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# A Survey of Environmental Performance Enhancement Strategies and Building Data Capturing Techniques in the Nigerian Context

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**Abstract:** The need to improve the performance of Nigeria's office buildings is due to, energy challenges, increasing population, changing user needs, and climate change. With the expansion of several Nigerian cities, existing buildings constitute a significant portion of the building stock, and improving their environmental performance could be more cost-effective than reconstruction. The use of simulation packages to assess alternative retrofitting enhancement scenarios is a straightforward approach. However, in Nigeria it is often challenging to get appropriate information to facilitate this type of evaluation; many buildings were not built to their original specifications, and when available, the records are often in a poor state due to deterioration. Studies that aimed at enhancing a building's performance hardly stated the acquisition of the required building information. This paper investigates current practices and future possibilities of improvement measures and data capturing of existing buildings using a questionnaire survey of 133 building professionals in Benin City. The inter-relationship between energy efficiency, the environment, and building design with a high potential for meaningful retrofit to mitigate energy inefficiencies is known but not fully utilized. The collected thought on current practices signifies the need for developing a more economical and reliable methodology for data capturing and evaluation.

**Keywords:** building performance improvement; data capturing techniques; energy efficiency; existing buildings; Nigeria



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## 1. Introduction

Nigeria is by far the most populated African country with multifaceted socioeconomic challenges exacerbated by population growth, excessive reliance on small businesses, and the lack of public services. Whereas the construction sector is of key importance to the development of the country with more than 80% of the business sector, comprising mainly small and medium-scale enterprises [1], depending on fuel-powered generators to get electricity. Inadequate electrical power is one of the factors undermining Nigeria's ability to meet the needs of the increasing population especially because the country only generates electricity for about a quarter of its population [2]. Strengthening the business sector requires appropriate facilities and infrastructure to boost productivity, businesses, and in turn the economy. However, businesses are left with a more expensive alternative of using oil-fired backup generators due to power inefficiency in Nigeria [3], significantly impacting the economy and poverty level.

Offices as part of commercial buildings consume a significant amount of energy for occupants' comfort needs and satisfaction translating to cost [4]. As Office workers spend a significant time of their day in the workspace, the working environment should offer the needed comfort to promote workers' health and productivity. Energy and environmental performance compliance frameworks in developed countries (e.g., the LEED rating system) facilitate environmentally responsive design solutions and energy efficiency [4,5]. These compliance frameworks also impact how buildings are designed, built, and used now and in the future. However, in Nigeria, there is widespread adoption of the western methods of buildings as compared to the previous traditional building methods that were originally constructed in response to the local climate [6]. The National Building Code [7], the main document used in Nigeria for all building works including specification, design, and alteration does not address achieving a building's environmental performance leading to criticisms and calls for a review [8,9]. In recognition of the need for buildings' energy efficiency in the country, efforts have been made by the Federal Government including through the Nigerian Energy Support Programme and the Federal Ministry of Power Works and Housing (Housing). Several documents including the Building Energy Efficiency Guidelines (BEEG) and the Building Energy Efficiency Code (BEEC) have been published as part of efforts geared to encourage energy efficiency and manage energy inefficiency in the Nigerian building sector. Despite these efforts, there is no detailed framework for designing energy-efficient buildings amidst the increasing population, urban growth, and increased rate of building development in Nigeria. As a result, the Nigerian building stock has not properly considered climatic adaptations and environmental enhancement strategies in their tropical climate, now exacerbated by the concurrent impact of climate change [10]. With the absence of such an institutional framework for energy-conscious buildings, it is essential to take measures to meet occupants' needs and reduce energy use.

Although population growth requires new building development, a significant proportion of the existing buildings remain in use [11]. Other than for historical reasons where a significant number of existing buildings cannot undergo demolition and reconstruction, improving the environmental performance of the existing building stock could be more cost-effective than reconstruction [11,12]. Traditionally, understanding the condition of buildings was conducted informally. Recently, there is a preference for a systematic approach to compare and validate how the building performs using set-out performance criteria [6,13]. The evaluation of the environmental and thermal performance of buildings requires the use of their technical and geometric characteristics which is also a requirement set aside in the BEEC [14]. In Nigeria, it is often challenging to get the functional details of existing buildings [6,15] for several reasons including insufficient or lack of 2D geometric documentation. Many buildings are not built to the original specifications shown in the drawings due to modifications by contractors or sometimes architects during construction [16]. Building projects designed by architects are often not constructed by the relevant building professionals in a bid to cut costs and therefore, they are not built as designed. The loss of building records due to degradation and poor storage has also led to a compromise in many building details coupled with storage inadequacy, whereas documentation forms the basis for modeling and simulation work [17]. Thus, carrying out efficient evaluation and testing of strategies for building performance enhancement necessitates the capture of the required technical characteristics that will benefit from simulation testing. The BEEC categorically states in its "compliance method 2—performance route to compliance" indicates that building modeling and simulation should be used to determine the building's overall building energy performance. While not much has been done on environmental building performance improvement in the study region, the limited studies carried out illustrate the use of building details for building performance enhancements through modeling and simulation but have either not specified how it was sourced or stated the limitations of getting as-built details. This study investigates current practices of building design professionals in Benin City to help identify the relevant building characteristics to be captured and used for building performance enhancement through modeling and simulation to achieve energy efficiency

## 2. Environmental Performance Enhancement Strategies

In addition to protecting building users from undesirable outdoor environmental conditions, office buildings should provide a healthy, comfortable, and productive indoor environment [18]. Studies by De Wilde [19] and De Wilde [20] also reiterate that an office environment should provide the necessary user comfort that promotes well-being, health, and productivity. New expectations and current challenges require the need to improve the environmental performance of existing office buildings given that around 87% of existing buildings will be standing by the year 2050 [11]. Thus, regular performance evaluation gives an insight into the percentage of effectiveness and efficiency of a building in meeting users' needs and expectations.

Evaluating the performance of existing buildings is crucial to improving their environmental performance. The built environment professionals have done less in committing resources to examine the original function and user satisfaction of buildings with everyday tasks while making the necessary adjustments [21,22]. Building performance evaluation (BPE) is a systematic and rigorous approach that covers several activities including exploration, comparison, and feedback that takes place throughout the building lifecycle [23]. It focuses on building designs and the technical performance of the buildings in response to human needs so that lessons learned can be used to inform future practices (enhancement). The Nigerian Federal Ministry of Power, Works, and Housing recognizes that energy and the performance of buildings are climate-related, and its Building Energy Efficiency Guideline (BEEG) publication [24] confirmed that the highest user requirements for building occupants are for cooling and lighting. It recommends environmentally friendly buildings through the consideration and integration of '*bioclimatic*' initiatives that could eliminate or reduce occupants' needs for cooling and lighting. Energy-efficient and bioclimatic design measures applied to the building through the external envelopes and its components can be advantageous, especially in Nigeria with energy poverty where less than half of the population can access electricity.

### *2.1. Bioclimatic Design*

The Arup and Genre's [24] '*Building Energy Efficiency Guide*' (BEEG) defines bioclimatic design as a design that bases its considerations upon climatic conditions and attempts to achieve physical comfort for occupants using fewer resources, while also accounting for the behavioral and emotional conditions. The bioclimatic approach is fundamental to achieving energy efficiency in buildings achieved through architectural design principles and the control and regulation of heat gains and heat loss from the building [25]. The adoption of bioclimatic design strategies in previous studies has shown a significant success rate, for example, there was a 40% to 60% decrease in energy consumption when applied by Ochedi and Taki [26]. Another study in Nigeria [27] also applied a bioclimatic design approach by using indigenous materials on the building envelope to enhance comfort by reducing the high operative temperature by 8% and a significant reduction in $CO_2$ emissions and construction costs by 32.31%, 35.78%, and 41.81% respectively. The level of adoption of bioclimatic design considerations such as 'site selection and orientation, building form and geometry, envelope design, and use of passive cooling is assessed as part of the questionnaires used in this paper. While understanding the bioclimatic design variables is a vital step in evaluating and enhancing the performance of existing buildings, it helps to identify the necessary building data needed for capturing especially due to the difficulty in getting as-built information in the study area. The captured building information is a key requirement for the evaluation and testing of environmental performance enhancement strategies for existing buildings.

### *2.2. Data Capturing*

While the adoption of bioclimatic design is recommended by both the BEEG and the BEEC. It is also stated in the BEEC [14] that a common method for exploring the effectiveness of building performance, its enhancements, and the integration of bioclimatic design initiatives is using digital building models and simulation. To do this, it is necessary to capture the required design variables (technical and geometrical characteristics) of the building. A range of data-capturing technologies with certain specifications, abilities, and limitations are currently in use for existing buildings to capture the data needed to create as-built replicated simulation models. In addition to the manual site surveying and traditional total station, there are more recent and modernized data-capturing techniques including Photogrammetry, Videogrammetry, Photo-Modelling, Image-Modelling, Laser scanning, GPS, Google Earth, Scanned 2D floor plans, Remote sensing, Barcode, Lidar, Ultrasonic Testing, and Thermal imaging. Given the various data capturing techniques available, this part informed the development of the questionnaire to understand the commonly used type of data capturing techniques in the study region.

## 3. Materials and Methods

The study relied on survey data carried out in Benin City, Edo State of Nigeria, where the prospective future of the city development and the State Government's commitment is to redefine the workplace and make it more conducive for workers. Benin City is regarded as a civil service city by Ekhaese and Adeboye [28] because of the several socio-economic activities carried out in the city. It also benefits from its position as the road transporter's central point that connects the north, east-west, and south of Nigeria while experiencing rural-urban migration and imminently increasing the need for social infrastructures, numerous small-scale establishments, and commerce already going on [29]. The data was gathered from the City's building design professionals whose main role is to oversee the design of buildings as stipulated in the NBC. Both hard-copy and digital-copy questionnaires were distributed, and responses were collected between 7 November 2020 and 11 May 2021. A total of 133 responses were collected and analyzed using based on the building designers' perception of the environmental building performance towards energy efficiency and building data capture of existing buildings. The survey used in this study is deduced from a questionnaire comprising four sections designed for a larger PhD study. Section 1 with questions numbered 1–6 is about the demographics of the building design professionals, and Section 2 (questions 7–9) gauges the architect's understanding of issues of energy efficiency. Section 3 comprising questions 10–15 relates to the environmental performance of buildings including design conception and post-occupancy evaluation. Section 4 (questions 16–20) focuses on factors of as-built data capturing and processing technology. After gaining the research's ethical approval, to manage time and cost alongside the travel restrictions caused by COVID-19 a combination of web-based and hard-copy questionnaires was used. Recruiting the participants was initially done with the help of third parties, in form of a link sent to the official WhatsApp group of the Edo State Chapter of the Nigeria Institute of Architects (NIA). Further hard copies were presented directly to members of the NIA when travel restrictions eased with weekly reminders both in-person and on the WhatsApp group.

Responses to the questionnaires were received both as hard copy documents and digital ones as Comma Separated Values (CSV) files as plain text easy to import into a spreadsheet. The CSV files were converted and collated together with responses from the hard copies into a Microsoft Excel spreadsheet for preparation, coding, and elimination of data errors for exploration using the Statistical Package for the Social Sciences (SPSS). Descriptive analysis using simple frequency distribution percentages, charts, mean value scores, and significant level analysis was utilized to satisfactorily meet the aim of the study.

## 4. Results

Tables 1–4 are some demographics of the survey carried out. A total number ($n$) of 133 questionnaires were completed by members of the Edo State Chapter of the Nigeria Institute of Architects, 125 (94%) of the participants carry out most of their projects in the city (Table 1). Table 2 shows that all survey respondents are involved in the design and construction of buildings either through private practice ($n$ = 47; 35.3%), construction ($n$ = 38; 28%), freelancing ($n$ = 29; 21.8%) or employed in an organization ($n$ = 19; 14.2%). All respondents have adequate knowledge of the practice of design and construction with a minimum of a BSc. degree in architecture or its ARCON (Architects Registration Council of Nigeria) equivalent. As shown in Table 3, a total of 58 (43.6%) associate members, 39 (29.3%) full members, 4 (3.0%) fellows, and 32 (24.1%) graduate members show that over 7% of the respondents have at least a master's degree or its ARCON requirement. A significant number ($n$ = 111; 83.5%) of respondents have practiced building design and construction for over 5 years in Benin city. The years of professional practice (Table 4) are 22 (16.5%) less than 5 years, 61 (45.9%) between 6–10 years, 32 (24.1%) between 11–15 years, 12 (9.0%) between 16–25 years and 6 (4.5%) over 25 years. The participant's significant years of practice give credence to their suitability for providing relevant information to achieve study results.

**Table 1.** Where respondents' projects are mostly carried out.

| Respondents Practice within Benin City | Frequency | Percentage (%) |
|---|---|---|
| Most of the jobs are carried out within Benin city | 125 | 94.0 |
| Most of the jobs are carried out outside Benin city | 8 | 6.0 |
| **Total** | **133** | **100.0** |

**Table 2.** The best description of the respondent's practice.

| Nature and Best Description of Practice | Frequency | Percentage (%) |
|---|---|---|
| Employed in a public or corporate organization | 19 | 14.3 |
| Construction | 38 | 28.6 |
| Own firm/Private practice | 47 | 35.3 |
| Free-Lancing | 29 | 21.8 |
| **Total** | **133** | **100.0** |

**Table 3.** Respondents' professional qualifications.

| Professional Qualification | Frequency | Percentage (%) |
|---|---|---|
| Fellow | 4 | 3.0 |
| Full Member | 39 | 29.3 |
| Associate Member | 58 | 43.6 |
| Graduate Member | 32 | 24.1 |
| **Total** | **133** | **100.0** |

**Table 4.** Years of Professional Practice.

| Years of Practice | Frequency | Percentage (%) |
|---|---|---|
| Under-five years | 22 | 16.5 |
| 6–10 years | 61 | 45.9 |
| 11–15 years | 32 | 24.1 |
| 16–25 years | 12 | 9.0 |
| Over 25 years | 6 | 4.5 |
| **Total** | **133** | **100.0** |

The demographic data were quantified and analyzed using descriptive statistics of simple frequency distribution. Quantifying the subjective thoughts of the survey respondents ensured that most questions after the demographics were based in the form of a Likert scale of "very significant/very often" to "least significant/never", with the options for evaluation allotted from a score of 5 (very significant) to 1 (least significant). Mean values greater than or equal to 3 ($\geq$3) indicated that the respondents' perception of the variable is significant, while those less than 3 (<3) suggest that the perception is less significant [11,30]. The mean was used to determine the levels of variation in the professionals' perception of building performance improvement and reasons for the selection of certain data-capturing technologies.

### *4.1. Perception of the Impact of Building Design on Energy Efficiency*

The respondents' description or application of energy efficiency in their projects include the use of renewables (*n* = 24; 18.0%), less use of electricity from the national grid (*n* = 30; 22.6%), less use of both the main source of electricity from the national grid alternative sources including generators and inverters (*n* = 68; 51.1%) and less use of alternative power source (*n* = 10; 7.5%). Given the poor energy situation in Nigeria, the participants also indicate how issues of energy efficiency in buildings are addressed, mostly through efficient building designs (*n* = 75; 56.4%), While some respondents never paid much attention to energy efficiency (*n* = 20; 15.0%), an equal number of respondents (*n* = 19; 14.3%) each considered renewable energy sources or left it to the end-users to implement. As earlier stated, improving a building's environmental performance is critical to enhancing energy efficiency and reducing cost. Most respondents, who had stated that they address energy efficiency in buildings through efficient building designs are clear on the correlation between energy efficiency and the environmental performance of a building. On a 5-point scale, they rated the impact of building design on energy efficiency as significant (>3) with a mean m = 3.93 (see Figures 1–3).

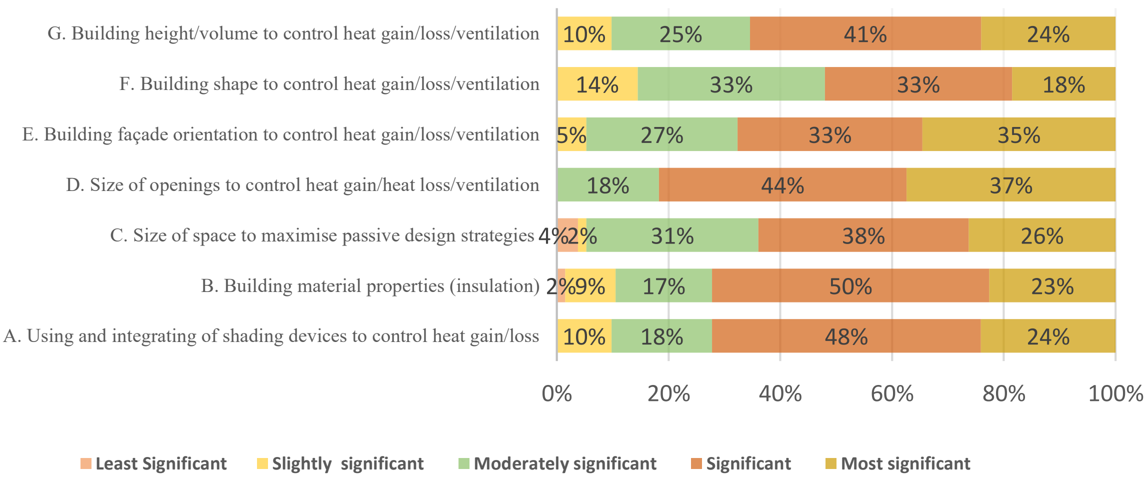


**Figure 1.** Significance rating of factors of building envelope configuration.

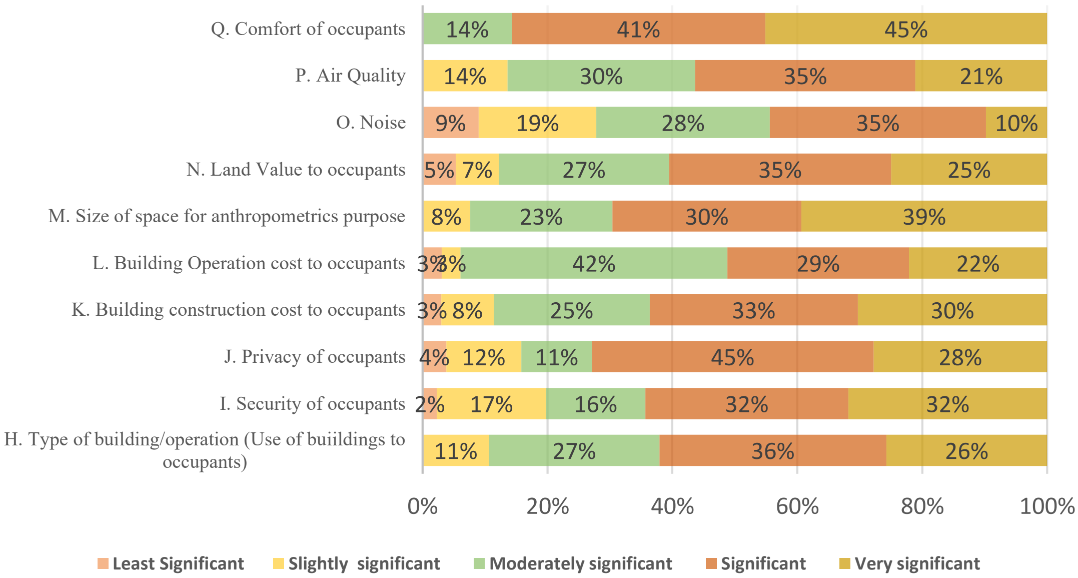


**Figure 2.** Significance rating for end-user-related considerations.

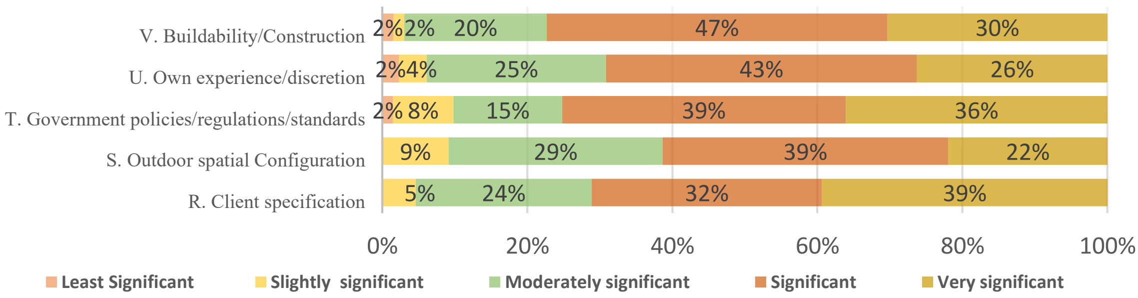


**Figure 3.** Significance rating for compliance considerations.

Figures 1–3 show various previously identified bioclimatic factors [5,6,24,26,31] influencing practitioners' choice of design on building energy efficiency, environmentally conducive indoor conditions, and enhancing comfort and productivity. The factors are categorized into three, according to how they are achieved. However, as the bioclimatic design approach imposes no particular style on building designers [24], the factors in each group are presented in no particular order of significance but to understand what extent each factor influences the professional's design decision.

4.1.1. Envelope Design Configurations

The respondents' perception of factors of 'Envelope design configurations' are rated as follows. Using and integrating shading devices to control heat gain or loss ($n$ = 120, 90.2%, m = 3.86), building materials properties ($n$ = 119, 89.5%; m = 3.83), and size of space to maximize passive design strategies ($n$ = 126, 94.7%, m = 3.81). When used with a proper understanding of environmental factors such as the sun, and the wind, envelope design configurations are effective strategies to improve building performance [6,24,26]. Other ratings of Envelope design configuration' are, the size of openings ($n$ = 131, 98.4%; m = 4.19) building façade orientation ($n$ = 126, 94.8%, m = 3.97), building shape ($n$ = 112, 84.2%; m = 3.56) and building height ($n$ = 100, 88.8%, m = 3.80). From the collected mean values, all factors are rated to be significant (>3) and support the previous indication of the respondent's view that the environmental design and performance of buildings impact energy efficiency. Only bioclimatic approaches, maximizing the potential of the building envelope design in response to environmental factors are considered in this study. Other important factors such as building occupancy profiles and internal heat gains from technology usage that also impact the heat gain or heat loss from a building [26] are not considered.

4.1.2. End-User Related Considerations

The End-User related considerations are those needs that are of high significance to the users or owners about the satisfaction they intend to derive from the facility. Considerations of the end-users rated by the building design professionals are, building use ($n$ = 119, 89.0%, m = 3.77), security ($n$ = 106, 79.7%, m = 3.74), privacy ($n$ = 112, 84.2%, m = 3.81), building construction ($n$ = 117, 88.0%, m = 3.80) are >3 supporting the opinion that successful improvement of existing office buildings should give more attention to end-users needs [7]. Other 'user-related considerations' ranked by the professionals are, building operation costs ($n$ = 123, 92.5%, m = 3.64), size of space for anthropometrics purposes ($n$ = 122, 91.8%, m = 4.02), land value ($n$ = 116, 87.2%, m = 3.68), noise ($n$ = 96, 72.2%, m = 3.17), air quality ($n$ = 115, 86.5%, m = 3.64), comfort ($n$ = 132, 99.2%, m = 4.31) indicating that end-user considerations are highly significant to the building design professionals when designing and retrofitting. The aforementioned factors are directly linked to the clients/end-users to understand how they influence respondents' design decisions. Its necessity is borne out of the enormous opportunity for end-users, like design professionals to reduce building energy demand in an energy-poor country, reduce reliance on mechanical energy sources and enhance comfort [26].

#### 4.1.3. Compliance Considerations

Also, factors of compliance including client's specification ($n$ = 126, 94.8%, m = 4.06), outdoor spatial configuration ($n$ = 130, 90.2%, m = 3.74), government policies ($n$ = 120, 90.2%, m = 4.00), the experience of the professionals ($n$ = 125, 94.0%, m = 3.87) and buildability ($n$ = 128, 96.2%, m = 4.03) are significant (>3) considerations during building design. They can influence building performance and its improvement as they set precedents that guide the design professional during decision-making. Its significance reinforces the respondents' awareness of the impact of design on building performance and is consistent with previous studies e.g., [22] indicating that building professionals hardly obtain feedback post-building occupancy to understand how their design decisions meet user needs.

Given that 1 is never and 5 is very often, the respondents' rating, with a mean of 2.58 (<3) depicts the poor practice of obtaining feedback on a project after completion and occupancy to understand if the building is meeting the occupant's intended need. Thus, impeding opportunities to improve the existing building stock. Periodic feedback about a building's performance is vital for continuous and consistent improvement [11]. While the plan for generators is becoming a fast-growing part of the architecture within the built environment to meet the desired comfort and productivity in offices there is also the argument that offices are built with little or no climatic adaptation [6]. It, therefore, reinforces the need to achieve the required comfort through a more economical and non-mechanical means due to the established link between building design and technology by capturing the desired building information for performance evaluation and enhancements [5].

### *4.2. Data Capturing Techniques*

Evaluating the performance of the existing building stock is important for assessing the effectiveness of integrating improvement measures. It is a vital step towards keeping occupants comfortable and productive in the study area as studies have indicated the poor performance of office buildings leading to the excessive use of energy mainly for cooling [10]. While evaluation and testing of improvement strategies require the use of the building's technical and geometric documentation, Figure 4 shows common data-capturing techniques known and adopted for use in Benin City. Using a simple frequency distribution, the manual tape measure is the most known ($n$ = 131, 98.5%) and frequently used ($n$ = 124, 93.2%) technique. Closely followed is Google Earth ($n$= 119, 89.5%), but used less ($n$ = 84, 63.2%) compared to photographs ($n$ = 94, 70.7%) which are not as known ($n$ = 118, 88.7%). The least known and used among the data capturing techniques are the most advanced methods; thermal imaging (known $n$ = 15, 11.3% and Used $n$ = 2, 1.5%) ground penetrating radar (known $n$ = 20, 15.0%, Used $n$ = 2, 1.5%), remote sensing (known $n$ = 22, 16.5% and used $n$ = 3, 2.3%) and ultrasonic testing (known $n$ = 23, 17.3% and Used $n$ = 4, 3.0%). Other than for the manual tape measure, use of photographs, and Google Earth, the data indicate that there is a great gap of about 50% between the capturing techniques known and their corresponding use.

The contributing factors to the choices of the capturing techniques used are rated by the professionals as follows. Availability of capturing tool (m = 3.99, 89.4%), ease of processing the captured data (m = 3.50, 74.5%), number of personnel needed to use a capturing tool (m = 3.27, 66.1%), cost of capturing tool (m = 3.46, 68.4%), ease of use of capturing tool (m = 3.63, 72.2%), the time required for capturing and processing (m = 3.20, 62.5%), less error-prone (m = 3.18, 62.4%) and less skill-intensive (m = 3.33, 73.6%). The collected mean values of these factors are significant (>3) and currently only a few data-capturing techniques are in use. The respondents also gave their perceived rating of significance on factors that would make them consider other data-capturing techniques (See Figure 5).

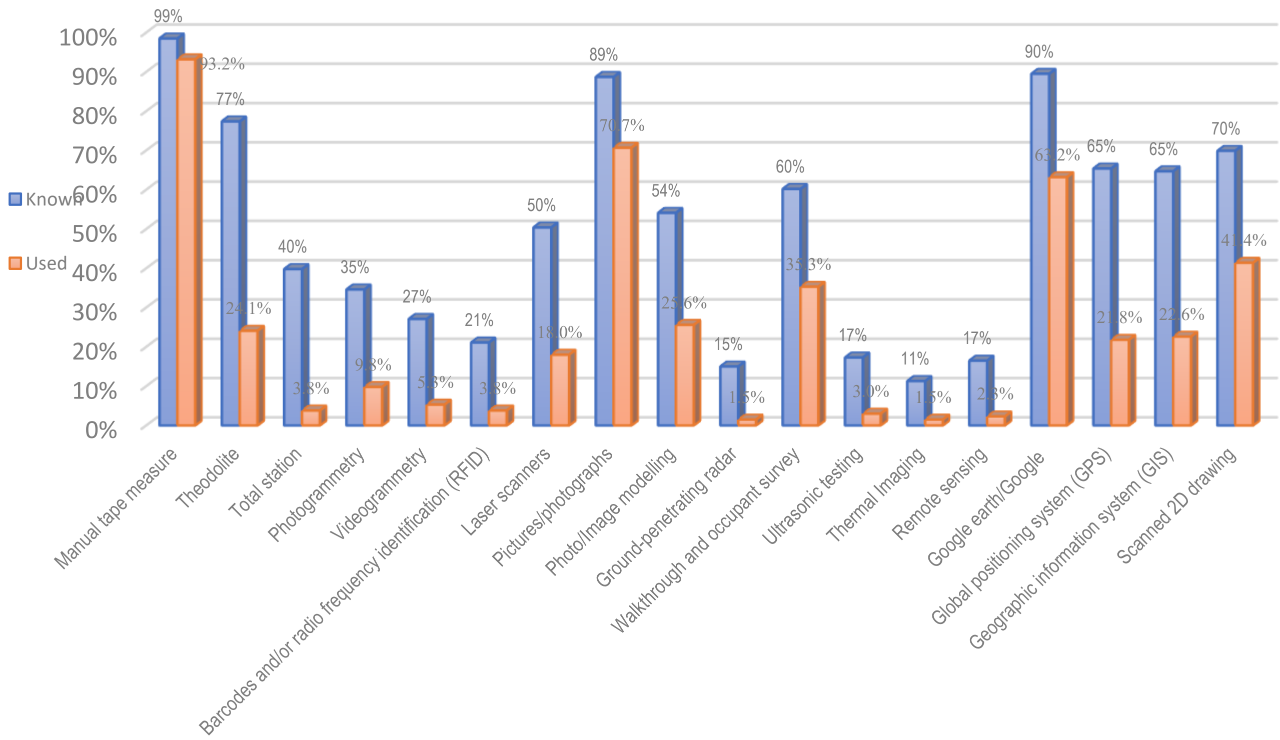


**Figure 4.** Known data capturing techniques used by building design professionals.

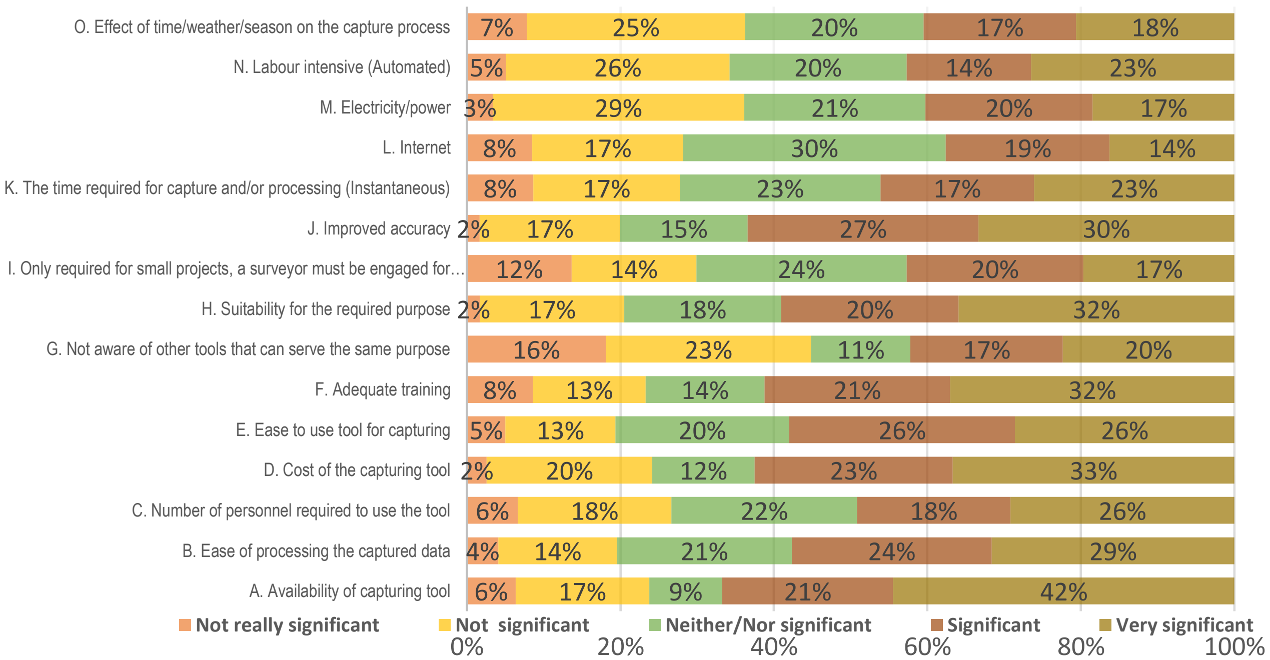


**Figure 5.** Reasons to consider other data capturing techniques.

From Figure 5, the availability of the data capturing tool (m = 3.81, 71.2%) has the highest significance rating, The other factors stated according to their perception of significance are improved accuracy (m = 3.75, 72.2%), cost of the capturing tool (m = 3.73; 68.4%), suitability for the required purpose (m = 3.73, 69.9%), ease of processing the captured data (m = 3.66, 66.9%), adequate training (m = 3.66, 66.9%), ease to use tool for capturing (m = 3.62, 72.2%), the number of personnel required to use the tool (m = 3.45; 66.1%), the time required for capture and/or processing (m = 3.36, 62.5%), labor intensive (m = 3.30, 57.9%), electricity/power (m = 3.19, 57.1%), only required for small projects a surveyor must be engaged for complex needs (m = 3.19, 61.7%), internet (m = 3.19, 63.3%), the effect of time/weather/season on the capture process (m = 3.17; 55.6%) and not aware of other tools that can serve the same purpose (m = 3.02, 48.1%). Assuming that only the five most significant factors are to be considered, the data indicate the professional's willingness to adopt other data capturing techniques by considering, the availability of the data capturing tool, improved accuracy, cost of the capturing tool, its suitability for the required purpose, ease of processing the captured data or adequate training.

Looking at the five most used data capturing techniques by the respondents, the manual tape captures a 2D input dataset, mostly spatial and other component-related information from an existing building provided contact is possible [32]. A Building Information Modelling (BIM) operator can utilize the knowledge input as a guide to efficiently trace around the derived 2D data in a BIM tool, interpret the scene and add the rich semantic information that makes the modeling process valuable [33]. This must be fed into any of the 3D creation software available with plugins or simulation applications for processing. Photographs usually complement other data-capturing techniques for future reference [34] including for progress reports, image interpretation, and risk assessment [35]. Applying certain guidelines, photographs can be captured and with the aid of special packages create 3D models in a Photo/image modeling process. Google Earth is a geographical data acquisition system used as a visual representation only possible for the visualization of geospatial environment purposes [36] thus, space analysis is not possible with Google Earth. It can be used for building modeling, however, there may be difficulty in using Google Earth solely for testing strategies through simulation on its own [37]. Scanned 2D drawings have proven to be effective and cheap in other geographical contexts [38]. The unavailability of drawings from some existing buildings as well as designs not updated post-construction pose a problem. Where drawings are available, they need to be complemented with the walkthrough and survey method of data capture as this method of capturing data helps to confirm and validate the inaccuracies or outdated existing drawings and is especially useful in the process of retrofitting, as technical and design deficiencies are easily recognized to inform decision making.

From the five most utilized data-capturing techniques by professionals, not much can be done to test retrofitting options for building performance improvements and mitigate energy inefficiencies without needing a corresponding modeling and simulation package. Figure 6 presents the common computer-enabled design and modeling software familiar to the survey respondents. The most used are AutoCAD (*n* = 121, 91%), Revit (*n* = 95, 71.4%), and Google SketchUp (*n* = 38, 28.6%). Both ArchiCAD and V-Ray follow (24.1%, *n* = 32) while at least 2 (1.5%) people each use Rhinoceros and Dynamo followed by Chief Architect (5.3%, *n* = 7). The data signifies the high use of computer software and encouraging use of 3D modeling packages for visualization purposes but with less emphasis on the performance of buildings. Figure 7 shows the commonly identified building performance simulation software that could assist designers to assess the effectiveness of energy-conscious and environmental performance initiatives. Design builder is the most used at 12.8% (*n* = 17) followed by Autodesk insight, EnergyPlus, and Autodesk Green building studio each at 4.5% (*n* = 6). Integrated Environmental Solutions Virtual Environment at 3% (*n* = 4) and Ecotect the least use at 0.8% (*n* = 1). The data indicate that building performance evaluation and enhancement have received less attention in the study area, a field that should be properly harnessed and encouraged to create a conducive indoor environment, enhance comfort, increase productivity, improve health, reduce reliance on energy or mechanical devices producing $CO_2$ and in turn reduce costs.

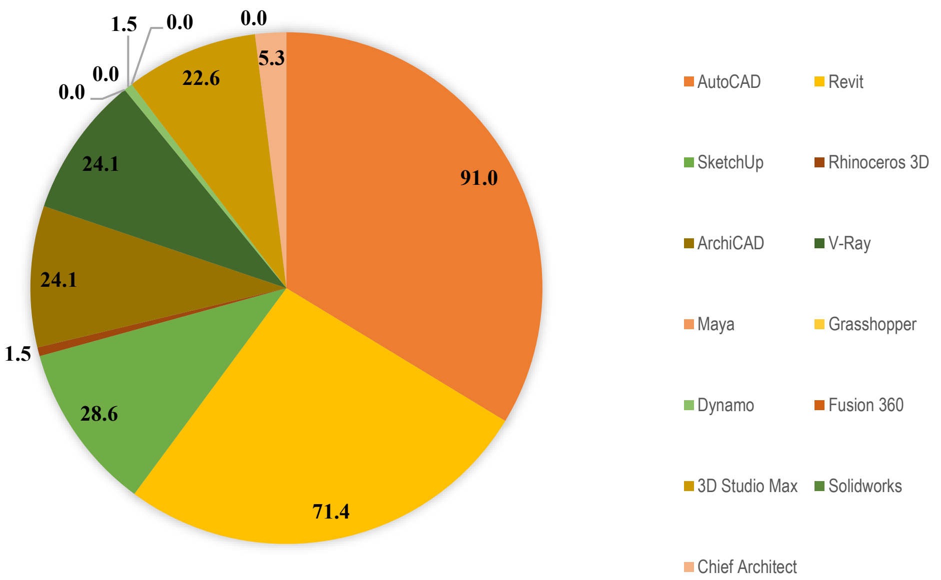


**Figure 6.** Computer software used by design professionals to process building information.

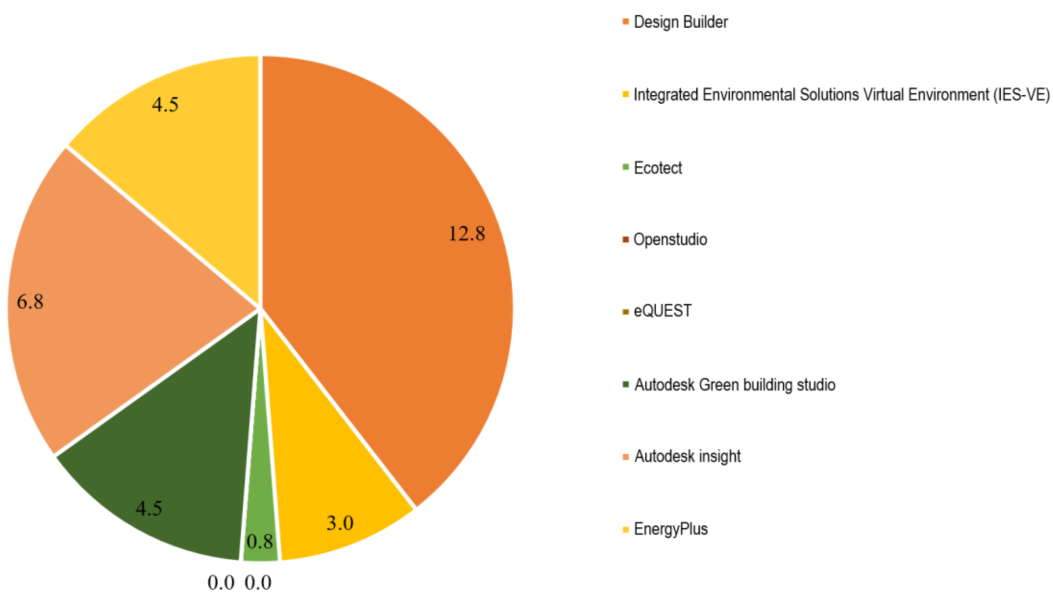


**Figure 7.** Simulation software used by design professionals to process building information.

## 5. Discussion

The survey of environmental performance enhancement strategies and building data capturing techniques in Benin City, Nigeria indicates the building design professionals' awareness of the relationship between building design, energy efficiency, and the environment. With power inefficiencies in Nigeria, to enhance comfort and boost productivity in office buildings resulting in reduced operational cost, indications suggest that such awareness is not fully utilized. While the need for retrofitting and redesigning existing buildings to meet the dynamic users' comfort needs in office buildings cannot be overemphasized [16,39], the result of the survey agrees with previous studies [21,22] indicating that the practice is uncommon as the building design professionals hardly get feedback on the performance of their projects post-occupancy. The vantage provided by the building design professional's awareness between building design, energy, and the environment, present the opportunities and potential for meaningful retrofit to mitigate earlier energy inefficiencies and their associated cost in office buildings. Current practices from this survey show that the most frequently known data capturing techniques used by the respondents are tape measure (98.5%), Google Earth (89.5%), and photographs (88.7%). Their corresponding uses are tape measure (93.2%), Google Earth (63.2%), and photographs (70.7%). Several factors are perceived to be significant both in the choice of the adopted data capturing techniques (availability of capturing tool, 89.4%; ease of processing the captured data, 74.5%; the number of personnel needed to use a capturing tool, 66.1%; cost of capturing tool, 68.4%) and for considering to use other data capturing techniques including due to availability of the data capturing tool (72.2%), improved accuracy (72.2%), cost of the capturing tool (68.4%) and suitability for the required purpose (69.9%). The survey results indicate the possibility of developing a suitable data-capturing technique that can carry out building performance enhancements as current practices of data capture is mainly used to model for visualization purposes mostly with AutoCAD (91%) and Revit (71.4%). Whereas testing retrofitting options for building environmental performance improvements and mitigating energy inefficiencies require corresponding modeling and certain simulation packages [19,20]. It, therefore, creates the vantage for developing a suitable and reliable methodology needed for building data capturing and evaluation towards performance improvement. The knowledge of the relationship between the environment, comfort, and building design by professionals can be harnessed and utilized through building performance and simulation software to test various retrofit options. It would be of great benefit in encouraging the evaluations and improvements of existing buildings as indicated by this study, subsequent studies as part of a larger PhD thesis tend to garner more information from the professionals saddled with building surveying in the study region. The information would be invaluable to developing a methodology for the data capture, modeling, analysis, and evaluation of existing office buildings before testing building performance enhancement (bioclimatic design) strategies.

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