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A Framework for Industry 4.0 Related Green Concept Integration of Services Component in Commercial Buildings

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Abstract: The effects of global warming are far-reaching and can affect and threaten every aspect of human existence. Human activities such as burning fossil fuels and deforestation have mainly contributed to the emission of these greenhouse gases into the atmosphere. Construction activities and practices are one such human activity. Building services are the aspects of a building that ensure the occupants are comfortable and secure within the building. However, building services use resources such as energy and water to create such comfort. The 4.0 era of industry has introduced dimensions to Green Building Concepts and practices of creating structures and processes that are environmentally friendly, responsible and resource efficient. This research, therefore, seeks to develop a framework for the integration of Industry 4.0-related green concepts into services in commercial buildings. A cross-sectional survey design was adopted in this research to provide information concerning integrating green concepts into building services in commercial buildings in Nigeria. Data were collected with questionnaires from 106 built environment professionals who also use commercial buildings in the study area of Abuja. Statistical tools for frequency, percentage, mean score, relative important index (RII), independent samples t test, Mann–Whitney U test and the factor reduction method based on eigen values were used to analyze the data. The results indicated that quality indoor air conditioning is the most critical satisfaction parameter for users within commercial buildings, with an average mean score of 3.81. The aesthetic effect of installed services on the building façade and high-quality building services components was ranked high, with an average mean score of 3.33 for each. The results also indicated that the lack of relevant technology and inadequate training of service personnel hindered the growth of green building concepts in Nigeria. These factors had a mean score of 4.35 each. Professionals ranked energy efficient/saving bulbs, e.g., CFLs, remote controlled, sensored lights, natural daylight, solar photovoltaic panels and building management systems, as the most effective green components that can be incorporated into commercial buildings. These factors and others were combined to create a framework for integrating green concepts for services into commercial buildings. When the construction industry and government in Nigeria adopt this framework, it can promote more integration of green concepts into commercial building services.

Keywords: Industry 4.0; green building; services; sustainability

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1. Introduction

Global warming is a phenomenon that is up in our faces and bedeviling humanity now. Climate change is because of the buildup of greenhouse gases trapped in the atmosphere, causing depletion of the ozone layer and making the direct rays of the sun reach the Earth's surface, therefore causing a rise in the temperature of the planet in what is referred to as global warming. Some heat-trapping gases include water vapors, carbon dioxide, methane, nitrous oxide and ozone. Others include hydro fluorocarbons, perfluorocarbons and sulfur hexafluoride. The effects of global warming are far-reaching and can affect and threaten

every aspect of human existence in areas of food security, aridification, killer heat waves, outbreaks of pandemic diseases, drought and flooding, etc. Human activities such as burning fossil fuels and deforestation have mainly contributed to the emission of these greenhouse gases into the atmosphere.

Construction activities and practices are human activities that cause the emission of greenhouse gases into the atmosphere and cause depletion of our natural habitat [1]. Over the last decade, the Nigerian building and construction industry has outgrown all other sectors of the Nigerian economy. Building services within the construction industry are becoming more and better accepted as humanity's quest for comfort and ease increases. Building services are systems installed in buildings to make them comfortable, functional, efficient and safe. Building services might include building control systems, energy distribution, energy supply (gas, electricity and renewable sources such as solar, wind, geothermal and biomass), escalators and lifts, facade engineering (such as building shading requirements), fire safety, detection and protection, heating, ventilation and air conditioning (HVAC), information and communications technology (ICT) networks, lighting (natural and artificial), lightning protection, refrigeration, security and alarm systems, water, drainage and plumbing (including sustainable urban drainage systems (SUDS)), and carbon emissions calculations and reduction. The needs, preferences and concerns for services within the building keep growing. The growing concerns over the environmental impacts of buildings and services have led to increasing demands for more environmentally friendly buildings, services and materials [2].

According to [1,3–5], it has become mandatory and vital for stakeholders within Nigeria's construction sector to begin looking at more sustainable and innovative ways to carry out construction activities to curb global warming. Sustainability is an area that all sectors/industries must start to look into to help save and preserve the Earth, even for the next generation.

By improving commercial, industrial, and institutional building design, building services experts can help building owners, tenants, and other building users reduce resource use while maintaining a better indoor environment [6]. New approaches are required in building services design and, in particular, in the selection, development and integration of technical services to combine the achievement of the needed energy savings with the fulfilment of high standards of comfort, health and safety in the internal spaces [7]. Therefore, this research seeks to develop a green concept framework for designing and installing services for commercial buildings.

For this study, the following pertinent questions are necessary. The major research question in this study is how possible is it to develop a framework for the integration of Industry 4.0-related green concepts into service components of commercial buildings? The major research question here is, what is the level of satisfaction of users of building services that is available in commercial buildings? What factors influence the adoption of green building systems in the Nigerian building construction sector? What challenges are involved in applying green building systems to service components of commercial buildings at selected research locations? What are the prevailing methods and processes for designing and installing building services? How can a framework be developed incorporating green and sustainable concepts when designing and installing service components in commercial buildings?

This research aimed to carry out an overview of commercial building services for incorporating green concepts to enhance service integration in buildings; to ascertain the level of satisfaction of users of building services available at the selected locations of the study; to identify factors that influence the adoption and implementation of Industry 4.0-related green building systems in the construction industry; to investigate challenges involved in the implementation of Industry 4.0-related green building systems in commercial buildings; to investigate the prevailing method and processes involved in the design and installation of buildings services; and to develop a framework that can be used in incorporating green concepts in the integration of services components into commercial buildings.

1.1. Literature Review

Green Concepts

According to [8], green buildings are a concept developed to reduce the environmental and social effects of the developed environment by supplying building residents with a more excellent quality of life. Various studies on green buildings have used different terminologies to denote the concept of a green building. A green building involves practices that reduce the environmental impact of components of the built environment, including green building, green design, sustainable infrastructure and low-impact development [9]. The green construction concept is a holistic method in line with [10], which is designed to restore and preserve peace between nature and buildings and provide for settlements that uphold human dignity and foster economic fairness. It was reported that the green idea could be seen as a road to sustainable growth for the construction sector in the light of [11]'s environmental, socioeconomic, and cultural foundations [3]. The call for sustainable or green building concepts accounts for the need to increase the incidence of the population; this is an immense risk to the scarce resources on earth. This means delivering development programs that fulfil existing needs without jeopardizing the future generations' ability to adapt to their needs [3,12]. As presented in [3,13]. Green building goals include comfortability, cost affordability, aesthetics, environmental friendliness, and weather resistance.

1.2. Factors That Influence the Adoption and Implementation of Green Building Systems in Nigeria Is the Building Construction Industry

Green buildings in most industrialized economies are quickly gaining momentum, and many obstacles to their adoption are progressively being eliminated. However, in most developed economies, the ideas and practices of sustainable construction still need to become mainstream. Despite various stated benefits of a green concept, such as energy efficiency, water efficiency, indoor air quality and sustainable site design in the built environment, the green building concept has faced various factors that inhibit its growth and usage.

1.3. Integration of Green Concepts into Buildings

In a green building system, there are two cardinal areas of control: systemic control and the physical system control. A technical control system is used to achieve optimal performance and systemic consistency, while the other function is to achieve systemic control and stability [14]. However, some aspects of integrating green building concepts in construction include the following: sun radiation energy could be harnessed as a solar system for heating purposes. The daylight effect could be achieved through the power of the sun. Similarly, waste management and control and clean air movement help create a green environment devoid of pollution, and the use of environmentally friendly goods and materials all assist in creating a sustainable environment [15]. Preconditions and credits for types of areas, water efficiency, electricity and climate, products and services, indoor air quality, and geographic particulars are all available through various prescriptive and creative approaches [16]. During the design and development of sustainable buildings, Ref. [17] have defined criteria that must be considered. These include proper alignment of the structure, technical approaches to wastewater and energy conservation of the building [18].

1.4. Challenges in Achieving Green Building Systems in the Nigerian Building Construction Sector

The study by [3] expressed the challenges involved in creating sustainable infrastructure in the construction field, as well as technical and non-technical challenges. Technical factors are project related and have the potential to cripple project efficiency. According to [8–11,14], the challenges can also be viewed from environmental and cultural perspectives. Exposure to appropriate technology has also played a crucial role in creating a

sustainable environment for people. It is also important to note that the lack of political and economic will to prosecute policy in the direction of demonic development has also been a point of consideration in contemporary times.

2. Materials and Methods

2.1. Population of the Study

The study population is a group selected based on inclusion and exclusion criteria related to the studied variables. The inclusion criteria include work experience, academic qualification, professional qualification, participation in green building construction projects, and familiarity with using Industry 4.0 tools on projects [18]. The defined population is a specific group from which inferences are drawn. Information is gathered from this population and later processed and analyzed. The population frame for this study was 150, while the population consists of built environment professionals (builders, architects, civil engineers, electrical engineers, and quantity engineers), surveyors, town planners and estate valuers who are users of commercial buildings in Abuja and are affected by the conditions of building services within these buildings.

2.2. Research Design

A quantitative research design was adopted in this study to provide information concerning integrating green concepts into building services in commercial buildings in Nigeria that will help the research create a framework for better implementation of green concepts in commercial buildings. A random sampling method was used to pick the samples. They were evaluated simultaneously, which usually involves collecting new data to measure the different variables.

2.3. Sampling Procedure

For this study, the simple random technique was adopted as it gives every population member an equal opportunity for selection. It is imperative to determine the sample size since it is impossible to sample the whole population. The sample size is the number of sampled populations to represent the entire population. The Yamane model was adopted to determine the study's sample size from the targeted population. It has a confidence level of 95%. Ref. [18] stated that sampling is a process or technique of choosing a subgroup from a population to participate in a study; it is selecting several individuals for a study. The quantitative research design method was used for this study, while a random sampling technique was used to pick the samples. A population frame of 150 construction professionals was used, while the sample size was 110 respondents:

$$\text{The Yamane model: } ns = N/[1 + N(e^2)] \quad (1)$$

where ns—Sample size, N—Population size, e—Precision level (at 95% confidence level, e = 0.05), N = 150, then:

$$ns = (150)/1 + 150(0.05^2) = 110 \quad (2)$$

Therefore, 110 professionals were randomly selected, and each respondent was given a questionnaire to fill and return.

The questionnaire designed with a Likert Scale 1–5 was used for the survey.

3. Results

3.1. Level of Satisfaction with Building Services in Commercial Buildings in Nigeria

The first research question was about determining the level of satisfaction with the building services in commercial buildings. The portion of the survey carried out is presented in this section. The level of satisfaction of building services in commercial buildings was carried out. The variables were ranked into four groups of professionals who responded to the questionnaires. There were 42 builders, 30 architects, and 14 mechanical and electrical engineers, who are services engineers. Twenty other professionals, who

included quantity surveyors, estate surveyors, civil engineers, and town planners, ranked their level of satisfaction with building services in commercial buildings by professionals as seen below.

According to [19–26], indoor air quality and architectural aesthetics are regarded as significant determinants of satisfaction of building users; therefore, in this study, builders ranked quality indoor air-conditioning as 1st with a mean score of 3.45. The aesthetic effect of installed services on building façade and frequency and ease of maintenance of building services components were ranked 2nd with a mean score of 3.40. Ease of usage of building services components and equipment was ranked 3rd with a mean score of 3.20. High-quality building services components was ranked 4th with a mean score of 3.10.

Human–machine compatibility was ranked 5th with a mean score of 3.00. Builders ranked functional building services equipment 6th with a mean score of 2.95. Low cost of installation and maintenance of building services was ranked 7th with a mean score of 2.85. Lastly, adequate safety precautions and operation was ranked 8th with a mean score of 2.60. Architects ranked the aesthetic effect of installed services on the building façade as 1st with a mean score of 4.00. They ranked the ease of usage of building services components and equipment as 2nd with a mean score of 3.80. Quality indoor air-conditioning and functional building services equipment were ranked 3rd with a mean score of 3.75. High-quality building services components, adequate safety precautions and operations, and human–machine compatibility were ranked 5th, with a mean score of 3.60. Frequency and ease of maintenance of building services components was ranked 6th with a mean score of 3.45, and low installation and maintenance costs of building services was ranked 7th with a mean score of 3.25. Further test statistics were carried out to validate the survey results' veracity.

Table 1 depicts the Mann–Whitney U test for the satisfaction level of building services' performance between builders and architects who responded to the questionnaires. It is seen that the exact significance of the two professionals is greater than the *p*-value, which is 0.05, i.e., $p > 0.05$. Therefore, the null hypothesis will be accepted, which shows no significant difference in the level of satisfaction with the performance of building services in commercial buildings as seen by builders and architects. It can be deduced that the satisfaction parameters for the majority of users of commercial buildings are similar. Therefore, any commercial building should prioritize quality indoor air conditioning [19–22].

Table 1. Statistical Analysis of Component Parameters.

Parameters	Architects	Builders
Mann–Whitney U	1.000	0.000
Wilcoxon W	4.000	3.000
Z	0.000	1.414
Asym. Sig (2-tailed)	1.000	0.157
Exact Sig [2 × (1-tailed sig)]	1.000 [b]	0.667 [b]

Note. [b]—Excluded.

3.2. Factors Influencing the Adoption and Implementation of Industry 4.0 [I4.0] Related Green Building Systems in the Nigerian Building Construction Industry

Green buildings improve the health, well-being, and quality of life of occupants and the surrounding community. The community also benefits from reduced pressures on local infrastructure and service delivery systems. One of the most often cited benefits of Industry 4.0 green buildings is the reduction in energy costs that stem from energy efficiency measures, which also help reduce greenhouse gases. Green buildings have benefited owners, occupants, the larger environment, and developers [27–30].

Some of the benefits of sustainable construction, as presented in [23,24,31,32], include a reduction in environmental emissions, conservation of planetary water bodies, collection of stormwater and usage, temperature regulation, and waste elimination and reduction, among other things. Therefore, Table 2 ranked factors influencing green building adoption

and implementation. Builders ranked a lack of adequate personnel training 1st with a mean score of 4.80. The need for more relevant technology was ranked 2nd with a mean score of 4.40. Government policies ranked 3rd with a mean score of 4.25. Technology transfer issue was ranked 4th with a mean score of 4.05. Poor installation technique and poor work supervision were ranked 5th with a mean score of 3.85. Lack of competent building services experts was ranked 7th with a mean score of 3.80. The scarcity of quality materials was ranked 8th, with a mean score of 3.65 [25,26,33–35].

Table 2. Factors that influence the adoption and implementation of green buildings.

Factors	Builders			Architects			M and E Engineers		
	RSI	Mean	Rank	RSI	Mean	Rank	RSI	Mean	Rank
Lack of relevant technology about I4.0 tools	0.9	4.4	2	0.88	4.4	1	0.86	4.3	3
Lack of competent building services experts in I4.0 tool applications	0.8	3.8	7	0.82	4.1	2	0.8	4	5
Poor installation technology	0.8	3.85	5	0.75	3.75	6	0.86	4.3	3
Poor work supervision	0.8	3.85	5	0.68	3.4	8	0.94	4.7	1
Scarcity of quality materials	0.7	3.65	8	0.77	3.85	4	0.63	3.15	8
High cost of the I4.0 service tools	0.8	3.65	5	0.68	3.4	8	0.94	4.7	1

Architects ranked the lack of relevant technology 1st, with a mean score of 4.40. The lack of competent building services experts was ranked 2nd with a mean score of 4.10. Lack of adequate personnel training was ranked 3rd with a mean score of 4.05. The scarcity of quality materials was ranked 4th with a mean score of 3.85. Government policies was ranked 5th with a mean score of 3.80. Poor installation technique and technology transfer issues were ranked 6th with a mean score of 3.75. Poor work supervision was ranked 5th with a mean score of 3.40. Mechanical and electrical engineers who are service engineers ranked poor work supervision 1st with a mean score of 4.70. Lack of adequate personnel training was ranked 2nd with a mean score of 4.45. Lack of relevant technology and poor installation technique were ranked 3rd with a mean score of 4.30. Lack of competent building services experts and government policies were ranked 5th with a mean score of 4.00. Technology transfer issue was ranked 7th with a mean score of 3.85. The scarcity of quality materials was ranked 8th, with a mean score of 3.15. Other professionals, including quantity surveyors, estate surveyors, civil engineers, and town planners, ranked a lack of relevant technology 1st with a mean score of 4.30. Lack of adequate personnel training was ranked 2nd with a mean score of 4.10. Government policies was ranked 3rd with a mean score of 3.90. Technology transfer issue was ranked 4th with a mean score of 3.50. Poor installation technique was ranked 5th with a mean score of 3.40. Poor work supervision was ranked 6th with a mean score of 3.20. Lack of competent building services experts and scarcity of quality materials were ranked 7th with a mean score of 2.80. This is supported by [35–37].

Hypothesis Test 2

H0. *There is no significant difference in the factors influencing the adoption and implementation of green building systems in the Nigerian construction industry.*

H1. *There is a significant difference in the factors influencing the adoption and implementation of green building systems in the Nigerian construction industry.*

In Tables 3 and 4 below, the analysis results are presented. The Mann–Whitney U test was conducted to determine the factors influencing the adoption and implementation of green building systems in Nigeria between builders and architects. The null hypothesis H0 is accepted where $p > 0.05$. It is derived that the opinions of builders and architects about factors affecting green building systems in Nigeria's manufacturing sector show no meaningful difference [35–37].

Table 3. Mann–Whitney U test for the factors influencing the adoption and implementation of green building systems.

	Builder	N	Mean Rank	Sum of Ranks
Architects	1	1	2	2
	2	1	1	1
	Total	2		
Builders	1	1	1	1
	2	1	2	2
	Total	2		
Architects	1	1	2	2
	2	1	1	1
	Total	2		

Table 4. Mann–Whitney U Results.

	Architects	Builders
Mann–Whitney U	0.000	0.000
Wilcoxon W	1.000	1.000
Z	−1.000	1.000
Asym. Sig (2-tailed)	0.317	0.317
Exact. Sig. 2 (1-tailed sig)	1.000 [b]	1.000 [b]

Note. [b]-Exclusive.

3.3. Challenges in Implementing Green Building Systems in the Nigerian Building Construction Industry

Table 5 investigates the challenges involved in the implementation of green buildings. Respondents ranked inadequate knowledge and research on green building systems 1st, with a mean score of 4.25. Low awareness of the concept of sustainability and green building systems among construction professionals ranked 2nd with a mean score of 4.15. The lack of adequate access to financial empowerment was ranked 3rd with a mean score of 4.09. Government policy and the absence of training and retraining programs for building services personnel were ranked 4th with a mean score of 4.06. The absence of a green building systems implementation policy was ranked 6th, with a mean score of 3.96. Inadequate technical expertise of construction processes and inadequate finance to carry out green building systems projects were ranked 7th with a mean score of 3.87. In contrast, the lack of raw building materials for service components manufacturing was ranked 9th, with a mean score of 3.30.

Table 5. Challenges involved in the implementation of green buildings.

Challenges Involved in the Implementation of Green Buildings	RII	Mean	Rank
Need more technical expertise in construction processes.	0.77	3.87	7
Construction professionals need to be more aware of sustainability and green building systems.	0.83	4.15	2
Need for more adequate knowledge and research on green building systems.	0.84	4.25	1
Need more finance to carry out green building systems projects.	0.77	3.87	7
Government policy	0.81	4.06	4
absence of green building systems implementation policy	0.79	3.96	6
Lack of adequate access to financial empowerment	0.84	4.09	3
Lack of raw building materials for service components	0.65	3.3	9
Absence of training and program for building services personnel	0.82	4.06	4

3.4. Methods and Processes Involved in the Design and Installation of Buildings Services in Industry 4.0 [I4.0] Era

Building systems are the critical systems for any facility. A building is not made only to provide shelter; it should also have the right ambience and conditions for people who live and work within the building. Building services are an aspect of a building that ensures occupants are comfortable and secure within a building space. These systems include electrical, heating, ventilation and air conditioning (HVAC), water drainage and plumbing, building façade, security and alarm systems, lighting, lifts and escalators, telecommunication and IT networks, fire detection and protection and energy management.

These building systems depend on themselves at all times to operate. When these services are implemented for building property, they create the right and productive environment for occupants to live, work and thrive in. According to [30,31], every building must provide these facilities for users. Table 6 presents methods and processes involved in designing and installing building services. The building services project design and drafting that must be carried out by engineers/professionals was ranked highest. Supervision of installed components was ranked 2nd with a mean score of 4.32, while consultancy and procurement process was ranked 3rd with a mean score of 4.23. This pattern was supported in works like [23,24,26,31,32]. Similarly, the testing of the effectiveness of building services components was ranked 4th with a mean score of 4.21. Load estimation and calculation was ranked 5th with a mean score of 4.17. Performance calibration was ranked 6th, with a mean score of 4.09. Post-occupancy assessment of building component performance was ranked 7th with a mean score of 4.02. Installation accessories systems were ranked 8th with a mean score of 3.95. Commissioning/maintenance was ranked 9th with a mean score of 3.90 [23–26].

Table 6. Method and process involved in designing and installing building services in Industry 4.0 [I4.0] era.

Method	RII	Mean	Rank
Consultancy/procurement process	0.83	4.23	3
Building services project designing	0.87	4.4	1
Load estimation and calculation	0.82	4.17	5
Performance calibration	0.8	4.09	6
Installation accessories systems	0.79	3.95	8
Supervision of installed components	0.85	4.32	2
Components effectiveness test	0.83	4.21	4
Commissioning/maintenance	0.78	3.9	9
Post occupancy assessment of building component performance	0.81	4.02	7

3.5. Issues Involved in Incorporating Industry 4.0 Related Green Concept to Building Services in Commercial Buildings

Incorporating green concepts in building services can be exciting; however, some factors influence this feat Refs. [19,20]. listed the interplay of microeconomic variables as one factor. [27] mentioned the effect of macroeconomic variables and high cost of green components among others as some of the vital factors that impact the effectiveness of incorporating activities. Therefore, issues involved in the effective incorporation of the green concept in the building services provided are presented in Table 4.

Table 7 identifies issues involved in incorporating green concepts into building services in commercial buildings. Respondents rated the answers on a Likert scale where 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Strongly Disagree, 1 = Disagree. Respondents ranked corruption and kickbacks 1st, with a mean score of 4.15. Cost efficiency of the service component and inadequate allocation of essential resources for research and development were ranked 2nd with a mean score of 3.95. The effect of macroeconomic variables (inflation, deflation, price levels, economic growth) supports the submissions in [19,20,27].

Table 7. Issues Incorporating Green Concepts into Building Services in Commercial Buildings.

Issues	RII	Mean	Rank
Impact of microeconomic variable (demand and supply)	0.75	3.75	7
Effect of macroeconomic variable (inflation, deflation, price levels, economic growth)	0.78	3.9	4
Cost efficiency of the service component	0.79	3.95	2
High cost of replacing defective component	0.78	3.9	4
Increased productivity and profitability	0.68	3.4	18
Improved project delivery time	0.68	3.4	18
Lack of effect of international bilateral agreement among nations	0.71	3.55	13
Lack of capacity to enforce some economic laws	0.72	3.6	12
Unstable government policy	0.78	3.9	4
Regional and ethnic consideration	0.69	3.45	15
Coordination and integration	0.71	3.55	13
Cultural and belief restrictions	0.68	3.4	18
Inadequate allocation of essential resources for research and development	0.79	3.95	2
Corruption and kickbacks	0.83	4.15	1
Non-readiness to learn new skills	0.69	3.45	15
Non-readiness to accept new technology	0.68	3.4	18
Lack of relevant technology	0.75	3.75	7
Poor and ineffective installation technique	0.75	3.75	7
Lack of trained professionals	0.74	3.7	10
Technology transfer issues	0.74	3.7	10
Scarcity of materials (lack of local materials and high importation cost)	0.69	3.45	15

Similarly, the high cost of replacing defective components in buildings and unstable government policy is a significant issue, as posited in [28,29]. Therefore, in this study, the high cost of replacing defective components and unstable government policy was ranked 4th with a mean score of 3.90. The impact of microeconomic variables (demand and supply), lack of relevant technology and poor and ineffective installation techniques were ranked 7th with a mean score of 3.75. Lack of trained professionals and technology transfer issues were ranked 10th with a mean score of 3.70. Lack of capacity to enforce some economic laws was ranked 12th with a mean score of 3.60. Lack of effect of international bilateral agreement among nations and coordination and integration were ranked 13th with a mean score of 3.55. Regional and ethnic considerations, non-readiness of professionals to learn new skills, and scarcity of materials (lack of local materials and high importation cost) were all ranked 15th, with mean scores of 3.45 for each. Increased productivity and profitability, improved project delivery time, cultural and belief restrictions and non-readiness to accept new technology were ranked 18th with mean scores of 3.40 each. From the above, the most significant issues identified are inadequate allocation of essential resources for research

and development and kickback and corruption, and this corroborates the presentations in [28,29].

3.6. Effectiveness of Some Industry 4.0 Related Green Components of Building Services in Commercial Buildings in Nigeria

Table 8 shows a comparative analysis of the effectiveness of someIndustry4.0 related green components of buildings services in commercial buildings in Nigeria.

Table 8. Comparative Analysis of the Effectiveness of Some Industry4.0 related Green Components of Building Services in Commercial Buildings in Nigeria.

Variables	Builders			Architects			Mechanical and Electrical Engineers			Others (Civil Engineers, Q.S., E.S.)		
	RE I	Mean	Rank	REI	Mean	Rank	REI	Mean	Rank	REI
Energy-efficient/saving sensored bulbs	0.8	4.3	1	0.84	4.2	3	0.89	4.45	5	0.94
Remote-controlled sensored lights	0.8	4.05	3	0.8	4	6	0.91	4.55	2	0.82
Natural daylight	0.8	4.25	2	0.87	4.35	1	0.91	4.55	2	0.9
Electrochromic glass	0.6	3.25	15	0.71	3.55	15	0.6	3	13	0.7
Bio-sensored walls (bio-filtration and photo-remediation)	0.6	3.3	14	0.73	3.65	11	0.3	1.5	15	0.72
Green/living roofs	0.7	3.7	6	0.77	3.85	8	0.69	3.45	10	0.74
Low emittance window	0.7	3.7	6	0.73	3.65	11	0.63	3.15	12	0.7
Ultra low-flow fixtures	0.7	3.55	11	0.72	3.6	13	0.57	2.85	14	0.82
Rainwater recovery systems	0.7	3.7	6	0.72	3.6	13	0.74	3.7	8	0.8
Automatic sensor based CCTV cameras	0.7	3.7	6	0.72	3.6	13	0.74	3.7	8	0.8
Retrofitting of old plumbing	0.6	3.45	13	0.77	3.85	8	0.69	3.45	10	0.74
Internet of Things innovative technologies	0.7	3.55	11	0.77	3.85	8	0.82	4.1	7	0.74

Builders ranked energy efficient/saving bulbs, e.g., CFLs, 1st with a mean score of 4.30. Natural daylight was ranked 2nd with a mean score of 4.25. Remote controlled sensored lights and solar photovoltaic panels were ranked 3rd with a mean score of 4.05. Rain garden with native plants ranked 5th with a mean score of 3.80. Wind panels, green/living roofs, low emittance windows and rainwater recovery systems were all ranked 6th with mean scores of 3.70. Building management system ranked 10th with a mean score of 3.65. Ultra low-flow fixtures and innovative water technologies were ranked 11th with mean scores of 3.55. Biowalls (bio-filtration and photo-remediation) was ranked 14th with a mean score of 3.30. Electrochromic glass was ranked 15th with a mean score of 3.25, as in [6] Anzagira, Duah, and Badu (2019).

Architects ranked natural daylight and solar photovoltaic panels 1st with a mean score of 4.35. Energy efficient/saving bulbs, e.g., CFLs, and building management systems, were ranked 3rd with a mean score of 4.20. Wind panels ranked 5th with a mean score of 4.05. Remote controlled sensored lights was ranked 6th with a mean score of 4.00. Similarly, rain garden with native plants was ranked 7th with a mean score of 3.90, while green/living roofs, retrofitting of old plumbing, and innovative water technologies were ranked 8th with mean scores of 3.85. This supports similar work presented by [7–10]. Biowalls (bio-filtration and photo-remediation) and low emittance windows were ranked 11th with mean scores of 3.65. Ultra-low to learn new skills and scarcity of materials (lack of local materials and high importation cost) were both ranked 15th with mean scores of 3.45 each. Increased productivity and profitability, improved project delivery time, cultural and belief restrictions and non-readiness to accept new technology were ranked 18th with mean scores of 3.40 each. The presentation above, therefore, lends credence to similar work carried out by [7–10].

3.7. Analysis of the Effectiveness of Some Industry 4.0 Related Green Components of Building Services in Office Buildings

Table 9 shows analysis of the effectiveness of some green components of building services in Office buildings in the research location. Respondents rated the answers with a Likert scale: 5 = Very Effective, 4 = Effective, 3 = Neutral, 2 = Very Ineffective, and 1 = Ineffective.

Table 9. Analysis of the Effectiveness of Some Green Components of Building Services in Office Buildings.

Variables	Builders			Architects			Mechanical and Electrical Engineers			Others (Civil Engineers, Q.S., E.S.)		
	REI	Mean	Rank	REI	Mean	Rank	REI	Mean	Rank	REI		
Energy efficient/saving bulbs	0.8	4.3	1	0.84	4.2	3	0.89	4.45	5	0.94		
Remote controlled sensored lights	0.8	4.05	3	0.8	4	6	0.91	4.55	2	0.82		
Natural daylight	0.8	4.25	2	0.87	4.35	1	0.91	4.55	2	0.9		
Electrochromic glass	0.6	3.25	15	0.71	3.55	15	0.6	3	13	0.7		
Biowalls (bio-filtration and photo-remediation)	0.66	3.3	14	0.73	3.65	11	0.3	1.5	15	0.72		
Green/living roofs	0.7	3.7	6	0.77	3.85	8	0.69	3.45	10	0.74		
Low emittance window	0.7	3.7	6s	0.73	3.65	11	0.63	3.15	12	0.7		
Ultra low-flow fixtures	0.7	3.55	11	0.72	3.6	13	0.57	2.85	14	0.82		
Rainwater recovery systems	0.7	3.7	6	0.72	3.6	13	0.74	3.7	8	0.8		
Retrofitting of old plumbing	0.6	3.45	13	0.77	3.85	8	0.69	3.45	10	0.74		
Innovative water technologies	0.7	3.55	11	0.77	3.85	8	0.82	4.1	7	0.74		

Builders ranked energy efficient/saving bulbs, e.g., CFLs, 1st with a mean score of 4.30. Natural daylight was ranked 2nd with a mean score of 4.25. Remote controlled sensored lights and solar photovoltaic panels were ranked 3rd with mean scores of 4.05. Rain garden with native plants ranked 5th with a mean score of 3.80. Wind panels, green/living roofs, low emittance windows and rainwater recovery systems were all ranked 6th with mean scores of 3.70. Building management system ranked 10th with a mean score of 3.65. Ultra low-flow fixtures and innovative water technologies were ranked 11th with a mean score of 3.55. Retrofitting of old plumbing was ranked 13th, with a mean score of 3.45. Biowalls (bio-filtration and photo-remediation) was ranked 14th with a mean score of 3.30. Electrochromic glass was ranked 15th with a mean score of 3.25.

Architects ranked natural daylight and solar photovoltaic panels 1st with a mean score of 4.35. Energy efficient/saving bulbs, e.g., CFLs, and building management systems were ranked 3rd with a mean score of 4.20. Wind panels ranked 5th with a mean score of 4.05. Remote controlled sensored lights was ranked 6th with a mean score of 4.00. Rain garden with native plants was ranked 7th with a mean score of 3.90. Green/living roofs, retrofitting of old plumbing, and innovative water technologies were ranked 8th with mean scores of 3.85. Biowalls (bio-filtration and photo-remediation) and low emittance windows were ranked 11th with a mean score of 3.65. Ultra low-flow fixtures and rainwater recovery systems were ranked 13th with a mean score of 3.60. Electrochromic glass was ranked 15th with a mean score of 3.55.

Mechanical and electrical engineers and service engineers ranked building management system 1st with a mean score of 4.7. Remote controlled sensored lights, natural daylight, and solar photovoltaic panels were ranked 2nd with a mean score of 4.55. Energy efficient/saving bulbs, e.g., CFLs, was ranked 5th with a mean score of 4.45. Wind panels were ranked 6th with a mean score of 4.30. Innovative water technologies was ranked 7th with a mean score of 4.10. Rainwater recovery systems was ranked 8th with a mean score of 3.70. Rain garden with native plants was ranked 9th with a mean score of 3.55. Green/living roofs and retrofitting of old plumbing were ranked 10th with a mean score of 3.45. Low emittance window was ranked 12th with a mean score of 3.15. Electrochromic

glass was ranked 13th, with a mean score of 3.00. Ultra low-flow fixtures was ranked 14th with a mean score of 2.85. Biowalls (bio-filtration and photo-remediation) was ranked 15th with a mean score of 1.50.

Other professionals, including quantity surveyors, estate surveyors, civil engineers, and a town planner, ranked energy efficient/saving bulbs, e.g., CFLs, 1st with a mean score of 4.70. Natural daylight was ranked 2nd with a mean score of 4.50. Solar photovoltaic panels was ranked 3rd with a mean score of 4.30. Remote controlled sensored lights and ultra low-flow fixtures were ranked 4th with mean scores of 4.10. Rainwater recovery systems and building management systems were ranked 6th with a mean score of 4.00. green/living roofs, retrofitting of old plumbing, innovative water technologies and rain garden with native plants were ranked 8th with mean scores of 3.70. Biowalls (bio-filtration and photo-remediation) and wind panels were ranked 12th with mean scores of 3.60. Electrochromic glass and low emittance windows were ranked 14th with mean scores of 3.50. This toes the line of submission in Refs. [6–10], 2.12 Issues and Challenges on Adopting and Implementing Green Building, and Industry 4.0 Related Concepts Building Services. Despite various stated benefits of a green concept, such as energy efficiency, water efficiency, indoor air quality and sustainable site design in the built environment, the green building concept has faced various factors that inhibit its growth and usage. Ref. [16] identified the multiple factors hindering the use of green architecture, including capacity barriers, the high initial cost of construction, and a lack of proper awareness and enlightenment.

Issues and Challenges in Adopting and Implementing Green Buildings was presented in Table 10. It was observed that, Ref. [15] believes that the need for green architecture expertise to initiate its concepts and principles from the early stages of building design and planning hinders the utilization of green architecture. This is an important factor identified by Refs. [14,17], which impedes the development of green architecture by the slow recovery of long-term costs. In addition, Ref. [17] identified the various factors that hinder the use of green architecture, including low priority for the sustainability agenda in the education system, lack of urgency surrounding the practice of sustainability, lack of enforcement by the relevant authorities, and lack of government intervention through policies and incentives. Other factors include financial constraints and scarcity.

Table 10. Issues and Challenges in Adopting and Implementing Green Buildings.

S.N.	Variables	RII	Mean
1	Inadequate technical expertise in construction processes	0.77	3.87
2	Low level of awareness of the concept of sustainability and green building systems.	0.83	4.15
3	Inadequate knowledge and research on green building	0.84	4.25
4	Inadequate finance to develop green building projects	0.77	3.87
5	Government policy	0.81	4.06
6	Absence of green building systems implementation policy	0.79	3.96
7	Lack of adequate access to financial empowerment	0.84	4.09
8	Lack of raw building materials for component manufacturing	0.65	3.3
9	Absence of training and retraining program	0.82	4.06
10	Impact of microeconomic variable (demand and supply)	0.75	3.75
11	Effect of macroeconomic variable	0.78	3.9
12	Cost efficiency of the service component	0.79	3.95
13	High cost of replacing defective component	0.78	3.9
14	Increased productivity and profitability	0.68	3.4
15	Improved project delivery time	0.68	3.4
16	Lack of international bilateral agreement among nations	0.71	3.55
17	Lack of capacity to enforce some economic laws	0.72	3.6
18	Unstable government policy	0.78	3.9
19	Regional and ethnic consideration	0.69	3.45
20	Coordination and integration	0.71	3.55

Table 10. *Cont.*

S.N.	Variables	RII	Mean
21	Cultural and belief restrictions	0.68	3.4
22	Inadequate allocation of resources for research and development	0.79	3.95
23	Corruption and kickbacks	0.83	4.15
24	Non-readiness of professionals to learn new skills	0.69	3.45
25	Non-readiness to accept new technology	0.68	3.4
26	Lack of relevant technology	0.75	3.75
27	Poor and ineffective installation technique	0.75	3.75
28	Lack of trained professionals	0.74	3.7
29	Technology transfer issues	0.74	3.7
30	Scarcity of materials (lack of local materials and high importation cost)	0.69	3.45

3.7.1. Factor Reduction Method Based on Eigenvalue for Framework Development

The extracted factors F1 to F6 are presented in Table 11 below. The factors contain six groupings, and each component factor is detailed based on the regulated eigenvalue between 0.9 and 1.0. The factors are arranged in the order of strength, with F1 being the strongest, followed by F2, F3, F4, F5, and F6. The factors can be interchangeably combined to interpret which to use to help integrate green concepts in building services.

Table 11. Extracted factors for framework development.

S/N		Eigen Value	Extracted	Factor
1	Training and retraining	1	0.99	F1
2	Cost efficiency of the service component	1	0.99	F1
3	International bilateral agreement	1	0.99	F1
4	Cultural and belief restrictions	1	0.99	F1
5	Availability of raw building materials	1	0.99	F2
6	Adequate allocation of basic resources	1	0.99	F2
7	More stable government policy	1	0.99	F3
8	Regional and ethnic consideration	1	0.99	F3
9	Adequate technical expertise	1	0.96	F4
10	High level of awareness of sustainability	1	0.96	F4
11	Adequate access to financial empowerment	1	0.96	F4
12	More effective(cheaper, faster) installation techniques	1	0.96	F4
13	Effect of macroeconomic variable	1	0.95	F5
14	Low cost of replacing defective component	1	0.95	F5
15	Total eradication of corruption/kickbacks	1	0.95	F5
16	Availability of local materials	1	0.95	F5
17	Adequate knowledge of green building.	1	0.94	F6
18	Availability of relevant technology	1	0.94	F6

3.7.2. Extracted Factors Matrix

$$F1 = F2F1 + F3F1 + F4F1 + F5F1 + F6F1\ F2 = F2F1 + F3F2 + F4F2 + F5F2 + F6F2$$

$$F3 = F3F1 + F3F2 + F4F3 + F5F3 + F6F3$$

$$F4 = F4F1 + F4F2 + F4F3 + F5F4 + F6F4$$

$$F5 = F5F1 + F5F2 + F5F3 + F5F4 + F6F5$$

$$F6 = F6F1 + F6F2 + F6F3 + F6F4 + F6F5$$

Figure 1 Extracted Factors.

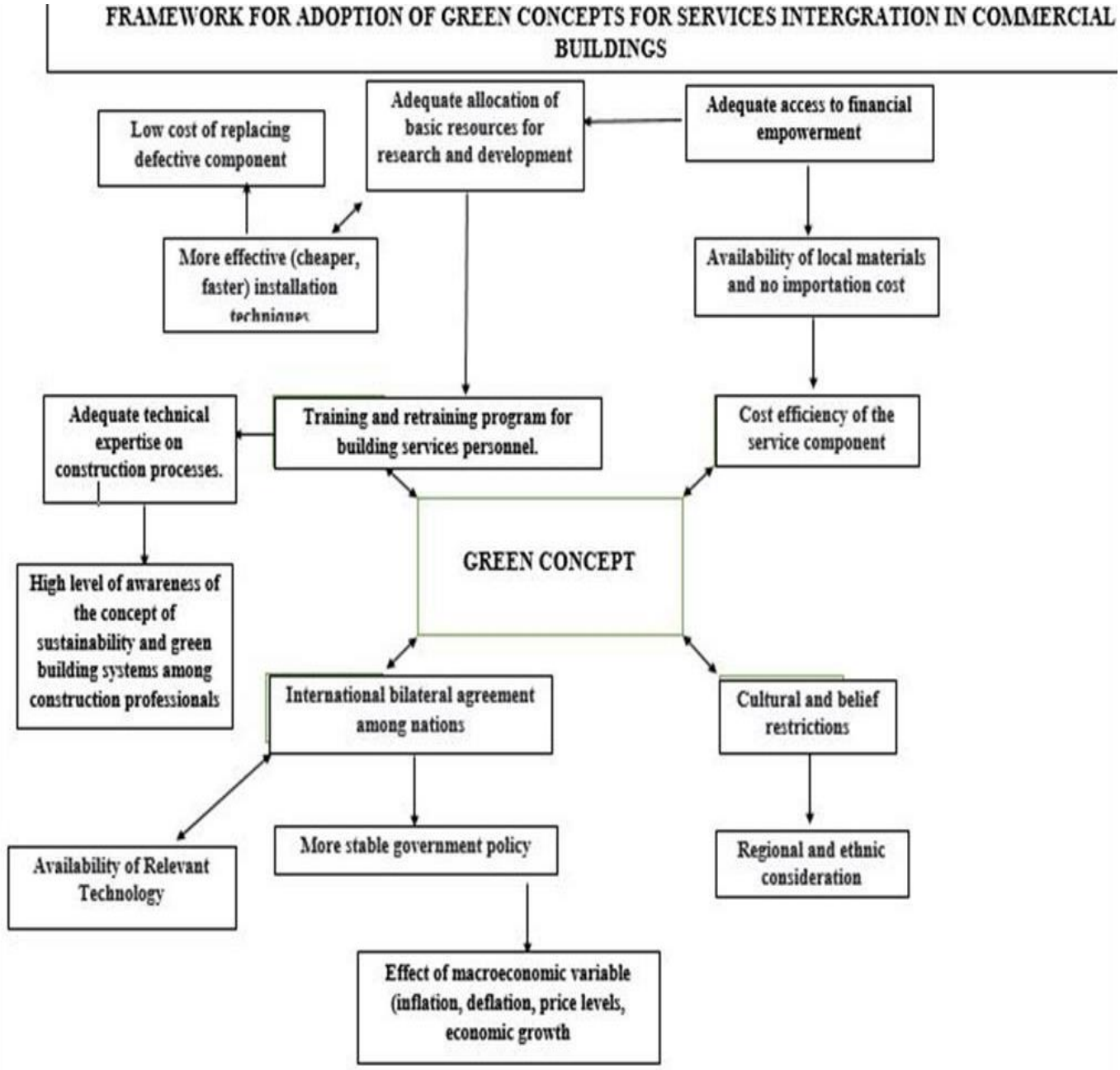


Figure 1. Framework for the integration of green concept into building services.

When the following cases apply as presented below:

$$F1 = 0.999F2F1 + 0.999F3F1 + 0.999F4F1 + 0.999F5F1 + 0.999F6F1$$

$$F2 = 0.998F2F1 + 0.998F3F2 + 0.998F4F2 + 0.998F5F2 + 0.998F6F2$$

$$F3 = 0997F3F1 + 0.997F3F2 + 0.997F4F3 + 0.997F5F3 + 0.997F6F3$$

$$F4 = 0.996F4F1 + 0.996F4F2 + 0.996F4F3 + 0.996F5F4 + 0.996F6F4$$

$$F5 = 0.995F5F1 + 0.995F5F2 + 0.995F5F3 + 0.995F5F4 + 0.995F6F5$$

$$F6 = 0.994F6F1 + 0.994F6F2 + 0.994F6F3 + 0.994F6F4 + 0.994F6F5$$

Framework for the integration of green concepts into building services in Commercial Buildings.

4. Conclusions

Building services are integrated into a building with the sole aim of providing comfort to users. The satisfaction and well-being of users in buildings are becoming essential in the Building Construction Industry. Ref. [13] mention user satisfaction as one of the best means to evaluate the outcome of any facility. According to the study, quality indoor air conditioning is paramount for building services output in commercial buildings. Other aspects of building services considered vital include the aesthetic effect of installed services on the building façade, high-quality building services components, ease of usage of building services components and equipment, and functional building services equipment.

Similarly, the most significant factors affecting the implementation of green buildings in Nigeria are a need for more relevant technology, inadequate personnel training, and government policies. Ref. [14] identified the various factors that hinder the use of green architecture, including low priority for a sustainability agenda in the education system, lack of urgency surrounding the practice of sustainability, lack of enforcement by the relevant authorities, and lack of government intervention through policies and incentive. Also, a lack of competent building services experts, technology transfer issues and poor installation techniques are significant factors that influence the adoption of green building systems in Nigeria [20].

Moreover, inadequate knowledge and research on green building systems was also a high challenge to implementing green building systems in Nigeria. This lack of research and development of green buildings and construction pushes building demand beyond regulation. These renewable technologies and systems are also non-prevalent, adding to the high price tags associated with their installation and execution [11]. Low levels of awareness of the concept of sustainability and green building systems among construction professionals was also identified as a problem; this agrees with [12], who attributed the low level of sustainability of construction projects delivered within the NCI to the low level of awareness of the concept of sustainability among construction participants. The lack of adequate access to financial empowerment, government policy and the absence of training and retraining programs for building services personnel was seen as a formidable force challenge that affects the implementation of green building systems in Nigeria. Similarly, the absence of a green building systems' implementation policy, inadequate technical expertise in construction processes, inadequate finance to carry out green building systems projects, and lack of raw building materials for service components manufacturing need to be considered.

Building services project design and drafting by building services engineers/professionals was ranked most significant in the methods and processes involved in designing and installing building services. However, the absence of green infrastructure during design and planning, according to [15,17], tends to hamper the usage and application of green architecture. In achieving green building initiatives such as being advocated all over the world, there is a need for green architecture expertise to initiate its concepts and principles from the early stages of building design and planning, which hinders the utilization of green architecture, for instance, Ref. [23] mentioned two significant ways to achieve green buildings. First is the design stage, where the properties and functions of the building are studied, and the materials to be used are decided upon. The choice of materials and provision of services are performed with the best sustainable choice as the goal. Secondly, a building is initially designed for something other than sustainability. The need to make it sustainable arises over time. Retrofitting such buildings with state-of-the-art green technology makes it possible to include green features. The early stage of the design process provides an ideal opportunity to establish design goals and objectives to optimize a design output. The design team of consultants can convey their ideas to set performance standards, whilst the integrated approach toward design enables them to incorporate and discuss a range of design solutions before implementation [19].

Supervising installed components and consultancy and procurement processes also ranked high in terms of methods and processes involved in the design and installation

of building services. Testing the effectiveness of building services components and load estimation and calculation were ranked as the most predominant methods and processes involved in the design and installation of building services. Performance calibration, post-occupancy assessment of building component performance, installation accessories systems and commissioning/maintenance were ranked the lowest.

Cost efficiency of the service components and inadequate allocation of essential resources for research and development were found to be essential in achieving green buildings. It was discovered that the interplay of economic variables has a high impact on a successful operation. The effects of macroeconomic variables (inflation, deflation, price levels, and economic growth), the high cost of replacing defective components, and unstable government policies are formidable variables.

So also, in the context of other studies like [15,17], the impact of microeconomic variables (demand and supply), lack of relevant technology, poor and ineffective installation techniques, lack of trained professionals, and technology transfer issues are some issues surrounding green concepts for building services

Building services, project design, and drafting by building services engineers/professionals were ranked as the most significant factors. This is also seen as the most critical stage or process where green concepts can be incorporated into services in commercial buildings. As ranked by professionals, the most effective green components that can be incorporated into services in Nigeria include energy-efficient/saving bulbs, e.g., CFLs, remote-controlled sensored lights, natural daylight, solar photovoltaic panels and building management systems. All of the above lead to the need to develop a framework that will continue to promote incorporating these green components into commercial building services.

5. Recommendations

Based on the facts from the analysis results, recommendations are made, among other things, and presented in this section. There should be more alternative energy supplies, and alternate building materials should be explored to ensure the continued use of commercial buildings. There should be a provision for cost efficiency for owners. More research and development should be conducted on green concepts to create relevant technology and ensure these green components are cost-effective. Also, there should be more innovative ways to conduct training for personnel—innovation and creativity to have the required and relevant technology to carry out green buildings. The government must create policies and incentives that will continue to encourage people to take hold of green building concepts. Professional training and retraining on green building concepts should be emphasized; therefore, professionals must create awareness through various professional bodies. Green Building Concepts should be part of the education curriculum for tertiary institutions. Finally, professionals must ensure that issues of green building concepts are included in project specifications from the design and planning stage. Finally, professionals must have synergy and cooperation to achieve this sustainability goal.

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