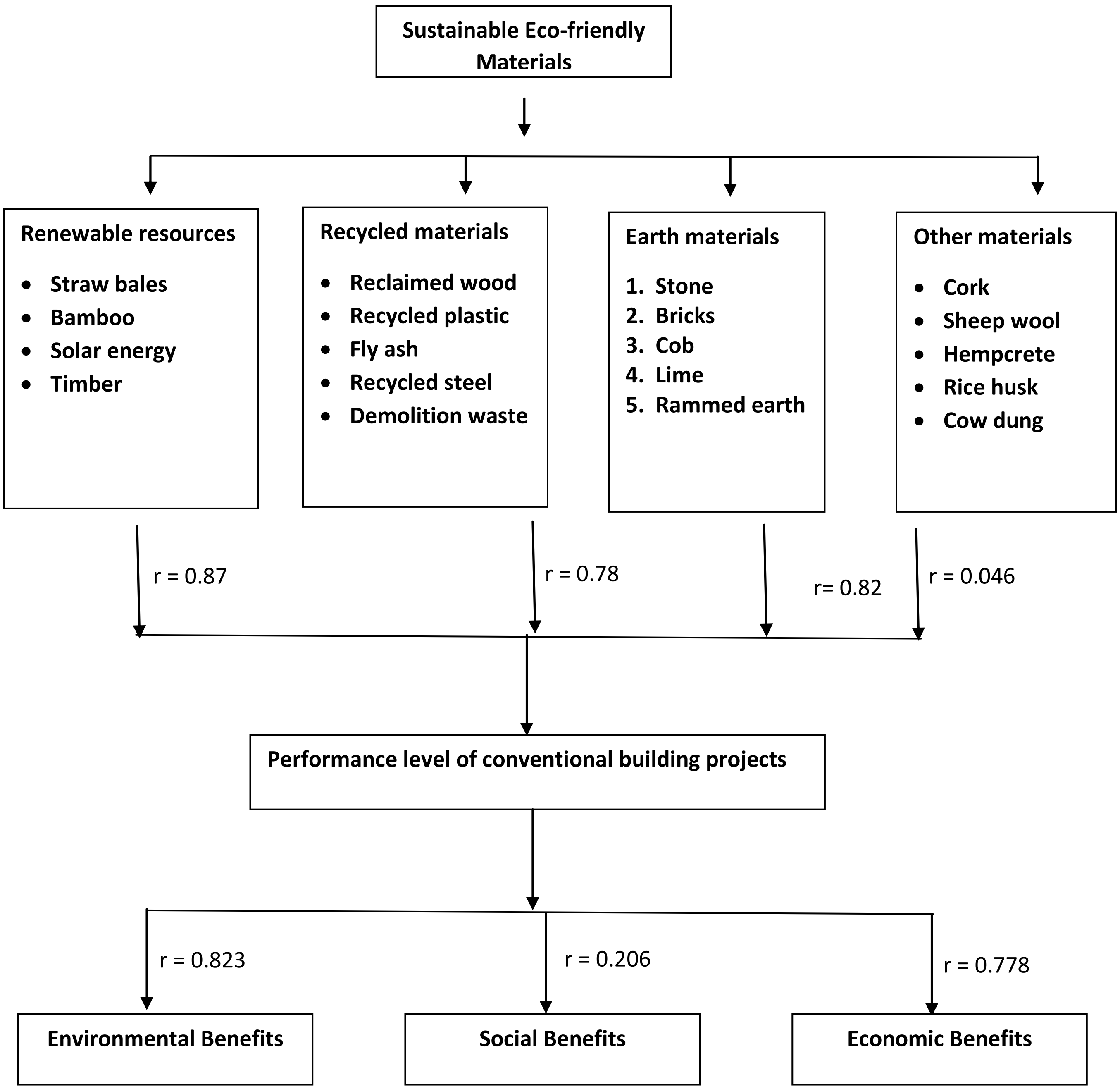


Fig 4.3: Developed framework for integrating sustainable eco-friendly building material (SEBM) on the performance of conventional building projects (CBP).

r = Pearson correlation coefficient of SEBM and EECS on CBP

4.2 Discussion of Result

This study was centered on investigating and evaluating the effects of sustainable eco-friendly building materials on the performance level of conventional building projects delivery in Port Harcourt metropolis, Rivers State. Results of data collected have been presented in Section 4.1. This section, will consider the discussion of the results obtained.

From Table 4.5, the RSI values showed that Government barriers ranked highest (0.95) in severity against the other barriers. This can be attributed to lack of government policy to support sustainable building project. In a similar study, Ebekozien et. al., (2021) found that government related barriers are major cause of the non-adoption of sustainable healthcare building projects. Although government related barriers ranked highest, other barriers (knowledge related barriers, human related barriers, cost and risk related barrier and market related barriers) studied can still play significant role in the choice of sustainable building project in Port Harcourt (Toriola-Coker et. al., 2020).

From Table 4.6, Renewable resources (RR) with Pearson correlation coefficient of 0.87 correlated more with the dependent variable CBP. This indicates the choice of renewable resources (RR) will significantly enhance the performance of conventional building projects (CBP) in Port Harcourt. The study by Ashish (2012) also showed that the use of renewable materials/resources can enhance the performance of conventional building projects. The relationship between the use of other sustainable options and the performance of CBP showed correlation coefficient 0.046 which signifies that there is no correlation between the two variables. Hence the use of materials such as rice husk cork, etc. will not enhance the performance of CBP and this can be as a result of these materials not being treated properly.

The use of SEBM in conventional building projects can lead to many benefits, some of which are grouped under environmental benefits, economic benefit and social benefits as presented in Table 4.8. The use of SEBM in conventional building projects was shown to have more environmental benefits, followed by economic benefits. SEBM are environmentally friendly and can be relatively cheap and affordable, adopting sustainable building project will directly lead to environmental benefits (reduction of greenhouse gases) and economic benefits (low operating and maintenance cost). This is in line with the study carried by INDIA CSR (2023) and WECD (1987), these studies stated that sustainable building minimizes environmental impacts resulting from conventional building projects. Social benefits have very low correlation (r = 0.206) with the use of SEBM in conventional building projects, this not in agreement with the studies of INDIA CSR (2023) which claimed that sustainable building improves not just the environment but also the wellbeing of its occupants. This disagreement can be attributed to varying individual responses which is based on their immediate surroundings.

Table 4.9 and Figure 4.2, showed the RII obtained for each possible solutions to constraining factors limiting the use of SEBM in conventional building projects. Educating building owners on the future benefits of sustainable building ranked highest with RII of 0.98 and will yield more results as compared to other possible solutions. Although the respondents didn't consider that the appraisal of the existing building code and establishment of sustainable building code will yield more results, it can actually set a baseline for the adoption of sustainable building projects (EPA, 2018).

HO_1: There is no significant correlation between the integration of SEBM and performance level of CBP.

The results obtained at 5% level of significance (Table 4.6) showed significant correlation between RR, RM, EM and performance level of CBP respectively. While that of OS and performance level of CBP showed no significant correlation. The significant correlation with the performance level of CBP shown by RR and EM is because materials grouped under these categories (RR and EM) are known sustainable eco-friendly materials, this is in line with the studies of Ashish (2012). On the other hand, correlation of OS and the performance level of CBP was not significant, this can be as a result of the materials grouped under this category not been locally available in Port Harcourt.

HO_2: There is no significant correlation between environmental, economic and social benefits respectively with performance level of CBP.

The results obtained at 5% level of significance (Table 4.8) showed significant correlation between EB, ECB and performance level of CBP, while that of SB and performance level of CBP showed no significant correlation. This is because SEBM which is a major component of sustainable building projects are environmentally friendly and economically viable. This is not the same with social benefits (SB) which showed no significant correlation with the performance level of CBP, this is due to the varying individual responses which is based on their immediate surroundings.

HO_3: There is no significant difference among the opinions of construction professionals on the use of SBM in the CBP delivery in Port Harcourt metropolis Rivers State.

From Table 4.10, the p-values for Architects, Builders, Quantity surveyors and Structural engineers are 0.000, 0.003, 0.001 and 0.000 respectively. Which showed that there is significant difference among the opinions of the construction professionals. This is in line with the studies of Toriola-Coker (2023) which also claimed that there is significant difference among the opinion of construction professionals. This can be attributed to the varying understanding of the construction professional on the subject topic.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5. I. Conclusion

Sustainable or green construction also known as eco-friendly construction, focuses on minimizing the environmental impact of building projects. It involves using renewable materials, energy-efficient designs, and reducing waste. Key concepts include incorporating solar panels, efficient insulation, rainwater harvesting, and natural ventilation to create buildings that are more resource-efficient and have lower carbon footprints. This approach helps reduce carbon emissions, conserve natural resources, and create more resilient and energy efficient structures for the future.

This study specifically was aimed at identifying and evaluating the effects of sustainable eco-friendly building materials on the performance level of conventional building projects delivery in Port Harcourt metropolis, Rivers State. The objectives of this study include investigating the barriers of integrating sustainable eco-friendly building materials for building projects in Port Harcourt, to evaluate the effects of sustainable eco-friendly building materials on the performance of conventional building projects, to correlate environmental, economic and social benefits of integrating sustainable eco-friendly building materials on the performance level of conventional building projects and proffer solutions to factors limiting the use of sustainable building materials in Port Harcourt.

The literature reviewed, the data collected, the analysis made, the findings obtained and the discussions help to develop the following necessary and important conclusions:

1. Government related barriers which include; lack of government policies and support to encourage sustainable building construction, absence of incentives by the government to encourage sustainable building construction, lack of or ineffective government programs focused on the promotion of green construction and lack of locally or a single unified/standard green building assessment system are major cause of the non-adoption of the use of sustainable eco-friendly building materials for building construction projects in Port Harcourt.
2. The choice of materials like; stone, bricks, clay, cob, lime, timber, straw bales, sheep's wool, solar energy e.t.c. will significantly enhance the performance of conventional building projects in Port Harcourt.
3. The use of sustainable eco-friendly building materials in conventional building projects was shown to have more environmental benefits, followed by economic benefits.

5.2. Recommendations

Based on the findings of the study, the following recommendations are made:

1. Building owners (the clients) should be properly educated on the future benefits of sustainable/eco-friendly building.

2. The government, should establish enticements to inspire invention in sustainable building construction
3. Intensive promotion of sustainable/green building by the government and professionals in building construction industry through television, radio and social media.
4. It is important to use resources or materials from more sustainable source for building construction purposes.
5. Establishment of sustainable building code by the relevant authorities that must be followed before the erection of any building in Port Harcourt.

5.3. Contributions to knowledge

In this study, effect of integrating sustainable eco-friendly materials on the performance of conventional building project delivery are expected to minimize negative impact on the environment resulting from the construction, operation and maintenance of conventional buildings. By integrating sustainable eco-friendly material on conventional building projects, one can achieve zero greenhouse gas emission, pollution reduction, energy efficiency and material conservation.

Some contributions to knowledge made by this research include;

i. The research has identified a clear theoretical understanding of the main barriers of integrating sustainable eco-friendly material into building project in Rivers

State. Thus, providing possible solution to the constraining factors limiting the use of sustainable eco-friendly materials for effective building project delivery.

ii. This research has also identified how the use of sustainable eco-friendly materials can influence the performance of conventional building projects by minimizing greenhouse gas emission, improving indoor air quality, improving energy efficiency and material conservation.

iii. The research has provided an understanding of the extent to which the use of sustainable materials for conventional building projects can benefit the general public. These benefits were grouped under economic, environmental and social benefits.

REFERENCES

Abeysundara, U.G.Y., Babel, S.; Gheewala, S. A (2019). Matrix in life cycle perspective for selecting sustainable materialsfor buildings in Sri Lanka. Build. Envrion, 44, 997–1004.

Abimaje J., & Baba A. N. (2019). "An assessment of timber as a sustainable building material in Nigeria". International Journal of Civil Engineering, Construction and Estate Management, vol. 1, no. 2, pp. 39 – 46, 2019.

Adam H., (2023). Will Eco home shape the future of sustainable design? https://www.aaa.co.tz.

Ahmed.A. and Gidado, K. (2008). Evaluating the potential of Renewable Energy Technologies for Buildings in Nigeria, In: Dainty, A (Ed) Procs 24th Annual ARCOM Conference, Cardiff, UK, Association of Researchers in Construction Management, 1175-1182.

Aigbavboa, C., Ohiomah, I., ang Zwane, T. (2017). Sustainable construction practices: "a lazy view" of construction professionals in the South Africa construction industry. The 8th International Conference on Applied Energy Procedia, 105, 3003-3010.

Aje, I.O. (2016). Effective Financing Options for Sustainable Construction in a Developing Economy. A Paper Delivered at a 2Day National Seminar on Sustainable Construction in a Developing Economy: Factors and Prospects organized by The Nigerian Institute of Quantity Surveyors, Ondo State Chapter Held at Theodore Idibiye Francis Auditorium, Federal University of Technology, Akure Ondo State.

Akadiri, P.O., Chinyio. E.A. and Olomolaiye, P.O. (2012). Design of a Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector. Buildings. 2(1), 126-152.

Akshay, B.M., Allaudin, I.S., Shamashree, S.R., Sushma, J .P. and Uday, J.P. (2015). Green Building Materials – A way towards Sustainable Construction. International Journal of Application or Innovation in Engineering and Management (IJAIEM), 4(4), 34-51.

Alabi, A.A. (2012). Comparative Study of Environmental Sustainability in Building Construction in Nigeria and Malaysia, Journal of Emerging Trends in Economics and Management Sciences, 3(6), 951-961.

Alaghbari, W., Salim, A., Dola, K., & Abdullah Abang Ali, A. (2011). Developing affordable housing design for low income in Sana'a, Yemen. International Journal of Housing Markets and Analysis, 4(1), 84–98. https://doi.org/10.1108/17538271111111857

Al-Saleh, Y.M. and Taleb, H.M. (2010). The Integration of Sustainability within Value Management Practices: A Study of Experienced Value Managers in the GCC Countries, Project Management Journal, 41(2), 50-59

AlSanad, S. (2015), "Awareness, drivers, actions and barriers of sustainable construction in Kuwait", International Conference on Sustainable Design, Engineering and Construction. Procedia Engineering, Vol. 118, pp. 969-983.

Aluko, O.O. (1997). Nigerian Traditional Architecture, A Case Study of South-west Nigeria. A Lecture Note book, Department of Architecture, Rufus Giwa Polytechnic, Ondo State (Unpublished). 1(10), 20-25.

Amal, G. M. & Halil, Z. A. (2017). The Use of Traditional Building Materials in Modern Methods of Construction (A case Study of Northern Nigeria), International Journal of Engineering Science Technology and Research (IJESTR). 2(6), 30 – 40.

American Institute of Architects. (n.d.). Passive Design. Retrieved from https://www.aia.org/resources/6125045-passive-design.

Ametepey, O., Aigbavboa, C., & Ansah, K. (2015). Barriers to successful implementation of sustainable construction in the Ghanaian construction industry. 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, Procedia Manufacturing, 3(6), 1682–1689.

Ashish, K. P. (2012). Construction of an Eco-Friendly Building using Green Building Approach. International Journal of Scientific & Engineering Research, 3(6), 12-24.

ASHRAE.(n.d.). Indoor Air Quality (IAQ). Retrieved from https://www.ashrae.org/technical-resources/indoor-air-quality-iaq

Attmann, O. (2019). Green architecture-advanced materials and technologies. New York: McGraw-Hill.

Ayarkwa, J., Acheampong, A., Wiafe, F. & Boateng B. E. (2017). Factors Affecting the Implementation of Sustainable Construction in Ghana: The Architect‘s Perspective. ICIDA 2017 - 6th International Conference on Infrastructure Development in Africa, 2(4), 377–386.

Baron, N. & Donath, D. (2016). Learning from Ethiopia – A discussion on sustainable building. In Proc. of SBE16 Hamburg International Conference on Sustainable Built Environment Strategies – Stakeholders – Success factors, Held in Hamburg, Germany.

Bartlett E., and Howard N. (2008). Informing the decision makers on the cost and value of green building, Building Research& Information, Volume 28 p. 315-324

Baumann, H., Boons, F. &Bragd, A. (2002). Mapping the green product development field engineering, policy and business perspectives. Journal of Cleaner Production, 10(5),409-425.

Ben-Alon, L.; Loftness, V.; Harries, K.A.; DiPietro, G.; Hameen, E.C. (2019). Cradle to Site Life Cycle Assessment (LCA) of Natural vs Conventional Building Materials: A Case Study on Cob Earthen Material. Build. Environ.160, 106150.

Berge, B., (2020). Sustainable action: overcoming the barriers. Abingdon, Oxon. ISBN 978-0-429-57873-1. OCLC 1124780147.

Berge, B. (2010). The ecology of building materials. Oxford: Architectural Press.

Biehl, Z.,(2019). The Amazing world of Hemp: Hempcrete – the most sustainable building materials on earth.

Biomimicry Institute. (n.d.) what is Biomimicry? Retrieved from https://www.biomimicry.org/what-is-biomimicry

Blewitt, J., (2015). Understanding Sustainable Development (2nd ed.). London: Routledge. ISBN 9780415707824. Retrieved 26 November 2017.

Bosia, D., Lorenzo S., Francesca, T., and Alessia, P., (2015). Sheep wool for sustainable Architecture.

Bugaje, I. M. (2006). Renewable Energy for Sustainable Development in Africa: A Review. Renewable and Sustainable Energy Review, 1-10.

Cazacu, C. and Chiţonu, G. C. (2015). Ecological criteria considering the connections between the construction, building-site and the spatial planning development. 3rd China-Romania Science and Technology Seminar (CRSTS 2018) IOP Publishing IOP Conf. Series: Materials Science and Engineering 399 (2018) 012006 doi:10.1088/1757-899X/399/1/012006.

Chandra, S., (2012). Straw bale as a sustainable material.

Chukwu D.U., Anaele E.A., Omeje H.O. and Ohanu I.B. (2019) Adopting green building constructions in developing countries through capacity building strategy: survey of Enugu State, Nigeria. Sust. Build. 4, 4.

Dania, A. A., Kehinde, J. O. & Bala, K. (2007). A Study of Construction Material Waste Management Practices by Construction Firms in Nigeria. Journal of Emerging Trends in Economics & Management Sciences (JETEMS). 1(2), 131- 211.

Darko A., Chan A.P.C. (2018). Strategies to promote green building technologies adoption in developing countries: the case of Ghana, Build. Environ. 130, 74–84 (2018)

Dickie, I. and Howard, I. (2018). BRE Digest 446: Assessing Environmental Impacts of Construction, BRE Centre for sustainable Construction, Watford.

Djokoto, S. D., Dadzie, J. &Ohemeng-Ababio, E. (2016). Barriers to sustainable construction in the Ghanaian construction industry: consultants‘ perspectives. Journal of Sustainable Development, 7(1), 134-143.

Dweiri, F. and Al-Oqla, F.M., (2022). Material selection using Analytic Hierarchy Process, International J. Computer Applications in Technol., 26(4): 182-189.

Ebekozien, A., Oisasoje, S.A.,Nwaole A.N.C., Aginah L.I., and Uwadia, F.E., (2021). Barriers in Nigeria's public hospital green building implementation initiatives. Journal of Facilities Management 1472-5967.

Elkington, J. (1997). Cannibals with fork: The Triple Bottom Line of 21st Century Business.

Eco House store (2023). Sustainable building materials: The Advantages of lime mortar. https://ecohousestore.co.uk.

Environment Protection Agency, Green Building (2018). Form: http://www.epa.gov/greenbuilding/pubs/about.htm. December 18, 2018

EPA, Contaminated site management (2017). https://www. epa.vic.gov.au/your-environment/land-and-groundwater/ contaminated. Retrieved: February 18, 201

Fehling E., Middendorf B., and Thiemicke J. (2016). Ultra-High Performance Concrete and High Performance Construction Materials, Kassel University Press, Kassel, Germany (2016), pp 59-67.

Geeta, M., Mehta, A. & Sharma, B. (2014). Selection of Materials for Green Construction.

Geng, X., Wen, Y., Zhou, C. and Xiao, C.(2017). Establishment of the ecosystem for the regional shipping industry based on system dynamics sustainability. Sustainability, Volume 9, p.742.

Georgescu, D.& Apostu A., (2015). The impact of reinforced concrete constructions on the environment. Technical University of Civil Engineering, http://civile.utcb.ro/metex/etapa33.pdf.

Gharehbaghi K., Georgy M., Rahmani F. (2018). Composite High-Rise Structures: Structural Health Monitoring (SHM) and Case Studies, Materials and Technologies in Engineering, pp 146-152.

Gharehbaghi K., and Rahmani F. (2018) Practicalities and Developments of High-Rise Composite Structures: Case Studies, Materials and Technologies in Engineering, pp 153-159.

Giovanni, V.,(2021). Why Bamboo is a sustainable building material.

Gosia, K., (2020). How to mix old tyres and building rubble to make sustainable roads.

Graham P. (2003). Building Ecology—First Principles for a Sustainable Built Environment; Blackwell, Publishing: Oxford, UK.

GRIHA (2010). Manual Volumn -1 Introduction to Rating System-GRIHA published by Ministry of New and Renewable Energy, Government of India, and TERI, the Energy and Resource Institute, New Delhi (2010).

Gupta, R. (2016). Sustainable Development and Green Building. Journal of Environmental Management, 2 (3), 41-64.

Halliday, S. (2018) Sustainable Construction; Butterworth Heinemann: London, UK.

Heakkinen, T. and Belloni, K. (2011), "Barriers and drivers for sustainable building", Building Research and Information, Vol. 39 No. 3, pp. 239-255.

Hoffman A. J, Henn R.(2008).Overcoming the social and psychological barriers to green building. Organ. Environ. 21, 390–419

International Energy Agency (IEA). (2019). Digitalization and Energy. Retrived from https://www.iea.org/topics/digitalization-and-energy

International Green Roof Association (IGRA). (n.d.). Green Roofs and Green Walls. Retrieved from https://www.greenroofworld.com/

Johnson, M., (2020). Waste not, want not: The Environmental Benefits of Reclaimed Wood. Environmental Conservation, 25(4), 210-225.

Jong-Jin, K., Brenda, R., Jonathan, G., (2018). Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials, College of

Architecture and Urban Planning The University of Michigan Published by National Pollution Prevention Centre for Higher Education.

Kellert, S. R., Heerwagen, J., and Mador, M.,(2008). Biophilic Design: the Theory, Science, and practice of Bringing Buildings to life.

Kilbert, C., Sustainable construction (2016). Green building design and delivery, Hoboken, Wiley pp 9-14.

Klemm, A., and David W.,(2016). Sustainability of natural stone as a construction material.

Knapic, S., Vanda, O., Jose, S.M., and Helena, P.,(2016). Cork as a building material.

Koru,U., (2017). Benefits of building with cob. www.Koruarchitects.co.uk.

Lenzen, M.; Treloar, G.J. (2012). Embodied energy in buildings: Wood versus concrete-reply to Borjesson and Gustavsson. 30, 249–244.

Lockrey S., Verghese K., Crossin E., and Nguyen H. (2018). Concrete recycling life cycle flows and performance from construction and demolition waste in Hanoi, Journal of Cleaner Production, vol. 179 pp. 593-604.

Magudeaswaran, P.,(2018). Development of Eco Brick and Contrete with the partially replacement of cow dung.

Marcelle, P.V.,(2023). Philippine Resources: Fly Ash an eco-friendly building material. www.philippine-resources.com.

Mayhoub, G.,(2020). Assessment of Green Building Materials' Attributes to Achieve Sustainable Building Facades Using AHP.

McDonough, W., and Braungart, M. (2002). Cradle to Cradle: Remarking the way we make things.

Megan, S.,(2021). Hempcrete: Creating Holistic Sustainability with plant.

Moeck, M., Yoon, J.Y. (2004). Green buildings and potential electric light energy savings. Journal of Architectural Engineering 10(4):143–59.

Morel, C., Mesbah, A.,Oggero, M., and Walker, P., (2001). Building houses with local materials: means to drastically reduce the environmental impact of construction, Building and Environment, Volume 36, Issue 10 p. 1119-1126.

Nalewaik, A., (2008). Costs and Benefits of Building Green, American Society of Engineers: Proceedings of the 5th International Engineering and Construction Conference, August 27-29, Los Angeles, U.S.A, p. 969-979

National Research Council Canada. (2014). Green Roofs: An Innovative Solution to Support the Future of Urban Ecosystems. Retrieved from https://nrc-publications.canada.ca/eng/view/accepted/?id+77f19045-5f6f-4c09-b0b0-40f3011a698a

Nduka, D. O. &Ogunsanmi, O. E. (2015). Construction Professionals‘ Perception on Green Building Awareness and Accruable Benefits in Construction Projects in Nigeria. Covenant Journal of Research in the Built Environment (CJRBE), 3(2),30-52.

Nduka, D. O. &Sotunbo, A. S. (2014). Stakeholders Perception on the Awareness of Green Building Rating Systems and Accruable Benefits in Construction Projects in Nigeria. Journal of Sustainable Development in Africa, 16(7), 118-130.

Nikyema, G.A. and Blouin, V.Y. (2020), “Barriers to the adoption of green building materials and technologies in developing countries: the case of Burkina Faso”, IOP Conference Series: Earth and Environmental Science, Vol. 410, 012079, doi: 10.1088/1755-1315/410/1/012079.

Nsesheye, S. M., Wolfram, S., Andreas, R., and Hans-Carsten, K., (2018). Rice husk ash as a sustainable supplementary cementitious material for improved concrete properties.

Odeyale, T. O. & Adekunle, T. O. (2008). Innovative and sustainable local material in traditional African architecture – Socio cultural dimension.

Ofori, G. and Kien, H.L. (2004), “Translating Singapore architects’ environmental awareness into decision making”, Building Research and Information, Vol. 32 No. 1, pp. 27-37, doi: 10.1080/ 09613210210132928.

Okafor, B.N.(2016). Green building for Nigeria public institutions towards effective administration of public properties: A case study of military barracks and police stations in Anambra State Nigeria. International Journal of Physical and Human Geography. Vol.4, No.2, pp.16-22.

Oloruntoba, K., and Ayodele E. O.,(2013): Local Building Materials: a Tool Towards Effective Low-Income Housing in Nigeria. Middle-East Journal of Scientific Research 18 (4): 492-497, 2013. ISSN 1990-9233

Opara, F. E. (1999). Formulating Standards for Building Materials in Nigeria proceedings of a Seminar organized by the Nigerian Building and Road Research Institute (NBRRI), Ota, Ogun State.

Osaily, N.Z. (2010). The key Barriers to Implementing Sustainable Construction in West Bank –Palestine. MSc Thesis, submitted to the Robert Kennedy College/Zurich University of Wales/ UK, March – 2010. available at: http://osaily.com/portal/wp-content/uploads/2017/05/.

Pallvika, K.,(2016). Merdacotta: New sustainable building material made from cow dung.

Passive House Institute. (n.d.). What is a passive House? Retrieved from https://passivehouse-international.org/index.php?

Patel A., Divya C., Patel A., Katrodiya Y., Jain A., Thakkar S. (2021). Slu-bricks - An innovative sustainable solution for solid waste management. Materials Today: Proceedings. Ttps://doi.org/10.1016/j.matpr.2021.09.175.

Peuhkuri, R., and Mahapatra, K. (2019). Environmental benefits of timber in construction. In: Mahapatra, K. (Ed.), Environmental Impact of Construction Materials and Practices (pp.203-223). Springer, Cham.

Pritchard M. and Pitts A. (2006). Evaluation of Strawbale Building: Benefits and Risks, Architectural Science Review, Volume 49, Issue 4, pp. 372-384.

Prutha, P., and Anant, P.,(2021). Use of Sustainable Green Materials in Construction of Green Buildings for Sustainable Development. IOP Conf. Series: Earth and Environmental Science 785 (2021) 012009.

Pulselli, R.M., Simoncini, E. andBastianoni, S., (2007). Energy analysis of building manufacturing, maintenance and use: building indices to evaluate housing sustainability. Energy and Buildings 39(5):620–8.

Qian Q.K., Chan E.H.W., Khalid A.G. (2015). Challenges in delivering green building projects: unearthing the transaction costs (TCs), Sustainability 7, 3615–3636

Rima, S. A.(2019). Re-engineer cob into sustainable new building materials.

Ross,B., Lopez-Alcala, M., (2006). Modeling the private financial returns from green building investments. Journal of Green Building 2(1):97–105.

Rydin, Y., Amjad, U., Moore, S., Nye, M. and Withaker, M. (2006), “Sustainable construction and planning”, The Academic Report, Centre for Environmental Policy and Governance, the LSE SusCon Project, CEPG, London School of Economics, London.

Sachs, J. D. (2015). The Age of Sustainable Development. New York: Columbia University Press. ISBN 9780231173155.

Sarvesh P. S. & Chouhan M. S. (2013). Eco-Friendly building analysis with reused building materials. Construction innovation. 1(2)45-134.

Sev, A. (2019). How can the construction industry contribute to sustainable development? A conceptual framework. Sustain. Dev. 17, 161–173.

Sheth, K. N. (2016). Sustainable Building Materials Used in Green Buildings, 9 th International Conference on Engineering and Business Education (ICEBE) & 6 th International Conference on Innovation and Entrepreneurship (ICIE), 4(3), 135-143.

Shittu, A. U. (2014). Assessing the Level of Stakeholders Awareness of Sustainable Design and Construction. Unpublished.

Singleton R.A., Straits B.C. (2009). Approaches to social research. New York: Oxford University Press.

Taleai, M. and Mansourian, A., (2008). Using Delphi-AHP method to survey major factors causing urban plan implementation failure.

Thomas, R., (2019). LEED AP, architect and Niklas Spitz.

Toriola-Coker L.O., Alaka h., Bello W.A., Ajayi S., Adeniyi A., Olopade S.O. (2021), Sustainability Barriers in Nigeria Construction Practice.

Torsten, L.,(2021). Could clay be the key to sustainable architecture? www.dw.com.

Ulrich, G., (2021). Deep roots — A conceptual history of "sustainable development".

Umar, U. A. &Khamidi, M. F. (2014). Sustainable Building Material for Green Building Construction, Conservation and Refurbishing. Management in Construction Research Association (MiCRA), 111-116.

UNESCO.(2013). "Education for Sustainable Development". Retrieved 17 October 2017.

United Nations (2015) Resolution adopted by the General Assembly on 25 September 2015, Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1 Archived 28 November 2020 at the Wayback Machine)

U.S Green Building Council (USGBC) (2017). Impact of Green Buildings on occupant's wellbeing.

Usman A., Khamidi M. F. & Hassan T., (2018) "Sustainable building material for green building construction, conservation and refurbishing" Management in Construction Research Association (MiCRA) Postgraduate Conference.

Vargas, J., (2019). Sustainable Rammed EarthCconstruction: understanding the material and the modern applications. Journal of Sustainable Architecture and Civil Engineering, 5(1), 45-58.

Venkatarama B.V., Jagadish K.S., (2003) Embodied energy of common and alternative building materials and technologies. Energy and Buildings 35(2):129–37.

Wang W, Zmeureanua R, Rivard H. (2005). Applying multi-objective genetic algorithms in green building design optimization. Building and Environment. 40(11):1512–25.

WCED. (1987). Our Common Future; World Commission on Environment and Development, Oxford University Press: Oxford, UK.

Yu, C.,(2008). Environmentally sustainable acoustics in urban residential areas. PhD dissertation. University of Sheffield, UK: School of Architecture.

Yudelson, J..(2017). the green building revolution. Washington, D.C.: Island Press.

APPENDIX 1

COPY OF THE QUESTIONNAIRE

POST GRADUATE SCHOOL
SDEPARTMENT OF PROJECT MANAGEMENT
SCHOOL OF MANAGEMENT TECHNOLOGY
FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI IMO STATE, NIGERIA

9th July, 2023

Dear Respondent,

Research Survey on: Effects of Integrating SustainableEco-friendly Materials on The Performance of Conventional Building Projects Delivery.

(A study of Port Harcourt, Rivers state)

Please find the attached, a research questionnaire designed to collect data on the above subject matter. It is part of the requirements for the award of Master of Science (M.Sc) in the above Institution. The research work is purely an academic activity aimed at evaluating the importance of integrating or introducing sustainable building materials in the conventional building projects (a study of Port Harcourt, Rivers state).

The information you provide will be handled with strict confidence and used solely for research purpose.

Thank you for your anticipated response.

Yours faithfully,

0duali, Nheomachi Faith
Researcher
08131368384

EVALUATION OF LITERATURE REVIEW ON EFFECTS OF INTEGRATING SUSTAINABLE ECO-FRIENDLY MATERIALS ON THE PERFORMANCE OFCONVENTIONAL BUILDING PROJECTS DELIVERY.

(A STUDY OF PORT HARCOURT, RIVERS STATE)

Section A: Demographic information of respondents

Please provide information about the respondent as requested by selecting one of the options provided.

A. Profession of respondent	1	Architect	
	2	Builder	
	3	StructuralEngineer	
	4	Quantity Surveyor	
	5	Others (specify)	

B. Education attainments	1	OND/NCE	
	2	HND/B.Sc	
	3	M.Sc	
	4	Ph.D	

C. Work experience of respondent	1	Less than 5yrs	
	2	5yrs – 15yrs	
	3	16yrs – 25yrs	
	4	More than 25yrs	

D. Employer	1	Client	
	2	Consultant	
	3	Contractor	
	4	Others (specify)	

SECTION B

Barriers of integrating sustainableeco-friendly building materials

Listed below are some likely barriers of integrating sustainable eco-friendly building materials. A set of ratings is required on the extent of the effect of these factors. Kindly use the five-point scale provided as follows:

5(SA) = Strongly Agree; 4(A) = Agree; 3(N) = Neutral, 2(D) = Disagree; 1(SD) = Strongly Disagree

S/N	Barriers of integrating sustainableeco-friendly building materials	1 SD	2 D	3 N	4 A	5 SA
	Government related barriers					
1	Lack of/or ineffective government policies/support					
2	Absence of incentives					
3	lack of/or ineffective government programs focused on green construction					
4	Lack of locally or a single unified/standard GB assessment system					
	Human related barriers					
5	Lack of interest in sustainable building development					
6	Insufficient integration and link up					

	within the industry, lack of commitment from professional bodies (such as NIA, NIOB, etc.					
7	Clients' preference for the traditional materials					
8	Divergent interests and views of success factors and success criteria of green building developments among stakeholders					
9	Cultural barriers					
10	Low Stakeholder demand					
11	Inadequate overall management actions					
12	Green building project is regarded as low priority and other issues take priority					
	Knowledge related barriers					
13	Inadequate awareness					
14	Poor knowledge of green building methods among professionals					
15	Poor sustainability education in academic institutions					
16	Lack of adequate research on green building					
17	Lack of green building cost and performance data					
18	Contractual procedure and					

	professional unconsciousness					
19	Difficulty in quantifying/measuring energy and environmental impact					
	Market related Barriers					
20	Unavailability of local GB materials					
21	Unavailability of indigenous green building technologies					
	Cost and Risk related barriers					
22	High cost of construction					
23	Longer payback period for sustainable resources					
24	Limited financial and human resources					
25	Green building construction is too complicated					
26	Green building conflicts with or complicates with existing laws or regulations					
27	Green facilities are hard to justify even on the basis of long-term savings					
28	Low perceived benefits					

Please state any other barrier(s) of integrating sustainableeco-friendly building material that have not been mentioned above

----

To what extent can the use of sustainable eco-friendly materials (SEBM) enhance the performance of Conventional building projects (CBP)in Rivers State?

The following five-point scale is required:

5(VHE) = Very high extend; 4(HE) = High extend; 3(NHL) = neither high or low extend; 2(LE) = Low extend; 1(VLE) = Very low extend

	To what extent can the use of the following SEBM enhance the performance of CBP in Rivers State?	**1** **VLE**	**2** **LE**	**3** **NHL**	**4** **HE**	**5** **VHE**
	Recycled materials					
1	Reclaimed wood					
2	Recycled plastic					
3	Fly ash					
4	Recycled steel					

5	Demolition waste					
	Renewable resources					
6	Straw bales					
7	Timber					
8	Bamboo					
9	Solar energy					
	Earthen materials					
10	Stone					
11	Bricks					
12	Cob					
13	Lime					
14	Rammed earth					
	Other sustainable option					
15	Cork					
16	Sheep wool					
17	Hempcrete					
18	Cow dung (it can be used for bricks production)					

19	Rice husk (it can be used as a binding material)					

Please state any other sustainable eco-friendly building material(s) that is easily available in Port Harcourt that have not been mentioned above

----

What are the levels of relationship between environmental, economic and social (EES) benefits of integrating SBM and performance level of CBP?

In this section, the following five-point scale is required:

5(VHE) = Very high extend; 4(HE) = High extend; 3(NHL) = Neither high nor low extend, 2(LE) = Low extend; 1(VLE) = Very low extend

	How can the following benefits of integrating SBM influence the performance level of CBP?	**1** **VLE**	**2** **LE**	**3** **NHL**	**4** **HE**	**5** **VHE**
	Environmental benefit					
1	Reduced greenhouse gas emission					
2	Improved air					
3	Reduced ecosystem degradation					
4	Reduced water wastage					
5	Reduced energy consumption					

6	Better health for building occupants					
	Economic related benefit					
7	Employment generation					
8	Low operating cost					
9	High property value					
10	worker productivity					
11	Resource efficiency/conservation					
12	Technological advancement					
13	Creates, expands and shapes market for green products and services					
	Social benefit					
14	Improved occupants' wellbeing					
15	Community improvement					
16	Knowledge transfer					
17	Stakeholders' satisfaction					
18	Neighborhood restoration					

Please state any other benefits of using sustainable building materials over the conventional building materials that have not been mentioned above

----

To what extent do you agree or disagree with the solutions to the barriers of integrating the use of sustainable eco-friendly building materials?

S/N	Solutions to the barriers of integrating the use of sustainable eco-friendly building materials	1 SD	2 D	3 N	4 A	5 SA
1	Establishment of enticements to inspire invention in sustainable construction by the Government					
2	Provision of adequate training centers with adequate funding of research and development					
3	Utility of technologies that license the reprocessing of the building components and deconstruction					
4	Rigorous sustainable or green building promotion by the government					
5	Use of resources from more sustainable source					
6	Provision of sustainable materials					

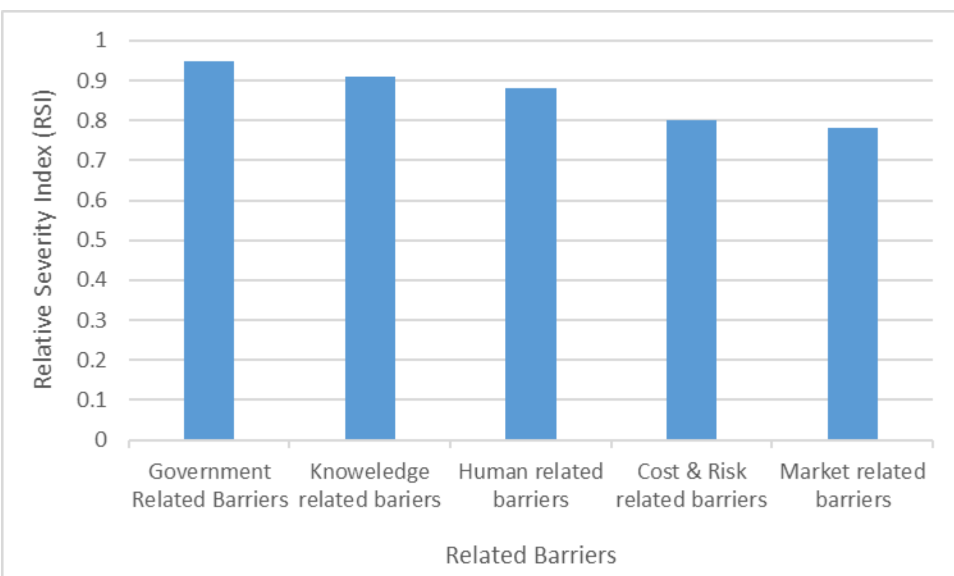
	selection criteria					
7	Promotion of sustainable construction by the building industry					
8	Regular inspection and monitoring of works with set rules and legislation					
9	Appraisal of building code and establishment of sustainable building code					
10	Employ natural resource management strategy					
11	Educating owners on the future benefits of sustainable building					

Please state any other solution that will improve or eliminate the barriers of integrating the use of sustainable eco-friendly building materials for construction purposes that have not been mentioned above

----

BARRIERS OF INTEGRATING SUSTAINABLE ECO-FRIENDLY BUILDING MATERIALS.

S/N	Barriers of integrating Sustainable Eco-friendly Building materials	5	4	3	2	1	RSI
1	Government Related Barriers	67	10	5	0	0	0.95
2	Knowledge related barriers	60	15	5	2	0	0.91
3	Human related barriers	51	20	8	3	0	0.88
4	Cost & Risk related barriers	30	31	15	4	2	0.8
5	Market related barriers	29	25	15	8	5	0.78



CORRELATION BETWEEN SEBM AND CBP

	Statistical Test	SEBM	CBP
SEBM	Pearson correlation Sig. (2-tailed) N	1 82	
CBP	Pearson correlation Sig. (2-tailed) N	0.86 0.003 82	1 82

CORRELATION BETWEEN SEBM (RR, OS, EM AND RM) AND CBP

	Statistical Test	RR	OS	EM	RM	CBP
RR	Pearson correlation Sig. (2-tailed) N	1 82				
OS	Pearson correlation Sig. (2-tailed) N	0.096 0.392 82	1 82			
EM	Pearson correlation Sig. (2-tailed) N	0.823 0 82	0.052 0.64 82	1 82		
RM	Pearson correlation Sig. (2-tailed) N	0.782 0.72 82	0.062 0.486 82	0.762 0.356 82	1 82	
CBP	Pearson correlation Sig. (2-tailed) N	0.87 0.003 82	0.046 0.683 82	0.82 0 82	0.78 0.003 82	1 82

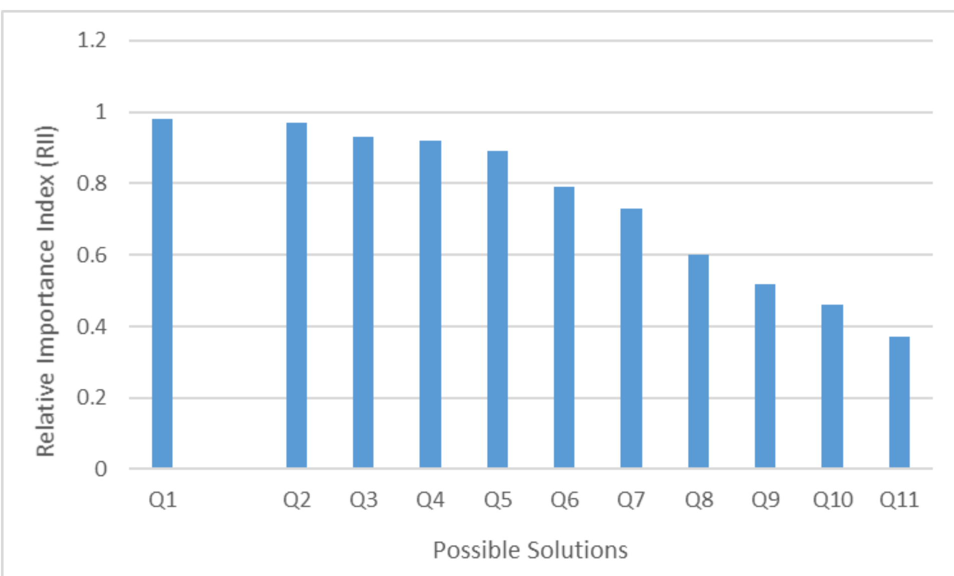
CORRELATION BETWEEN EB, ECB AND SB AND CBP

	Statistical Test	SB	EB	ECB	CBP
SB	Pearson correlation Sig. (2-tailed) N	1 82			
EB	Pearson correlation Sig. (2-tailed) N	0.758 0 82	1 82		
ECB	Pearson correlation Sig. (2-tailed) N	0.576 0.001 82	0.432 0.005 82	1 82	
CBP	Pearson correlation Sig. (2-tailed) N	0.206 0.063 82	0.823 0 82	0.778 0 82	1 82

SOLUTIONS TO BARRIERS OF INTEGRATING SUSTAINABLE ECO-FRIENDLY BUILDING MATERIALS

Key	Possible solution	5	4	3	2	1	RII
Q1	Educating building owners on the future benefits of sustainable building	75	4	2	1	0	0.98
Q2	Intensive promotion of sustainable or green building by the government, via: Radio, televisions and social media.	74	5	3	0	0	0.97
Q3	Establishment of enticements to inspire invention in sustainable construction by the Government	60	16	5	2	0	0.93
Q4	Use of resources from more sustainable source	60	15	5	2	0	0.92
Q5	Provision of adequate training centers with adequate funding of research and development to	48	25	8	1	0	0.89

	enhance sustainable development						
Q6	Provision of sustainable materials selection criteria	31	24	15	10	3	0.79
Q7	Utility of technologies that license the reprocessing of the building components and deconstruction	29	24	15	10	3	0.73
Q8	Promotion of sustainable construction by the building industry	12	16	25	20	19	0.6
Q9	Employ natural resource management strategy	9	10	20	25	18	0.52
Q10	Regular inspection and monitoring of works with set rules and legislation	6	9	16	25	26	0.46
Q11	Appraisal of building code and establishment of sustainable building code	3	5	12	22	40	0.37



Significant difference among the opinions of construction professionals on the use of SEBM in the CBP delivery in Port Harcourt.

Stakeholders	**Architect (AR)**	**Builder (BD)**	**Quantity Surveyor (QS)**	**Structural Engineer (SE)**
P value (p)	0.000	0.003	0.001	0.000
Alpha value (α)	0.05	0.05	0.05	0.05