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Effect of Perceived *Muda* on Design Features in Public Office Buildings in Nigeria

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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: The claim that the concept of lean thinking, especially the application of *muda* is applicable to a vast range of operations and processes in widely differing industries, offices, health care, etc. with only "tweaking of details" was tested in this paper on design features as a further step to determine its relevance to sustainable improvement of existing public office buildings in Nigeria. The substantial argument was that the concept had delivered large improvements in manufacturing, in particular the motor vehicle industry, and where already applied in construction, hospitals, etc.

Study Design: The theoretical framework study adopted an objective positivist philosophy from a deductive approach, using survey and case study strategy. The method is quantitative while the time horizon is cross-sectional.

Place and Duration of Study: Federal Secretariat office complex, Bauchi, Nigeria, between June 2014 and September 2014.

Methodology: AMOS regression was used for the confirmatory study on a sample size of 339 respondents from a diagnostic POE. The unique contribution, causal effect, effect size and practical significance were used in determining the effect of *muda* on design features.

Results: The study revealed that *muda* is inherent in public office buildings. The result indicated that perceived *muda* has a causal effect of 0.757 on design features such that if *muda* goes up by

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1 unit, design features will also go up by 0.757 unit. The R^2 of 0.57 showed a strong effect size of *muda* on design features, while the estimates have highly significant coefficients with P-values of <.05, confirming its practical significance in daily life.
Conclusion: This study concludes that perceived *muda* has strong influence on design features, especially by affording end-users to contribute to their requirements in office buildings. Perceived *muda* explained 57% of the variance in design features and has high practical significance. This had confirmed that lean thinking is applicable to public office buildings in Nigeria and therefore relevant to their sustainable improvement.

Keywords: Lean thinking; muda; design features; sustainable improvement; user requirement.

1. INTRODUCTION

Over 20 years (termed Rio + 20) after the UN Earth Summit of 1992 in Rio de Janeiro, Brazil in which it called on member States to adopt and integrate the principles of Sustainable Development (SD) into their national policies and programmes, many countries, especially in the developing world were yet to make significant headway in their quest for SD of their built environment [1,2].

A major cause for this was attributed to the neglect of existing buildings which form the bulk of built assets in our cities [3]; they were developed decades ago when sustainability was not an issue [4]. Wood [5] argued that sustainability is not achievable without addressing existing building stock as it is improbable that new build alone would deliver a sustainable built environment in the near future.

This paper thus looks at the sustainable improvement of existing public office buildings in Nigeria, especially the impact of *muda* on design features. Brandon & Lombardi [3] estimated that 87% of existing building stock will still stand by 2050 which is an indication that existing building stock requires effective sustainable improvement that will sufficiently reflect users' requirements, especially in developing countries like Nigeria with an estimated population of over 170 million people [6], the 6th most populous country in the world, the most populous and largest economy in Africa [7]. Public office buildings in Nigeria was selected, because they are constant subjects of discussion by eminent Nigerians and scholars alike in the country, while they form the bulk of Nigerian property news in publications and on the internet.

2. LITERATURE REVIEW

2.1 Waste and Inefficiencies (*Muda*)

Failures of basic building functions can range from defects in single components such as windows to extensive deficiencies in an entire exterior wall system. The source of these deficiencies can include inadequate design, improper execution of the work, defective materials, or simply normal and expected aging perhaps coupled with lack of maintenance [8]. Womack & Jones [9] equated these failures to waste and inefficiencies (or *muda* in Japanese), which was defined as any facility that absorbs resources but creates no required value. The Advanced English Dictionary [10] defined *waste* as any material unused and rejected as worthless or unwanted, while *inefficient* was defined as not producing desired results, or lacking ability to perform effectively. Waste and inefficiencies incurred in utility costs on a building can be reduced when day-lighting is properly designed to replace electrical lighting. While day-lighting is essential and can provide substantial benefits to occupants, improper usage can lead to unpleasant conditions within the structure; the benefits of day-lighting will only be realized if it is implemented correctly. 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 [8,11]. According to Spring [12], architects are often criticized for giving preference to aesthetics rather than functionality and are mainly responsible for most waste and inefficiencies inherent in building designs.

This paper appreciates that waste is extensively used in a different perspective in environmental management, especially for garbage, refuse, scraps, etc.; which could be termed tangible waste. However, in recent times intangible waste had also been identified, especially in operations and has been promoted by models such as Lean Thinking, Zero Emissions and Green Building. In this paper therefore, the intangible waste was emphasized above tangible waste and it was considered as anything that does not provide required value to the ultimate user [9]. In order not to confuse the two, waste and inefficiencies in this study were henceforth referred to as '*muda'* (Japanese word for intangible waste and inefficiency, as promoted by lean thinking).

2.2 The Concept of *Muda* in Lean Thinking

According to Lamb [13], lean determines what is truly important to the end-user and consequently reshapes, to deliver it; along the way, *muda* drops out. The model has the underlying philosophy that, by identifying and eliminating inherent *muda*, standards (hence performance) can be improved [14]. The concept of lean tries to minimize non-value adding activities (i.e. *muda*) thereby increasing efficiency; it stressed that value is defined by end-user thus gave preference to end-users' requirements [15]. Taiichi Ohno, a famous production engineer with Toyota Motors in the early 1950s, classified *muda* into 7 drivers, namely: Defect/error, inventory, waiting/delay, motion, transportation, over-processing and overproduction [16]; this later metamorphosed into what is now branded as lean thinking by Womack et al. [17]. Womack & Jones [9] subsequently added the 8th driver - human talent.

Nicholas & Soni [18] opined that the concepts of lean thinking 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 and lean design emerged. The substantial argument was the claim that the approach had delivered large improvements in manufacturing, in particular in the motor vehicle industry, and where it had already applied in construction.

Schipper & Swets [19] and Finch [20] also argued that *muda* is universal, appearing in every situation and they remain constant, but the definitions of the terms will change and adapt to describe the situation to which it is to be applied. They argued that as any new situation is approached for the application of lean thinking, the definitions of the drivers of *muda* can be customized to fit the specific circumstances. Table 1 depicts the concept of *muda* adopted for this study with regards to the targeted concept and objectives. DeVellis [21] claimed that theory plays a vital role in the conceptualization of measurement variables.

2.3 Design Features

Arge [26] listed 3 improvement concepts based on the Norwegian Building Research Institute (NBRI) definitions, related solely to physical design of buildings, and do not include, for example, financial or contractual flexibility, namely:

(a) *Generality* - the ability of a building to meet changing functional user or owner needs without changing its properties;
(b) *Flexibility* - the ability of a building to meet changing functional user or owner needs by changing its properties easily; and
(c) *Elasticity* - the ability of a building to be extended or partitioned related to changing user or owner needs.

Arge [26] defined generality in architectural terms as design of a building and its space and services for multifunctional use (Table 2). Flexibility on the other hand refers to the built-in possibilities of a building to be re-arranged, taken away or added new elements and systems when the needs of the users change, while Elasticity means the possibility of dividing the building into different functional units or to be extended horizontally or vertically).

These NBRI concepts were adopted for this study because they are related to the physical design of the building, which is in line with the scope of this study and was thus used as a check for the feasibility of the adoption of the case study. Arge [26] also classified design features into 3 (Table 3), namely; *Spatial plan* (offices and ancillary spaces layout/design); *Structure* (building elements and finishes); and *Facilities* (facilities and services/utilities); these were adopted for the study because they are relevant to the study objectives and scope, which was limited to the super structure only.

3. METHODOLOGY

Quantitative method was adopted for the theory testing study, which was supported by qualitative method, while the research strategy involved the use of survey, direct observation and case study approach. Qualitative method involved the review of relevant literature from which questionnaires were designed and administered to the occupants of case study building. Quantitative method involved the use of SPSS, AMOS (being a confirmatory analysis tool), while the causal effect, effect size and practical significance [27] were used in determining the effect of perceived

Table 1. Concept of *muda* drivers for office buildings [22]

S/N	*Muda* drivers	Modified description
1	Defect	Situation where one or more elements of a building do not perform their intended function [23]; and failure in the function, performance, statutory or user requirements of a building that manifests itself within the structure, fabric services or other facilities of the building [24].
2	Inventory	Storage facilities; and building materials kept for maintenance that are not necessary or have short life spans.
3	Waiting	Delay, due to inadequate provisions for access to carry out maintenance activities, etc.
4	Motion	Wasted human motion is related to workplace: ergonomic design negatively affecting productivity, quality & safety e.g. walking, reaching and twisting [25].
5	Transportation	Distant location of complimentary offices and other ancillary rooms causing unnecessary movements for users.
6	Over-processing	Adding Design Features not needed by users, e.g. bath tubs in general convenience; irregular office shapes that reduces functionality; etc.
7	Overproduction	Large accommodation space, too many corridors, etc. not appreciated by users.
8	Human talent	Non-inclusion of end-users' input (or talent) in design, maintenance or improvement policies. How could people be better involved in continuous improvement?

Table 2. Measures involved in the NBRI concepts of improvement [26]

S/no.	Description	Implication
1	Generality	Allows for different work place design or solution
2	Flexibility	Most commonly used as flexibility measure in buildings Allows for fast changes of layouts or technical parts of services Contributes to rapid & easy moving of internal walls
3	Elasticity	Allows for parts of the building to be used by different organisations or user groups Separates functions with different functional performance, allowing for the building to be used by different organisations or user groups Allows for large continuous space units Eases changes in the configuration of spaces

Table 3. Three components of design features (adapted from [26])

S/no.	Design features' sub-constructs	Items (observed variables)
1	Spatial plan	Offices design (OFFD)/layout (OFLT); ancillary rooms' design (ARMD)/layout (ARML); and overall building design (BLGD).
2	Structure	Walls (WALL); floors (FLOR); windows (WIND); doors (DORR); ceiling (CEIL).
3	Facilities	Water (WATR); electricity (ELTR); ICT facilities (ICTF); security (SECU); and other facilities such as Parking lot, fire-fighting equipment, safety measures, storage facilities, cooling devices, etc. (OFAC).

muda on design features. Preliminary analyses were performed on all the measurement models using the Confirmatory Factor Analysis (CFA) to ensure no violation of the assumptions of unidimensionality, validity, reliability and normality, such that any item that does not fit the measurement model was removed.

The diagnostic POE tool was adopted for this study, while its working depth was limited to the systematic evaluation of opinion to establish perceived *muda* and its effect on design features from occupants' perspective through questionnaires, in order to assess how well the building match their satisfaction, expectancies and needs, and identifies ways to sustainably improve the building standard, performance and fitness for purpose [28]. Acquired data relates to the SD triple bottom line (TBL) components of environmental, economic and social dimensions [29], but limited to:

(a) Issues covered by the 'environment' include temperature, ventilation, air quality, glare, daylight and noise [30];
(b) Issues covered by the 'economy' include occupants' satisfaction and comfort through the provision of adequate space, services and facilities thereby increasing job productivity. Satisfaction with the physical working environment seems to be directly related to job productivity [31].
(c) Issues of aesthetics covered by 'sociality'; where buildings having pleasing aesthetic qualities with prompt repair and regular upkeep, enhancing their surroundings and the well-being of humans [32].

The Federal Secretariat complex, Bauchi (Fig. 1); a massive public building in Nigeria was chosen as case study because of more dire need for improvement in developing nations [2,33,34]. Eisenhardt [35] suggested that a single case study method tends to be more appropriate to confirm or challenge a theory or address a rare or unusual situation.

The case was selected because of the circumstances surrounding it and the researcher's in-depth local knowledge of the building as listed below:

i. The building was designed and constructed decades ago when sustainable development was not a consideration [4];
ii. It has not undergone any major improvement work since its construction;
iii. The building is still operational and not abandoned;
iv. It is a massive structure with 26 government offices and large number of staff;
v. The staff combination reflects the federal character and quota system of the nation [36], and;
vi. The building meets the measures of the NBRI improvement concepts [26].

The variance in design features was diagnosed from an integrated perspective [37], first using the simple frequency distribution of the processed data from user standpoint based on the design feature data sets [26] after which AMOS regression analyses were conducted to determine whether the sub-constructs loads well and to evaluate the causal effect.

4. RESULTS AND DISCUSSION

4.1 Establishment and Ranking of Perceived *Muda*

Fig. 2 depicts the regression weights of the *muda* drivers predicting perceived *muda,* while Table 4 showed the summary of the good Fitness Indexes (FI). The study confirmed that *muda* is inherent in the subject building thus confirming Nicholas & Soni [18], Schipper & Swets [19], and Finch [20] who argued that *muda* is universal, appearing in every situation and they remain

Fig. 1. Federal secretariat complex, Bauchi [22]

constant. The results showed the respective standardized beta coefficients of the drivers (Fig. 2). According to Pallant [38], the *muda* driver with the largest beta coefficient makes the strongest unique contribution to explaining perceived *muda*. Thus the drivers were ranked in order of prominence based on their respective beta coefficients and corresponding R^2 in the following order: Inventory; Defect; Over-processing, Over-Production, Motion, Transportation, Human Talent and Waiting (Table 6).

The effect size of R2 of the *muda* drivers are all strong, save Waiting (WAT) with a moderate range of 0.22. Table 5 shows the interpretation of effect sizes by [27,39].

Table 6 shows the regression weights of the *muda* drivers have significant coefficients; the drivers were thus ranked according to their beta coefficients, which is an indication of the unique contribution of each driver to explaining perceived *muda* [38].

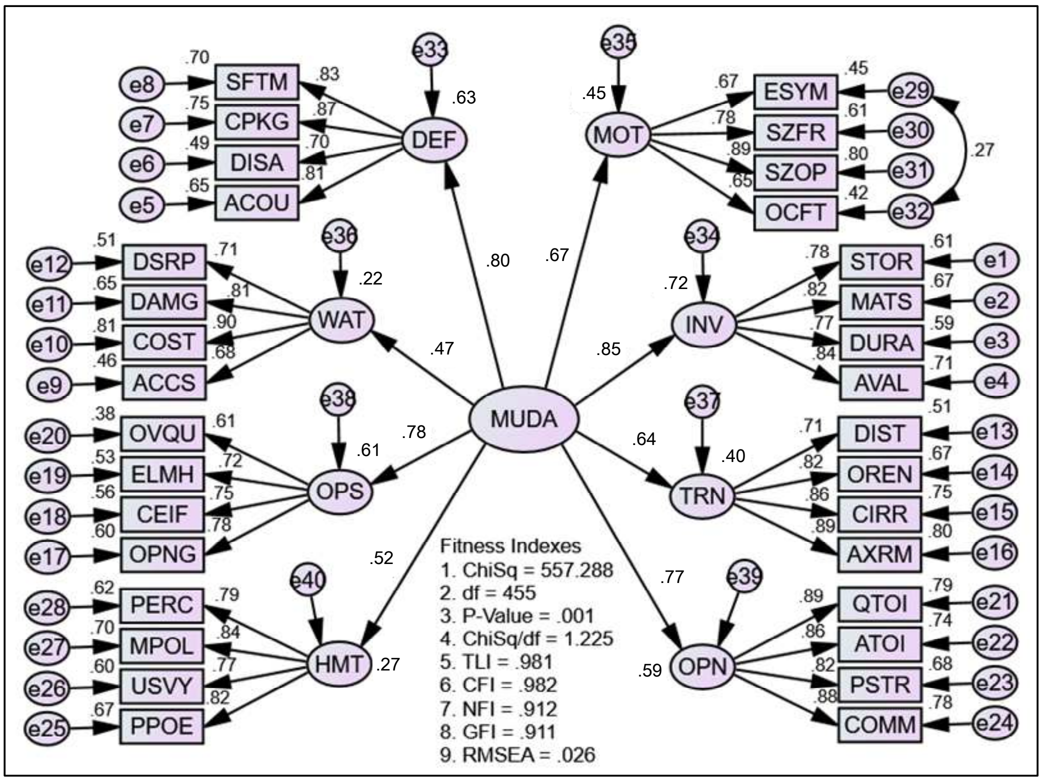

Fig. 2. Regression weights of sub-constructs predicting *muda*

Table 4. Summary of fitness indexes for *muda* constructs

Name of category	Name of index	Index value	Comments
Absolute fit	RMSEA	0.026	The required level is achieved
	GFI	0.911	The required level is achieved
Incremental fit	CFI	0.982	The required level is achieved
Parsimonious fit	Chisq/df	1.225	The required level is achieved

Table 5. Interpretations of effect sizes (R^2)

Cohen (1988)		Adams & Lawrence (2015)	
Range of R^2	**The effect size**	**Effect size range**	**Interpretation**
Below 0.13 (i.e. 13%)	Small range	1-4%	Weak
Between 0.13 to 0.26	Medium range	9-25%	Moderate
Above 0.26	High range	25-64%	Strong

Table 6. The regression weights and P-value of sub-constructs predicting *muda*

Sub-constructs	Path	Main construct	Beta estimate	S.E.	C.R.	P-value	Result	R^2	Beta ranking
HMT	⟵	*MUDA*	.523	.109	7.000	***	Significant	0.27	7
OPN	⟵	*MUDA*	.770	.231	7.082	.004	Significant	0.59	4
OPS	⟵	*MUDA*	.782	Reference point				0.61	3
TRN	⟵	*MUDA*	.636	.101	7.531	***	Significant	0.40	6
MOT	⟵	*MUDA*	.669	.237	5.980	***	Significant	0.45	5
WAT	⟵	*MUDA*	.472	.057	3.814	.025	Significant	0.22	8
INV	⟵	*MUDA*	.848	.098	9.006	***	Significant	0.72	1
DEF	⟵	*MUDA*	.796	.092	5.730	***	Significant	0.63	2

**** indicates highly significant at <0.001 [40,41].*

4.2 The Variance in Design Features from Users' Perspective

The simple frequency distribution of the data acquired during survey depicted in Table 7, showed users' perception of the variance of design features within the office complex; only Facilities was perceived poor from end-users perspective.

4.3 Design Features Construct Loads Well on Its Sub-Constructs

Fig. 3 depicts the regression weights of design features' constructs with good FI (Table 8). The results showed that design features load well on its 3 sub-constructs; with factor loading of 0.78 on Spatial Plan (SPL), is 0.69 on Structure (STR) and 0.97 on Facilities (FAC) (Fig. 3). They are also above the threshold of 0.6 and thus confirm that design features consist of the three components and can thus be used for further analysis [40]. Table 9 shows the path analysis of design features on its sub-constructs, together with their respective level of significance and beta estimate.

4.4 Causal Effect of Perceived *Muda* on Design Features

Fig. 4 is the proposed structural model with good FI (Table 10), and it depicts the causal effect of perceived *muda* on design features (Table 11). The beta estimate of 0.757 reflects the amount of causal effect of perceived *muda* on design features i.e. when *muda* goes up by 1 unit job productivity will also go up by 0.757 unit. Furthermore, the R^2 of 0.57 (Fig. 4) revealed a strong effect size on job productivity, with a highly significant coefficient. This implies that *muda* explained 57% of the variance in design feature and that it has practical significance.

Table 7. Summary of respondents' perception of design features

S/no.	Construct	Mean before modification	Mean after modification	Users' perception	Ranking
1	Spatial Plan (SPL)	3.05	3.04	Good	1
2	Structure (STR)	3.04	3.00	Good	2
3	Facilities (FAC)	2.57	2.59	Poor	3

Table 8. Summary of FI for design features' constructs

Name of category	Name of index	Index value	Comments
Absolute fit	RMSEA	0.079	The required level is achieved
	GFI	0.933	The required level is achieved
Incremental fit	CFI	0.973	The required level is achieved
Parsimonious fit	Chisq/df	3.091	The required level is achieved

Table 9. Effect of design features on sub-constructs and significance

Sub-construct	Path	Main construct	Beta estimate	S.E.	C.R.	P-value	Result
SPL	⟵	DSF	.783	.107	10.813	***	Significant
STR	⟵	DSF	.685	Reference point			
FAC	⟵	DSF	.966	.131	10.621	***	Significant

**** indicates highly significant at <0.001 [40,41]*

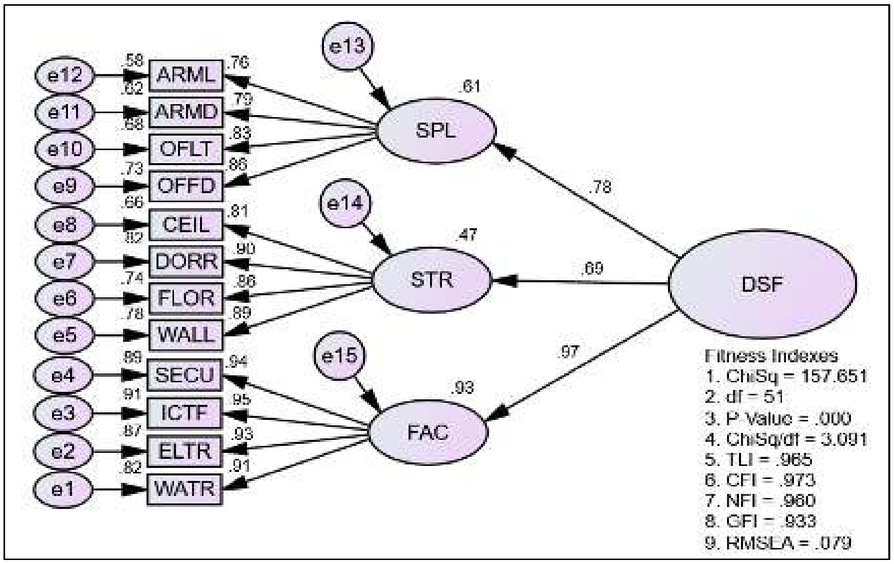

Fig. 3. Regression weights of design features' sub-constructs

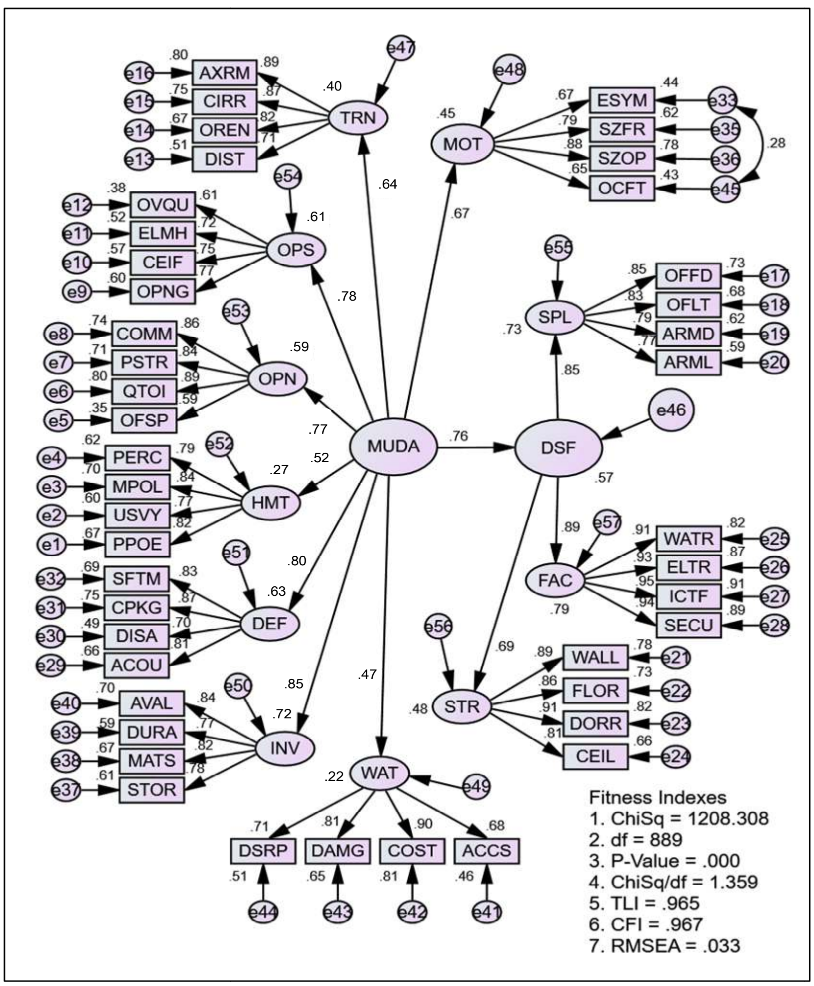

Fig. 4. The proposed structural model

Table 10. Summary of FI for the structural model

Name of category	Name of index	Index value	Comments
Absolute fit	RMSEA	0.033	The required level is achieved
	TLI	0.965	The required level is achieved
Incremental fit	CFI	0.967	The required level is achieved
Parsimonious fit	Chisq/df	1.359	The required level is achieved

Table 11. Causal effect of perceived *muda* on design features

Construct	Path	Construct	Estimate	S.E.	C.R.	P-value	Result
DSF	←	*Muda*	.757	.311	5.803	***	Significant

**** indicates highly significant at <0.001 [40,41]*

5. CONCLUSION

This study concludes that perceived *muda* has strong influence on design features, especially by affording end-users to contribute to their requirements in office buildings. Perceived *muda* explained 57% of the variance in design features and has high practical significance. This had confirmed that *lean thinking* is applicable to public office buildings in Nigeria and therefore relevant to their sustainable improvement. Although, there are a number of other factors and barriers that affect the ability to sustainably improve existing building stock, however, until the major issue of *muda* is addressed from end-users' perspective, the pace of SD may remain slow, especially in developing countries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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