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Research Framework for Identification of Waste and Inefficiencies in Existing Public Office Buildings in Developing Nations for Sustainability

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Many countries, especially in the developing world, did not meet the UN target of 2002 to achieve sustainable development (SD) in their built environment mainly because the issue of existing buildings which form the bulk of building stock were not adequately addressed. This research paper examined the improvement of existing public office buildings in developing countries, using the *Lean Thinking* strategy for the identification of perceived waste and inefficient facilities for sustainability.
Study Design: The paper did a literature review on improvement models for sustainability.
Place and Duration of Study: Department of Real Estate Management, UTHM, Johor, from May, 2013 to date.
Methodology: The identified improvement models were examined from the perspective of their scope; the triple bottom lines of SD addressed; research framework; philosophies, paradigms; and their applications to decide an appropriate model for improvement of existing buildings for sustainability. A research framework was subsequently developed for the adopted model.
Results: The lean model and the diagnostic post-occupancy evaluation (POE) tool were adopted for the study, with a working depth limited to the systematic evaluation of opinion to determine

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waste and inefficiencies in the building from the perspective of the occupants, in order to assess how well the building match their satisfaction, expectancies and needs, and identifies ways to improve the building design standard, performance and fitness for purpose.
Conclusion: There is no doubt that there are a number of other factors and barriers that affect our ability to make existing building stock more sustainable. However, until these two major issues of *waste*, and *inefficient facilities* are addressed in built assets, the pace of SD in the developing countries may remain slow. The paper also revealed that the improvement of existing buildings is cheaper and more environmental friendly than rebuild, and will also reduce maintenance cost.

Keywords: Sustainable development; improvement; building performance; existing buildings; waste and inefficient facilities; lean thinking; zero emissions; green building.

1. INTRODUCTION

Over twenty years after the 1992 Rio UN Earth Summit, many countries especially in the developing world are yet to make considerable headway in the sustainability of their built environments. [1] In [2] observed that the developed world has huge numbers of buildings designed and constructed to standards that were barely adequate in their day and inadequate for today and tomorrow; and that those in the developing world are even poorer. [3] Also in [2] reported that despite efforts at both the local and international levels, current realities suggest that the goal of achieving sustainability in Nigeria is yet to be realized.

One of the major reasons attributed to this is the neglect of existing buildings which form the bulk of built assets in cities; they were developed decades ago when sustainability was not a consideration [4]. According to [5], sustainability cannot be achieved without addressing the existing building stock; even if every new building was a 'sustainable building', their impact on sustainability as a whole will be minimal for some time. Another reason ascribed is the top to bottom policy formulations and implementations approach prevailing in most developing countries [6]. Noted that one peculiar feature of governance in Nigeria is the use of Top-down approach to policy formulation and implementation. The principle of delegation is that authority should be delegated as far down the line as possible; an advantage is that those who are closest to the 'scene of action' may be regarded as the best persons to analyze and deal with the problems that arise [7]. Therefore, for any noteworthy impact to be achieved by developing nations in SD, it is vital that existing building stock should be given more considerations.

1.1 Statement of the Problem

In most countries, the improvement of existing buildings' standards (hence the performance) for sustainability have mainly been through retrofitting for energy and carbon dioxide emission reduction [8,9,10,11]. Some research have however revealed that even green building performance does not always reflect occupants' expectations [12,13,14], while [15] observed that fewer published studies have reported the use of end-user surveys during the design process to inform the improvement of the facility.

According to [16], current assessment systems of performance of existing buildings pose challenging problems because they do not provide a full profile of sustainability since they excluded inputs from building occupants; the performance of an end-user satisfaction survey can identify ways to improve the building performance and create a sustainable environment at little cost [17]. Observed that the scale and nature of interventions for any improvement measure can only be ascertained after gaining detailed knowledge of the building. For the sustainability of existing buildings to be achieved therefore, perceived waste and inefficiencies inherent in existing buildings should first be identified from the end-users' perspectives, since their contributions were not initially taken into consideration [18,19], after which improvement measures should be well-thought-out to upgrade the original building standard by minimizing or possibly eliminating inherent wastes and inefficiencies; thereby enhancing the building performance [19]. Defined end-users as the people who use or occupy the building; they are not experts in managing it, but have knowledge and opinions, nonetheless, about its performance in relation to their own objectives.

A shortcoming of existing buildings is that they were constructed based on past standards, while standards as measured by building regulations have tended to increase over time in as far as they improve sustainability. According to [5], there is no requirement generally to bring existing buildings up to the standards applicable to new buildings; thus most existing buildings are some way below sustainable standard. Therefore, the question that had risen is – can exist building's standard in developing countries be sustainably improved through the identification and eventual elimination of perceived waste and inefficiencies inherent in the design from occupants' viewpoints? There is a claim that UK businesses throw away £18 billion a year through the inefficient use of space [20,21]. This paper equally promotes a 'Bottom-up' approach, whereby improvement strategy and subsequent implementation would stem from occupants, being (as it were) closest to the 'scene of action'.

1.2 Research Questions

The research questions prompted in this paper are:

1. What are the perceived waste and inefficient facilities inherent in public office buildings in Nigeria from occupants' viewpoint?
2. How have these perceived inherent waste and inefficient facilities negatively affected public office buildings from occupants' perspective? and
3. How can these buildings' standard be sustainably improved through the elimination of the perceived waste and inefficiencies and guard against in future designs?

2. LITERATURE REVIEW

2.1 Concept of Sustainable Development

SD was defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs, it and came into general usage following the publication of the UN Brundtland Commission report [22]. [8] Observed that SD has emerged as a guiding paradigm to create a new kind of built environment. Fig. 1 is an illustration of typical issues addressed in SD: [24] listed other 60 published definitions of SD, while [25] also estimated between 30 to 60 separate definitions of SD; both observed that there is little agreement as to its meaning in practical or even theoretical terms. [26] Argued that SD is seen as a complex issue that is not consistently definable in practical terms owing to its very broad nature. According to [27], despite the efforts of the EU and national governments to provide a cohesive policy to address the negative impacts of SD, there is still considerable difficulty in providing a consensus definition of the term. Slessor, cited in [28] suggested that the Bruntland's commission definition only serves as a starting point and hardly sufficed as an analytical guide or policy directive. [25] went on to explain that, a particular difficulty with the considerable disagreement over its precise meaning is that it combined the political, philosophical and technical issues that remain unresolved from the "environment versus growth" debate [29]. Also identified SD as the most challenging and controversial issue with respect to its interpretation and application.

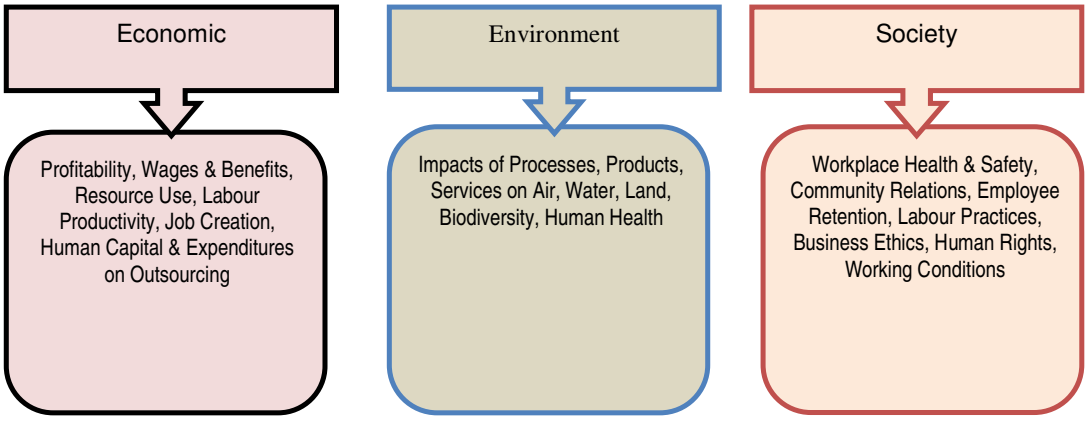

Fig. 1. Issues involved in the triple bottom line of SD [23]

In spite of the vagueness in its meaning, [30] presented SD as a universal challenge, in which *practical responses can only be defined nationally and locally*. Hence, it is more feasible for developing nations to define responses to SD within their local environmental, economic and social content. Thus, the application of SD principles should be tailored to local settings within a particular country, which should include the ethnic origin, culture, class, religion, gender, population, etc. as demonstrated by [31] in their study on public buildings in Malaysia. Many authors have noted that the same approach cannot be used universally to achieve SD noting that the same goal of sustainable city will not be suitable in quest of sustainability in all cities of the world, while societal and cultural resources are different [32,33]. This paper therefore addressed the issue of SD locally (i.e. considering ethnicity, culture, class, religion, gender, politics, etc.) from the perspective of occupants in public offices in the Nigerian context along the triple bottom line approach. Authors have researched on SD in Nigeria (a developing nation), but hardly on the improvement strategies for SD with respect to perceived waste and inefficient facilities inherent in built assets.

2.2 Waste and Inefficient Facilities in Existing Buildings

According to [34] *waste* is any activity, which absorbs resources but creates no value. *Waste* was defined as any material unused and rejected as worthless or unwanted; a trait of wasting resources, while *inefficient* was defined as not producing desired results, or lacking ability to perform effectively [35]. Adopting these definitions to buildings, *waste* could be seen as those partitions within or without the building(s), which the occupants do not need or find useful, for example, multiple passages or corridors in a building which could have been more useful to the occupants if converted to store(s) [36]. Referred to such as *inefficient spatial layout*.Utility costs of a building can also be increased when day lighting is not properly designed to replace artificial lighting.

Inefficiencies in built assets can be seen as a building or its components not having the qualities (or ability) to function efficiently. An example is a building having two-ply sliding window in a humid and hot environment without provision for artificial ventilation; in such situation, the window can only provide a maximum 50% opening as compared to louvres that can provide up to 95% opening. Thus the former has more of aesthetic value than functional value, which is the opposite of the latter. The sliding window may therefore be regarded as inefficient because it does not have the 'ability' to provide enough ventilation in a hot and humid environment without further provision for artificial ventilation, whereas it can be more efficient in temperate regions or in buildings with further provision for artificial ventilation such as air conditioners. This problem is more pronounced in developing countries where electricity supply is very erratic and thus, even the provision of artificial ventilation may still not solve the problem of the 'inefficient' windows.Again, day lighting is essential and can provide substantial benefits to occupants, but improper usage can lead to unpleasant conditions within the structure. Improper use of day lighting due to wrong design or placement of window(s) can reduce productivity in offices and increase employee absenteeism due to the possibility of extremely high lighting levels, excessive glare, and high temperatures [21]. Architects are often criticized for giving preference to aesthetics rather than functional values [37] thus creating most wastes and inefficiencies in buildings.

This paper appreciates that *waste* is extensively used in a different perspective in environmental management, especially for garbage, refuse, scraps, etc.: these could be termed *tangible waste*. However, in recent times *intangible waste* had also been identified, especially in production and management processes and has been promoted by models such as *Lean Thinking* and *Zero Emissions*. In this paper therefore, the *intangible waste* is been emphasized and it is considered as anything that does not provide value to the ultimate user, as in the concepts of *Lean Thinking* and *Zero Emissions*. In order not to confuse the two, waste and inefficiencies are many at times referred to as *muda* (Japanese word for intangible waste), as promoted by the lean model [38].

Thus, the improvement strategy of identification and eventual minimization or elimination of perceived waste and inefficiencies inherent in public office buildings from the perspectives of end-users would enhance building performance and ensure sustainability. There is no doubt that there are a number of other factors and barriers that affect our ability to sustainably improve our existing building stock. However, until these two

major issues of waste and inefficient facilities are addressed from end-users' perspectives, the pace of SD in developing countries may remain slow.

2.3 Improvement and Maintenance

This paper re-evaluated existing buildings and their role to sustainability through the improvement (as against maintenance) of their standards and it adopted the definition of improvement as a condition superior to an earlier condition [35]. In the context of this paper, maintenance means to hold, keep, sustain or preserve the building or structure to its original standard [39]. It is an act of maintaining, in which repairs or indeed replacement may well be necessary, but *the primary objective of all maintenance procedures is to avoid as far as practicable the need to repair or replace the structure* or its components [40]. The real problem in defining maintenance therefore is a lack of universal agreement as to what constitutes an acceptable standard [41]. This is of course a matter of conjecture and is generally subjective as each owner or tenant will have to establish his own standards based on factors such as usage of building; anticipated life; availability of capital, materials and manpower; changes in usage and personal or business prestige.

Improvement on the other hand means to upgrade; thus in maintenance activities, the original standard at construction is restored, while in improvement, it is upgraded Fig. 2. Maintenance measures carried out on non-sustainable existing building can therefore at best reinstate it to its original non-sustainable standard [5]. Pointed out that, "There is no requirement generally to bring existing buildings up to the standards applicable to new buildings; thus most existing buildings are some way below the standard of new buildings." According to [42], there is need for standards to be continuously revised to keep pace with continuous improvement.

The improvement of existing buildings' standard (hence performance) is considered by many authors to be an effective strategy for their sustainability [43,44,45]. [36] also observed that, "Improvements carried out during adaptive *reuse* were considered to provide the opportunity to link the performance of a building directly to the objectives of sustainability." *Reuse* was defined as "use again after processing" [35]. [46] noted that, capital sustainable improvement "resets the building life, improves performance, and makes the building's use more predictable for an extended period of time". [47] identified three stages in improvement process, namely: The *analysis*, *strategy* and *tactics* stages respectively. According to him, the analysis of the existing building leads to the development of a strategy that will provide an overall plan for the design of the building whilst the tactics provide the detail of what the improvement strategy looks like. This understanding can generate the strategy and tactics of the redesign. This paper thus dwelt more on the analysis stage, while the technical latter stages are best addressed by other professionals in the built environment, especially the architects and engineers, who are better qualified to do so.

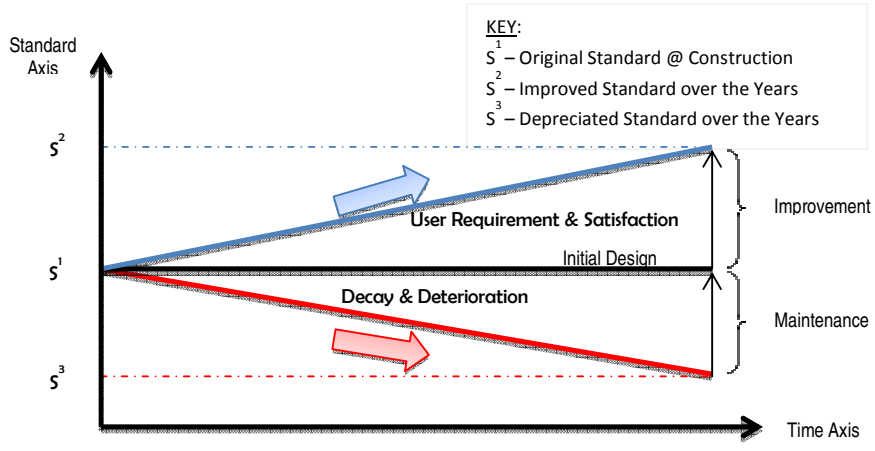

Fig. 2. Maintenance and improvement [48]

In literature, many terms are used to describe improvement tactics, but such terms were not used in this paper save in relevant quotations in a bid to produce consistency. The terms include a*daptation*, *refurbishment*, *rehabilitation*, *remodeling*, *retrofitting*, *revitalization,* among others; this paper adopted [49] suggestion that in a discipline, there is need for a common language which allows communication across related topics without fear of misunderstanding.

2.4 Improvement of Existing Buildings for Sustainability

The rate and scale of improvements needed to existing buildings to "save the planet" are immense and extensive programmes are seen as necessary by [1]. It would be difficult to achieve SD in our cities if the issue of existing buildings is not addressed since they form the bulk of buildings. [5] noted that, "No building is an island. Buildings relate one to another and to the infrastructure, which links and serves them and their users. There are, for instance, cultural, heritage and physical links to be built upon and added to by new buildings and improvements to existing buildings." [50] added that, not only does improvement extend the economic life of existing buildings; it also improves "the living environment, increase property values, reduces the urgency for redevelopment, and enhances public safety and the image of city".

[47] observed that improvement of existing buildings is an attempt to preserve our cultural heritage, and thus large numbers of existing buildings are improved in preference to demolition. Also in agreement, [51] observed that building improvement finds it significant in "combating building deterioration and delivering building sustainability." [1] observed that in spite of their poor construction and condition, older properties are more attractive to many because they are part of existing urban communities and often cheaper to purchase than new homes on barren estates at the town periphery. Many writers have also agreed that increasing the life of a building through reuse can lower material, transport and energy consumption and pollution and thus make a significant contribution to sustainability (e.g. [16,52,53].

2.5 Benefits of Improvement of Existing Buildings over Rebuild

One benefit is that when a building standard is sustainably improved, it is expected that the maintenance cost would considerably reduce. [54] Noted that "maintaining infrastructure is a constant and expensive process which is often neglected in favor of more attractive political goals." Adequate maintenance financing is but one of the major factors affecting the sustainability, because poorly managed infrastructures steadily deteriorate, become congested, or become unsafe and clearly are not sustainable. [55] Also argued that, compared to newly built, improvement of existing buildings would postpone, if not avoid the obsolete process of buildings and it will greatly enhance the building performance. [56] advised that the principles of sustainable development must take into account operating and maintenance costs so as not to 'burden' in the future.

Another benefit of improvement of existing stock is the growing perception that the improvement of existing building is far cheaper financial-wise than to demolish and rebuild [57,11]. [58] reported a major research finding in Indonesia that cost of improvement is less compared to the cost of demolition and rebuilding. The improvement option further saves the cost as it is time saving and the downtime is less. [59] Also supported this view, that improvement is inherently sustainable because it involves less of resources consumption, transport energy, energy consumption and pollution during construction.

[60] however advised that it is potentially cheaper to improve than to demolish and rebuild as long as the structural components already exist, and the cost of borrowing is reduced, as contract periods are typically shorter. Improvement is applied to buildings capable of modernization, while rebuilding is necessary where buildings are too worn out to be renovated. On the contrary, [59] believes that since new build is comparatively more straightforward, then costs are often lower than improvement.

A third benefit of improvement is its environmental friendliness. The weight of enlightened opinion favours improvement of existing buildings because it offers a more efficient and effective process of dealing with buildings than demolition. It is deemed to be a safer strategy as it reduces the amount of disturbance due to hazardous materials, contaminated ground and the risk of falling materials and dust. In particular, site work is also more convenient as the existing building presents a work enclosure that reduces downtime from inclement weather [53,61,62].

Again, improvement enhances building performance and is considered to be an effective SD implementation tool for existing buildings [43,44,45]. [63] said that the challenge of achieving SD in the 21st century will be won or lost in the urban areas with policy makers believing that improvement of existing buildings will deliver sustainability in the built environment.

2.6 Factors Affecting Improvement Implementation

Notwithstanding the evidences clearly suggesting that improvement has significant long-term benefits to offer, the decision as whether to improve or demolish can be exacerbated by an array of interacting variables that converge around financial issues and include the following: Building's structural layout and its capacity to accommodate required spaces and functions; Energy efficiency of the building's walls, windows and roof; Building's potential for meeting building, heath, safety and accessibility requirements; condition of mechanical, plumbing and electrical systems and their capacity for modification; The presence of hazardous materials; ability of the building and site to provide a safe and secure environment; and Convenience and safety of the building's location [11,60,61,62].

2.7 Sustainable Improvement Models

Three models were examined during the literature review that mainly deal with sustainable improvement, they are: (1) *Lean Thinking*, (2) *Zero Emissions* and (3) *Green Building*. They promote elimination of waste and inefficiencies for sustainability.

2.7.1 Concept of lean thinking

Lean thinking has the underlying philosophy that, by identifying and eliminating *muda* (Japanese word for waste), standard and performance can be improved and costs reduced [64]. According to [65], lean thinking is an improvement model that emphasizes continuous minimizing (or ultimately eliminating) all types of *muda* and the delivery of high quality products. It has its origin in the philosophy of achieving improvements in most economical ways with special focus on reducing *muda* [34]. [38] classified these *muda* into seven categories namely: *transportation*, *motion*, *inventory*, *over-processing*, *waiting*, *overproduction*, and *defects*; many have however added the eighth - *muda* of "*unused human talent*" e.g. [34,66,67].

[42] wrote that the two overarching philosophy of lean thinking for sustainability are *elimination of waste* and *continuous improvement* (or *kaizen* in Japanese). [68] explained that *kaizen* is "a system of continuous improvement in quality, technology, and safety", while [69] defined it as the effort for perfection which is never reached, but creates the urge to make improvements: there is no end for waste elimination. The concept emphasized that value is defined by the customer (i.e. the end-user).

[42] explained that the concepts of lean production applies to a vast range of operation and processes in widely differing industries, offices, health care, etc. with only "tweaking of details". Thus, varying industries have since adopted the concept, including the construction industry from whence terms such as "lean construction", "lean design" and "lean management" emerged. The substantial argument was the claim that the approach had delivered large improvements in manufacturing, in particular the motor vehicle industry, and where already applied in construction.

2.7.2 Concept of green building

According to [10], SD gave rise to green buildings, because a primary goal of sustainability is to reduce humanity's environmental footprint on the planet. The green building concept is also observed as an improvement strategy just like lean thinking. [65] noted that there is a natural connection and synergy between *lean thinking* and *green building*: both disciplines are dedicated to limiting waste and increasing process efficiency." Fig. 3 illustrates some key components of Green Building.

2.7.3 Concept of zero emissions

The Zero Emissions concept was postulated by Gunter Pauli in 1994, it advocates for complete elimination of waste, termed "zero waste" by converting waste in value as an improvement strategy [71]. It derived its motivation from the ecosystem in which nothing in nature is a waste, but rather what is waste for one is food for another [72]. According to [71], sustainability can only be achieved if the final target is Zero Emissions. The three main objectives of Zero Emissions are summarized as: (a) No waste; (b) all inputs are used in production; and (c) when waste occurs, it is used to create value

elsewhere, such that "the integrated whole produces no waste of any kind" [72].

The research scope, framework, philosophies and application of *lean thinking* approach compliments this study research design as highlighted in Table 1, and were thus adopted in this study.

Fig. 3. Key components of green building [70]

Table 1. Research approaches of the improvement models

Description	Lean	Zero emissions	Green building
Scope	Identifies and eliminates waste wherever it exists	Converts waste into value	Energy and CO_2 emission reduction for climate change
Triple bottom line of SD addressed	Environment, social and economy	Mainly the environment and economy	Chiefly the environment
Research framework	Theoretical framework	Conceptual framework	Theoretical/ conceptual framework
Philosophies & paradigms	Positivism (realism); objective (value free); deductive	Interpretivism (idealism); Subjective (value laden); Inductive	Positivism (realism); objective (value free); deductive
Applications	Social sciences	Pure science	Pure science

3. METHODOLOGY

The research design adopted the quantitative method which was supported by qualitative method, while the research strategy involved the use of survey, observation and case study approach. Qualitative method involved the review of relevant literature, which include the concepts of SD; end-users' satisfaction; and sustainable improvement models which deal with identification and eventual elimination of waste and inefficiencies, to determine the most relevant for the study; and from which questionnaires are designed and administered to the occupants of case study building through quantitative method. Quantitative method would involve the use of SPSS to analyze data.

The diagnostic post-occupancy evaluation (POE) tool was adopted for this study, while its working depth was limited to the systematic evaluation of opinion to determine waste and inefficiencies the building from the perspective of the occupants through questionnaires, in order to assess how well the building match their satisfaction, expectancies and needs, and identifies ways to improve the building design standard, performance and fitness for purpose [23].

This paper re-evaluated existing buildings and their role to sustainability through the improvement of their standards and it focused on enhancing the performance of existing public office buildings through the identification of perceived waste and inefficient facilities inherent in them from end-users' viewpoints. To this, a massive public building in Nigeria – The 4-storey, double-winged Federal Secretariat building, off Yakubun Bauchi Road, Bauchi, Bauchi State (see Plate 1),was adopted as case study for the following reasons:

a. It was designed and built in 1989,when sustainability was not an issue [4];
b. It is massive with tens of offices and over a thousand staff reflecting federal character and quota system of the nation;
c. It reflects and provides a rich blend of the varied ethnic groups, culture, language and religious beliefs; reflecting federal character and quota system in which every part of the country is fairly equally represented [30];
d. It is still operational and not abandoned; and
e. It has not undergone any major improvement work since its construction.

Nigeria was chosen mainly because the research student is a Nigerian, and thus it eased the time frame, cost implication and data collection for the study.

The *Lean thinking* model was adopted using the POE tool to acquire data from occupants regarding perceived waste and inefficiencies inherent in the building. This was related to the SD triple bottom line (TBL) approach [73], covering environmental, economic and social dimensions, but limited to:

(a) The 'environment' involves issues of temp., ventilation, air quality, glare, daylight and noise.
(b) The 'economy' includes issues of occupants' satisfaction through the provision of adequate space, services and equipment thereby increasing performance. A leading argument for economic sustainability is the belief that sustainable buildings are healthier and lead to less employee absenteeism and higher levels of productivity thereby boosting the overall profitability of business occupiers [74].
(c) The 'social' embraces the issue of aesthetics; where buildings having pleasing aesthetic qualities enhance their surroundings and the well-being of people within the immediate neighbourhood [75,76]. [77] however noted that undoubtedly there is a strong and often overlapping relationship between the three components of the TBL Fig. 4.

The study dwelt only on the building superstructure i.e. that part of the building which is above the ground and serves the purpose of building's intended use. The lean thinking framework for undertaking improvement activities in a systematic way bears the acronyms RDMAIC [79] and involves the following stages:

Plate 1. Federal secretariat building, Bauchi, Bauchi State, Nigeria (Field survey, 2014)

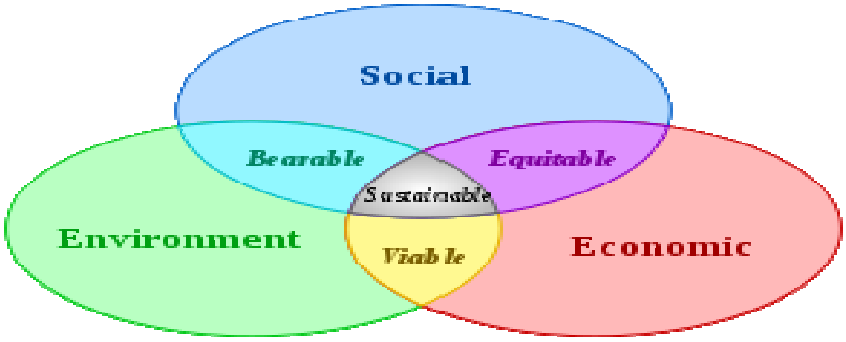

Fig. 4. Overlapping triple bottom line components of SD [78]

- Recognize the right problem to work on.
- Define the problem, voice of the end-user, and project goals, specifically.
- Measure key aspects of the current design and collect relevant data.
- Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
- Improve or optimize the current standard based upon data analysis.
- Control: the need to ensure that the goal is achieved and held. Putting a control plan in place is vital to ensure that the process is carried out consistently. There is also need for the design to be flexible.

The current study's scope of study, using RDMAIC is however limited to the identification of the perceived waste and inefficiencies from occupants' viewpoint as explained in Fig. 5 below:

The *lean thinking* variables, as modified for this study are shown in Table 2.

3.1 The Research Framework

Fig. 6 explains the proposed research framework for this study, which basically comprises the identification, of *muda* (waste & inefficiencies) in existing public office buildings through the use of diagnostic POE, and their eventual elimination (through an improvement strategy), thereby giving rise to an environmentally, socially and economically sustainable building which meets the needs of the present without compromising the ability of future generations to meet their own needs.

This study employed three (3) inquiry levels based on the research questions earlier determined, and objectives of the study as presented in Table 3.

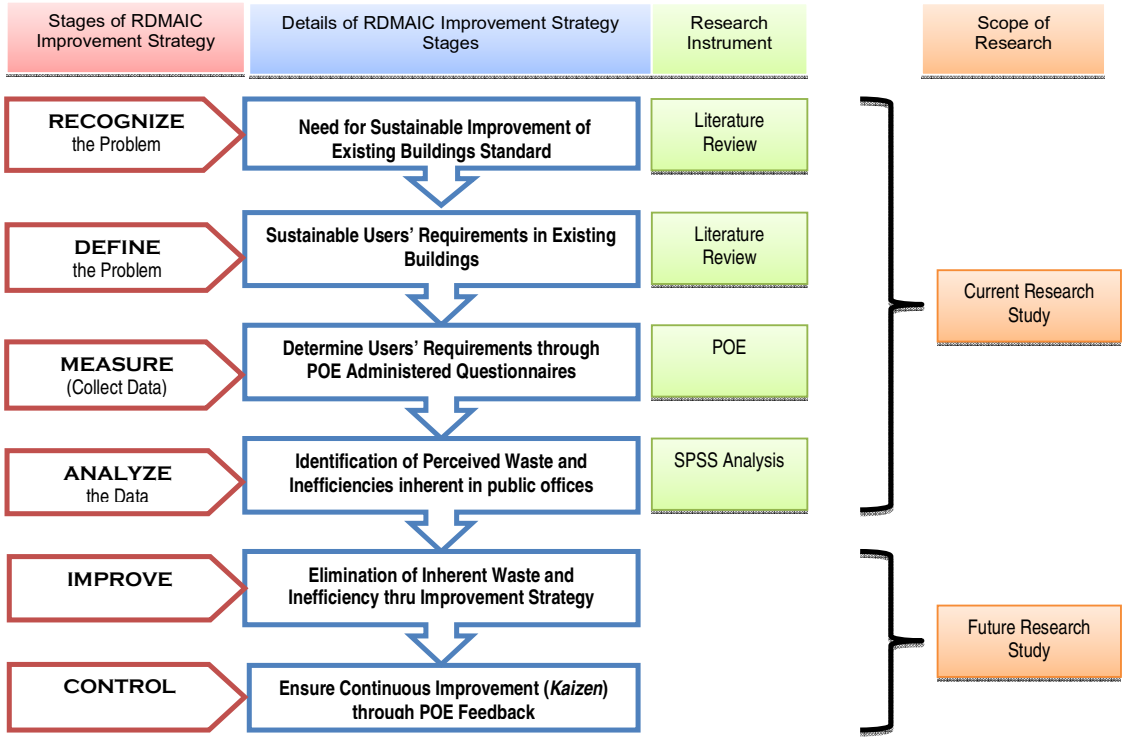

Fig. 5. Proposed scope of current research

Table 2. Types of *muda* for current research [2]

S/N	Type of *muda*	Modified description
1	Waiting	Delay, due to inadequate provisions for access to carry out maintenance activities, etc.
2	Overproductio n	Large accommodation space, too many corridors, etc. not needed or appreciated by users.
3	Inventory	Building materials kept for maintenance that are not necessary or have short life spans.
4	Motion	Wasted human motion is related to workplace: ergonomic design negatively affecting productivity, quality & safety e.g. walking, reaching and twisting [80].
5	Over-processing	Adding design features not needed by users, e.g. bath tubs in general convenience; irregular office shapes thereby reducing functionality; etc.
6	Transportation	Distant location of complimentary offices causing unnecessary movements for users.
7	Defects & Errors	Inadequate design, improper execution of the work, defective materials: including inflexibility; wrong specifications leading to dampness, excessive condensation and possibly electrical faults, etc.; inadequacies (e.g. toilets, ventilation, lightening); etc.
8	Human talent	Non-inclusion of end-users' input in design, maintenance or improvement. How could people be better involved in continuous improvement?

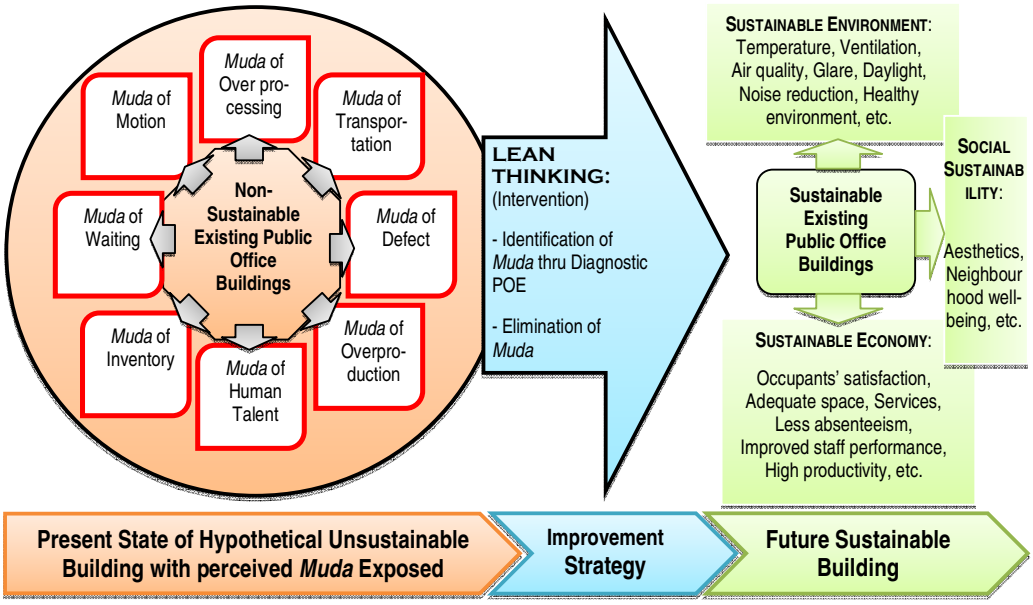

Fig. 6. Research framework for the study

Table 3. Research framework to identify *muda* in public office designs in Nigeria

Area of investigation	Data collection method	Method of data analysis	Purpose/aim	Expected results
Identification of perceived waste and inefficiencies in public office buildings in Nigeria.	Questionnaires/ Personal observation.	Simple percentage distribution tables, charts, use of SPSS for data analysis, narrations and discussions.	Answer to research Objective 1: To establish perceived waste and inefficiencies inherent in the public office buildings in Nigeria from occupants' perspective.	The prevalent inherent waste and inefficient facilities in public offices in Nigeria from occupants' viewpoint.
Effects of waste and inefficiencies in public office buildings in Nigeria from occupants' perspective.	Questionnaires/ Personal observation.	Simple percentage distribution tables, charts, use of SPSS for data analysis, narrations and discussions.	Answer to Research Objective 2: To examine the effects of these perceived waste and inefficiencies inherent in public office buildings in Nigeria from occupants' perspective.	Significances of inherent waste and inefficiencies in existing public office buildings.
Elimination of inherent waste and inefficiencies in future public office buildings in Nigeria.	Questionnaires, personal observation, survey.	Simple percentage distribution tables, charts, use SPSS for the data analysis narrations and discussions.	Answer to Research Objective 3: To identify features to be incorporated in future designs with a view to eliminate or minimize waste and inefficient facilities in public office buildings.	Performance based outline for sustainable improvement of existing public offices in Nigeria.

4. CONCLUSION

It is hoped that the findings of this study will highlight perceived waste and inefficiencies inherent in public office buildings' design and layout from end-users' viewpoints, and further outline features to be incorporated in future designs with a view to eliminate or minimize waste and inefficient facilities in public office buildings based on performance metrics. This seeks to generate more sustainable public office buildings from existing stock in developing nations. The significance of this research thus includes the following:

Firstly, it will inform developers as to the actual requirements of end-users in public offices, based probably on culture and education: it is expected that future design of sustainable office buildings with adequate provision for users' requirements will enhance building performance with respect to acoustic; thermal; day-lighting; and air/ventilation qualities, and produce healthier buildings which leading to less employee absenteeism and higher levels of productivity thereby boosting the overall profitability of business occupiers [21].

Secondly, it would promote a system of "Bottom-up" approach to policy formulation and implementation as against the Top-down approach prevalent in many developing countries [6]. Delegation is essential in any organization, because those who are closest to the scene of action may be regarded as the best persons to deal with the problems that arise and considerable times may be saved by not sending information up and down the reporting authority line.

Thirdly, it would give advice to designers and planners on how to combine aesthetics with functionality. Architects are often criticized for giving preference to aesthetic values rather than functional [37], and in so doing are mainly responsible for most *waste and inefficiencies* in building designs. [11] Observed that each building type is unique with different characteristics and that the improvement strategy used in one type may not be suitable for use in another.

Fourthly, the roles of end-users will be highlighted in SD as they make contributions to building designs, thus promoting synergy of more stakeholders in which each contributes discipline-specific data in the built environment as against far narrower definition of success by different individual participants. Finally, this research will also promote SD as a whole whereby we do not 'steal' from future generations by spending more resources than necessary today [5,81].

There is no doubt that there are a number of other factors and barriers that affect our ability to make existing building stock more sustainable. However, until these two major issues of *waste*, and *inefficient facilities* are addressed in built assets, the pace of SD in the developing countries may remain slow.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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