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The Relevance of Lean Thinking to Sustainable Improvement of Public Office Buildings in Nigeria

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Abstract: This study looked into the relevance of lean thinking, particularly the application of muda as a supplement to the sustainable improvement diagnosis technique of existing office buildings, for a fuller assessment of user's requirement in Nigeria. The impact of muda as related to the triple bottom line of sustainable development on perceived job productivity and design features was estimated from end-user's perspective, using diagnostic POE as data acquiring tool while the confirmatory analysis was done through AMOS, SPSS and MS Excel to explain the relationship between the different variables. The findings showed that muda is inherent in public office buildings and it has highly significant causal effects of 0.66 and 0.76, respectively on perceived job productivity and design features; it also has strong effect sizes of 44 and 58% in explaining both their variances, respectively. The result revealed that users require more improvement in facilities as against spatial plan and structures while there is a medium and positive correlation of 0.48 between perceived job productivity and design features implying that the improvement of one will consequently lead to the improvement of the other. The study concludes that lean thinking is relevant to building improvement and could serve as good supplement to the current improvement diagnosis of existing public office buildings but not as a substitute since data were only collected from users who are not able to provide the required technical data that would otherwise warrant use of equipment.

Key words: Sustainable improvement, user requirement, lean thinking, job productivity, design features

INTRODUCTION

Over 20 years after the 1992 earth summit (termed Rio +20) many countries, especially in the developing world were yet to make significant headway in their quest for Sustainable Development (SD) of their built environment; Wood and Muncaster (2012) observed that the developed nations have in common, huge numbers of buildings built to standards that were barely adequate in their day and inadequate for the present and future and that those in the developing world are even apparently worse. Jiboye (2009) also noted that despite efforts at both the local and international levels, current realities suggest that the goal of achieving sustainability in Nigeria (a developing nation) is yet unrealized.

A major reason attributed to this was the neglect of existing buildings which form the 78 bulk of built assets in our cities (Brandon and Lombardi, 2010); they were developed decades ago when sustainability was not a consideration (Miller and Buys, 2008). Wood (2006) argued that sustainability cannot be achieved without addressing existing building stock as it is unlikely that new build alone would deliver a sustainable built environment in the near future. Thus, for any noteworthy impact on SD in the built environment, particularly in developing nations, it is essential that existing building stock should be given due consideration (Adeyemi *et al*., 2015).

In Nigeria as in most other countries, the sustainable improvement of existing building's standards had been mainly through retrofitting for energy and GHG emissions reduction, incorporating the KPIs parameters as related to the TBL components of SD, for reliable diagnosis and decision-making nonetheless SD in the built environment is still a far cry, especially in Nigeria (Nwokoro and Onukwube, 2011) as in most developing countries (Jiboye, 2009; Wood and Muncaster, 2012). Studies have shown that purported sustainably improved building's performance had not adequately reflected occupant's expectations (Ekbatan *et al*., 2010; Wilkinson *et al*., 2011; Monfared and Sharples, 2011; Deuble and de Dear, 2012) (Table 1).

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Table 1: User requirement reflection in improvement (Ekbatan *et al*., 2010)

		Experienced comfort based on occupant survey (%)	
Comfort parameters	Predicted comfort from certification system (%)	Satisfied/very satisfied	Dissatisfied/very dissatisfied
Thermal comfort in Winter	100	43	31
Thermal comfort in Summer	100	45	26
Air quality	100	50	16
Acoustics	100	66	6
Visual comfort	85	73	18
User control**	67	46	26

**Includes air quality, temperature in Winter and Summer, daylight, artificial light, shades and blinds

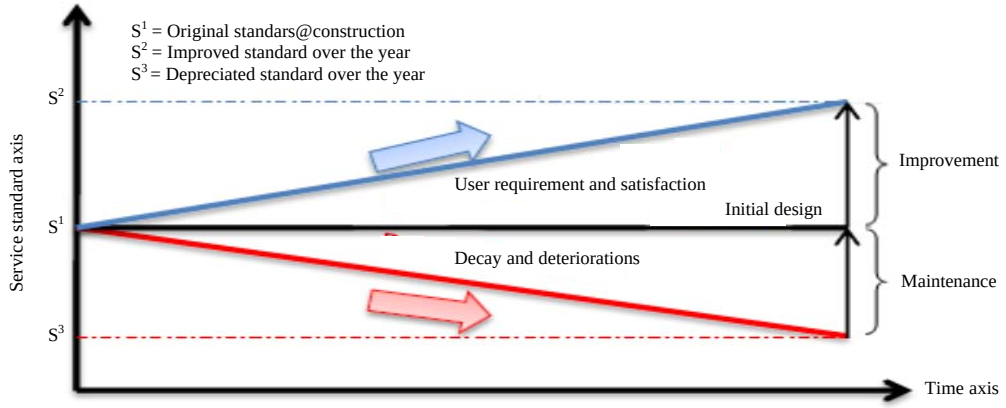

Fig. 1: Differences between improvement and maintenance (Adeyemi, 2010)

Hebert and Chaney (2012) also observed that very few published studies have reported the use of end-user surveys during the design process to inform the improvement of a facility while according to Bordass feedback is not routine in improvement; though, major failures are noted by designers and builders but disappointing performance is often forgotten while the mistakes are repeated. The implication of this is that the essence of SD which is to meet the requirements of people had not been achieved. Thus, the diagnosis process applied for the sustainable improvement of existing buildings requires a supplement for a fuller assessment of the end-user requirement in order to determine and address what is important to the user who will ultimately benefit from it.

Literature review: This study re-evaluated existing buildings and their role to sustainability through the improvement (as against maintenance) of their standards and it adopted Marir and Watson definition of improvement as a work carried out on existing buildings in the attempt to upgrade or update them to modern standards whilst retaining their current use; thus a condition superior to an earlier condition. In maintenance therefore, the original standard at construction is restored while in improvement, the original standard is upgraded, thus maintenance strategy carried out on non-sustainable existing building can at best reinstate it to its original non-sustainable standard (Fig. 1).

An improvement makes something better than it was originally and provides something in a new and more desirable form. Maintenance becomes an improvement when you go beyond simply restoring an item to its original function. Love and Bullen (2009) opined that current assessment systems of performance of existing buildings pose challenging problems because they do not provide a full profile of sustainability since they excluded major inputs from end-users. Jylha and Junnila (2014) argued that the ultimate goal is to produce and deliver occupant's requirements and only the occupants themselves can define it. Hence, the question that had risen is how can existing building improvement diagnosis technique be supplemented in order to obtain a fuller assessment of user requirement for sustainability, especially in developing countries? Three sustainable improvement models lean thinking, Green Building (GB) and Zero Emissions (ZE) which emphasized end-user requirement as the primary basis of improvement were examined for the possibility of application to the improvement diagnosis of existing building (with focus on public office buildings) as a supplement to the typical diagnosis technique; the models had been successfully applied elsewhere and mainly deal with the identification

Table 2: Research approaches of the models (Adeyemi *et al*., 2014)

Descriptions	Lean	Zero emissions	Green building
Principles	Identificationand elimination of perceived inherent muda (waste in Japanese) and Kaizen	Conversionof waste into value (or other uses)	Energy and GHG emissions reduction for climate change
Triple bottom line factors	Environment, social and economy	Mainly the economy and environment	Environment, social and economy
Research framework	Theoretical framework	Conceptual framework	Theoretical/conceptual framework
Philosophies and paradigms	Positivism (realism); objective (value free); deductive	Interpretivism (idealism); subjective (value laden); inductive	Positivism (realism); objective (value free); deductive
Applications	Social science	Pure science	Pure science

and eventual elimination or minimization of perceived waste and inefficiencies (or muda in Japanese). The lean thinking was however adopted because its principles, research framework and paradigms and application fall within the boundaries of the study (Table 2).

A major objective of ZE is that it does not search for traditional scientific proof for each step it undertakes (Pauli, 1998) rather, it combines intuition with traditional knowledge and technologies: intelligence accumulated by cultures from all around the world over millennia (i.e., conceptual framework) while in addition notwithstanding its achieved successes in many of its application; the studies were principally in pure science (Pauli, 1998) which is also outside the scope of this study. Lean in addition identifies perceived muda in a system and plans for its eradication (which is the aim of this research) while zero emissions primarily converts waste to value. However, both models see muda as the opposite of value but lean emphasized the importance of end-users more. Past studies had shown that retrofitting for green buildings is essentially for reduction in energy consumption and GHG emissions in buildings which are technically outside the scope of this study. Moreover, some studies had revealed that even green building performance does not always reflect occupant's expectations (Ekbatan *et al*., 2010; Monfared and Sharples, 2011; Deuble and de Dear, 2012; Gou *et al*., 2011). GB addresses mainly the environmental component of the TBL of SD whereas lean touches all the three.

The problem statement therefore is "Is leanthinking relevant to sustainable improvement of existing public office buildings as a supplement to its diagnosis technique, in order to deliver a fuller assessment of end-user requirement?" Hence, for sustainable improvement to be achieved, perceived muda in existing building design would first be identified from the end-user's perspectives, since their contributions were not initially taken into consideration (Pemsel *et al*., 2010) after which improvement measures should be well-thought-out to improve the original building standard by way of possibly eliminating or minimizing the perceived inherent muda; thereby enhancing building performance. Schipper and Swets (2010) argued that an inventive solution from intensive research is required to determine and address the requirements of the occupants, i.e., what is important to the user, who will ultimately benefit from it. A shortcoming of existing buildings however 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 sustain ability, both in quality and quantity (Wood, 2006).

According to Nicholas and Soni (2005), the two overarching philosophy of lean thinking for sustainability are elimination of muda and continuous improvement (or kaizen in Japanese). Lean thinking has the underlying philosophy that by identifying and eliminating muda, standard can be improved to meet user's requirement. Ohno and Bodek (1988) classified muda into 7 drivers, namely: defect/error, inventory, waiting/delay, motion, transportation, over-processing and overproduction; Womack and Jones (1996) later added the 8th human talent. Nicholas and Soni (2005) and Schipper and Swets (2010) opined that muda is universal, appearing in every situation and they remain constant but the definition of its drivers will change and adapt to describe the situation to which it is applied. They argued that as any new situation is approached for the application of lean thinking, the definitions of the drivers can be customized to fit the specific circumstances. Likewise, Finch argued that the tools and principles of lean thinking cannot simply be exported from one environment to another without carefully analyzing the nature of the new environment. Thus, the muda drivers adopted for this study were modified to suit the concept and objectives of this study as depicted in Table 3. According to DeVellis (2012), theory plays a vital role in the conceptualization of measurement variables.

In addition to the concept of muda, the self-assessed theoretical framework of job productivity seen as the quintessence of office building by Haynes (2007) was adopted for the study (Fig. 2, Table 3 and 4).

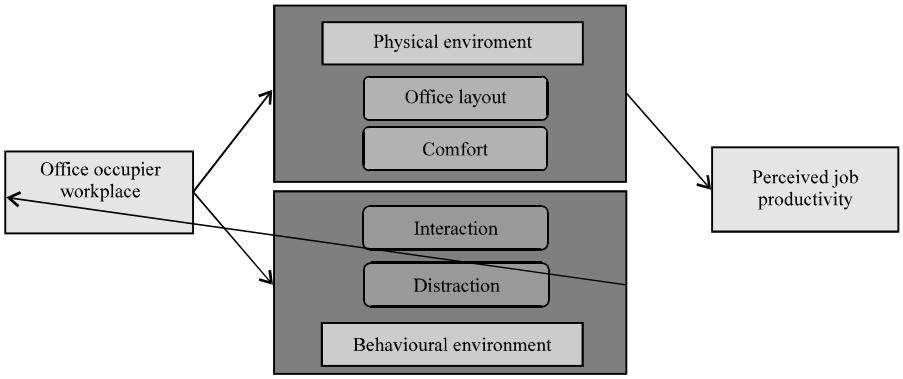

Fig. 2: Theorical framework of job productivity (Haynes, 2007)

Table 3: Concept of muda drivers for office buildings (Adeyemi *et al*., 2014)

Muda	Modified description
Defect/error	Situation where one or more elements of a building do not perform their intended function (Georgiou, 2010) 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 (Ilozor *et al*., 2004)
Inventory	Storage facilities and building materials kept for maintenance that are not necessary or have short life spans
waiting/delay	Delay, due to inadequate provisions for access to carry out maintenance activities, etc.
motion	Wasted human motion is related to workplace: ergonomic design negatively affecting productivity, quality and safety, e.g., walking, reaching and twisting (Dennis, 2007)
Transportation	Distant location of complimentary offices and other ancillary rooms causing unnecessary movements for users
Over-processing	Adding design features not needed by users, e.g., bath tubs in general convenience; irregular office shapes that reduces functionality, etc.
Overproduction	Large accommodation space, too many corridors, etc., not appreciated by users
Human talent	Non-inclusion of end-user's input (or talent) in design, maintenance or improvement policies. How could people be better involved in continuous improvement

Table 4: Perceived job productivity sub-constructs (adapted from Haynes, 2008)

Sub-constructs	Items (observed variables)
Comfort (CFT)	Temperature (TEMP); natural lighting (DAYL); decor (OVRF); cleanliness (HYGN); Security (SCTY)
Office Layout (OFL)	Storage facilities (STRR); Office shape (OFSH) and size (OFSZ); ergonomics (OFEG); circulation routes (PSSG)
Interaction (INT)	Social interaction (SINT); Work interaction (WINT); Aesthetically pleasing (AEST), i.e., modern attractiveness with regular upkeep; Refreshment areas (RFSH); Creative Environment (CREN)
Distraction (DST)	Noise/concentration (NOIS); Toilet sanitary condition (TOIS); Downtime (DNTM); Health due to IAQ (HLTH); Electricity (ELEC)

Vischer (2008) argued that the relationship between users and the office building cannot be reduced to functionality as users do not assess their requirement on the basis of simple physical comfort but bring their feelings, memories, expectations and preferences into their assessment which increases the complexity of the outcomes being measured. This argument had promoted and therefore led to the acceptance of self-assessed performance (Deuble and de Dear, 2012; Feige *et al*., 2013) and thus adopted for this study. Haynes (2008) argued that since there was no universally accepted means of measuring job productivity there appears to be acceptance that a self-assessed measure of productivity is better than no measure of productivity while Oseland and Bartlett also opined that self-assessment of productivity was not a new measure and went on to argue that perceived productivity could be as important as actual productivity. A public office building in Nigeria (a developing nation) 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. The design features as classified by Arge (2005) was also adopted for the study (Table 5).

This study appreciated 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 operations and has been promoted by models such as lean thinking, zero emissions and green building. In this study, therefore, the intangible waste was emphasized above tangible waste and it was considered as anything that does not provide value to the ultimate user (Womack and Jones, 1996). In order not to confuse the two, waste and inefficiencies in this study were referred to as muda' (Japanese wordfor intangible waste which was promoted by Ohno and Bodek (1988).

Table 5: Design features sub-constructs (Arge, 2005)

Design features sub-constructs	Items (observed variables)
Spatial Plan (SPL)	Offices design (OFFD)/layout (OFLT); Ancillary Room's Design (ARMD)/layout (ARML) and overall Building Design (BLGD)
Structure (STR)	Walls (WALL); Floors (FLOR); Windows (WIND); Doors (DORR); Ceiling (CEIL)
Facilities (FAC)	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)

MATERIALS AND METHODS

The study promotes the virtues of a more positive outlook that starts with what had been inherited from the past, how to realize its value and improve on it, through focus on the improvement of past building's standard as a means of achieving sustainability in existing public office building stock. The confirmatory study was however restricted to the relevance of lean thinking to sustainable improvement diagnosis of existing public office buildings, through the identification and elimination of perceived muda inherent in them from end-user's standpoint. The study design adopted the quantitative method, supported by qualitative method while the research strategy involved the use of survey, direct observation and case study approach.

The Federal Secretariat, Bauchi (Fig. 3); a massive public building in Nigeria was chosen as case study because of dire need for improvement in developing nations (Nwokoro and Onukwube, 2011; Wood and Muncaster, 2012). Eisenhardt (1989) 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 (Fenno, 1986; Yin, 1994), namely:

- The building was designed and constructed decades ago when sustainable development was not a consideration
- It has not undergone any major improvement work since its construction
- The building is still operational and not abandoned
- A massive structure with 26 government offices with a combined staff strength of 971
- The staff combination reflects the federal character and quota system of the nation

According to McIntyre (2004), a representative sample is crucial if evidence from the sample is being used to make generalizations about the larger population from which the sample was selected. However, all the occupants of the Federal Secretariat building, Bauchi, Nigeria were adopted as the research sample size, to reflect the federal character and quota system of the nation (Strzelecka, 2008). The questionnaire was distributed to the 971 staff at the case study thus no sampling technique was employed. However, a sample size calculator was used to estimate the minimum sample size of 280 required for the study (Bartlett *et al*., 2001). The retrieved and useable questionnaires was 339. The Post-Occupancy Evaluation (POE) tool was adopted for acquiring data from end-users and related to the SD Triple Bottom Line (TBL) components of environmental, economic and social dimensions (Pope *et al*., 2004) but limited to:

- The 'environment' covering issues which include temperature, ventilation, air quality, glare, daylight and noise (Kim *et al*., 2012)
- The 'economy' covered issues of occupant's satisfaction and comfort through the provision of adequate space, services and facilities thereby increasing job productivity. A leading argument for economic sustainability is the belief that sustainable buildings are healthier and lead to job satisfaction, less employee absenteeism and higher levels of productivity thereby boosting the overall profitability of business occupiers (Croome, 2006; Wilkinson *et al*., 2011; De Been and Beijer, 2014)
- The 'social' covered the issue of aesthetics where buildings having pleasing aesthetic qualities with prompt repair and regular upkeep, enhancing their surroundings and the well-being of humans (Wilkinson *et al*., 2011)

According to Meir *et al*. (2009), users may either be satisfied or otherwise with a sustainable building depending on the balance of incorporation of the TBL components in the design while Adams and Lawrence (2014) and Wilkinson (2012) observed 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 the building intended use.

Fig. 3: Federal secretariat complex, bauchi, Nigeria (Adeyami *et al*., 2015)

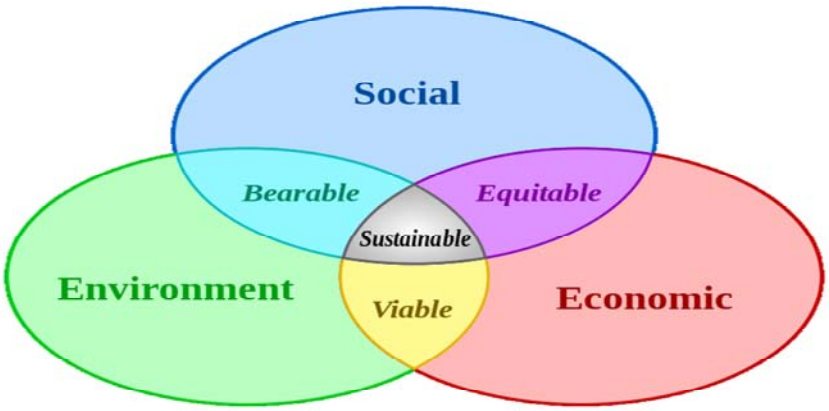

Fig. 4: Overlapping TBL components of SD (Adams and Lawrence, 2014)

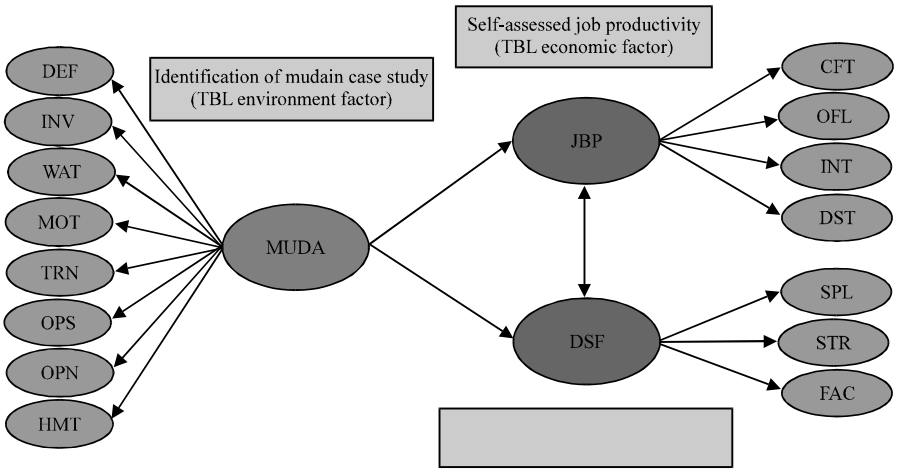

Fig. 5: Assessment framework relating all the variables

Table 6 summarizes the framework for the evaluation of the relevance of lean thinking to the sustainable improvement of public office buildings while Fig. 5 depicts the assessment framework relating all variables developed for the study. Preliminary analyses were performed on all the measurement models using the Confirmatory Factor Anaysis (CFA) to ensure no violation of the assumptions of unidimensionality, validity, reliability and normality,

Table 6: Framework for the evaluation of relevanceoflean thinking (Adeyemi *et al*., 2015)

Area of investigation	Data collection	Data analysis	Purpose/Aim	Expected results
Identification of perceived muda inherent in existing public office buildings in Nigeria	Question-naires/ personal observation	SPSS v.22, MS Excel and AMOS v.22, narrations and discussions	Answer to Research Question 1 (RQ) 1: What are the perceived muda inherent in existing public office buildings in Nigeria from occupant's standpoint?	Establishment and ranking of perceived muda prevalent in existing public office buildings from user's standpoint (environmental factor)
Effects of the established perceived mudaon perceived job productivity from user's standpoint	Questionnaires/ personal observation	SPSS v.22, MS Excel AMOS v.22 regression analysis, narrations and discussions	Answer to RQ2: How has the perceived muda affected perceived job productivity from occupant's standpoint? Test for hypothesis H_1 The perceived mudahas significant effect on perceived job productivity	Impact of perceivedmuda on perceived job productivity in existing public office buildings in Nigeria from user's stand-point (Economic factor)
Effects of the established perceived mudaon design features from user's standpoint	Questionnaires/ personal observation	SPSS v.22, MS Excel, AMOS v.22 regression analysis, narrations and discussions	Answer to RQ3: How has the perceived muda affected existing public office buildings Design features from occupant's standpoint? Test for hypothesis H_2 the perceived mudahas significant effect on design features	Impact of inherent muda on design features in existing public office buildings in Nigeria from user's stand-point (social and environmental factors)
Elimination or minimization of inherent muda in future public office buildings in Nigeria	Questionnaires, personal observation and survey	AMOS v.22 correlation analysis narrations and discussions	Answer to RQ4: How can the public office building's standard be sustainably improved thru the elimination or minimization of perceived muda and guard against in future designs? Test for hypothesis H_3 there is a significant relationship between perceived job productivity and design features	Elimination or minimization of perceived muda and performance based outline for sustainable improvement of existing public offices in Nigeria (social factor)

such that any item that does not fit the measurement model was removed. The unique contribution, causal effect, effect size and practical significance (Adams and Lawrence, 2014) were used to determine the relevance of leanthinking with respect to the study objectives and hypotheses. The diagnostic POE tool was adopted for this study while its working depth was limited to the systematic evaluation of opinion to determine muda in the building and its effect on perceived job productivity and design features from occupant's 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 (Shah, 2008).

RESULTS AND DISCUSSION

The establishment of perceived muda from user's perspective: Figure 6 shows the respective standardized beta coefficients of the muda drivers which compares their contribution to explaining perceived muda. According to Pallant, the driver with the largest beta coefficient makes the strongest unique contribution to explaining the perceived muda. Table 7 shows the ranking of the drivers based on their respective beta coefficients which ranged from 0.848-0.472 from inventory to waiting in order of prominence. The corresponding R^2 sare deemed strong (Adams and Lawrence, 2014), except for waiting (WAT) with R^2 of 0.22 construed as moderate. Table 8 shows the range of effect sizes.

Table 7: Interpretation of effect size (R^2)

Awang		Adams and Lawrence (2015)	
Range of R^2	The effect size	Effect size range (%)	Interpretation
<0.13 (i.e., 13%)	Small range	1-4	Weak
Between 0.13-0.26	Medium range	9-25	Moderate
>0.26	High range	25-64	Strong

The result also revealed that the regression weights have $p<0.05$, implying significant coefficients (Table 9). This is consistent with Nicholas and Soni (2005), Schipper and Swets (2010) and Finch who argued that muda is universal, appearing in every situation and they remain constant but the definition of its drivers will change and adapt to describe the situation to which it is applied. The muda drivers were ranked according to their beta coefficients which indicate the unique contribution of each sub-construct to explaining perceived muda.

The causal effects of perceived muda from user's perspective: Table 10 provides the estimates from the proposed structural model depicted in Fig. 6 and 7, it shows the causal effect of perceived muda on self assessed perceived job productivity and design features.

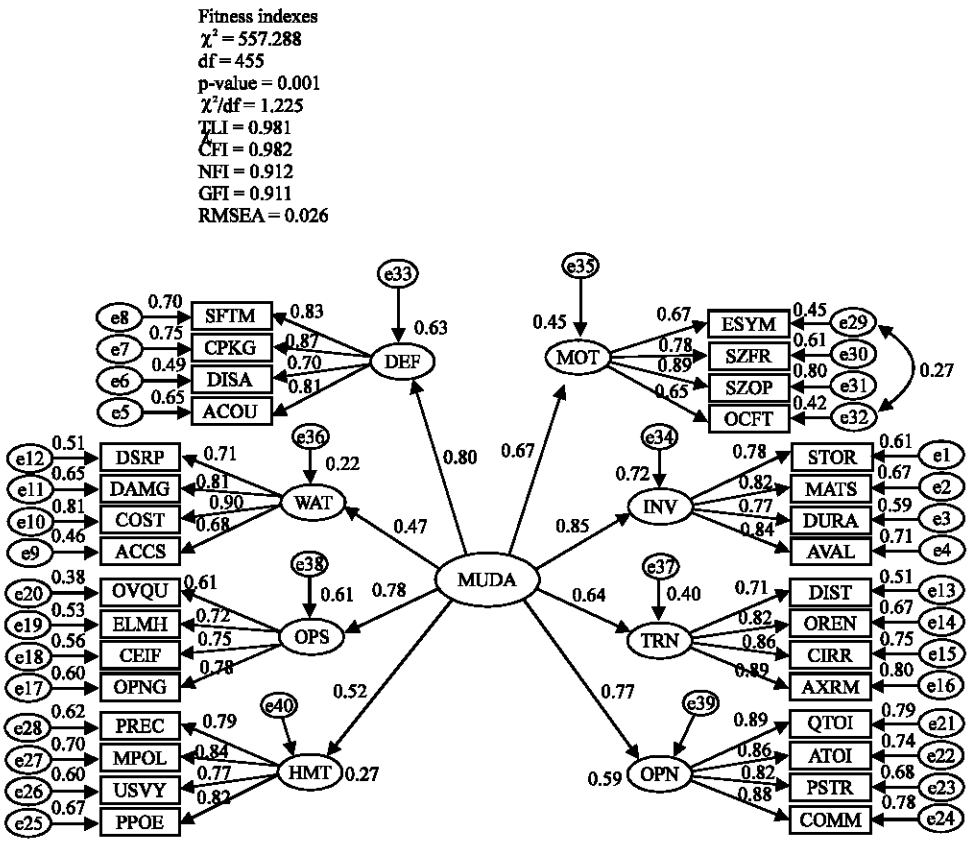

Fig. 6: Regression weights of sub-constructs predicting muda in standardized estimates

Table 8: The Regression weights, p-value and ranking of sub-constructs in predicting muda

Muda drivers	Path	Construct	β estimate	SE	CR	p-values	Result	R^2	β ranking
Human talent	←	MUDA	0.523	0.109	7.000	***	Significant	0.27	7
Overproduction	←	MUDA	0.770	0.231	7.082	0.004	Significant	0.59	4
Over-processing	←	MUDA	0.782		Reference point			0.61	3
Transportation	←	MUDA	0.636	0.101	7.531	***	Significant	0.40	6
Motion	←	MUDA	0.669	0.237	5.980	***	Significant	0.45	5
Waiting	←	MUDA	0.472	0.057	3.814	0.025	Significant	0.22	8
Inventory	←	MUDA	0.848	0.098	9.006	***	Significant	0.72	1
Defect	←	MUDA	0.796	0.092	5.730	***	Significant	0.63	2

***Indicates highly significant at <0.001

Table 9: Causal effects of perceived muda on perceived job productivity and design features

Construct	Path	Construct	Estimate	SE	CR	p-values	Result
JBP	←	MUDA	0.661	0.162	5.944	***	Significant
DSF	←	MUDA	0.760	0.265	6.397	***	Significant

***Indicates highly significant at <0.001

Table 10: Summary of respondent's perception of design features

Construct	Mean before modification	Mean after modification	User's perception	Ranking
Spatial Plan (SPL)	3.05	3.04	Good	1
Structure (STR)	3.04	3.00	Good	2
Facilities (FAC)	2.57	2.59	Poor	3

The beta estimate of 0.661 reflects the amount of causal effect of muda on Perceived Job Productivity (JBP), thus when muda goes up by 1 unit job productivity will also go up by 0.661 unit. Likewise, the estimate of 0.760 reflects the causal effect of Muda on design features such that when Muda goes up by 1 unit, design feature will also go up by 0.760 unit. The result also showed highly significant coefficients and supported hypotheses H_1 and H_2 (Table 10). The muda effect size (i.e., R^2) explained 44% of the variance for perceived job productivity (Fig. 7) while the muda effect size explained 58% of the variance for design features; these are seen as having strong effect sizes according to Adams and Lawrence (2015).

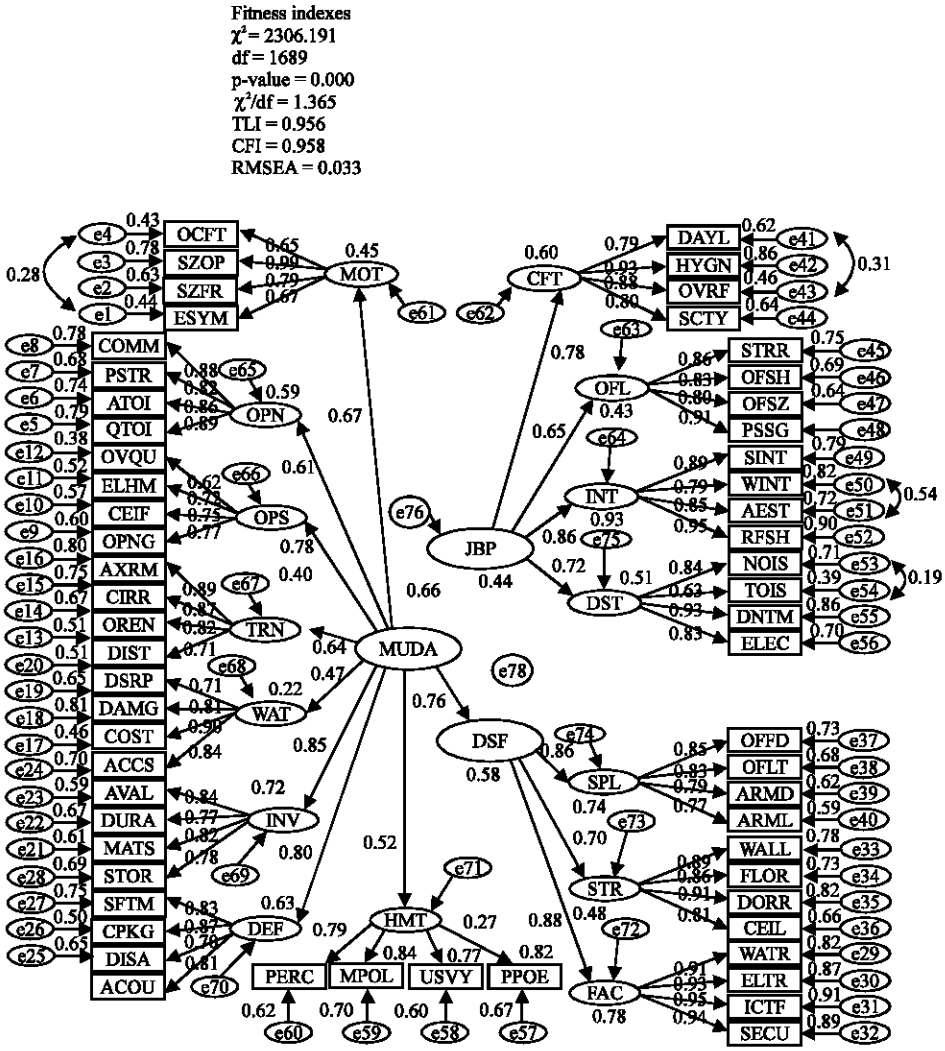

Fig. 7: The Proposed structural model in standardized estimates

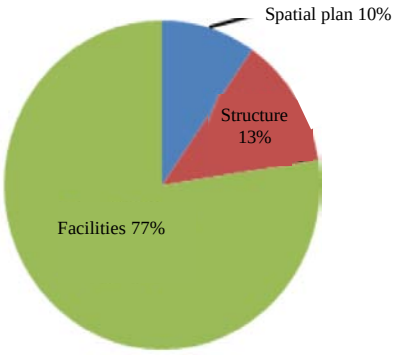

Fig. 8: User requirment by features themes (Field survey, 2014)

Elimination of muda in existing public office buildings from user's perspective: The respondent's perception of

Table 11: The estimate of the relationship between job productivity and design features

Endogenous construct	Path	Endogenous construct	β estimate	SE	CR	p-value	Result
JBP	←	DSF	0.484	0.029	6.062	***	Significant

***Indicates highly significant at <0.001

design features is summarized in Table 11 spatial plan and structure were deemed "Good" with mean scores of ≥3.00 (Haynes, 2007) while facilities was deemed "Poor" with a mean score of <3 (Haynes, 2007) thus rated the lowest. Likewise, Fig. 8 summarized the respondents comments on design feature themes as classified by Arge (2005), it shows that user's requirements are concentrated on facilities rather than spatial design (i.e., spatial design and layout of building) or structure (i.e., building components and materials). In other words, if facilities are well improved, users would have more satisfaction and comfort in the building. Figure 9 shows the covariance

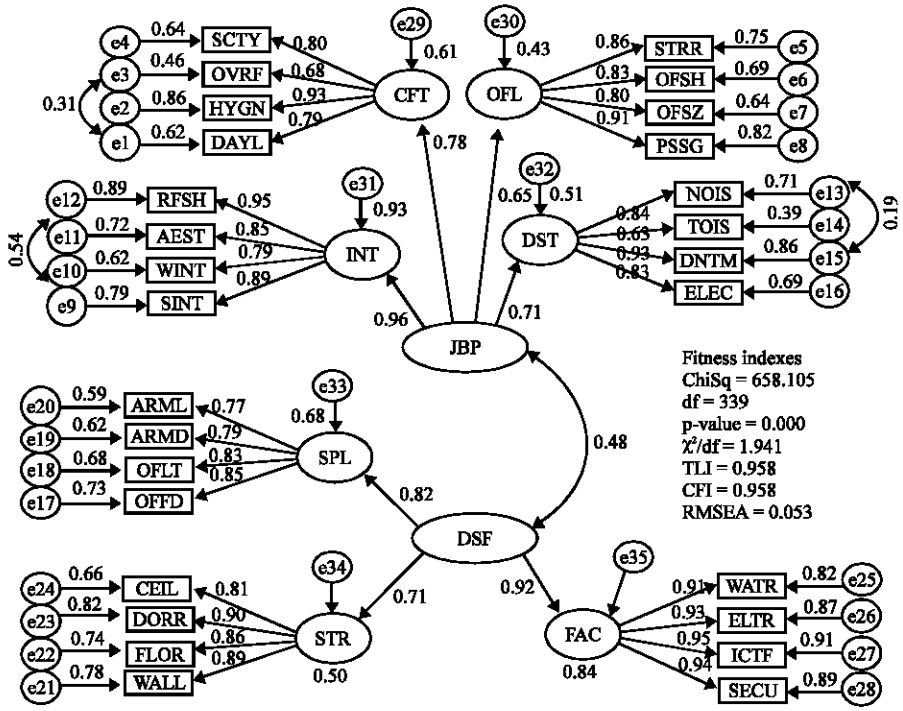

Fig. 9: Correlation between job productivity and design features in standardized estimates

between perceived job productivity (the quintessence of office buildings by Haynes (2008) and design features and it revealed a (particularly facilities) is improved, job productivity will also improve; thereby killing two birds with a stone. The result indicated a highly significant coefficient which supported hypothesis H_3.

CONCLUSION

This study concludes that lean thinking is relevant to sustainable improvement of public office buildings as a supplement to the diagnosis technique but not as a replacement since all data were collected from users who are not able to provide other technical data that warrants the use of equipment for assessment. 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-user's perspective, the pace of SD may remain slow, especially in developing countries.

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