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Assessing the relative importance of sustainability indicators for smart campuses: A case of higher education institutions in Nigeria

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ABSTRACT

The appraisal of educational institution campuses' sustainability performance has been on the rise within the past decades. This appraisal is primarily due to the importance of establishing and executing planning policies targeted at designing smart, healthy, and sustainable campuses. In ensuring environmental sustainability for smart development in Nigeria tertiary institution campuses, allocating relative importance and weights to selected indicators was carried out via the analytic hierarchy process (AHP). The relevant indicators peculiar to Nigeria's higher education institutions were identified based on social media user-generated content. The AHP involves a pairwise comparison survey with 18 certified town planning professionals from different parts of the country. The study prioritized transportation as the most important sustainability attribute for planning the smart campuses of tertiary-level education institutions in Nigeria elsewhere with similar environments. The study proposed the development of a spatial data infrastructure for achieving the Africa smart city agenda.

1. Introduction

Cities in the developing world are currently experiencing an alarming urbanization growth rate with several cultural, socio-economic, environmental, and health consequences (OECD, 2012). The rapid urbanization growth in Africa's continent is increasing at an alarming rate, with a projection of 0.96% between 2030 and 2050 (UNDESA, 2012). One of the targets of the eleventh goal of sustainable development goals (SDGs) was initiated in addressing these challenges. The target aims to ensure the number of cities creating and implement resource efficiency, resilience to disasters, and climate change adaptation plans and policies increase by 2020 (United Nations General Assembly, 2015). The current situations demand that cities look for innovative and smarter ways to mitigate these challenges. Several approaches that have been adopted in combating the challenges facing the cities were mostly technology base. These technologies have been assisting in creating what is referred to as smart cities. The smart city concept offers viable strategies for tackling modern-day city challenges by government officials and policymakers' decisions.

Findings from a comprehensive review of the literature revealed that there are two significant schools of thought as to what constitutes a smart city, which are: the (i) "techno-centric" proponent and (ii) "human-centric" proponent. The techno-centric group perceives smart cities from [only the ICTs] perspective. In contrast, the human-centric group perceives it from the interaction between technology and humans' socio-cultural dimension. The techno-centric group such as IBM, Cisco, Fujitsu, etc., believe that it is via the utilization of ICTs [alone] that the cities' challenges could be resolved to bring about a smart city. On the other hand, the human-centric proponent opined that the use of only ICTs could not bring about a smart city without incorporating the socio-cultural and local environment into perspective (Mora et al., 2017). The human-centric approach to the smart city, in the authors' opinion, is more appropriate as there are many scholars such as Bakici et al. (2013); Caragliu et al. (2015); Kourtit and Nijkamp (2012) that have defined smart city regarding human. Therefore, based on a comprehensive analysis of several smart city definitions, the International Telecommunication Union (2014) came up with the most suitable illustration. It is defined as "*an innovative city that uses ICTs and other means to improve quality of life (QOL), the efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations concerning economic, social and environmental aspects*."

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Hence, cities are regarded as smart when their investment in assets relating to the citizens' social needs is incorporated into their ICTs infrastructure. It is after this incorporation that citizens will experience sustainable growth, quality lifestyle, and smart living. Many cities in the western world have adopted the smart city approach (Marsal-Llacuna et al., 2015). According to Lee et al. (2014), an estimated 143 different smart city projects were either completed or ongoing during 2013. Examples include Ottawa's "Smart Capital" project and Quebec City in Canada as well as the Riverside in California, San Diego, and San Francisco in the United States of America (USA) (Lee et al., 2014). Initiatives and actions related to smart cities exist in several European cities such as Bath, Manchester, Amsterdam, Barcelona, Edinburgh, and Berlin. Two decades ago, Southampton was alleged to be the first smart city in the United Kingdom. In a similar vein, Tallinn, the capital of Estonia, harnessed ICT (Albino et al., 2015) while Seattle city in the USA and Friedrichshafen in Denmark are other cities with several smart city initiatives (Lee et al., 2014). In an attempt to turn one of the most developed countries in Asia into one of the best smart cities in the world, Hong Kong recently developed the Smart City Blueprint (Smart City Consortium, 2016). The Hong Kong smart city blueprint is launched to address its challenges in an efficient, innovative, and "people-centric" manner based on six major areas. Other nations in Asia striving to achieve the best smart cities globally are Singapore, United Arab Emirates, Qatar, etc.

Despite the rise in the adoption of smart city initiatives, studies, publications, approaches, and implementation since 2009 (Marsal-Llacuna et al., 2015; Mora et al., 2017); it can be observed that the initiation and the adoption of a smart city that incorporates urban QOL are still lagging in Africa. Several comprehensive studies of literature also established that African authors' and organizations' contributions are insignificant compared to their counterparts from Europe and North America (Mora et al., 2017). Recently, some of the African leaders came together and launched the Smart Africa strategic vision to ensure that the promotion of sustainable development and agenda for social and economic growth is achieved via the adoption of ICTs (Smart Africa, n.d.). The smart Africa manifesto also set out five pillars and four enablers to ensure that the continent's significant challenges are adequately addressed. African countries such as Rwanda, Uganda, Kenya, Mali, and Guinea have initiated different smart cities and ICTs master plan to ensure that their countries' development follows the smart Africa strategic vision. However, these smart cities initiatives are still lagging in Nigeria. To ensure that smart city initiatives are well incorporated into Nigeria's sustainable development cities scheme, the research and higher education institutions (HEIs) in Nigeria need to initiate smart city research like that of their counter path in Europe, North America, and Australia.

After a comprehensive literature search on search engines and databases such as Google Scholar, ISI Web of Science, and Scopus databases, the authors discovered a dearth of studies on smart cities and QOL from HEIs perspectives in Nigeria. The few studies that have incorporated smart cities' concepts into HEIs campuses have all been carried out in developed countries such as the USA, Italy, United Kingdom, and Germany (Mora et al., 2017). However, no study was identified to have been carried out in Nigeria campuses. It has also been observed that socio-economic and environmental development plans, as well as activities at local, state, regional, and federal government levels, are mostly initiated and manifested at the universities (Boucher et al., 2003; Karatzoglou, 2013; Peer and Stoeglehner, 2013; Sedlacek, 2013). Many research findings have also unanimously agreed that encouraging and implementing sustainability practices at the HEIs level will minimize environmental degradation, waste, and pollution (Adenle and Alshuwaikhat, 2017; Alshuwaikhat et al., 2016, 2017).

In Nigeria, the high level of dependence on non-renewable resources within the university campuses due to lack of sustainability practices had resulted in a high carbon footprint in some universities (Ologun and Wara, 2014). For instance, most government universities' supply of electrical energy depends on oil (Akpama and Okoro, 2012). The majority of HEIs in Nigeria have involved themselves in several complex activities. Some have many campuses in different geographical locations within a state or geopolitical region. In contrast, many of them have grown beyond the original master plan guiding the [phase plan] of their campus development. The demand for land, housing, and necessary infrastructure (i.e., efficient transportation network) between the HEIs campuses and the adjoining settlement are some of the challenges generating debates and arguments within the last few decades. The level at which these challenges can be resolved depends on the heads of institutions and community leaders' willingness and the utilization of smart spatial innovative techniques. It is evident from the literature that cities that can incorporate new technology and a smart-driven innovative solution can resolve their challenges. At the same time, those that fail to do so experiences more difficulties with no growth.

Unless the smart campus sustainability model and assessment practices are adopted in Nigerian HEIs, most campuses will be consuming a larger percentage of local oil, and other significant challenges will escalate in the nearest future. The challenges of restricted access to data for an appraisal process will also be eliminated. The indicators will be based on environmental-dimension that can be spatially retrieved and integrated into the smart-spatial technique software (Adenle et al., 2020). Therefore, moving toward adopting and developing a smart framework using spatial software for campus sustainability has become an urgent need for Nigerian HEIs. Also, the significance and importance of developing a smart spatial-based framework to measure the suitability and sustainability performance of Nigerian HEIs campuses arise from the global axiom of "think globally, act locally". Another justification is having a country-specific-appropriate model that provides a comprehensive information base for government and HEIs administrators. This study seeks to fill this research gap by first determining the relative importance of spatial-based indicators that align with the stakeholders' awareness level and the nature of Nigeria's local context. This relative importance will facilitate developing an approach for smart HEIs campuses in Nigeria to incorporate the local context toward achieving Africa's smart city agenda.

2. Methodology

A framework of spatial software such as geographic information system (GIS) using campus-wide indicators to examine the practices and performance of sustainability in HEIs campuses that affect QOL is one way to ensure smart campus planning and appraisal. This section presents the methodology utilized in identifying the selected spatial-dimension sustainability attributes and their respective relative importance for campus-wide planning and assessment.

The adopted methodology for this study comprises several stages depicted in Fig. 1. First, the identification of the research gap was established after a comprehensive review of (a) smart city initiatives and implementation, (b) extant tools for sustainability assessment in HEIs, and (c) some frequently used multi-criteria decision-making (MCDM)

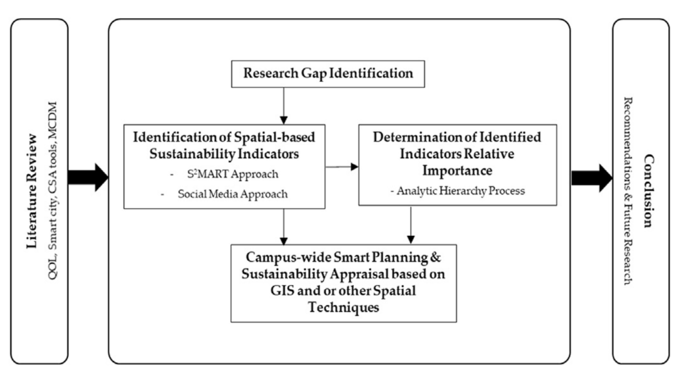

Fig. 1. Study research approach.

techniques. This research gap identification was followed by identifying spatial-based campus sustainability attributes with more significant awareness/preferences by social media users concerning the peculiarities of HEIs in Nigeria. After that, the authors determined the relative importance of the identified indicators via weighting that involves assigning greater or lesser value to the indicators. In ensuring that the smart city concept is appropriately integrated into the framework of campus sustainability assessment (CSA) using the identified spatial-based attributes, a spatial-based infrastructure model was proposed.

When developing a spatial data infrastructure for planning and appraising HEIs campuses for smart and QOL attainment, it is important to involve stakeholders' local priorities. Unlike other CSA tools that mostly rely on a few experts in localizing the indicators' relevance or priorities, this study utilized the social media user-generated content (UGC) of stakeholders. It is also paramount for the scholars or developers to identify the relative importance of the sustainability categories and the indicators before designing a smart campus spatial data infrastructure to prevent delay or stoppage before or during the implementation stage.

2.1. Identification of the spatial-based sustainable indicators

Indicators are context-dependent embedded with normative characters and affect the administrative decision-making process (Krank and Wallbaum, 2013). Indicator systems are usually designed to foster rationality in decision-making and give insight into campus sustainability by collecting information about key sustainability aspects. Thus, indicators must not only be clearly defined, but their selection criteria should also be done in a transparent and participatory manner. When properly designed and utilized, indicators can offer valued information for reducing resource usage in unnecessary information generation. The relevance of sustainability indicators is usually determined through experts' opinion surveys, case studies that analyze existing indicator programs, or criteria-based theoretical analyses (Krank and Wallbaum, 2013). The indicator selection process adopted in this study is presented in the next sub-sections.

2.1.1. S^{2}MART (spatial-dimension, specific, measurable, achievable, relevant, time-specific) filtering process approach

In this study, the first step in identifying the sustainability indicators was reviewing 13 existing campus-based appraisal frameworks. The existing tools were selected for extracting a comprehensive list of indicators as a starting point due to their (i) availability in English as well as in the published article, report, and technical report format (ii) appraisal based on different levels of indicators (iii) establishment being focus on institutions of higher education. Table 1 contained the selected extant tools with their corresponding sustainability attributes.

After extracting the 541 attributes (i.e., 486 indicators within 55 categories) from across the 13 existing CSA frameworks, the stage that follows ensures that all attributes were subjected to the S^{2}MART filtering process. The approach ensures that the selected indicators are analytically sound and can effectively appraise Nigeria's sustainability performance.

Table 1
Overview of the 13 campus sustainability appraisal frameworks.

Selected Extant Sustainability Assessment Tools	Total Attributes
Sustainability Assessment Questionnaire	7
Graphical Assessment of Sustainability in University	71
Sustainable University Model	27
University Environmental Management System	34
Assessment Instrument for Sustainability in Higher Education	35
Unit-based Sustainability Assessment Tool	9
Three dimension University Ranking	18
DPSEEA-Sustainability index Model	81
Graz Model for Integrative Development	20
Sustainable Campus Assessment System	63
Adaptable Model for Assessing Sustainability in Higher Education	37
UI's GreenMetric University Sustainability Ranking	45
Sustainability Tracking Assessment and Rating System	94
Total	**541**

The filtering process outcomes based on the S^{2}MART method are highlighted as follows: **Spatial-dimension**: The filtering process that limits the comprehensive list of attributes to spatial-dimension attributes reduces the overall attributes to 115 indicators in 13 categories. After that, attributes that appear more than once or with similar meaning were merged to ascertain, specifically sustainable spatial-dimension attributes leading to 9 categories and 81 indicators. This stage led to spatial-dimension attributes that are too generic and complex for sustainability appraisal. Also, all remaining attributes could not be measured and not relevant to the Nigerian HEIs context leading to the continuation with the other attributes of the S^{2}MART Approach. **Specific**: At this stage, 24 indicators were too generic and therefore filtered out from the list limiting only the indicators to 60. **Measurable**: The remaining attributes' measurability characteristics led to 6 categories and 38 indicators at this stage. **Achievable**: Here, all the indicators were perceived to be feasible, and no reduction was carried out at this stage. **Relevant**: After filtering by the relevance nature of the attributes, there were six categories and 35 indicators. **Time-specific**: At this stage, all the remaining indicators have the characteristic of a time frame in which any observable change could be calibrated.

After ensuring that potential indicators have satisfied the S^{2}MART attributes, the step that followed was selecting the indicators to be included in the framework based on the filtering process within Twitter Social Media data from 142 Nigerian universities' official accounts. This Twitter Social Media data filtering was carried out to ensure that people-centric smart campus design based on the people's needs and awareness level within the study's national context is achieved.

2.1.2. Social media filtering process approach

In literature, there are two general approaches for selecting sustainability indicators (Reed et al., 2006). (a) a top-down approach where a group of experts first define both the framework and the indicator set, after which decision-makers and communities do minor modifications to meet local conditions where necessary. This top-down approach often yields a set of tag indicators as more standardized and scientifically valid, even though community priorities might be excluded. (b) the bottom-up approach, a more participatory approach where decision-makers, community opinion leaders, and other stakeholders first define and select the indicators and assessment framework, some experts will review and finalize. This method tends to reflect community priorities more than the top-down approach, although coverage of sustainability issues may be partial.

This study utilized the participatory approach based on the reliance on disclosed campus-based information on Twitter social media (reflecting university community priorities) after evaluating the S^{2}MART criteria. Unlike the traditional participatory process that involves town hall meetings, interviews, and surveys embedded with several challenges and limitations, such as substantial financial costs and difficulties, stakeholders and participants' inability to express opinions and views fully. These challenges are eliminated on social media platforms (Sun et al., 2018) because the stakeholders can express their opinion and contribute in their convenient environment without intimidation, fear, compulsion, and inclusion of bias. From amongst the close to 3 billion active social media users, Twitter social media platform has around 300 million engaging members (with Nigeria boasting of approximately 6 million daily end-users), releasing around half a million tweets daily in different parts of the world. The utilization of this technology-driven and participatory approach of stakeholders to identify preferred sustainability indicators is also in line with some SDGs targets that raised concern on information, technology, and telecommunication.

In actualizing the purpose of the participatory approach in indicator selections based on Twitter social media, data of stakeholders of HEIs in Nigeria are obtained based on (i) data from Twitter (ii) content filtration.

(i) **Data from Twitter**: The study first utilized Logstash to mine UGC from the official Twitter account of 142 Nigerian universities. (Logstash is one of the three internet-based tools for analyzing different types of big data from sources. The remaining two are called Elasticsearch and Kibana, and they are jointly known as Elastic Stack). After that, a Python 3 library (GetOldTweets3 0.0.11) was used to extract more than half a million UGC from the 142 Nigerian universities' official Twitter account in comma-separated values (CSV) format. The mining via the Python 3 library was successfully carried out after specific command lines within some detailed timeline were inputted. The timeline was stated as the day each official Twitter account was created and limited to December 31, 2019. Another series of command lines to ensure that the UGC transfer in CSV file format is converted to a new line JavaScript Object Notation (nlJSON) layout was later performed. The mined UGC conversion from CSV to nlJSON was carried out to actualize the appropriate configuration during data filtering, cleaning, and analysis. Logstash was, after that, utilized in piping the extracted UGC into Elasticsearch to ensure the data are appropriately filtered/cleaned and Kibana for the actualization of data analysis.

(ii) **Content Filtration**: The approach adopted at this stage of the study identifies UGC that contains the environmental-based sustainability indicators identified at the end of the S^2MART Approach. The final filtering/selection process ensures that only UGC containing the targeted indicators was carried out on the Elasticsearch interface (i.e., Elastic Stack 7.5.0 version). The social media filtering outcome led to spatial-based sustainability indicators of six categories and 14 indicators in Fig. 2.

2.2. Determination of identified indicators level of importance

2.2.1. Analytic hierarchy process

The process of assigning significant weight adopted in this study is known as the Analytic Hierarchy Process (AHP). It was utilized to identify the spatial-dimension sustainability attributes relative importance and weight. AHP is required in city development (Lee and Chan, 2008), campus planning, and sustainability appraisal because the tasks involved are sensitive. The outcomes might have repercussions on the people's QOL within the campuses and the environment in totality. As such, the utilization of AHP for integrated appraisal concerning sustainable campus development is paramount.

The challenges of resolving the multifaceted, complicated, complex, and multivariable projects led to the establishment of the AHP in 1980 by an architect known as Thomas L. Saaty. AHP aids in arriving at the selections that are symbolized by multiple connections, linkages, and mostly competing for variables, and it provides preferences from amongst the decision variables. The most crucial part is that the variables to be considered for final decisions are appraised in considerations to the level of importance to ensure an adjustment between them.

AHP has been used in campus sustainability studies (Li et al., 2018; Sanchez et al., 2018; Wiganingrum et al., 2018); however, none of the existing studies utilized the indicators selection process adopted in this study. Also, this study adopted the technique of AHP due to its several strengths. First, its ability to schematically reveal the challenges being resolved. Second is the method simplification of the pairwise comparison for experts and faster application. Another is the small sample size and a higher level of consistency among experts' judgments. Finally, its versatility makes it an excellent choice for making strategic and sound campus appraisal decisions. However, there exist criticism of AHP in extant literature such as (i) inconsistencies introduced by the method's 1–9 scale, (ii) transformation of the oral process of comparison to numerical scale, (iii) reversal of the indicator relative importance with addition/removal of indicators (Barfod and Leleur, 2014).

In this study, five stages were involved in conducting the level of importance and weightage via AHP, which are (i) hierarchy formulation (ii) pairwise comparisons (iii) pairwise comparison matrix (iv) verification of consistency, and (v) important weight calculation. They are as follows:

i. **Formulating the Hierarchy**: This stage entails constructing three-level hierarchies based on the identified spatial-based, environmental campus sustainability indicators. The top-level is the overall goal, followed by the categories level and the last level that consists of the indicators. At level 1, the task's overall goal is to appraise Nigerian HEIs campuses' sustainability performance level. Level 2 comprises the six categories (i.e., energy, environment, infrastructure, transportation, waste, and water) of the sustainability indicators, and level 3 consists of all the 14 indicators that describe every single category. Fig. 2 illustrates the hierarchical structure.

ii. **Pairwise Comparisons**: After the 3-level hierarchy formulation, a pairwise comparison was carried out to calculate each spatial-based campus sustainability indicators' weight. The pairwise comparison survey was adopted because of a more straightforward and effective comparison rather than a simultaneous comparison between six categories. The pairwise comparison between the categories and the six categories' indicators was carried based on Saaty's nine-point scale (see Table 2) (Saaty, 1987).

iii **Pairwise Comparison Matrix**: The geometric mean method was utilized to retrieve the weights of the experts' responses after

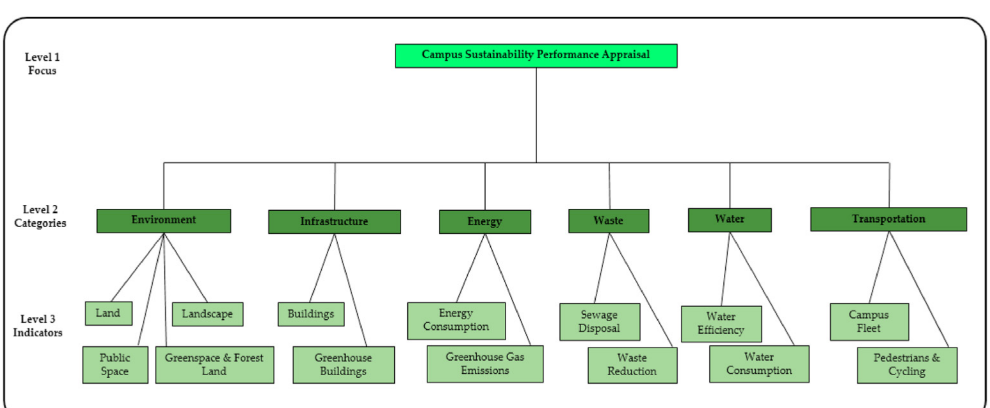

Fig. 2. Hierarchy for the preference of appraisal indicators for campus performance.

Table 2
Pair-wise comparisons underlying scale.

Intensity of importance	Definition	Explanation
1	Equal importance	Neither of the two alternatives is preferable over the other
3	Moderate importance of one over another	One alternative is preferred slightly over the other
5	Essential or strong importance	One alternative is preferred clearly over the other
7	Very strong importance	One alternative is preferred very strongly over the other
9	Extremely importance	One alternative is preferred very strongly over the other
2,4,6,8	Intermediate values between the two adjacent judgment	Can be used for graduation between evaluation
Reciprocals of above	If activities i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit

constructing the pairwise comparison matrix. The overall weight of the various levels of the indicators concerning the categories and level one was aggregated using equation (1).

$$w(C_{ij})_A = \sum_{ij}^{N}[w(C_{ij})_{Bj}w(B_j)_A] \tag{1}$$

where $w(C_{ij})_{Bj}$ represent the weight of the hierarchy third level (containing 14 indicators) concerning the second level (containing six categories). $w(C_{ij})_A$ is calculated concerning the overall goal (A) of actualizing campus sustainability.

iv. **Important Weight Calculation**: The spatial-based sustainability indicators relative weight was computed based on the results are presented.
v. **Consistency Ratio**: As a result of the subjective nature of AHP, there is the need for the optimization of the results via the process known as the verification of the consistency. However, this consistency verification involves a consistency ratio calculation. The consistency of a study's judgment that utilized AHP can be guaranteed only if the consistency ratio's outcome is not more than 0.1 (Saaty, 1987). If the consistency ratio is more than 0.1, a need for revision will be required before prioritizing the study's categories, and indicators can be concluded.

3. Results and discussion

3.1. Results of the analytic hierarchy process

The identified spatial-based campus sustainability indicators for sustainable campus appraisal for Nigerian HEIs were then validated by experts registered members of the Association of Town Planning Consultants of Nigeria (ATOPCON). ATOPCON is an umbrella body that consists of all the registered urban planning firms in Nigeria. The association was established during the last two decades, with more than 50 registered Town planning firms and organizations. Each registered Town Planning firm is registered and certified for carrying out spatial development practice and consultant by the Nigerian Institute of Town Planners (NITP) and the Town Planners Registration Council (TOPREC). Since the registered firms in Nigeria are responsible for the planning and executing physical planning, policies, and programs that include the campuses of HEIs, obtaining the experts' subjective judgment seems to be perfect for this study. Before the commencement of the AHP, experts within the firms that have carried out designing, planning, campus feasibility, and impact analysis, environmental impact assessment, etc., were consulted for validation of the spatial-based indicators to Nigeria HEIs. They all validate that the identified indicators with their categories reflect the nature of Nigerian HEIs. After that, the authors applied the AHP technique to assess the relative importance and allocation of the verified indicators' appropriate weight.

A total of 18 experts from amongst the 120 registered town planning firms with the ATOPCON were consulted to express their subjective judgments of the relative importance of the identified sustainability indicators. The 18 experts were selected to ensure that the experts' preferences serve as the country's representative. Although there are 36 states and a Federal Capital Territory (FCT) in Nigeria, the 120 firms were only situated in 17 states and the FCT. One expert from each of the firms across the 17 states and the FCT was identified for consultation.

Based on the steps of the AHP discussed in the methodology section, the relative importance weight of the spatial-based sustainability indicators is calculated, and the results are depicted in Fig. 3. Transportation, with a value of 0.2665, received the highest level of importance. One reason for this might be the absence of high capacity parking space and the lack of multiple transportation modes to ease mobility challenges in most campuses. Energy received the least weight with 0.1156. although outcomes of some past studies reveal high dependence of HEIs campuses in Nigeria on non-renewable resources in electrical power (Ologun and Wara, 2014; Akpama and Okoro, 2012). Unlike other government institutions, the authors are not surprised because most HEIs in Nigeria experience an uninterrupted electricity supply.

In this study, after the consistency ratio computation was carried out, none of the values were more than 0.1. The consistency ratio was obtained based on equation (2), where R_C is the consistency ratio, the values of R_I are provided by Saaty, the developer of the AHP technique, and I_C as the consistency index. The consistency index is calculated based on equation (3) where λ_{max} represents the calculated eigenvalue with a value of 3.0092, while N is the order of the judgement matrix.

$$R_C = \frac{I_C}{R_I} \tag{2}$$

$$I_C = \frac{\lambda_{max} - N}{\mathrm{N} - 1} \tag{3}$$

This value shows that the experts' assigned relative importance is consistent, and the indicators can be used in assessing the practices of sustainability within Nigeria HEIs campuses.

3.2. Spatial data infrastructure framework for Nigeria HEIs campuses

The selection and identification of spatial-based campus sustainability indicators for smart and quality campus-wide sustainability appraisals have been discussed in the previous sections. In this section, the discussion on spatial software/techniques such as GIS and Building Information Modelling (BIM) integration into sustainability appraisal for HEIs campuses in Nigeria would be presented. The utilization of spatial techniques results from studies of existing smart city concepts from across the globe and the ability and the capacity of these spatial data infrastructure platforms to integrate massive amounts of geospatial data. For instance, in the Hong Kong Smart City Blueprint (Smart City Consortium, 2016), from 2018, the city planned the adoption of BIM during the implementation of essential construction projects by the Hong Kong Special Administrative Region (SAR) government. The blueprint also seeks to develop a spatial data-based portal for distributing digital maps, geospatial information, etc., between different government agencies. Regarding addressing the challenges of data accessibility, the city advocates for the utilization of open data for achieving smart city innovations and strategies and initiatives for smart city infrastructure.

The utilization of these spatial-techniques-based indicators model in Nigeria HEIs campuses will improve sustainability performance in various dimensions. With transportation being the attribute with the

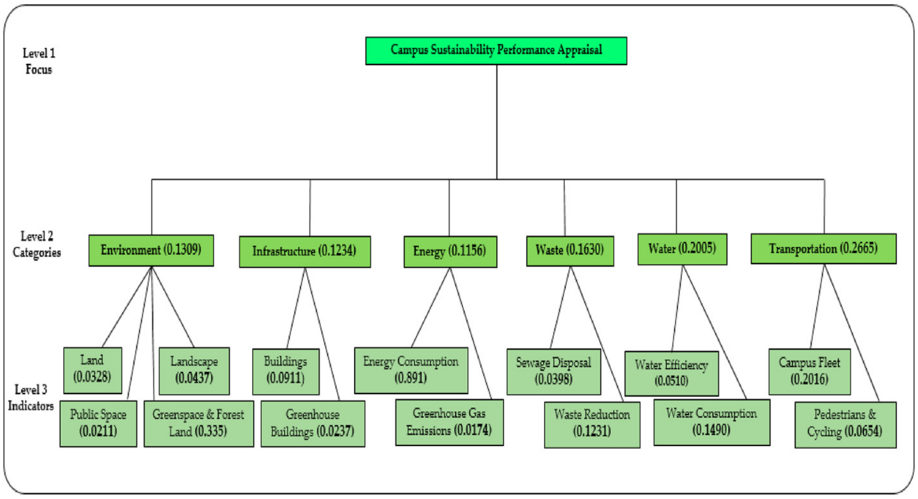

Fig. 3. The relative importance of weight.

highest level of importance, the spatial data infrastructure framework integration with CSA could be used for campus walkability evaluation to retrieve, assess, and share traffic and pedestrian routes information. This walkability evaluation will assist in reducing several needless transportation challenges and allow for more efficient smart mobility. With the continuous rise in the number of established HEIs campuses across the country, some practitioners have regarded these campuses as CenterPoint of different sustainability challenges. Nonetheless, the implementation of this proposed framework might lead to a paradigm shift in the educational system.

4. Conclusions and recommendations

QOL covers a relevant topic for appraisal in ensuring the sustainable development of HEIs campuses. The continuous dismay with QOL and environmental-dimension challenges led to innovative development and implementation in different parts of the world. This innovative approach is known as smart cities. Its relevance covers areas such as quality environment, healthy living, and vibrant community with various transportation and other land use options and CSA. Several CSA frameworks have been designed to measure the environmental performance of a variety of HEIs. These frameworks also support the decision-making process either to the whole campuses or for specific phases. Although there is a wide variety of sustainability rating systems that can be adopted for HEIs in Nigeria, locational variation has prevented any of these tools in Nigeria, which necessitated this study. Most higher education campuses with complex infrastructure, massive resource consumption, and waste generation can generate consequential environmental impacts. Therefore, it is paramount to conduct a sustainability appraisal of the performance level of these institutions. In this study, the authors identified a set of spatial-based and environmental-dimension indicators peculiar to the nature of Nigeria campuses for establishing a CSA process. The indicators were first extracted from 13 existing frameworks after a comprehensive literature review followed an elimination process via the S^2MART Approach. After that, the indicators were filtered based on Twitter social media UGC in Nigeria to identified only the indicators that reflect the campus environmental sustainability situations in Nigeria. The AHP methodology was subsequently utilized to determine the indicators' level of importance.

The challenges of assessing university campuses' environmental sustainability in developing countries include the absence of or difficulties in obtaining useful campus-wide attributes; integrating spatial data infrastructure into indicator frameworks could help minimize these challenges. The proposal's limitation consists of remote sensing, the Internet of Things, fifth-generation (5G) mobile networks, and computer skills required to build the system. These technologies and skillsets could be lacking in some HEIs within Nigeria, requiring the financial requirement to install the portals and infrastructure and workforce skill training. Future research on CSA using the proposed spatial data infrastructure framework is needed to test its applicability. There is a need for sentiment analysis via any selected machine learning software to ascertain the campus sustainability behavior of the key HEIs stakeholders in Nigeria. Lastly, to increase the number of relevant stakeholders in future studies, there is a need to expand social media UGC sources to unofficial Twitter accounts and UGC associated with all the HEIs in Nigeria.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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