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TOPSIS analysis for sustainable redevelopment potential of abandoned infrastructure in Nigeria

Abstract

Purpose: Abandonment poses a range of effects detrimental to the development of a country such as Nigeria. Restoring such infrastructure in a sustainable manner is a challenge identified in the literature. The aim of this study is to evaluate a novel approach - TOPSIS to identify the sustainability criteria for the redevelopment of abandoned infrastructure in Nigeria. The literature evidences use of TOPSIS in various development contexts, but not in the context of redevelopment of abandoned infrastructure.

Design / Methodology: This study explores the potential of TOPSIS in the sustainable redevelopment of abandoned infrastructure in Nigeria through a combination of a quantitative method of data collection – questionnaire – and a case study. The case study focuses on the abandoned Federal Government Secretariat in Lagos. One hundred and sixty-one (161) participants responded to the questionnaire. Data collected were analysed using TOPSIS Analytical Technique.

Findings: Refurbishment is considered as the most sustainable alternative for the redevelopment of abandoned infrastructure. For criteria consideration, Structural Integrity and Foundation categorised under the technological attributes ranked highest for Refurbishment and Conversion alternatives. Waste Generation and Prevention, and Profitability top the list for Demolition and Procurement respectively.

Social implications: The social benefit of this study is to bring building considered to be an eyesore back into use.

Originality/value: The findings from the analysis orchestrates the importance of the built environment research concentrating on innovative frameworks for sustainable redevelopment of abandoned structures in the construction industry.

Keywords: Abandoned, Infrastructure, Redevelopment, Refurbishment, Sustainable Development, TOPSIS.

Paper Type: Research Paper

1.0 Background

The prosperity of a country depends on functional and readily available infrastructure (Nwannekanma and Gbonegun 2019). Developing nations are attempting to develop their infrastructure to advance their economic development (Hamma-adama et al., 2021). Some infrastructure that would have enhanced the economy of Nigeria became redundant. The landscape of the country is encumbered with abandoned and uncompleted infrastructure at all level of governance from the federal to the states and local governments (Ubani and Ononuju, 2013; Olalusi and Otunola, 2012; Oyewobi et al, 2017; Amadi, 2019; Elijah Olusegun and Olumuyiwa 2011). The abandonment of infrastructure therefore becomes a threat, slowing down the rate of development and causing nuisance to the environment (Abdul et. al. 2018).

Abandoned infrastructure as depicted by Olalusi & Otunola, (2012); Ubani & Ononuju, (2013); Hanachor (2012) are construction projects that commenced at an earlier date and were either halted before completion for one reason or the other, or were completed, initially occupied and vacated with no intention of resuming utilisation. These abandoned infrastructures have adverse effect on many stakeholders of the project, the society, economy, and environment. Okafor et al., (2018) stated that Nigeria has turn out to be the world's junkyard of abandoned and failed projects. This causes severe problems as these buildings tend to become a hideout for criminals as well as other undesirable activities thereby calling for mitigation plans to prevent further problem from re-occurring (Muzenda, 2018; Ariffin et al., 2018; Doraisamy et al., 2015). The sustainability of these infrastructure is questionable. Pavlovskis et al., (2017) states that sustainable development is not only about constructing new infrastructures but also about developing abandoned structures. Bearing this in mind, there is a need for a paradigm shift, reverting inwards to the use of abandoned infrastructure to alleviate poverty, improve the economy and sustain the environment.

Consequently, using a case study, the aim is to identify the sustainability alternatives and criteria for the redevelopment of abandoned infrastructure in Nigeria. Despite the array of literature on abandonment, sustainability, sustainable development and infrastructure in Nigeria, none has applied *the technique for order preference by similarity to an ideal solution* (TOPSIS) technique in proffering possible solution to the problem.

2.0 Redevelopment in other countries

Abandoned buildings are critical and pressing issue that necessitate urgent interventions, and re-adaptation for new use helping with waste reduction while maximizing the value of limited resources (Buitelaar 2021). Therefore, one of the purposes of this study is to make a case for the Nigerian government to consider the redevelopment of these abandoned structures to align with sustainable development. As practiced in some of the developed countries such as United Kingdom and United States of America, governments are innovatively repurposing abandoned infrastructure to meet the current need and the needs of the future generation. For

instance, 10 Abandoned cinemas in Italy were recovered, refurbished and converted to student accommodations (Cascone & Sciuto, 2018).
Araszkiewicz (2016) highlighted the transformation of a big cotton mill belonging to the Federal Government in Poland into Puuvilla Shopping mall to accommodate office spaces and other government functions. The remodeling of the big cotton mill was made possible with the use of green BIM.

2.1 The socio -economic implications of infrastructure abandonment on Nigeria's drive for sustainable environment.

Atamewan (2020) studied the environmental and socio-economic implications of abandonment in Nigeria and concluded the outcome as insecure, unhealthy economy which would be a threat to the sustainability of the built environment. Most of these projects that were once celebrated are now considered 'white elephant' projects in recent years. For instance, given foreign exchange devaluation between 2013 and 2017, a project abandoned can accrue multiple fold increase in cost at completion (Odutola and Adeniran, 2017). Impact of abandonment as identified by Olumide Odeyinka (2018); Scales (2013); Hoe (2013); Tijan and Ajagbe (2016); Amade, et al.(2015) were increase in unemployment and other social vices, delay in free flow of traffic, creation of abode for pests, marred environmental aesthetics, threat to public health, economic value deficit, and waste of material and financial resources. Garba (2019) identified the effect of abandoned building projects on the economy stating the negative impact on government taxes causing reduction of budget for services such as the provision for police and fire services, reduction in the measure of economic activities, reduction in accrued revenue to the government and lowered standard of living. These pose adverse effects on the socio-economic activities resulting in lower property values within neighborhoods.

The problem of abandoned and incomplete projects is yet to be resolved and it has a ripple effect on the whole economy of the nation and the construction industry specifically. The next section will discuss the criteria and alternatives for sustainable redevelopment.

2.2 The Criteria and the Alternatives

The selection of the criteria and alternatives are based on a literature review as shown in Table 1 and Figure 2. The ratings were identified into four levels. They will be evaluated against the case study in section 3.

>>>Insert Table 1<<<

The following alternatives were defined for consideration in the redevelopment of abandoned infrastructures:

Refurbishment and adaptation to current needs while maintaining or slightly changing the original building and its historically established purpose. Croatto et al., (2016) and Balaras &

Dascalaki, (2019) considered refurbishment as one of the approaches to saving money and cultural preservation with long-term consequences on environmental sustainability such as upgrade to energy efficiency to cut CO2 emissions, limits to waste materials from demolition. Further to these findings, the significant relationship among the variable factors of *research conducted by Ogunnusi et al., (2021) pointed out the need for the Nigerian government* to consider the environmental, economic, and social impact of refurbishing abandoned infrastructure in the country.

Conversion of the building into apartment housing and preservation of its architectural-urban expression. Pavlovskis et al., (2017) considered conversion of buildings as more apposite for redevelopment owing to the reduced consumption of energy, CO2 and other *resources, and the materials lengthier life. Petković-Grozdanovića et al., (2016) argued the conversion procedure should not be restricted to the prior intent of the building, rather should respect the cultural background and the historical structures in which the building was created. Nevertheless, architectural and structural criteria should be considered in evaluating the suitability of conversion processes.*

Demolition of the building and the implementation of a new construction project. Rathi & Khandve, (2014) defines demolition as the process of dismantling, collapsing down or *destroying down of big buildings after its valuable lifetime period. Su et al., (2021) noted that demolition support carbon emissions and the waste accounts for a large percentage of about 70% to 80% of total construction waste. Nevertheless, demolition waste can be considered for landfilling and recycling. The environmental, economic and social benefits of recycling demolition waste supersedes that of landfills by reducing materials production in new projects, saving landfill spaces, reducing emissions and saving energy. To achieve energy-absorbing construction materials, Naeini et al., (2021) recent studies identify the blends of recovered plastics with construction and demolition waste.*

Procurement or selling of these structures to private sector/ entities or investors. OECD (2015) emphasised the need for countries to reform their procurement process of infrastructure for their long life and the need to reform their governing administrations to ascertain a balance between the need of the private and public investor to recover the cost of infrastructure investment. For viability, Balogun (2016) noted that it is imperative for project sponsors to work with co-investors with similar interest as it relates to investment horizon, risk and expected returns.

It is imperative to note that the above-mentioned criteria and alternatives are from Lithuania, United Kingdom, and other developed countries. Although, there are publications on multi criteria decision making (MCDM), there exists a major gap in the application of MCDM to the redevelopment of abandoned infrastructure using TOPSIS technique in Nigeria.

Figure 1 displays the conceptual framework of the research. Phase 1 includes literature review of articles capturing global view of abandoned infrastructure, abandoned infrastructure and sustainability in Nigerian context, evaluation of criteria and alternatives applicable to sustainable development. The literature review allows critical evaluation of resources to identify gap in knowledge and provide recommendation for future research (Creswell 2014).

>>>Insert Figure 1<<<

3.0 Research Methods and Materials

A case study is presented in this section to investigate and appreciate how the proposed methodology can function with an actual building (Pavlovskis et al., 2017, Sanda et al., 2021). The Federal Government Secretariat, Lagos State, Nigeria considered for this purpose is among the array of public office buildings abandoned due to relocation of the seat of the Federal Government of Nigeria from Lagos State to the Federal Capital Territory (FCT) Abuja in 1991 (Wahab, 2020). Ayeyemi (2021) and Nwannekanma, and Gbonegun, (2019) estimated the value of the abandoned 12-storey building complex as N72 billion (128million pound) with the suggestion that if reformed into luxury apartment, it could generate income for the Federal government. Hence, the necessity arises to evaluate the abandonment and develop a model that includes the selection of the best alternative through the application of MCDM TOPSIS method.

To conduct the empirical study, a quantitative method of data collection (questionnaire) was considered as the most applicable method for obtaining data as it can provide a possibility of access to a broader population with a constrained choice of questions (Dawson 2011). The targeted sample size using random sampling was 120 participants. However, 161 professionals indicated interest and participated in the survey. The additional 34% were mostly the non-built environment professionals. Since the research focuses on sustainability, other allied professionals who are knowledgeable in building sustainability but not necessarily construction professionals were also encouraged to participate in the survey.

3.1 Demographic analyses of respondents

165 responses were initially received with 161 of them validated. Two responses came without demographic information while another two were repeated submissions from an individual. Microsoft Excel was used to analyse the demography of the participants. 60% of the respondents operate in the private sector and 6% in the public sector. The rest of the respondents (34%) operates in both public and private sectors.

The respondent by profession includes engineers, quantity surveyors, project managers. The other allied professionals as mentioned in section 3.0, an environmental scientist, soil scientist, financial analysts, urban planners, bankers, real estate managers, environmental technologists, public analysts, lawyer, academics amongst others. Additional information on the participants including the amount of experience they hold is detailed in table 2.

>>>Insert Table 2<<<

The majority of the respondents are in the high end of the experience range (15+years). This shows that a larger number of the participants are well knowledgeable in the subject. Their input reflected their wealth of knowledge and experience.

3.2 The participants awareness of sustainability issues

In addressing abandonment and sustainability issues, the participants were provided with five sustainability options to gauge their level of awareness. The environmental, economic, technological, social, and political were provided as five option attributes. This is necessary to ascertain their level of awareness that informed their decisions about the best option to select. About 60% of the participants have good awareness of these fives options. From further evaluation, 24% of the highly experienced participants were highly aware of the environmental sustainability. These can be an added advantage to awareness of the impact of the subject of discussion.

Considering the MCDM, four (4) close-ended questions are the most appropriate as they are quicker to administer and effective to code (Dawson 2011).

Q1- How relevant would you consider the following criteria while **refurbishing** the original buildings for their historical purposes?

Q2 - How relevant would you consider the following criteria while **converting** the buildings into apartment housing and preserving the architectural-urban expression?

Q3- How relevant would you consider the following criteria for the **demolition** of the building and the implementation of a new design?

Q4- How relevant would you consider the following criteria with **procurement or selling** of the building to private sector / entities or investors?

The questions were carefully collated employing the 5-point Likert scale format (Least relevance -1, Low relevance - 2, moderate relevance - 3, High relevance -4 and Highest relevance -5) to appraise the perception of the participants in the relevance of the ten (10) criteria to the four (4) alternatives (Please refer to Figure 2, level 3 & 4). The interpretation of 1 to 5 scale can be based on relevance as adopted from Omotayo et al., (2020) and Balioti et al. (2018).

SPSS Cronbach's alpha was used to measure consistency of the data collected with the minimum acceptable criterion of 0.7 Cronbach alpha (α=alpha) for measuring the reliability of the data (Pallant 2016). The Cronbach alpha result obtained for the data was α=0.823.

4.0 Multi Criteria Decision Making (MCDM)

The MCDM tool has been utilized in many spheres. Decisions identified by Tan et al., (2021) are judgements centered on information knowing that poor-quality information unavoidably leads to poor decision making. It is necessary to determine the configuration of the problems and assess multi criteria decision making. Usually, it is imperative to apply the decision maker's aspiration to differentiate amongst solutions in situations where there are no optimum solutions available to these problems. Preferred solutions could mean selecting best or most preferred alternative from a set of alternatives, or selecting a small set of good alternatives, or grouping alternatives into different preference sets (Aruldoss et al., 2013). Aruldoss et al., (2013) enlisted the various type of MCDM methods. While considering their advantages, the disadvantages of ELECTRE as "Time consuming" and Grey Theory as "not provide optimal solution" made the two types not considered for the analysis. Balioti et al., (2018) identifies the analytical hierarchy process (AHP) for "decomposing a complex MCDM problem into a system of hierarchies". However, TOPSIS was selected as discussed in the next section based on the nature and the flexibility of the data.

4.1 The technique for order preference by similarity to an ideal solution (TOPSIS)

TOPSIS is one of the valuable MCDM techniques explored by Kabir and Hasin (2012) that is appropriate for relatively simple and large-scale data. It is relevant when an enormous number of criteria and alternatives are involved as the TOPSIS algorithm is direct with no complication in calculation despite the large-scale data. Hence, calculation with the application of TOPSIS principle is efficient to perform and execute (Ghorpade & Vasatkar, 2015).

The MCDM challenge with (m) alternatives (A_1, A_2, A_3…… A_m) being appraised by (n) criteria (C_1, C_2, C_3………, C_n) can be experimental as a geometrical system with (m) points in (n) "dimensional space". A component x_{ij} of the matrix signposts the performance score of the *i*th alternative, A_i, regarding the *j*th criteria C_j .

The TOPSIS method presumes that each criterion possesses the tendency of monotonically decreasing or increasing utility which results in easily defining the negative and positive ideal solutions. An Euclidean distance approach can be applied to assess the comparative closeness of the alternatives to the ideal solution (Ghorpade & Vasatkar, 2015).

Kabir & Hasin, (2012) adopted a hierarchical structure of four (4) levels: Goal, Attributes, Criteria and Alternatives. Hence Figure 2 presents the main goal sequence for this study.

>>>Insert Figure 2<<<

4.2 The performance average rating of the criteria

Prior to the TOPSIS analysis, with the use of Microsoft Excel, the performance average ratings of the responses from the 161 participants were cross referenced in the decision matrix (Table 3). The decision matrix was utilised for the TOPSIS analysis.

>>>Insert Table 3<<<

From Table 3, "***Structural Integrity and foundation***" one of the two criteria under *Technological* attributes in Figure 2 emerged top on the list for the *refurbishment* and *conversion* alternatives. This is necessary to ensure the stability of the structural elements of the structure before any of the two alternatives (Refurbishment - Q1 and Conversion - Q2) can be considered.

Waste Generation and Prevention as criteria top the list of the four criteria under environmental attributes in Figure 2 and Table 3. Noor et al., (2020) identifies demolition wastes as debris that emanates from renovation, construction and demolition work with demolition representing 90% of the construction and demolition waste. The participants concerns are of modalities and logistics of how this waste can be managed if the buildings are demolished. Villoria Sáez et al., (2012) posit that efficient waste management should be considered.

For Procurement alternatives, ***Profitability*** ranked as the highest in the list of criteria for the economic attributes of Figure 2 and Table 3. Investors are keen on the profitability of the infrastructure anticipated for procurement. There is a need to understand the profit possibilities and the challenges positioned for the investment to be successful. For instance, with significant prospects for profits, international investors have taken stakes in United Kingdom airports infrastructure which made it remain an appealing investment proposal (BIS, 2011).

5.0 TOPSIS Analysis

This is the analysis of the four alternatives in Level 4 of Figure 2 with the application of TOPSIS**.** The MS Excel presentation of the analysis was adopted from Wilson (2013) as tables and simple displays are often required in some instance to present reasoning and thoughts.

The values of the four alternatives were obtained from the decision matrix in Table 3.

Normalisation: This works towards attaining equivalent scales which permit the comparison of alternatives. The vector normalisation method divides the rating of every alternative by its standard to compute the (x_y) the normalised value. With the terminologies previously discussed, the adapted TOPSIS method from Mathew (2018a) is described as follows:

Step -1 Calculate Normalised Matrix.

This step transforms the different alternative sections into non-sectional alternatives, which permits appraisal across criteria. The normalised matrix of Table 3 is calculated using the formula in step 1 to achieve Table 4

$$\overline{X_{ij}} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}}$$

>>>Insert Table 4<<<

Step - 2 Calculate weighted Normalised Matrix

Compute the weighted normalised matrix by assuming a set of weights for each of the criteria $w_j = 1/n$. The mean weight (MW) can be adopted in the absence of information or when the information is not sufficient or available to attain a decision (Odu 2019; Mathew 2018b)

W_j= 1/n i.e 1/10 that is 0.1 (Table 4)

where n is the number of criteria

Multiply the associate weight with each column of the normalised matrix. A component of the new matrix will emerged as the content in table 5:

>>>Insert Table 5<<<

Step -3 Calculate the ideal best and ideal worst value

This is achieved by evaluating the maximum value (V+) and the minimum value (V-) (Table 5).

Positive ideal best value, {V+ = V_i ,………,V_n } = { max (v_{ij}) if j ϵ J; min (v_{ij}) if j ϵ J'}

Negative ideal worst value, V- = { v_i ,……..,v_n }, where v'= { min (v_{ij}) if j ϵ J; max (v_{ij}) if j ϵ J'}

J is referred to as a set of benefit attributes (larger – the - better category) and J’ is referred to as a set cost attributes (smaller – the- better category)

Step - 4 Calculate Euclidean distance from the ideal best (S_i^+) (Table 6). Compute the measures for each of the alternatives. The seperation of each of the alternatives from the positive ideal alternative is stated below:

$$S_i^+ = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^+\right)^2 \right]^{0.5}$$

Step – 5 Calculate Euclidean distance from the ideal worst (S_i^-) (Table 6). The seperation of each of the alternative from the negative ideal alternative is stated below:

$$S_i^- = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^-\right)^2 \right]^{0.5}$$

Step - 6 Calculate Performance Score (Table 6). The Performance score as stated in the formula below is the division of the Euclidean distance from the ideal worst by the addition of both the Euclidean distance from the ideal best and the Euclidean distance from the ideal worst.

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

>>> Insert Table 6<<<

In summary, the sixth-step formula ranked the alternatives according to Table 6 as Refurbishment > Conversion > Procurement > Demolition. With respect to the final scores, it can be determined that refurbishment is considered as the most sustainable development alternative for abandoned Federal Secretariat building in Nigeria. This study was steered to provide a model to the Federal Government of Nigeria to adopt a sustainable redevelopment strategies of abandoned infrastructure with the integration of processes (*The technique for order preference by similarity to an ideal solution* **-** TOPSIS).

6.0 Discussion

The robustness of MCDM techniques in general and TOPSIS specifically enabled the robustness of analysing the data collated during this study. To confront decision making, this study has generated diverse MCDM techniques as obtained from (Tan et al., 2021; Aruldoss et al., 2013). Some literature reviewed by Tan et al., (2021) either uses these techniques as an individual (single) approach or hybrid (multiple) approaches for providing a solution. TOPSIS has been a feasible approach when specific performance rating is obtainable. This will also expedite the decision-making process.

According to TOPSIS method with consideration of five alternatives and ten criteria as listed in Figure 5, it is obvious that *Refurbishment and adaptation to current needs while maintaining or slightly changing the original building and its historically established purpose* (**Q1-Refurbishment)** is considered most suitable and sustainable option for the redevelopment of the abandoned Federal Government Secretariat.

6.1 Refurbishment and Adaptation to current needs

It may augur well to consider incentives for refurbishment as suggested by Buitelaar et al., (2021). This proposal will create a platform for energy efficiency and technological innovation. Another benefit of refurbishment as mentioned by Croatto et al., (2016) are environmental preservation, money saving and cultural heritage, longer life cycle, positive long-term effects on environmental sustainability, waste reduction, and climate change mitigation on a broader scale. Refurbishment will also reduced polarization and social segregation in the city by attracting people from other parts of the city. Balaras & Dascalaki, (2019) argued the need for refurbishment stating that while new structures are built according to more stringent energy codes, the existing infrastructure commonly have low energy operations and therefore in need of renovation to improve “indoor environmental quality (IEQ)”, the well being of occupants and lower their energy operating costs. This can be possible especially when incentives are considered by the policy makers to encourage refurbishment as against wide spread of static buildings.

6.2 Conversion of the building into apartment housing

Housing shortage can be resolved by the adaptive reuse and conversion of buildings into residential ones (Petković-Grozdanovića et al., 2016). The revitalisation of these existings structure through conversion provides renewal of outdated and obsolete urban areas, positive impacts with regards to energy and material resources, negligible negative effects on the

environment, and protection of architectural and historical integrity of the structure. However, the conversion of these abandoned buildings into dwellings can be effectual when the attained conversion meets with the needs and the wishes of probable users.
The dimension and spatial orientation of the office buildings mentioned in the case study may affect the conversion of the office spaces into residential dwellings. To fulfil the basic requirement of residential dwellings for living space, it is imperative for the spaces to be naturally lit and ventilated. To realise a functional result that is cost effective, the conversion process should be properly managed after the initial evaluation of the buildings. The evaluation will include the process of exploring the spatial requirement for functionality, the existing sustainability and legislative requirement, the location of the building, natural lighting, and spatial capacity of the structure.

6.3 Demolition of the building and the implementation of a new construction project
Su et al., (2021) confirmed that the tools that can appropriately quantify the impact and estimate the amount of demolition waste are lacking and later mentioned the Building Information Modelling (BIM) as one of the major tools required to develop an evaluation and estimation system for demolition waste from buildings. The building products may not be fit for reuse, disassemble or recycle after demolition. They can be rejected and typically end up in landfill. However, Naeini et al., (2021) supported the usefulness of demolition waste obtained from construction material and can be blended with recovered plastics.

6.4 Procurement or selling of the infrastructure to private sector or investors
With the cash position and the current realities of the Nigerian government, Balogun (2016) posit that the infrastructure development will entail a substantial funding by the private sector with a robust collaboration between the private sector and the government, and a medium to long term perception on the economic returns and benefits of investment to the nation. The author further states that the political willpower is required to ensure that the Nigerian environment is “investor ready” for new ways of partnership between private investors and government agencies to ensure a realistic medium to long term benefits to all key parties involved in the infrastructure investment. Significant opportunities also abound for the investor to generate returns. With assurance of guaranteed safety on investment and possible opportunity for a return on investment (ROI), the private investors are likely to be willing to collaborate with the government (Arimoro 2018).

6.5 Socio-economic Implications of findings
The socio- economic need to repurpose the abandoned infrastructure is imperative for a sustainable environment (Foster 2020; Amade et al., 2015; Tijani and Ajagbe 2016). The outcome of the revitalisation will not only create a paradigm shift from new developments to reusing existing buildings, but will also improve the economic development of the country. This study was steered to evaluate the impact of abandoned infrastructure to the socio - economic stability of the Nigerian environment and also developed a model that will be adaptable for the redevelopment of abandoned infrastructure in Nigeria. The TOPSIS is an efficient model that

will enables the evaluation of attributes, criteria and alternatives to support the choice of the ideal best alternatives (Aruldoss et al., 2013) . The responsibility rests with the decision makers such as Infrastructure Concession Regulatory Commission- (ICRC), The Federal Ministry of Works and Housing (FMWH), Nigeria Institute of Architects (NIA), and Nigeria Institute of Building (NIOB) to promote the adoption of TOPSIS in the sustainable redevelopment of abandoned infrastructure in Nigeria. The outcome of the findings proffers more acumen into further research on redevelopment possibilities of abandoned infrastructure using MCDM most especially TOPSIS and Green BIM.

Redeveloping these structures will contribute to the change required by the decision makers towards transformation to the new normal. In addition to that, it will also broaden the knowledge of efficient use of these existings structures within the academia. Topics such as “decision making outcome study for abandon buildings redevelopment” and “effectiveness in the multi criteria decision tools for sustainability” can be considered for future research.

7.0 Conclusion and Limitation

This study has successfully identified Refurbishment as the most sustainable way for the redevelopment of the presented case study- the abandoned Nigerian Federal Secretariat building in Lagos. Considering sustainable development, the redevelopment of the public buildings such as the Federal Secretariat is a multifaceted challenge, hence, the TOPSIS technique is proved to be extremely suitable to validate the selection of the most sustainable decisions. With TOPSIS method, ten (10) criteria were identified and sectioned into four alternatives as refurbishment, conversion, demolition and procurement. Structural Integrity and Foundation of the Technological attributes ranked highest out of the five (5) attributes of social, economic, environmental, political and technological attributes. This indicated that there is a relationship between Refurbishment and technological attributes. Innovative tools such as green BIM will be needed to ascertain the integrity of the infrastructure to know how exactly to address refurbishment. It is obvious that the confirmation of the structural stability of abandoned infrastructure with the consideration of the four alternatives is dependent on the application of innovative tools for integrity confirmation.

This study will contribute to the body of knowledge and create a pathway for extended research in the Nigerian construction industry sustainably. There is no doubt that this study has created a paradigm shift both academically and professionally from continous development of infrastructure in aligning with sustainable development goals to include the refurbishment of abandoned existing infrastructure. The implication of this study also buttress the necessity for the government to consider the adoption of TOPSIS in the sustainable redevelopment of abandoned infrastructure in Nigeria.

The limitation of this study is the inability to extend the TOPSIS to the grey area to determine the weight of each criteria and this may be achieved through interview of expert groups to determine the diverse weight of each criteria. Nevertheless, the outcome of this study proffers a better understanding for consideration of sustainable redevelopment of abandoned infrastructure. This will pave the way for further research on possibilities of redeveloping abandoned infrastructure using TOPSIS and green BIM

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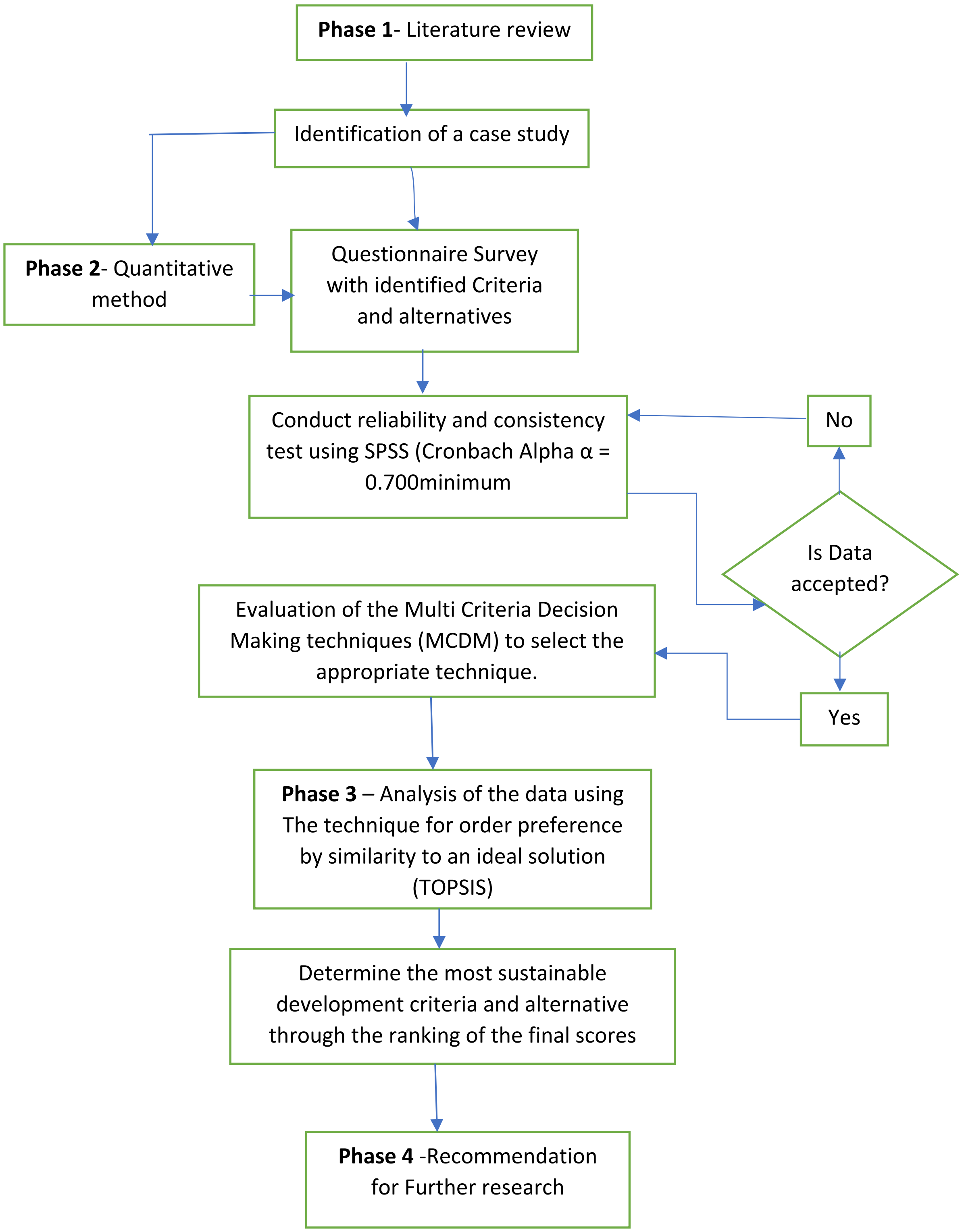

Figure 1**:** Conceptual framework.

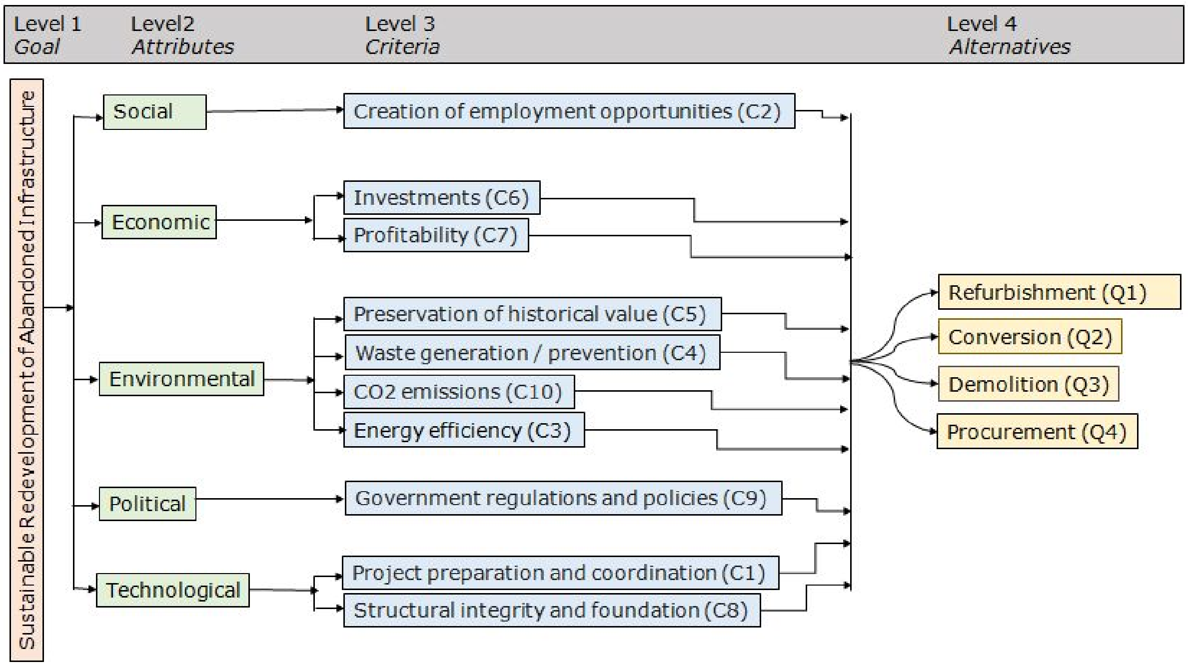

Figure 2 : The main goal sequence for the sustainability appraisal of the abandoned infrastructure redevelopment (Pavlovskis et al., 2017; Kabir & Hasin, 2012; Mcguinn et al., 2020)

List of Tables

Table 1: The ten (10) criteria for sustainable redevelopment alternatives (*in italics*)

N	Criteria
C1	Pavlovskis et al., (2017) considered *Project preparation and coordination* under technological attributes.
C2	With expert perception into social sustainability concept and the means of addressing it in legislation and policy making, Mcguinn et al., (2020) identified *creation of employment* as one of the main determinants for social sustainability
C3	An *energy efficient* construction generates comfortable living conditions with the minimum likely amount of energy consumption while maximizing the efficient use of resources (Gupta et al., 2021)
C4	To curb and manage these *waste generation*, a complete understanding of issues around the waste generation in construction is essential (Luangcharoenrat et al., 2019).
C5	Pavlovskis et al., (2017) considered *preservation of historical value* as one of the key aspects of sustainable redevelopment consideration of infrastructure
C6	Ahmad et al., (2012) critically evaluated the relationship between investment and economic growth. *Investment* expenditure creates direct contribution to economic activity as the most unpredictable component of GDP
C7	*Profitability* is the achievement of an organisation or an entity base of financial performance (Fatihudin et al., 2018).
C8	The building lifetime in Pavlovskis et al., (2017) was changed to *Structural Integrity and Foundation*. This is also part of the technological criteria with the intention of evaluating the structural stability of the projects
C9	Vizzarri, (2020) considered political attributes *as government regulations and policies* which includes national laws, the urban management and landscape protection
C10	Ali et al., (2020) claimed that the construction sector plays a vital role in the *carbon dioxide (C02) emission* into the atmosphere in large number resulting to diverse issues that needs to be addressed.

Table 2: The demography of the respondents.

Description	Category	Number	%
Profession	Architects	34	21.11
	Building Engineers	6	3.72
	Civil Engineers	21	13.04
	Electrical Engineers	5	3.13
	Construction/Project Managers	25	15.63
	Quantity Surveyors	32	19.87
	Property Developers	4	2.48
	Contractors	4	2.48
	Others	30	18.63
Years of experience	Somewhat experienced (<5)	24	14.90
	Experienced (5-10years)	49	30.43
	Very experienced (11-15)	32	19.87
	Highly experienced (more than 15 years)	56	34.78
Academic qualification	College / Ordinary National Diploma (OND)	1	0.62
	Higher National Diploma (HND)	12	7.45
	First Degree	48	29.81
	MSc	94	58.38
	PhD	6	3.72
Sector of operation	Public Sector	10	6.21
	Private Sector	97	60.24
	Both (Public and Private)	54	33.54

Table 3: Decision Matrix.

N	Criteria	Q1	Rank	Q2	Rank	Q3	Rank	Q4	Rank
C1	Project preparation and coordination	4.15	3	4.09	3	3.74	3	3.74	
C2	Creation of employment opportunities	4.17	2	4.05		3.51		3.81	
C3	Energy efficiency	3.99		3.99		3.54		3.58	
C4	Waste generation / prevention	3.83		3.82		3.93	1	3.44	
C5	Preservation of historical value	3.48		3.24		3.63		3.19	
C6	Investments	4.11		4.11	2	3.63		4.12	2
C7	Profitability	3.99		4.05		3.45		4.17	1
C8	Structural integrity and foundation	4.47	1	4.38	1	3.85	2	3.96	3
C9	Government regulations and policies	3.58		3.58		3.44		3.48	
C10	CO2 emissions	3.61		3.73		3.58		3.29	

Table 4:

Weightage	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Alternatives	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
(Q1))	0.527	0.535	0.527	0.509	0.513	0.514	0.509	0.536	0.508	0.507
(Q2)	0.519	0.52	0.527	0.508	0.478	0.515	0.516	0.524	0.509	0.524
(Q3)	0.476	0.451	0.469	0.522	0.535	0.454	0.439	0.461	0.489	0.503
(Q4)	0.476	0.49	0.474	0.458	0.471	0.515	0.531	0.475	0.494	0.463

Table 5:

Table 5										
Altern	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
(Q1))	0.0527	0.0535	0.527	0.0509	0.0513	0.0514	0.0509	0.0536	0.0508	0.0507
(Q2)	0.0519	0.052	0.527	0.0508	0.0478	0.0515	0.0516	0.0524	0.0509	0.0524
(Q3)	0.0476	0.0451	0.469	0.0522	0.0535	0.0454	0.0439	0.0461	0.0489	0.0503
(Q4)	0.0476	0.049	0.474	0.0458	0.0471	0.0515	0.0531	0.0475	0.0494	0.0463
v+	0.0527	0.054	0.053	0.052	0.054	0.052	0.053	0.054	0.051	0.052
v-	0.0476	0.045	0.047	0.046	0.047	0.045	0.044	0.046	0.049	0.046

Table 6:

Alternatives	S_i^+ (C1-10)	S_i^- (C1-C10)	P_i (C1-C10)	Rank
Refurbishment (Q1)	0.003838492	0.018367905	0.82714476	1
Conversion (Q2)	0.006389463	0.017400313	0.7314198	2
Demolition (Q3)	0.017823215	0.009894978	0.35698496	4
Procurement	0.015315897	0.011796972	0.435106	3