Environmental and Sustainability Indicators 9 (2021) 100101

Contents lists available at ScienceDirect

Environmental and Sustainability Indicators

journal homepage: www.journals.elsevier.com/environmental-and-sustainability-indicators/

Critical indicators of sustainability for mixed-use buildings in Lagos, Nigeria

Shakirat Folashade Salami, Abubakar Danladi Isah *, Isa Bala Muhammad

Department of Architecture, School of Environmental Technology, Federal University of Technology Minna, Nigeria

ARTICLE INFO

Keywords:
Mixed-use buildings
Sustainable cities
Mixed-use indicators
Model city plans

ABSTRACT

Sustainable cities' growth and developmental pattern relies on design and planning that meets its inhabitants' needs. Seemingly, in these cities mixed-use buildings exists as skyline dots of vertical, horizontal and as shared 'premises' building dimensions. Essentially, mixed-use buildings are gradually replacing urban neighbourhood zooning design and building configurations particularly along major streets in the built environment. Significantly, Lagos state government in Nigeria has invested in the development of Model City Plans (MCPs) as district and neighbourhood regenerating process of which mixed-use building concept is an essential part of the scheme. Hence the need to develop a sustainability guide for mixed-use buildings leveraged on the experience of stakeholders particularly the inhabitants of these environments. The study therefore aims to establish critical indicators applicable for a sustainable mixed-use building development in Lagos, Nigeria. The study adopted questionnaire survey in soliciting for data which was thereafter analysed using inferential statistics. In this regard 341 respondents inhabiting mixed-use buildings were surveyed after selection through random sampling. Thereafter a trail of inferential statistics with empirical evidences evolved relating the critical indicators necessary for sustainability of mixed-use building as inspired by the users. The outcome established six (6) domains termed critical indicators because of the significant association of their factors for mixed-use building sustainability in Lagos, Nigeria. Notably, these developed domains adequately considered the pillars of sustainability relevant to mixed-use unlike existing guides that are mostly mono-dimension. Hence it is expected that the proposed indicators promote sustainable mixed-use, enhance sustainable city growth, creates resilient and self-sustaining cities.

1. Introduction

The combination of diverse activities within a physical architectural form in order to integrate urban life is termed hybrid or mixed-use (Komossa, 2011; Mayekar 2017). Similarly, the trend in the development of any urban settlement over time has the traces of the concept of mixed-use building planning (Crawford, 1995; Gentin, 2009; Heath et al., 2013). Meanwhile, Gentin (2009) and Bhargava (2018) described the progression in the development of mixed-use as traditional, undesirable, debatable and revolutionary. Therefore, 'healthy' urban growth lies in the integration of land-use because urban sprawl is associated with sole land-use and is ecologically unsustainable (Bhargava, 2018). According to Luna (2010), mixed-use building could be vertical, horizontal or shared premises dimension with jointly use building facilities. Basically, a mixed-use building involves both vertical and horizontal development of building structure to accommodate multiple functions.

Additionally, the concept of development and environment are mutually dependent and strengthens each other. This fact remains a fundamental principle of sustainable development (Oritola, 2009). The interconnectivity between development and environment suggest the needs for appropriate consideration towards sustainable development. Meanwhile, several understanding and interpretations of sustainable development reoccur in literature focusing and aligning with the dimensions of social, economy and environment (Ando et al., 2005; Olawumi *and* Chan, 2020). However, the inclusion of culture and institution perspectives is employed in international development application (UN, 2014). Accordingly, Epstein (2018) asserts that cultural values are important and are of equal importance to sustainability development because for a purposeful development to occur there is need for cultural appraisal (Go-Sam and Keys, 2018). Therefore, these dimensions are interrelated and there is need for their equal consideration while measuring sustainable development (Shari, 2011). As such Nahla et al. (2020) conclude that cultural and environmental conditions are germane to determination of criteria for evaluating the sustainability level of buildings.

Mixed-use concept which is a part of compact city idea has become

* Corresponding author.
E-mail address: arcmuzaifa@futminna.edu.ng (A.D. Isah).

https://doi.org/10.1016/j.indic.2021.100101
Received 29 April 2020; Received in revised form 29 December 2020; Accepted 6 January 2021
Available online 12 January 2021

universal plan for urban development and renewal strategy envisioned at attaining sustainable development (Ezema and Oluwatayo, 2014; MPPUD, 2011). Urban density and upsurge in land value account for the widespread of mixed-use approach of building development (Fenton, 1985). Metropolitan Area Planning Council, Boston (MAPC, 2010) alluded to the significance of mixed-use development advancing from considerable planning. It avowed uncoordinated mixed-use development as an outcome of unguided growth devoid of guidelines. Although, momentous devotion to mixed-use guidelines is evidence in developed countries, there are limited efforts palpable in developing countries.

There are several studies conducted on assessing sustainability performance of building with over 400 register software to access various aspect of sustainability (Nguyen and Altan, 2011). Also, there exist numerous sustainability rating systems (Olawumi et al., 2020). However, there is no-existence of sustainability rating system that suited the developing countries in sub-Saharan Africa (Olawumi et al., 2020). Thus there is need and quest to promote sustainable city in developing countries (Shen et al., 2010) because there is significant effect of local content on sustainability criterion (Todd and Geissier, 1999; Banani et al., 2013). Therefore, there exist some significant gap in the existing body of knowledge as Alyami and Rezgui (2012) & Xiaoping et al. (2009) argue that consideration of regional variation is essential and should be prioritise while developing sustainability criteria. Thus the aforementioned gap and limited literature relating sustainability to mixed-use building noting the peculiarity of the mixed-use phenomenon and the pursuit for indices that are prerequisites to the sustainability of mixed-use building development propel this study.

This is because the classification for sustainability assessment and measures are based on purpose, scope, and context (Brandon and Lombardi, 2011; Mahmoud et al., 2018). In line with the aforesaid, The Lagos state government of Nigeria revised their master plan to accommodate provision of Model City Plans (MCPs) for the urban area. This is a planning and operational strategy that includes mixed-use development to support the envisaged future growth and development of the city (MPPUD, 2011) in order to align Lagos with other megacities in the world. Against this backdrop, the study goal is to establish mixed-use building indicators that are critical for a sustainable mixed-use building development within MCPs in Lagos, Nigeria. The development of the guide for mixed-use building is leveraged on the experience of stakeholders particularly the inhabitants.

2. Renaissance of mixed-use development

The renaissance of mixed-use development could be traced back to Brundtland report (Walker, 2004). Similarly, the act of combining functions in a building has been in existence since the beginning of ancient building itself (Artscape, 2013; Briney, 2015). However, the advancement in the developmental processes due to improvement in Hi-Tech necessitated the changing nature of cities in the 21st century. The reduction in the hazardousness of the procedures for manufacturing inspires the revitalisation and development of multi-functional activities within a community (Artscape, 2013; Norman, 2003). The impact of mixed-use development on urban planning and real estate development over the years is unprecedented because it aligns with principles of smart growth, urbanism, and compact city. Therefore, this suggests the universality of the fundamental ideas of mixed-use development in the enhancement of the built environment (Herndon, 2011).

Predominantly Fenton's (1985), study on North America cities was a leading effort promoting and suggesting the concept of mixed-use as a recurrent concept throughout history in America context. Similarly, Jacob (1961) is frequently referred to when discussing mixed-use development resurgence (Rowley, 1996; Grant, 2002; Hoppenbrouwer and Louw, 2005; Rabianski et al., 2009). In particular Jacob (1961) earlier propagates the conditions for attaining the goal of mixed-use development, which includes that a district must perform more than two functions with jointly used facilities. Also, that edifices should be closely grained together, or densely populated and as well be pedestrian oriented.

Studies have revealed that there are intricacies surrounding mixed-use development though at a glimpse it seems direct, signifying that real estate development involves mixed-land use. Accordingly, among the complexity of mixed-use is its multidimensional nature, and lack of clear and precise definition of what constitute and the level of its corporation in the urban setting (Coupland, 1997; Grant, 2002; Hoppenbrouwer and Louw, 2005; Rabianski et al., 2007; Van Den Hoek, 2008). The divergence of experts' views on what constitute mixed-use contributed to the nebulousness surrounding the concept (Geyer and Quin, 2019). Nevertheless, in spite of the divergence view, the industrial survey and the urban and land institute classification of mixed-use concept is recurrently cited (Niemira, 2007; Wardner, 2014).

Accordingly Niemira (2007) summarized their outcomes to infer integration of diverse functions to accommodate the trio of "live – work – play". This is imperative in order to create a pedestrian-oriented area that would alleviate traffic and urban sprawl. The Urban and land institute asserts that mixed-use concept is an integration of mutually supporting structure that should also be complemented by pedestrian connection (Van Den Hoek, 2008). Thus, industry survey and ULI assertion clearly establish the underlying mechanism constituting mixed-use concept. Summarily, mixed-use concept involves physical and functional integration of activities. However, the activities should be adequate to entice its own market and also involve space maximization through intensive land use oriented towards pedestrian and coherent plan (Niemira, 2007; Rabianski and Clements, 2007).

2.1. Dimension of sustainable development

The World Commission on Environment and Development [WCED], 1987 established the concept termed sustainable development during the popular Brundtland Report. The concept- "sustainable development" according to the commission infers the development that support and meets the need of present generation, and also consider the aptitude of future generation meeting their need (Hák et al., 2018). Meanwhile, Roberts and Lloyd-Jones (2005) assert that the WCED report spurred the urban development guidelines particularly for developing countries due to the effects of economic development on the environment. However, aside leading to several interpretations these has also steered political and academic debate.

Therefore, the establishment of sustainable development was through series of political meetings ranging from Rio Conference, the Johannesburg Conference, and the Rio +20 between 1992 and 2012. The conferences coupled with multi-lateral convections among which are United Nations Framework Convention on Climate (UNFCC) and United Nations declarations like Agenda 21 which institutionalised the concept of sustainable development (Clemencon, 2012). For instance, Agenda 21 connotes progressive economic growth with equal opportunity for the populace and it signifies development without destruction to the eco-system.

The foregoing reinforces the assertion that sustainable development is generally addressed from three dimensions of social, environmental and economic perspectives. These dimensions are inter-dependent, inseparable, and also integrated (UN, 2014; Olawumi et al., 2020). Equally, cultural values are found to stimulate the development of a healthier environment and are usually considered as a dimension for sustainable development (Artscape, 2013; Epstein, 2018). This is important because cultural assets assist in addressing local needs because for practical development there is the need for cultural assessment integration (Go-Sam and Keys, 2018). Further still, this idea is buttressed by Isah (2016) when he asserted that cultural values are basis upon which all other dimensions are built. Accordingly, as cities grow distance between workplace and residence diminishes (Beckman, 2013) which infers propensity of cultural trait influences developmental process and growth of a city. Therefore, in analysing the critical indicators for Mixed-use

Table 1
Thematic Evaluation of Criteria reflective for Sustainable Development.

Criteria reflective of Sustainable Development Indicators				Joachim, Odile
Dimensions	Agenda 21 elaborated by Kahan	Michigan University	Gibbered (2008)	
Economic	Growth	Cost saving	Local economy	Solvability
	Development	Economic Growth	Efficiency of use	Profitability
	Productivity	Profit	Adaptability & flexibility	Growth (return increase; market share)
	Trickle down	Research and development	On-going cost	
			Capital cost	
Social	Equity	Living Standard	Occupant comfort	Education
	Empowerment	Education	Inclusive environment	Employment
	Accessibility	Community	Access to facilities	Gender balance
	Participation	Equal opportunity	Participation & control	Health
	Shearing		Education, health & safety	
	Cultural identity			
	Institutional stability			
Environmental	Eco-system integration	Natural resource use	Water	Success of dematerialisation
	Carrying capacity	Environmental management	Energy	Material input
	Biodiversity	Pollution prevention (air, water, land and waste)	Waste	Emission
			Site	
			Materials & components	

buildings, considering economic, environmental, social and cultural values becomes worthwhile.

2.2. Operationalization of sustainable development variables

The 17 goals for sustainable development are global and transformative strategy in order to achieve sustainable development for the benefit of all people. However, there is need to contextualise and operationalize the goals to local contexts (UN, 2014). This is because for instance in developing countries the standard of living is lower than what is experienced in developed countries. Thus there is a great need to cater for human needs that are yet to be met in developing countries. In this regard Gibberd (2001) and UN (2014) emphasises the need for development that address basic needs with positive environmental impact. Invariably, techniques for sustainable development assessment involve both tangible and intangible indicators which suggest non-absolute standards to indicators' factors (Brandon and Lombardi, 2011).

Therefore, indicators are pivotal in decision making on sustainability goal because they are measures that satisfy particular and peculiar needs. Accordingly, several indicators were developed along the dimension of sustainability. However, Miles et al. (2014) method of checking representativeness and meaning of outlier in confirming findings was used as a guide in operationalising the variables. Therefore, Table 1 shows sustainability development indicators according to previous studies that are adopted for this research.

As a result of the logical chain of evidence and also based on varied indicators suggested by scholars, attaining effective development requires a flexible and adaptable economic growth while considering economic dimension of sustainability. Meanwhile, when measuring social dimension of sustainability empowerment is important in order to advance the health and living condition in line with varied cultural differences for an overall inclusiveness. In sum, sustainable development in general ensures improvement of the eco-system and also encourages the use of sustainable materials.

3. Methodology

The strategy adopted for this research is confirmatory research method. Confirmatory research approach using statistical technique in order to determine critical indicators necessary to ensure sustainability of mixed-use building was employed. This approach according to Kennedy (2015) forms the basis for valid scientific outcomes. Furthermore, acquaintance with prior surveys that demonstrated valuable ideas informed the questionnaire design. Additionally, prolonged engagement with the study area as well as persistent observation on the subject matter during preliminary engagement directed the contextual peculiarities. Thus, data were collected among users of mixed-use buildings because they are major stakeholders. The selection of users was informed by their familiarity with the effectiveness and performance of mixed-use buildings. This aids the realism of mixed-use concept and informs means of achieving sustainability.

Probability sampling scheme through random sampling method which gives chance to individual being selected and representative of the population was employed (Kumar, 1999; Creswell, 2012). Thus, a total of 341 responses with high statistical power were gathered after sorting out incomplete attempts. Accordingly, Comrey and Lee (2009) recommends a sample size not less than 300 for factor analysis. Also, 384 respondents for a population of one million are suggested by Krejcie and Morgan (1970). This is because gradual increase in population results into a rise in sample size but at a diminishing rate which becomes constant when above 380.

The data analysis involved reliability testing of the instrument using Cronbach's Alpha. This was swiftly followed by the Kaiser-Meyer-Olkin Measure (KMO) of Sampling Adequacy. Afterwards, principal component analysis and exploratory factor analysis with factor loading set at $\geq$ 0.40 was employed in order to establish variables with stronger prediction potentials. The total variance explained establishes the extracted sums of squared loadings such as predictor (independent) variables. Finally, inferential statistics-multiple regression analysis was performed to measure socio-cultural, socio-economic and environmental dimensions rooted in contextual cultural peculiarities on the search for appropriate indicators as means of mixed-use building sustainability. This was done in order to test the hypothesis towards predicting the dependent variable as well as establishing the best predictor (independent) variables.

3.1. Research questions and respondents used for survey

The strategy adopted for the questionnaire design was based on the study requirement which was centred on the criteria essential for sustainable mixed-use building. The development of the questions was grounded on acquaintance with literature on the background of the study and familiarisation with valuable ideas that are beneficial to the study from previous questionnaires. This led to the identification and adoption of critical indicators for the phenomenon under study. Thus, the questionnaire developed was divided into three sections that include socio-cultural, socio-economic and environmental dimensions.

Precisely, the mixed-use building inhabitants who are also stakeholders are the target respondent. The choice was based on their familiarity with the effective performance because they use the building rather

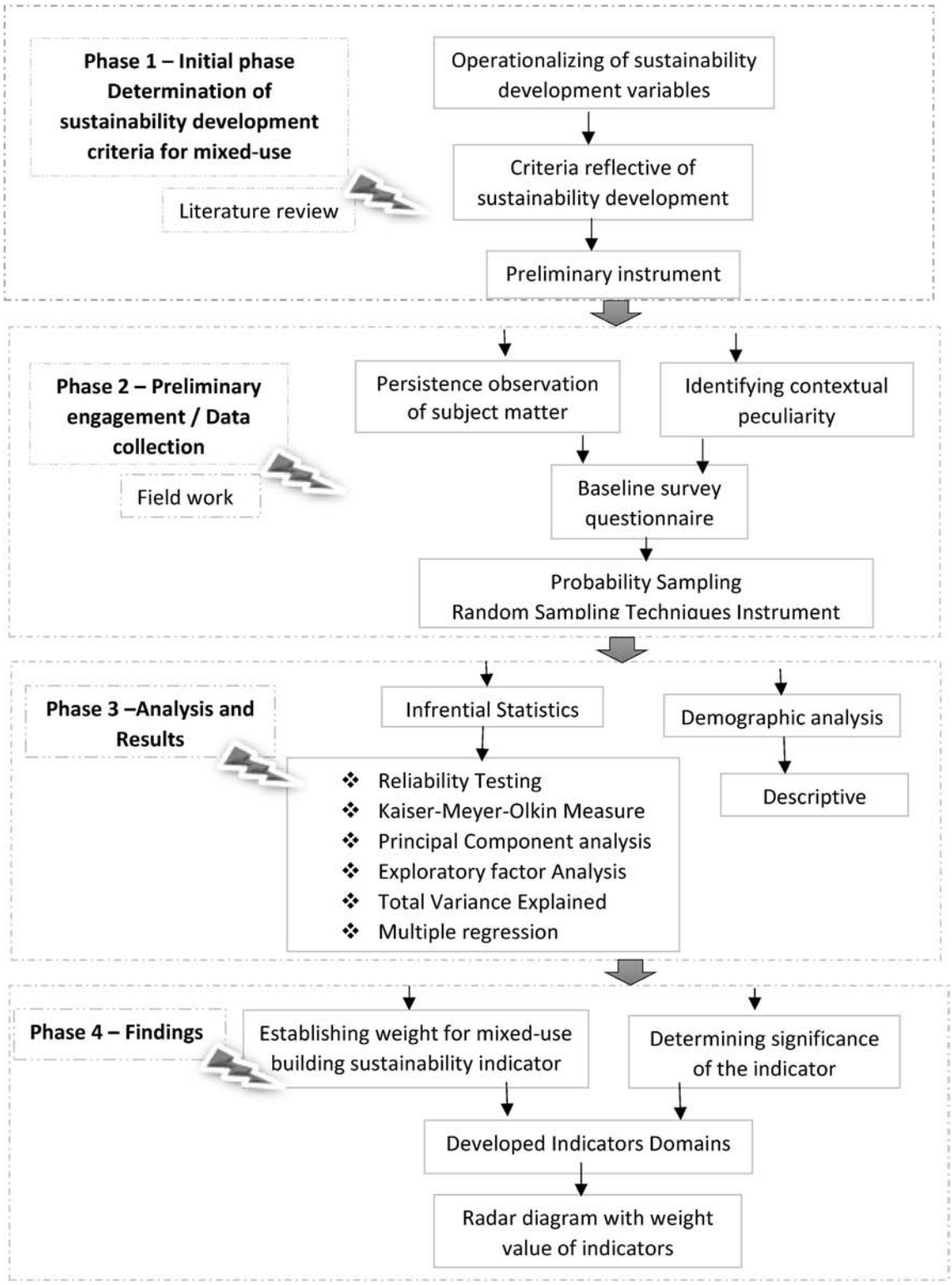

Fig. 1. Research method flow diagram.

than rely on their understanding of sustainable development concept. The understanding of the practicality of the concept which is brought to bear signifies the worthiness of this approach. However, population of targeted users covers and were limited to the mixed-use corridors identified in the MCPs and action area in Lagos State. This is because there is optimal concentration and practise of mixed-use building as well as users in this part of Lagos State-Nigeria. Consequently, in order to minimise the risk of sample biasness and the result being skewed to a particular area of study the questionnaire forms were self-administered using on time contact data collection technique (Keeves, 1988a,b; Cottrell and McKenzie, 2010). The methodological approach employed is highlighted in Fig. 1.

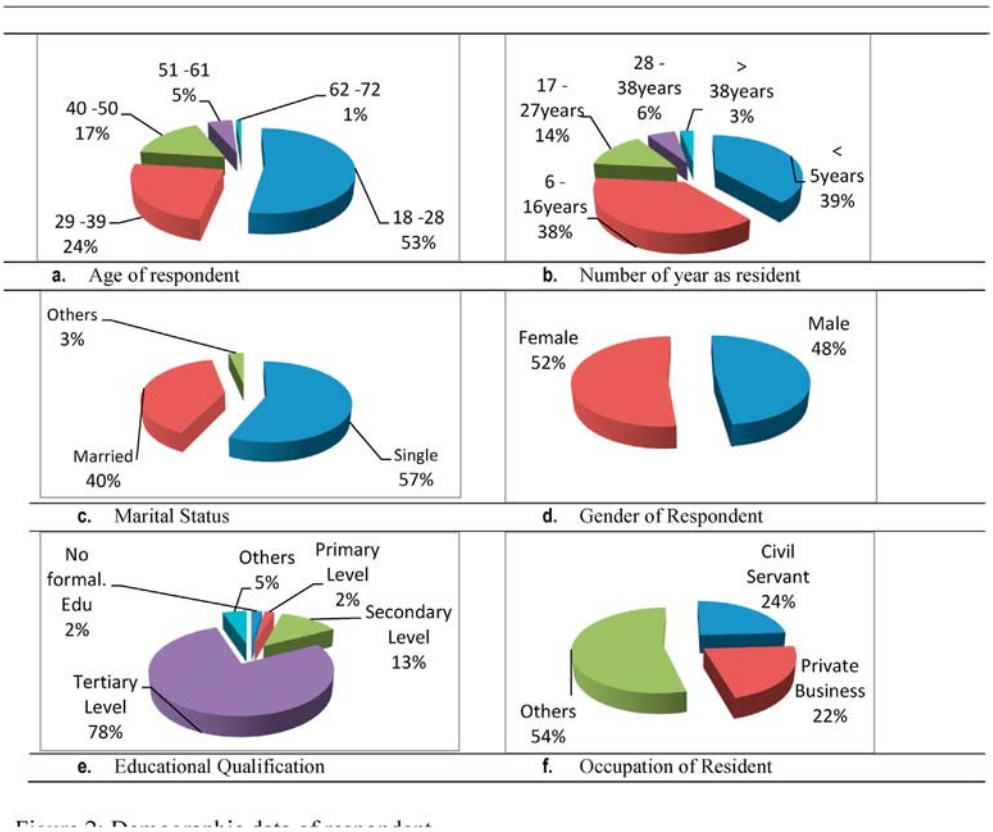

Fig. 2. Demographic data of respondent.

4. Analysis and results

4.1. Demographic data

The variables which include age, duration of stay as resident, gender and marital status are used to generate demographic data used to describes the characteristics of the respondents. Also, educational qualification and occupation of the inhabitant were also determined. The result shows that resident with age range between 18 and 28 has highest response rate at 53% followed by age range 29–39 which recorded 24% as highlighted in Fig. 2a. This infer that majority of the inhabitants are at their productive phase of lives. The enthusiasm existing with these age ranges might also have influenced the choice of mixed-use building, where consideration of proximity to work is place above other considerations. Meanwhile, the duration of stay as resident diminished over the years as shown in Fig. 2b. The respondents' duration as resident ranged between <5 years and 6–16 years which accounts for 38% and 39% respectively. This implies that as the family or businesses grows, the choices and needs of inhabitants changes.

Additionally, marital status and gender of respondent shows that 57% of inhabitants examined are single while 40% are married. Gender distribution shows 52% of the respondents are female while 48% are male as presented in Fig. 2c and d respectively. Thus the data on sustainability indicators established from the survey emanates from both genders with varied marital status. This outcome of the demographic data shows adequate consideration of all gender and marital status. Hence reduces the skewedness of the findings and thus reinforces the strength of the outcome. The educational qualification of respondents shows that 78% of the respondents had tertiary education while 13% had up to secondary education. This indicates the supposed level of exposure and competence of respondent to issue under-study. Although soundness of thought could not entirely be based on educational qualification, however the level of awareness and ability to evaluate issues on building sustainability and the environment is assured. The educational qualification reflected on the respondent occupation as civil servant and private business categories accounting for the highest value of 24% and 22% respectively. Meanwhile, 54% of respondents captures majorly dependant of the civil servant and private business owners. The demographics results are descriptively presented in Fig. 2.

4.2. Inferential analytical process

The first inferential analytical process on the sustainability indicators' data was reliability test which determined the Cronbach's Alpha. Then exploratory factor analysis (EFA) through the use of principal component analysis with varimax determined the factor weight. The adoption of exploratory analytical approach is applauded in investigating until a satisfactory level is attained (Tabachnick and Fidell, 2007), with a prior factor loading of ≥0.4. This was followed by measuring the sample adequacy using KMO and Bartletts test, which afterwards led to the identification of the proportion of variance explained. Subsequently, multiple regression analysis was conducted in order to confirm the predicting value of variables on sustainability of mixed-use buildings. Therefore, the ability of the model to explain the dependent variable according to Gupta (1999) was determined by the significance value.

4.2.1. Reliability test

In determining the worthiness and excellence of research instrument, the Cronbach's Alpha is imperative (DeVellis, 2011). Therefore, the Cronbach's Alpha value of 0.870 was achieved when the questionnaire items measuring the sustainability indicators were subjected to internal consistency reliability test. The Alpha threshold of 0.70 according to Nunnally et al. (1967) and Pallant (2013) are tolerable value while 0.80 and 0.90 are better values (Bride, 2004; DeVellis, 2011). Thus 0.87 Alpha value established indicates worthiness and reliability of the instrument.

Table 2
Factor matrix for PCA analysis of sustainability indicators.

Sustainability indicator for mixed-use building	Factor Loading	Extraction sums of squared loadings			Rotation sums of squared loadings		
		Eigenvalues	% of variance	Cumulative Percentage of variance explained	Eigenvalues	% of variance	Cumulative Percentage of variance explained
Mixed-use building ensures safety, reduces crime and anti-social behaviour	.750	6.333	22.616	22.616	4.189	14.959	14.959
Shared spaces such as access road, stairs, entrance lobby and parking in mixed –use building are satisfactory	.735	2.553	9.118	31.735	2.902	10.364	25.324
Mixed-use building development ensure healthy living among occupants	.720	1.613	5.761	37.495	2.299	8.211	33.535
Shared facilities improve social well –being within the premises	.706	1.361	4.860	42.356	1.963	7.011	40.546
Occupants are guided by rules in the management and operation of the building premises	.559	1.208	4.315	46.671	1.441	5.146	45.692
Mixed-use buildings development improves social well-being among occupants	.554	1.109	3.959	50.630	1.383	4.938	50.630
Combination of different activities in this buildings eases access to basic needs of occupants	.550						
Access to basic needs and services accounts for success of mixed-used building development	.536						
Flexibility of spaces (internal and external) influence the occupancy rate in mixed-use building	.406						
Home-based businesses and trading in domestic workplaces influence the type of mixed-use buildings development	.690						
People interaction with the environment influences the development of mixed-use building	.671						
Renting cost influences the rate of occupancy of mixed-use building	.659						
Cost implication on maintenance and operation influence mixed use building occupancy	.557						
User's lifestyle affects the maintenance and operation of mixed-use building	.539						
Cultural personality of people determines their choice of renting mixed-use building	.432						
Level of income determines the choice of mixed-use buildings	.679						
Nature of occupation influences the choice of mixed-use building	.615						
Locations such as city Centre, sub–urban area have influence on the activities in mixed - use building	.515						
Inclusion and user's Participation towards policy formation improve the development of mixed-use building	.506						
Local economy benefit from the development of mixed-use building	.500						
Inclusion and user's Participation towards policy formation at initial stage	.419						
Mixed –use building is influenced by activities in adjoining properties	.807						
Mixed-use building has effect on adjoining (neighbouring) properties	.799						
Mixed – use building influences the nature and mode of parking spaces provision	.691						
Small scale businesses influence the rate of development of mixed – use buildings	.560						
Educational status influence choice of renting mixed-use	.420						
Different kind of waste generated in mixed-use building makes recycling difficult at disposal point	.770						
Closeness of uses in mixed-use building discourage use of cars, thereby reducing emission of poisonous gas to the environment	.494						

4.2.2. Factor analysis

Testing the strength of relationship among the variables was attained through the use of Bartlett's Test of Sphericity. Accordingly, Yong & Pearce (2013) suggests that a p-value of <0.05 infer a significant level of relationship among the variables. Therefore, a p-value of 0.00 attained indicates a good strength of relationship among the variables. Furthermore, the sampling adequacy and adequacy of sampled responses was measured using the KMO. This is imperative while determining the suitability of variables for Exploratory Factor Analysis (EFA). According to Kaiser (1974), KMO values of 0.5 are barely acceptable while values between 0.7 and 0.8 are acceptable and above 0.9 are considered excellent. In this regard, the KMO value of the variable under study is 0.846 and is within the acceptable threshold. Therefore, the variables are considered suitable for EFA. Factor analysis exhibits both differentiation pattern and structural modelling in the form of scores and loadings respectively. Therefore, variables were subjected to Principal Component Factor analysis (PCA) with a threshold factor weight of ≥ 0.04 so as to establish fundamental variables with strong prediction potentials and

Table 3
Transformation of data to Indicator domains.

Indicator domains / Indicators	Healthy management operation	Social Interaction	Choice Determinant	Adjoining properties	scale of operation	Waste management
	Crime and anti-social behaviour	Home-based business	Level of income	Functions in adjoining properties	Nature and mode of parking space	Varied waste generation and recycling
	Satisfactory Shared space	Inhabitant interaction with the environment	Nature of occupation	Effect of adjoining properties	Small scale business integration	Pedestrian oriented
	Healthy living	Rent cost and occupancy	Location		Educational status	
	Social well-being	Operation and maintenance cost	Users participation			
	Operation management	Cultural personality and lifestyle				
	Access to basic need and services					
	Flexible spaces					

Table 4
Model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig.
1	.511[a]	.262	.195	.775	.262	3.934	25	311	.000

Table 5
ANOVA.[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	66.109	25	2.361	3.934	.000[b]
	Residual	186.653	311	.600		
	Total	252.762	399			

[a] Dependent Variable: There is need to ensure sustainability of mixed-use building among users.
[b] Predictors: (Constant).

establish the underlying factor. This is because previous studies have already established the grouping of the variable. Thus, the variable has factor loading ranges from 0.406 to 0.807 as displayed in Table 2.

Furthermore, the total variance explained presents the number of significant factors and shows that the extracted sums of squared loadings are imperative. It is important to note that only extracted and rotated values are meaningful for interpretation (Yong and Pearce, 2013). The extracted sums of squared loadings of first six variables accounted for 22.65%, 9.12%, 5.76%, 4.86%, 4.32%, and 3.96% of the variance respectively as illustrated in Table 2. Thus, the outcome shows a significant relationship between these variables (indicators).

4.2.3. Data transformation

Subsequently, the components from the principal component analysis (PCA) were summed up through data transformation. The summation was to identify domains and establish factors for the domains. As a result, six (6) domains were established which include healthy management operation, social interaction, choice determinant, adjoining properties, scale of operation and waste management each with 7, 5, 4, 2, 3, and 2 attributes as indicators respectively after transformation. Altogether twenty-three (23) indicators evolved from this process as outlined and presented in Table 3. These were effectively utilised for further analysis.

4.2.4. Regression analysis

The study further hypothetically tested the indicators (variables) to establish statistical significance in predicting sustainability of mixed-use building. The threshold for p-value is < 0.05 which infer significant relationship between dependent and independent variables. This implies that the lower the p-value the better the model. The result shown in Table 4 infers that there is statistical prediction of the indicators towards ensuring sustainability of mixed-use building with the attainment of 0.00 p-value of significance. Hence, the consideration of predictors used in this study during design, construction and operation will ensure sustainability of mixed-use buildings. Also, the regression equation shows the relationship between the 28 considered indicators (predictors) and the dependent variable. Accordingly, the overall regression model is significant with $F(28,311) = 3.934$, $p = 0.00$ and R^2 0.262 as highlighted in Tables 4 and 5.

The variance explained by the variation in the predicting variable which is the adjusted R^2 is 19.5%. Similarly, the R^2 measures the amount of variation in the dependent variable that was explained by the predicting (independent) variables which recorded 26.2%. Hence, the percentage prediction of the variables on mixed-use building sustainability in Lagos state is 26.2%. This infers that the model could explain the aberrations in the dependent variable and R^2 is significantly different from zero.

5. Thematic inferences of the critical indicators

The principal focus of the study is to establish critical indicators applicable and appropriate for mixed-use building sustainability in Lagos, Nigeria. Sustainability has proved to be key in developmental process and imperative in almost all sphere of live. This is consistent with some previous studies that have identified the needs for appropriate mix of functions for a sustainable built environment. For instance, Coupland (1997), Grant (2002), Hoppenbrouwer &Louw (2005) and Rabianski et al. (2007) found the need for clarity of what constitute mixed-use development due to its multidimensionality as key mechanism for ensuring healthy living and development in urban setting.

Therefore, in achieving critical indicators for mixed-use buildings sustainability, this study considered the three dimensions of sustainability (social-cultural, economic and environmental) as it relates to mixed-use building. Also, the regression analysis shows that the predicting variables can ensure sustainability of mixed-use building. This is because R^2 is significantly different from zero and the predictors are predicting sustainability of mixed-use building in Lagos state, Nigeria. Thus predictors with higher factor loading weight of >0.60 are considered form the suggested six (6) indicator domains. This is because these variables have a more significant association with the search for critical indicators for mixed-use building sustainability. These domains are

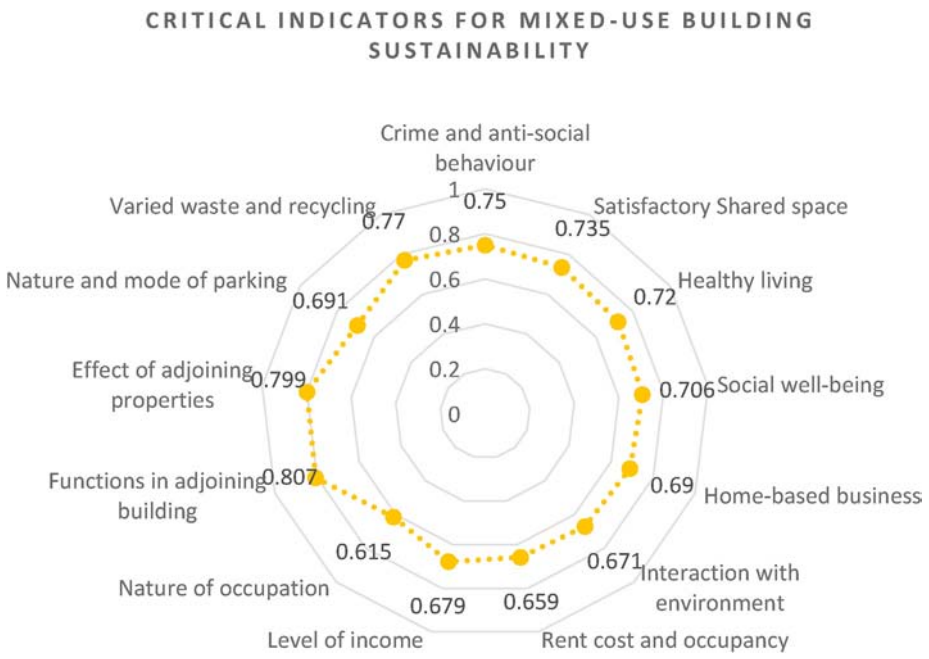

Fig. 3. Radar weight value distribution of mixed-use building critical indicators.

fundamental and Van Den Hoek (2008) MXI (Mixed-use index) could relate with this finding.

Impliedly, the healthy operation management domain suggest that appropriate operational management ensure healthy and social well-being while providing access to basic needs and services. On the other hand, social interaction domain proposes that inhabitant interaction with the environment usher home based businesses and trading in domestic workplace which influences the type of functional combination in a mixed-use building. Likewise, cost implication of operation and maintenance has effect on rate of occupancy of mixed-use building. Also worth noting on the social interaction domain is the inhabitants' lifestyle which is a reflection of their cultural backgrounds. However, modernization of building development and homogeneousness in the pattern of urban area lessen impact of cultural lifestyle.

The respondents through representativeness illustrated the significance of choice determinant domain in the development of critical indicators for mixed-use building. It stresses the fact that level of income and occupational nature influences choice of mixed use building as a preferred means of habitation. In furtherance to these, adjoining properties domain proclaims and suggests that prevailing activities in neighbouring buildings overtime have significant influence and effect on possible functional combination that could create a healthy living. The scale of operation domain proffers that nature and mode of parking provision is key to every building construction and more crucial due to peculiarity in mixed-use building. It also recognises imperativeness of integrating small scale company or businesses because they influence the rate of mixed-use building development. These aligns with waste management domain that established a disposal pattern which considers varied waste generation and recycling as germane perquisites to the search for critical indicators for mixed-use building sustainability as illustrated in Fig. 3.

6. Conclusion

The prime goal of this study is to establish mixed-use building indicators that are critical for a sustainable mixed-use building development. The data collected from the respondents were analysed through descriptive and inferential statistics which was later content analysed. This resulted into critical sustainability indicator domains for evaluating mixed-use building sustainability. The superiority and advantage of these findings were its contextual nature specifically on mixed-use building in developing urban cities that have similar characteristics with Lagos, Nigeria. Also, this study used more unified sustainability evaluation criteria which comprise socio-cultural, economic and environmental dimension as against mono-dimension with its shortcoming which were reported in literature as inadequate. As revealed in the weight value for the respective factors in the domains, considerable proportion of the aforementioned sustainability dimension is appropriate. Hence, indices such as activities in adjoining buildings, modes of parking, diverse categories of waste generated and level of income influences and are germane in achieving healthy living. Also it is evident that mixed-use building reduces crime, ensure safety and improve social well-being.

Ultimately, indicators are guide and parameters that are pointer to sustainable development in general and critical determinant of mixed-use building sustainability. The configuration and subsequent operation of mixed-use building allows several functions which prompted assertions by this study towards realisation of appropriate parameters for both design and evaluation of mixed-use buildings. Among the practical contributions of the study to knowledge and practice was the determination of key decision domains and critical indicators which are specific to mixed-use building through literature and opinion from the respondents. This is necessary because measures for sustainability vary due to purpose, focus and context as earlier proved from literature. The critical indicators eventually will aid decision makers and professionals in the building industry in evaluating sustainable performance of mixed-use buildings and make informed sustainable decisions. The study also contributes to existing body of knowledge being one of the foremost attempts aimed at developing critical indicators to enhance sustainability practice within mixed-use building environment. The limitation of this study is that the developed indicator domains and indicators were based on a section of stakeholders and regional specific. As such it is recommended that future study explore professional perspective and consider other regions with aspects of sustainability that deals with energy management and indoor acoustic performance in mixed-use buildings.

Declaration of competing interest

The authors believe that this research is carried out under necessary

global and national ethical requirements. Confidentiality of respondents was ensured. Necessary permissions were sought and granted. As such no potential conflict of interest was identified during the research.

Further still the authors declare that this manuscript has not been submitted for publication previously. As such the authors wish to publish the manuscript with your journal.

References

Alyami, S.H., Rezgui, Y., 2012. Sustainable building assessment tool development Approach. Sustain. Cities Soc. 5, 52–62.

Ando, S., Amira, T., Bogaki, K., Hoyano, A., Ikega, T., 2005. Architecture for Sustainable Future (Tokyo).

Artscape DIY Resources, 2013. Approaches to Creative Place Making retrieved from. www.artscapediy.org/.

Banani, R., Vahdati, M., Elmualim, A., 2013. Demonstrating the Importance of Criteria and Sub-criteria in Building Assessment Methods, vol. 173. WIT press Ecology and environment, pp. 443–454. https://doi.org/10.2495/SDP130371.

Beckman, G., 2013. How mixed-use building create healthy, sustainable cities. Interview Brian Barth.

Bhargava, A., 2018. Sustainable urban environment-conceptualization and policy parameters. J. Environ. Stud. (1).

Brandon, P.S., Lombard, P., 2011. Evaluating Sustainable Development in the Built Environment, second ed. John Wiley & Sons Ltd.

Bride, B.E., 2004. The Impact of providing psychosocial services to traumatized populations, *Stress*. Trauma, and Crisis Journal 7 (1), 29–46.

Briney, A., 2015. New Urbanism. About Education retrieved August 2016 from. http://geography.about.com/od/urbaneconomicgeography/a/newurbanism.htm.

Clemencon, R., 2012. From Rio 1992 to Rio 2012 and beyond: revisiting the role of trade rules and financial transfer for sustainable development. J. Environ. Dev. 21 (1), 5–14.

Cottrell, R., McKenzie, J.F., 2010. Health Promotion & Education Research Methods: Using the Five Chapter Thesis/Dissertation Mode, second ed. Jones & Bartlett Publishers, London.

Comrey, L.A., Lee, H.B., 2009. A First Course in Factor Analysis, second ed. Psychology Press, New York, London.

Coupland, A., 1997. Reclaiming the City: Mixed Use Development. Taylor & Francis, London.

Crawford, M., 1995. Building the Workingman's Paradise: the Design of American Company Towns. Verso, London.

Creswell, W.J., 2012. Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research, fourth ed. Pearson Education, Inc, Boston.

DeVellis, R.F., 2011. Scale development: theory and applications. In: Applied Social Research Methods Series, vol. 26. Sage Publications, Los Angeles.

Epstein, M.J., 2018. Making Sustainability Work: Best Practices in Managing and Measuring Corporate Social, Environmental and Economic Impacts. Routledge, London.

Ezema, I.C., Oluwatayo, A.A., 2014. Densification as sustainable urban policy: the case of ikoyi, Lagos, Nigeria. In: CIB W107 International Conference: Construction in Developing Countries and its Contribution to Sustainable Development, January 28-30, 2014, Lagos, State, Nigeria retrieved in March 2016. http://eprints.covenantuniversity.edu.ng/id/eprint/2448.

Fenton, J., 1985. Pamphlet Architecture II: Hybrid Buildings. Princeton architectural press, New York.

Gentin, M., 2009. All Mixed up - A Critical Analysis of Mixed Use. (An Unpublished Planning Thesis).

Geyer, H., Quin, L., 2019. Social diversity and modal choice strategies in mixed land-use development in South Africa. S. Afr. Geogr. J. 101 (1), 1–21.

Gibberd, J.T., 2001. The sustainable building assessment tool; assessing how buildings can support sustainability in developing countries. Continental Shift 11–14.

Gibbered, J., 2008. The sustainable building assessment tool: integrating sustainability into current design and building processes. https://citeseerx.ist.psu.edu/327096/Assessing_sustainability. Retrieved 23rd April, 2016.

Go-Sam, C., Keys, C., 2018. Mobilising indigenous agency through cultural sustainability in architecture: are we there yet? In: Grant, E., Greenop, K., Refiti, A., Glenn, D. (Eds.), The Handbook of Contemporary Indigenous Architecture. Springer, Singapore.

Grant, J., 2002. Mixed use in theory and practice: Canadian experience with implementing a planning principle. J. Am. Plann. Assoc. 68 (1), 71–84.

Gupta, V., 1999. SPSS for Beginners. Published by VJ Books Inc. Publishers, USA.

Hák, T., Janoušková, S., Moldan, B., Dahl, A.L., 2018. Closing the sustainability gap: 30 years after "Our Common Future", society lacks meaningful stories and relevant indicators to make the right decisions and build public support. Ecol. Indicat. 87, 193–195.

Heath, T., Oc, T., Tiesdell, S., 2013. Revitalising Historic Urban Quarters. Routledge, London.

Herndon, J.D., 2011. Mixed-Use Development in Theory and Practice: Learning from Atlanta's Mixed Experiences. Georgia Institute of Technology retrieved from. http://hdl.handle.net/1853/40790.

Hoppenbrouwer, E., Louw, E., 2005. Mixed-use development: theory and practice in Amsterdam's Eastern Docklands. Eur. Plann. Stud. 13 (7), 967–983.

Isah, A.D., 2016. Urban Public Housing in Northern Nigeria: the Search for Indigeneity and Cultural Practises in Design. Springer International Publishers, Switzerland.

Jacobs, J., 1961. The Death and Life of Great American Cities. Random House, New York.

Kaiser, H.F., 1974. An index of factorial simplicity. Psychometrika 39 (1), 31–36.

Keeves, J.P., 1988a. Educational Research Methodology and Measurement: an International Handbook. Pergamon Press, Sydney.

Keeves, J.P., 1998b. In: Educational Research, Methodology, and Measurement: an International Handbook. Pergamon Oxford, Washington DC.

Kennedy, J.E., 2015. Beware of inferential errors and low power with bayesian analyses: power analysis is needed for confirmatory research. J. Parapsychol. 79 (1), 53–64.

Komossa, S., 2011. Researching and designing GREAT; the extremely condensed Hybrid urban block. Architectural and Education Journal.

Krejcie, R.V., Morgan, D.W., 1970. Determining sample size for research activities. Educ. Psychol. Meas. 30 (3), 607–610.

Kumar, R., 1999. Research Methodology: a Step by Step Guide for Beginners, third ed. Sage publication, Los Angeles.

Luna, R.R.A., 2010. A Flexible Infra-architectural System for a Hybrid Shanghai a Doctoral Dissertation. Massachusetts Institute of Technology (MIT) retrieved from. http://hdl.handle.net/1721.1/57525.

Mahmoud, S., Zayed, T., Fahmy, M., 2018. Development of sustainability assessment tool for existing buildings. Sustain. Cities Soc. 44, 99–119.

MAPC, 2010. Metropolitan Area Planning Council Boston with Support from the Minuteman Advisory Group on Inter Local Coordination and the Commonwealth's Priority Development Found. Mixed Use Zoning, a Planners' Guide. http://www.mapc.org/sites/default/files/mixed-use.planners_Toolkit.pdf.

Mayekar, H., 2017. *Under One Roof: Hybrid Architecture for Auckland* a Master's Thesis. Unitec Institute of Technology, New Zealand retrieved from. https://hdl.handle.net/10652/4384.

Miles, M.B., Huberman, A.M., Saldana, J., 2014. Qualitative Data Analysis: A Method Sourcebook. Sage Publications, CA, US.

MPPUD, 2011. Ikeja and Oshodi Model City Plan, 2011-2033. Ministry of Physical Planning and Urban Development, Regional and Master Plan Department. Lagos State Government.

Nahla, H., Mohamed, A., Fahim, I.S., El-Omari, S., 2020. A novel green rating system for existing building. Sustainability 12 (17), 7143.

Nguyen, B.K., Altan, H., 2011. Comparative review of five sustainable rating systems. Procedia Eng. 21, 376–386.

Niemira, M.P., 2007. The concept and drivers of mixed-use development: insights from a cross-organizational membership survey. Res. Rev. 4 (1), 53–56.

Norman, F., 2003. Architecture and Sustainability. https://www.fosterandpartners.com/media/546486/essay13.pdf.

Nunnally, J.C., Bernstein, I.H., 1967. Psychometric Theory, vol. 226. McGraw-Hill series of physiology, New York.

Olawumi, T.O., Chan, D.W.M., 2020. Application of generalised choquet fuzzy integral method in the sustainability rating of green building based on the BSAM scheme. J. Sustain. Cities Soc. 61.

Olawumi, T.O., Chan, D.M.W., Chan, A.P.C., Wong, J.K.W., 2020. Development of a building sustainability assessment method (BSAM) for developing countries in Sub-Saharan Africa. J. Clean. Prod. 263.

Oritola, E.O., 2009. Forestry for sustainable development in Nigeria. Int. J. Afr. Stud. 1, 11–16.

Pallant, J., 2013. SPSS Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS, fifth ed. McGraw-Hill Education, (UK).

Rabianski, J., Clements, J., 2007. e. Mixed-Use Development: A Review of Professional Literatur. The National Association of Industrial and Office Properties Research Foundation.

Rabianski, J.S., Gibler, K.M., Clements III, J.S., Tidwell, O.A., 2009. Mixed-use development and financial feasibility: Part I-economic and financial factors. R. Estate Issues 34 (1), 11–18.

Roberts, M., Lloyd-Jones, T., 2005. Mixed uses and urban. 149. In: Coupland, A. Reclaiming the City: Mixed-Use Development. Routledge, Spon Press, London.

Rowley, A., 1996. Mixed-use Development: ambiguous concept, simplistic analysis and wishful thinking. Plann. Pract. Res. 11 (1), 85–98.

Shari, Z., 2011. Development of a Sustainability Assessment Framework for Malaysian Office Buildings Using a Mixed-Methods Approach a Doctoral Dissertation. University of Adelaide retrieved from. http://hdl.handle.net/2440/73200.

Shen, Y., Ochoa, J.J., Shah, M.N., Zhang, X.L., 2010. The application of urban sustainability indicators: a comparison between various practices. Habitat Int. 35, 17–29.

Tabachnick, B.G, Fidell, L.S, 2007. Using Multivariate Statistics 5th Edition. Pearson Education, Boston.

Todd, J.A., Geissler, S., 1999. Regional and cultural issue on environmental performance assessment for building. Build. Res. Inf. 27, 247–256.

United Nations, 2014. The Road to Dignity by 2030: Ending Poverty, Transforming All Lives and Protecting the Planet, Synthesis Report of the Secretary-General on the Post2015 Agenda retrieved from. http://www.un.org/disabilities/documents/reports/SG_Synthesis_Report_Road_to_Dignity_by_2030.pdf.

Van Den Hoek, J.W., 2008. The MXI (Mixed-use Index) as tool for urban planning and analysis. In: Conference Proceedings on Corporations and Cities: Envisioning Corporate Real Estate in the Urban Future. joostvandenhoek.com, Brussels.

Walker, H., 2004. Mixed use development as an agent of sustainability. In: Coupland, A. (Ed.), *Reclaiming the City: Mixed-Use Development*, Routledge. Spon Press, London, pp. 63–86.

Wardner, P.A.M.E.L.A., 2014. Explaining mixed-use developments: a critical realist's perspective. In: 20th Annual Pacific-Rim Real Estate Society Conference, Christchurch, New Zealand, pp. 10–22.

WCED, 1987. Report of the World Commission Environment and Development Our: Common Future. Oxford University press, Oxford retrieved January 2016 from. http://www.un-documents.net/ocf-ov.htm.

Xiaoping, M., Huimin, L., Qiming, L., 2009. A comparison study of mainstream sustainable/green building rating tools in the world. In: Proceedings of the International Conference on Management and Service. IEEE, Wuhan, China, pp. 1–5 retrieved from. https://doi.org/10.1109/ICMSS.2009.5303546.

Yong, A.G., Pearce, S., 2013. A beginner's guide to factor analysis: focusing on exploratory factor analysis. Tutorials Quantitative Methods Psychol. 9 (2), 79–94.