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AN INTEGRATED BUILDING PERFORMANCE INDEX FOR ASSESSING OFFICE BUILDINGS IN NIGERIA

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ABSTRACT: *Building performance is a function of a number of variables each of which is important to analyse concurrently when conducting a POE study. The development of framework for assessing buildings is significant as it will provide an evaluation tool for ensuring sustainable buildings. This study developed an index for evaluating the overall performance of office buildings in Nigeria. A Total of 51 professionals in the built environment were surveyed. The data obtained were analysed using content analysis technique, pair wise comparison (one sample t-test) and regression analysis. The results showed that; the performance criteria which are pertinent to the performance of office building in order of their importance were building integrity (54.54), indoor air quality (53.69), safety and security (64.04), thermal (46.77), spatial (7.27%), visual (44.01), spatial (43.33) and acoustic performance (43.62); priority placed by individual professional, architects rated safety and security and building integrity (18) most important and acoustic least (9) important, builders rated IAQ and visual performance (20) most important and building integrity (8) least important, estate surveyors ranked safety (21) and building integrity (17) performance most important and acoustic performance (7) least important, mechanical engineers rated safety (22) and building integrity (0) performance most important and acoustic performance (7) least important. A regression model based on the TBP criteria identified was developed (TBP Index = $13.36\eth+12.57\eta+12.46\gamma+15.34\omega+12.38\phi+15.58\varphi+18.30\psi$). It was concluded that safety and security was rated most significant of all the performance mandates, followed by indoor air quality, building integrity, thermal performance, spatial performance, visual performance and acoustic performance.*

KEYWORDS: Total Building Performance, Office Buildings, Building Performance, Building Diagnostics, Building Performance Framework

INTRODUCTION

For many decades, scholars and professionals in built environment carried out investigations to understand how buildings performed after they have been constructed and occupied. Specifically to understand how satisfied occupants were with the workplaces they occupied (Marans and Spreckelmeyer, 1982; Oldham and Rotchford, 1983; Ornstein, 1999). Building performance assessment was done either in the context of fire safety, indoor air quality, thermal efficiency and result of oil crisis in the western world, which has led to the design of air tight building systems. This kind of performance evaluation of buildings was carried out with the aim of determining the success of physical design solutions that have been employed. Evaluation of this kind is useful in assessing a specific area of performance of particular type of building

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Although each of these micro-level criteria is important in facilitating understanding on how well the building is fulfilling the users' and functional requirements. It is equally true that individual building system has been designed to meet the specific performance criteria, but as it was demonstrated in 1970's, an emphasis on one performance such as energy, without consideration for the range of performance areas, often results in failures in other performance areas, such as Sick Building Syndrome (SBS) and loss of productivity due to lack of adequate indoor environmental quality as well as degradation failures (Leaman, 2004; Loftness *et al*., 1989). This is because current assessment protocols are either unitary in discipline or are focused only on one specific aspect of whole host of performance issues.

Building performance is a function of a number of variables each of which is important to analyse concurrently when conducting a POE study. It is now known that one performance mandate cannot be dissociated from the other performance qualities.

The submissions of various studies are that performance requirements in each of the performance categories cannot be understood in isolation from the other, thus to deliver a project that is acceptable in all the performance areas, conflicts must be resolved between performance mandates. Jiun (2005) concluded that building performance is only achievable through the holistic integration of all building performance criteria which results from the interactions between the identified performance mandates. He went further to say that the performance success of any performance mandate is dependent on the result of effective integration among individual systems and components and their interface with the building's occupancy. In the opinion of Lukuman *et al*. (2012), although individual building system has been designed to meet the specific performance criteria, evaluation of office space should go beyond looking at a single building requirement and that there exist a need to look at the interrelationship of performance mandates to provide healthy buildings for occupants and most important to reduce energy consumption during the construction and operation of buildings.

The implication of the above statements is that, to assess how well the building is behaving overall and in the long term, a more holistic approach is needed. Good building performance is thus dependent upon the satisfactory performance of all the mandates as they share an interrelated relationship. By itself total building performance evaluations techniques are desirable to consider these complex interrelationships in the conception, design, specification, installation and use of components and assemblies within buildings (Hartkopf *et al*, 1986). The ability to define and measure building performance holistically has potentially important long lasting benefits related to the evaluation and valuation of buildings (ORNL, 2000). This is where the concept of total building performance can play an important role (Douglas, 1996).

Office is a place where people spent a substantial amount of time, about 90% of their time (CIB, 2004; Jiun 2005). As the industry moves towards service sector, office has become the predominant work place and financial centers today. Therefore, its performance has a significant impact on indoor environment and indirectly the wellbeing and productivity of the workers. The health, safety, wellbeing and comfort of employees in a high-performance office building are of paramount concern. To achieve these impacts, however, the office building must form an integrated design approach that focuses on meeting a list of objectives: productivity, improved health, greater flexibility and enhanced energy and environmental performance.

Thus knowing the indicators for assessing its performance become imperative (Jiun, 2005). There is growing interest on the part of clients and construction professionals in Nigeria to

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design and construct office buildings which meet business and people objectives. Lack of reliable data and knowledge of the relevant indicators of building, their ability to make correct decision may be impaired. In view of this, there is the need advance a comprehensive performance in Nigeria. With these various aspects taken into consideration, the concept of Total Building Performance (TBP) concept appears to be very attractive solution in the development of an assessment framework to ensure good indoor air quality, thermal comfort conditions, energy efficiency as well as fostering occupant wellbeing, health and productive in Nigerian office buildings.

Modern trends in building performance evaluation demand a paradigm shift from one aspect of performance criteria to holistic approach, which is manageable yet developed enough to encompass performance dimensions along a broad range of aspects. Presently, there are various building assessment systems developed internationally to evaluate buildings in different parts of the world. These systems might not be applicable in the context of Nigeria due to geographical and cultural differences. In addition, when there is lack of reliable data and the knowledge of the relevant indicators of office building performance, the designers, built environment professionals and organization's ability to make a convincing case for its recommendation is also significantly reduced. Through the evaluation of occupied facilities, there performance can be reviewed to assure users satisfaction.

For long term strategic planning and design, developing a framework based on TBP paradigm for assessing building performance will provide information about what kinds of a building will be needed in the future to accommodate organization's expected development. The development of framework for assessing buildings is significant as it will provide an evaluation tool for ensuring sustainable buildings. Data generated from the assessment results can also be fed back into the design, operate and maintenance process to improve the performance of future building stock. The performance assessment methodology developed would create a yardstick by which building performance can be benchmarked. Hence, this paper aims to develop an index for assessing overall performance of office buildings with a view to improving quality of future office building design in Nigeria by examining performance criteria which are relevant to the assessment of office buildings; evaluating the priority placed on the identified criteria; and developing a regression model based on the identified TBP criteria.

LITERATURE REVIEW

There has been a worldwide movement to develop systems that can provide all-inclusive but manageable performance assessment fragment for buildings the concept of Total Building Performance (TBP) developed by the Building Research Advisory Board (1985) and Hartkopf *et al* (1986) has been identified as a suitable approach for the development of the assessment framework as it addresses a set of coordinated strategies aimed at bringing about a performance and quality driven construction industry. The concept examines and develops processes contributing to the delivering of integrated and high performance buildings with respect to needs and resource availability. It is contended by researchers (Building Research Advisory Board, 1985; Hartkopf *et al*., 1986) that a minimum of six performance areas are needed to describe the performance of the built environment for building occupant effectiveness. The TBP concept embraces these six principal performance mandates, namely, spatial, acoustic, thermal, visual, Indoor Air Quality (IAQ) and building integrity. The TBP approach is the most holistic as well as being performance based. It is a user oriented building diagnostic and appraisal tool. The performance mandate connotes a set of user's preference and response with respect to the spaces created. The main drivers are the users perceived needs within a building.

Early studies on building performance evaluation have focused on measuring and assessing one aspect of performance criteria as well as performance of products rather than whole buildings (Jiun, 2005). Criteria such as durability, water tightness, air permeability and so on were used to measure the performance of specific components at micro-level. Nevertheless, an emphasis on one performance area often resulted in the failure of the other performance areas. Considerable number of clients/occupants dissatisfaction has also arisen despite this effort. Thus, building evaluations that continue in singular areas are going to create more problems by doing so. Hence, the resulting dictum can only be that the evaluating community must began with a comprehensive outline of TBP to be achieved, which is finite enough to be manageable in the field, yet developed enough to represent that 'integrated multi-sensory evaluator' known as human being.

Several studies have been conducted on various building types and in different parts of the world using the concept of total building performance. Researchers like Hartkopf *et al* (1986), Anderson and Barrett (1993), Aronoff and Kaplan (1995), Ang and Wyan (1998), Ang et al (2001), Jiun (2005) and Okolie (2011), had put in a lot of research effort which had led to the development of assessment models or frameworks for evaluating building performance.

Although, interest in building performance evaluation has significantly increased in recent years, and development of holistic assessment framework for building performance evaluation has presumed a wider interest which is now a more widely practiced for passing judgment upon the merits and demerits of completed buildings. In Nigeria, performance evaluation of buildings in use had traditionally been carried out with the aim of determining the success of physical design solutions in terms of either thermal comfort, adaptive behaviour or optimization of energy use (Ajibola, 1993, 1995, 2001; Olanipekun, 2002; Ogunjimi, 2007; Adunola, 2011; Agunbiade, 2011). Despite this, sufficient anecdotal evidence and studies by Akinbami (2003) and Lawal (2009) have shown that office buildings are not 'bio-climatic' responsive and indoor comfort is always a problem, which affect the habitability of the occupants.

Vischer (1990) has shown that the performance concept is the most organized approach for appraising buildings. Measurability is a key criterion and crucial element to the whole performance concept (Douglas, 1996). It is vital to the objective understanding of performance issues and processes. However, measurement of performance does not only depend on measurability alone. It also takes factors that are significant and may not yet be measurable into account. The methodologies adopted in the process of evaluation are also significant factors. The performance approach involves two basic stages, namely; identification and selection of the required standards are undertaken in the first stage which is the measurement or audit stage. The second stage involves a comparison of the measured results with the optimal standards or benchmark. This is the assessment stage. The actual process and procedures may be complex. The most critical step is to understand before embarking on a performance measurement exercise, what performance really means and the leading indicators which provide a measure of the defined performance. If one cannot measure performance, it cannot be understood nor improved (Williams, 1993).

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Criteria such as durability, water-tightness, and air permeability and so on can be used to measure the performance of specific components at the "micro-level". However, this approach has limitations in evaluating the total performance of a building which by implication needs to be carried out at the "macro-level" (i.e. the building as a whole) (Douglas, 1996). Tools which specializes in measuring specific features and attributes of a building and environment are available (Gajendran, 1998), among which are Post Occupancy Evaluation (Preiser, 1988, 1997; Anderson &Barrett, 1993), Building In Use (Vischer, 1996), Concept of Total Building Performance (TBP) and Building Diagnostics (Building Research Advisory Board, 1985; Hartkopf et al. 1986), Building Quality Assessments (Bruhns & Isaacs, 1993), and ORBIT (Davis et al., 1985).

RESEARCH METHODOLOGY

In order to identify the relevant performance indicators. Seven performance mandates namely Thermal Performance, Visual Performance, Acoustic Performance, Indoor Air Quality, Spatial Performance, Building Integrity as well as Safety and Security were identified and defined under the TBP approach adopted in this study. Through the review of literature survey, a number of existing and relevant performance indicators that served as means of evaluating each of the seven mandates were identified.

It has been documented that buildings have certain basic attributes that are essentially the same for all buildings (Zeisel, 1985). In view of this, this study categorized the performance indicators identified into two types: Basic Attributes and Features. Basic attributes are the fundamental performance indicators against which each performance mandate is to be evaluated, upon while basic features are the additional indicators that aid in enhancing the performance level. By differentiating between these two groups of indicators, it is possible to assess the fundamental performance of office buildings on a common basis, yet at the same time be able to reward the high performance buildings which have specific features to further improve its overall performance. Questionnaire was used to elicit information on the identified performance mandates and their corresponding performance indicators from selected respondents. Given the complexity of modern buildings and the array of variables that are involved in them, development of a meaningful performance assessment system has to be trans-disciplinary, rather than purely a uni-disciplinary process. This would thus require the expertise and inputs of professionals within the building industry who have to translate and implement the requirements of the developers and users. Although the TBP concept is fundamentally users-oriented, but experts-based system would make a better choice for the purpose of this study as the expert respondents would have gathered more feedback and experience of what users require in buildings. At the same time, they are also equipped with technical knowledge of the buildings. Their perspectives can aid in facilitating a better evaluation in which it considers a range of key factors which affect overall performance of the building. As most building problems call for an interdisciplinary approach, it is necessary to include experts from various disciplines. While the views of these individuals are associated to their unique disciplines, the expertise of the group is often greater than the sum of the expertise of its individual members (Building Research Advisory Board, 1985). So, it would be more useful to gather the opinions from a multi-disciplinary group of experts. However, it must be reiterated that ultimately the needs of the user should take precedence, so the role of the experts is to construe those needs into building performance requirements. The study population includes professionals with relevant experience and knowledge in the field of office buildings

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design and construction. Data was collected through questionnaires with 51 building professionals consisting of architects, builders, estate surveyors, and mechanical engineers

The technique used for the sampling is purposive sampling. The respondents were made to rate the importance of each mandate as compared to one another in a supposedly ideal office building on a Visual Analog Scale (VAS).

The scale consists of a straight horizontal line that measures 100mm in length with verbal descriptors at each end to facilitate easy understanding of the mandates that are being rated. It is important that the use of the VAS is explained clearly to each respondent. Respondents were instructed to mark the location on the line that corresponds to the degree of importance they placed as they compared each of the mandates to one another. This gave them the greatest freedom to choose the extent of importance they placed on each mandate relative to other mandates. Figure 1 shows the usage of the VAS in the study. If one finds that visual performance in an ideal typical office building is more important than thermal performance, one would mark on the line provided at a location that is nearer to Visual Performance. The shorter the distance of the mark from the end of Visual Performance, the higher the degree of importance placed on visual performance in relation to thermal performance. In Figure 1, greater importance is placed on visual performance as compared to thermal performance because the mark on the line is nearer to the end of Visual Performance.

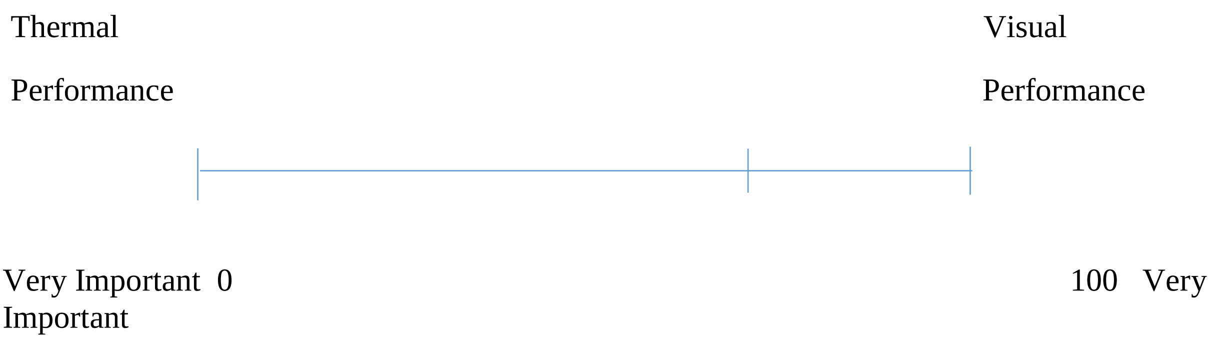

Figure 1: Visual Analog Scale used for the study

The data obtained were analysed using Content analysis, Paired Comparison Analysis, Kendall coefficient of agreement, and Tukey Kramer procedure. One-Sample T-Test was used to compare each VAS score of every basic attribute and feature to the neutral point of 50 mm. relevant performance criteria are identified and scoring method is proposed to serve as a benchmark against which to evaluate performance of the attributes and features within each mandate. Weights were also calculated from the survey results to determine the relative importance or desirability level of the various performance indicators. The proposed TBP assessment framework is then developed by incorporating all these components together using regression analysis. The building professionals were first interviewed to list the attributes they deemed important in a high performance building in an open-ended interview. This serves to elicit their independent views on the criteria of a high performance office building. Content

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analysis is employed to determine the performance aspects deemed important by the professionals.

In the second section of the survey, the professionals were asked to rate the relative importance of each performance mandate to other mandates with respect to an ideal typical high performance office building using a pair-wise comparison approach. The objective of data analysis is thus to determine the degree of consensus among the experts' ratings and also the relative importance of each performance mandate to the others in assessing the overall building performance. Subsequently, weights were developed for each performance mandate based on the survey results. This serves to justify greater priority to be allocated to performance mandates that command a higher weightage.

The third section of the survey required the experts to rate the importance of basic attributes and desirability of features within the respective performance mandates. Identification of significant attributes and features which are crucial to office building performance was made possible through the analysis of the collated data. In a likewise manner, weights were also developed for individual performance attributes and features based on the survey results. Similarly, this justifies greater attention to be focused on evaluation of attributes and features which carry a higher weightage.

RESULTS AND DISCUSSION OF FINDINGS

Examination of office building performance criteria

Content analysis revealed that most of the survey data collected through the open-ended interview fits very aptly or are closely related to the seven performance mandates adopted in this study: Thermal Performance, Visual Performance, Acoustics Performance, Indoor Air Quality (IAQ) Performance, Spatial Performance, Building Integrity and Safety & Security. Table 1 shows the ranking of the total building performance concepts that fit into the seven categories and related to them based on the frequency of times mentioned by the experts. The total number of responses related to each performance mandate and the relative frequency based on percentage of times it is mentioned is shown in Table 1. It also shows a breakdown on the number of responses related to individual criterions and the relative frequency in terms of percentage as well.

Indoor air quality and security were by far the most frequently mentioned (14.55%) category or concept relating to respondents' comments about important factors that they would look for in a high performance office building. This implies priority and often preference for good indoor air and security performance in a building. This finding is not surprising especially in a tropical country like Nigeria where air-conditioning has almost become a necessity in buildings. Included under this heading is green environment. Included under the Security Performance category was mention of corridor safety as shown in Table 1.

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Table 1: Ranking of other performance issues based on frequency of times mentioned

	Criterion Mentioned				
	Overall Mandate Level			**Individual Criterion Level**	
Criterion	F	%	Rank	F	%
Indoor air quality	1		1	1	14.55%
Green environment				7	6.36%
Safety and Security	1		2		12.73%
Corridor safety				8	7.27%
Thermal Performance	9		3	9	8.18%
Spatial performance	8	7.27%	4	8	7.27%
Building integrity	7		5	7	6.36%
Energy efficient					10%
Adequate water supply				4	3.63%
Internet facilities				8	7.27%
Computer appliances				2	1.82%
Refrigerator, television				1	0.91%
Fittings				1	0.91%
Functionality				7	6.36%
Visual performance	5		6	5	4.55%
Acoustic performance	2		7	2	1.82%
Column Total	**61**	**56.17%**		**110**	**100.0%**

Thermal Performance criterion, receiving 8.98% of the survey sample's mentions, is the third most frequent response as seen in Table 1. It is observed from the results that the percentage of mentions for Spatial Performance (7.27%), Building integrity (6.36%) and Visual Performance (4.55%) only differs very marginally although they are ranked in the first and second place respectively. In terms of total number of responses, there were 8 mentions for Spatial Performance, 7 mentions for Building integrity and 5 mentions for Visual Performance which represents a small difference too. Hence, these three mandates command a comparable level of importance to the experts as evident in the open-ended interview.

Acoustic performance concept was also reflected in the response as shown in Table 1.

However, it is important to note that majority of the respondents' most frequently mentioned performance issue is 'air quality'. This category ranked first in terms of frequency of mentions (16.55%). Security comes next receiving 12.73% of the sample survey's mentions and corridor safety is the only mentioned performance criterion within this category at a response rate of 7.27%. This finding is not surprising as the safety and security of the building has an impact on the operation efficiency of the building throughout its whole life cycle. Thermal performance ranked after Security at 8.89% in terms of percentage of responses. Acoustics Performance (1.82%) is ranked the lowest, receiving relatively fewer mentions as compared to the other 6 categories mentioned earlier. This might be attributed to the perception of the professionals: users are generally more tolerant towards acoustic discomfort as compared to other factors as long as the noise level is within the acceptable range.

Responses apart from the seven performance mandates adopted were also recorded and

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analyzed separately. It emphasized that these additional concepts are closely related or may constitute subsets of the seven performance mandates adopted under the TBP approach.

The most frequent issue the sampled building experts had expressed concern for is

Energy Efficiency (10%). Some respondents indicated in their responses that energy efficiency is a crucial factor not to be overlooked as it affects the company's bottom line. More than half of the respondents feel that energy efficiency is a crucial factor in ensuring a high performance building. Also mentioned is its relation to thermal and visual performances in a building.

Evaluation of the priority placed on office building criteria

In Section II of the questionnaire, the respondents were asked to rate the level of importance among the seven mandates pair-wise at a time between all 21 possible pairs by marking on the VAS. No numerical values were shown on the scale to allow greater flexibility in rating the importance level so that respondents were not "forced" to confine their ratings to certain range as in the case of conventional questionnaires using ordinal scales.

If the respondent perceives Thermal Performance of a high performance building to be more important than Visual performance, the respondent would mark a stroke on the scale nearer to the end of Thermal Performance. The importance rating of each performance mandate in comparison to another mandate is measured from the VAS, this is 100mm long.

A rating below 50 indicates that one performance mandate is perceived to be less important to the other mandate in comparison. On the other hand, a rating above 50 indicates that the performance mandate is perceived to be relatively more important than the other mandate. If the two mandates in comparison are equally important, this would be reflected by a rating of 50. T he experts' ratings were first analyzed to determine the degree of consensus among them. Although it is expected that the experts will express a wide form of opinions due to their different backgrounds and this trend has already been reflected from the content analysis results obtained from the open-ended survey, it is nonetheless desirable to determine the degree of agreement among the experts concerning mandates affecting total building performance.

Since the data in this study are paired comparisons, the Kendall coefficient of agreement used to determine the degree of agreement among the experts.

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Table 2: Preference matrix showing the total frequency of pair-wise comparison ratings of the 50 experts.

Mean Importance Rating	ð	ŋ	Ɣ	ω	ɸ	φ	ψ
ð		46.68	45.74	70.85	41.28	52.34	64.47
ŋ	46.68		52.98	53.4	43.19	67.23	63.83
Ɣ	45.74	52.98		64.89	54.68	61.06	56.38
ω	70.85	53.4	64.89		46.17	51.7	69.15
ɸ	41.28	43.19	54.68	46.17		53.83	71.49
φ	52.34	67.23	61.06	51.7	53.83		58.94
ψ	64.47	63.83	56.38	69.15	71.49	58.94	

ð= Thermal Performance, ŋ= Visual Performance, Ɣ= Acoustic Performance, ω= Indoor Air Quality, ɸ= Spatial Performance, φ= Building Integrity, ψ= Safety and Security

The result from the test of significance had shown that the degree of agreement among the experts did not occur by chance. Thus there is consensus among the experts despite their various backgrounds in their ratings of the importance of the performance mandates in total building performance. In this sense, it would then be important to use the experts' ratings to compute the weights of the performance mandates subsequently.

In addition to knowing that the ratings did not occur by chance but that there is agreement among the experts in their importance ratings, it is also useful and interesting to examine the rate of recurrence for each mandate. This helps to illustrate the degree of agreement the experts have in their importance ratings of each mandate in comparison to other mandates.

A matrix which tabulates the mean pair-wise importance ratings of each pair of performance mandates is shown in Table 3. The overall importance rating of each performance mandate is obtained by summing up the individual ratings of that mandate in comparison to each of the other six mandates across the rows.

The matrix provides a good overview of the relationships between the performance mandates, reflecting the mean comparative importance rating of one mandate to the others, as well as the overall importance of each mandate relative to the others. The entries tabulated in the 2nd to 8th column constitute the mean importance ratings of the 50 experts in the pair-wise comparison between the mandate in each row to every other mandate from the 2nd to the 8th column.

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Table 3: Overall importance rating of each performance mandate in an office building

Mean Importance Rating	**ð**	**ŋ**	**Ɣ**	**ω**	**ф**	**φ**	**ψ**	**Raw Score**
ð		28	28	15	30	24	18	143
ŋ	23		27	24	22	17	18	131
Ɣ	23	24		18	23	20	18	126
ω	33	27	33		27	25	16	161
ф	21	29	28	24		24	16	142
φ	27	34	31	26	27		15	160
ψ	33	33	33	35	35	36		205

The last column in the matrix shows the overall importance rating of each performance mandate obtained by aggregating the mean pair-wise ratings of that mandate across the row. Thus each row score in the last column represents the relative importance of each performance mandate in total building performance taking into account its relationship with the other six mandates. It is seen from Table 3 that Safety and Security got the highest row score (205) while Acoustic Performance obtained the lowest score in comparison (126) among all the mandates.

The means, standard deviations, maximum and minimum VAS scores associated with each basic attribute and feature of the seven performance mandates are presented in Table 4 and Table 5. In this analysis, a VAS score of 50 is taken to be the cut-off point beyond which an attribute or feature is considered to be important or desirable. As shown in Table 4, it is observed that the mean ratings of the basic attributes within the seven mandates are on the whole considered high (with VAS score exceeding 50) indicating that the experts perceive these attributes to be important indicators in the assessment of building performance. Likewise, it is also observed from Table 5 that the mean VAS score for the features generally lie above the 50 mark. It can be inferred that the experts appear to rate most of the features as desirable in their contribution towards the performance of the respective mandates.

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Table 4: Rating of Basic Attributes relevant to each performance mandate

Basic attributes	Mean	Standard deviation
Air Temperature	79	25
Relative Humidity	66	33
Mean Radiant Temperature	71	32
Air Velocity	70	33
Illuminance level	88	7
Daylight factor	81	22
Daylight Glare Index	64	35
View to outside	62	35
Background noise level	51	37
Speech privacy	66	34
Speech intelligibility	54	37
Sound insulation quality	67	31
Problem of echo	64	35
Ventilation rate	86	13
Amount of air pollutants	69	33
Odor in office	78	28
Air temperature	88	7
Relative humidity	72	30
Way-finding performance	81	19
Occupancy density	81	21
Provision for disabled	61	37
Structural stability	89	3
Building Envelope integrity	57	33
Interior system integrity	72	28
Building maintainability	89	7
Fire integrity	84	20
Escape time	81	25
Emergency evacuation plan	89	5
Utility provisions & protections during emergency	80	25
Design for control of ingress & egress	78	26
Security measures after normal operating hours	83	18

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Table 5: Rating of Features relevant to each performance mandate

Basic attributes	Mean	Standard deviation
VAV with individual control	79	22
Sensor control (body heat +movement)	76	24
Occupancy sensor	63	33
Day-lighting systems	52	36
Sun-shading features on façade	59	37
Operable windows	78	24
CO2 sensors to control fresh air intake	61	34
Centralized waste & human cleaning System	70	30
Flexibility in workplace transfiguration	56	36
Availability of social meeting area	65	33
Quality of Public Address (PA) system	57	35
Leakage detection system	74	29
Personal safety / evacuation kits	79	25
Alarm activation system	74	29
Intruder sensors	74	30

However, it is noteworthy to observe that the standard deviations of the VAS scores are in general relatively high. This can perhaps be explained by the extreme difference in ratings as reflected by the maximum and minimum VAS scores. As expected, it is not possible for the experts to have total agreement on the importance and the desirability of the basic attributes and features respectively thus resulting in the great standard deviations. In view of this, the survey data is carefully scrutinized for ratings that fall outside the 95% confidence interval.

Upon further examination, it is discovered that the number of experts who rated the basic attributes and features as considerably very different from the others in the group i.e. their ratings fall outside the 95% confidence interval, is still considered small, comprising less than 10% of the sample at the very most. It is the occurrence of these few outliers that caused the great diversity in the standard deviations and since the outliers only constitutes a very small percentage (less than 10%), the survey results are still considered reliable. Notably, the dispersion in ratings varies for different attributes and features which implied that the experts had differing opinions on different attributes and features. The differences are most probably attributed to their professions and experiences. However, observation of the data revealed that there is still good consensus and consistency among majority of the experts in their ratings of these basic attributes and features.

While a VAS score of 50 and above for a basic attribute or feature may be considered to be important or desirable in its contribution towards the respective performance mandates, it is insufficient to conclude that they are indeed important or desirable solely based on the mean rating value alone. The attributes and features have to be proven statistically as being important or desirable in their contribution towards total building performance to justify their inclusion in the assessment framework. The one sample T-test is appropriate in this case to

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statistically determine the attributes and features that are considered significantly important or desirable by the experts. Those that are not can then be excluded in order to further streamline the assessment framework.

In using the one sample T-test, it is usually assumed that the dependent variable is normally distributed. As such, prior to conducting the one sample T-test, the normality in the distributions of basic attributes and features have to be checked. The one sample t-test was carried out for all the basic attributes and features under their corresponding performance mandates to compare their VAS scores with the midpoint of 50. This is the cut-off point beyond which any basic attribute or feature is considered to be important or desirable respectively by the experts. The test value used in the one- tailed t-test was 50.

Analysis of top basic attribute and feature within each performance mandate

As all the basic attributes within the seven mandates had been found to be significantly important, they would be included in the assessment framework as key performance indicators in the later stage. Based on the list of existing basic attributes and features, the top basic attribute and feature within each performance mandate is identified in accordance to the highest computed mean rating. The top basic attributes and features within each performance mandate are presented in Table 6.

Table 6: Basic attributes and features identified within each performance mandate

Performance Mandate	**Top Basic Attribute**	**Mean**	**Standard**	**Top Feature**	**Mean**	**Standard Deviation**
Thermal Performan	Air Temperatur	79		VAV	79	22
Visual Performance	Illuminance level	88	7	Occupancy sensor	63	33
	Daylight	81	22			
Acoustics Performance	Sound insulation quality	67	31	Quality of PA system	57	35
IAQ Performance	Air temperature	88	7	Operable windows	78	24
	Ventilation	86	13			
Spatial Performance	Way-finding performa	81	19	Availability of social meeting	65	33
	Occupancy density	81	21			

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Building Integrity	Structural stability	89	3	Leakage detection system	74	29
	Building maintainability	87	7			
Safety & Security	Emergency evacuation	89	5	Personal safety	79	25

As seen from the table, air temperature obtained the highest mean importance rating (79) in comparison to the other attributes within the mandate Thermal Performance. This result is not unexpected because air temperature has always been the key indicator of thermal performance of the indoor environment as it is the most directly felt element as compared to the rest of the attributes. Temperature largely governs a person's general feeling of hot or cold and office workers had often reported that temperature fluctuations tend to be more irritating than conditions that are consistently cold or hot (Aronoff and Kaplan, 1995). This aptly reflects that people are generally more sensitive to changes in air temperature.

As different people have different perception on the level of thermal comfort, it is no wonder that VAV is considered as a desirable feature in the building by the experts. In order to deliver conditions that are more closely tailored to the needs of the individuals, VAV whereby the supply air temperature is adjusted by sensors located in the area that the system serves can help to improve thermal comfort.

The top basic attribute within Visual Performance is illuminance level with a mean importance rating of 63 and this makes sense because adequate lighting for visibility and carrying out of tasks is the predominant indicator of visual comfort in the office setting. If there is insufficient illuminance and conduction of tasks is impaired, it would cause major dissatisfaction among the occupants even if other lighting criteria are fulfilled thus this explains why illuminance is rated the most important. It is not surprising to note that sound insulation quality is considered the most important attributes of Acoustic Performance in the modern workplace with a mean rating of 57. Sound insulation quality of the office refers to the efficiency in isolation and blockage of unwanted noise sources and has a direct impact on provision for speech privacy. This is probably why this attribute is given the highest importance rating for its contribution to Acoustic Performance of a building. A Public Address (PA) system of good quality is also considered to be the most desirable feature in the building that can serve to enhance the acoustic performance of the workplace. In the event of emergencies especially, a good PA system which allows announcements to be made coherently and clearly without interference is certainly a crucial feature in the building. Way finding performance and occupancy density are rated to be the most important attributes of Spatial Performance of a building which are probably not unexpected as the workers in the building love to work in a place that is not rowdy and easily work around in their office.

Air temperature has been identified to be the most significant attribute of Indoor Air Quality in a workplace by the experts. On the other hand, it is quite interesting to note that operable window is considered the most highly desired feature to enhance the indoor air quality in an office building. In Nigeria, most of the windows are just 50% operable but it is advisable to make the windows in office buildings to be 100% operable (louver).

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The structural stability of the building is without doubt the most important attribute of Building Integrity at a mean rating of 89. The ability of the building to withstand the structural load and stresses over the building's lifespan is of utmost importance as it concerns the safety of the occupants. In addition to this, the emphasis on the structural stability of the building in the event of terrorist attacks is reinforced in the aftermath of the 911 attacks made on the World Trade Centre. Leakage detection system, on the other hand, has been identified as the most desirable feature with a VAS of 74 to enhance Building Integrity in a building. This type of system is useful for enabling plant and equipment to be monitored for leakage to avoid hazard to the occupants and damage to the environment as well as office property.

It is evident from Table 4.6 that emergency evacuation plan is rated to be the most important attributes of Safety & Security performance of the building at mean rating of 89. Emergency evacuation plan here refers to the ability of the building to have planned for the evacuation of the workers during emergency cases. The lesson from the collapse of World Trade Centre in the 9/11 terrorist attack where the steel structure of the building was unable to withstand the immense heat caused by the sudden explosion has increased the awareness of the building community in this aspect. In order to give real time warning to occupants instantaneously at the time of emergencies and intrusion, an efficient alarm activation system is highly desired to enhance the safety and security performance of the building as rated by the experts. This would alert the occupants so that they can be prepared to evacuate the building in time of emergencies.

Generally, it is noted that the standard deviations of the top basic attributes and features within each mandate are comparatively smaller than that of the other variables within the corresponding mandate. Hence the variability of the ratings is not that great, i.e. in other words, the distribution of ratings for the top attributes and features is not overly diverse and dispersed, indicating a good degree of consensus in the experts' judgments for placing the highest priority on these parameters.

Analysis of top ten basic attributes and features among all the performance mandates

Almost half of the top ten basic attributes singled out are categorized under the Safety& Security performance mandate, indicating a strong concern and need for proper precautions in the case of a disaster. These four attributes are emergency evacuation plan (89), fire integrity (84), security measures after closing hours (83) and escape time (81). Likewise for the list of top ten features, survey respondents found the alarm activation system (83) and in-building repeater system (74) for the purpose of safety and security in a building most desirable. The increasing concern for safety & security is not unfounded, especially with heightened building security and continued awareness of safety issues creating a raised level of anxiety in most people.

Table 7: Top Ten Attributes and Features identified among all seven performance mandates

Top Ten Basic Attributes	Mean Importance	Performance
Emergency evacuation plan	89	Safety & Security
Structural stability	89	Building integrity
Air temperature	88	IAQ performance
Illuminance level	88	Visual
Building maintainability	87	Building Integrity
Ventilation rate	86	IAQ performance
Fire integrity	84	Safety and
Security measures after closing hours	83	Safety and security
Escape time taken occupant	81	Safety and security
Occupancy density	81	Spatial performance
Way finding performance	81	
Top Ten Features	**Mean desirabilit**	Performance mandate
Personal safety/evacuation kits for building occupants	79	Safety &security
Variable air volume with individual control	79	Thermal
Operable window	78	IAQ
Sensor based on body heat and movement	76	Thermal
Leakage detection system	74	Building integrity
Alarm activation system	74	Safety and security
Intruder sensor	74	Safety and security
Centralized waste and human cleaning	70	IAQ performance
Availability of social meeting area	65	Spatial
Occupancy sensor	63	Visual

Of the top ten basic attributes, two of them fall under the category of Building Integrity as reflected in Table 7. The attributes are, namely, structural stability (89) and building maintainability (87) respectively, in descending order of mean importance ratings. The emphasis on building integrity is expected. The question of upgrading current building codes in the face of the World Trade Center (WTC) collapse has touched off a debate in the design, construction, and real estate communities that will impact facility management operations across the country. As such, the results from this survey have amply demonstrated this increased awareness of the structural performance of our built environment.

The two basic attributes from the top-ten list which are related to the Indoor Air Quality (IAQ)

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Performance with reference to Table 7, it is observed that the survey respondents perceived air temperature (88) and ventilation rate (86) to be the two most important factors in IAQ performance, indicating the severe need for less temperate and well ventilated work environment. On the other hand, under the list of the top ten features, two of which fall under the category of IAQ performance mandate. These two features are operable window (72) and centralized waste and human cleaning system (70). The desirability for these two features in a building further reiterates the need for movement of clean air that is free from pollutants and smell and yet at the same time does not compromise with the habits of some of the occupants

The two basic attributes from the top-ten list which are related to the Visual Performance with reference to Table 7, it is observed that the survey respondents perceived illuminance level (88) and daylight factor (81) to be the two most important factors in Visual performance, indicating the severe need for workable environment with good sight. On the other hand, under the list of the top ten features, one of which fall under the category of Visual performance mandate. This feature is occupancy sensor (63). The desirability for this feature in a building reiterates the need for work under good lighted environment to improve work level and speed.

The two basic attributes from the top-ten list which are related to the Spatial Performance with reference to Table 7, it is observed that the survey respondents perceived way finding performance (81) and occupancy density (81) to be the two most important factors in Spatial performance, indicating that workers like to be few in their offices and be able to move around at the same time with ease. On the other hand, under the list of the top ten features, one of which fall under the category of Spatial performance mandate. This feature is availability of social meeting area (65). The desirability for this feature in a building reiterates the need for having all the workers together at a meeting place during meetings for discussing of important issues. Although the basic attributes of Thermal Performance did not come up under the top ten basic attribute list (See Table 7), survey respondents expressed the desirability of some of these features under the top ten features list. Survey respondents found VAV with individual control (79) and sensor based on body heat and movement (76) to be the two most desirable features under Thermal Performance Mandate.

It is noted that neither attribute nor feature under the respective top ten lists is related to Acoustics Performance Mandate. This implies that most building professionals generally place less emphasis on acoustical performance in an office building. As discussed, this might be because in comparison to other performance mandates, acoustics performance is perceived to play a smaller role in total building performance. However as emphasized previously, it must be reiterated that acoustic performance of a building must still be within acceptable level. Otherwise this would become a source of problem and one of major concern in building performance assessment if annoyances and complaints are invoked.

The results showed that in the content analysis of the responses from the open-ended interview, IAQ Performance and Safety and Security Performance were the most frequently mentioned concepts in a high performance building. This was followed by Thermal Performance, Spatial performance, Building Integrity Visual performance and then Acoustic Performance. The frequency of mentions was used as an indicator of the importance of a performance mandate in a high performance building. Although IAQ Performance, Safety and Security and Thermal Performance were ranked in the first, second and third place

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respectively, their frequency of mentions differs very marginally, at 16%, 14% and 9% correspondingly. As such, the results indicate that these three mandates are considered to be the more important factors in a high performance building.

Although there was little agreement among the experts in their overall individual pair- wise ratings of the performance mandates with a low coefficient of agreement u=0.12, the results of the test of significance showed that the ratings could not have occurred by chance. Hence this indicate that there is still a degree of consensus among the experts as they did not assign the ratings randomly. Further analysis showed that there is significant agreement on the overall importance of certain mandates over another in total building performance. The results of the Tukey Kramer test showed that the overall importance ratings between certain pairs of performance mandates are significantly different, indicating that there is reason to conclude that one performance mandate is significantly more important than another in total building performance.

The results showed that Safety & Security is without doubt the most important performance mandate with respect to the other mandates in its contribution towards total building performance. This is followed by IAQ Performance, Building integrity, Thermal performance, Spatial Performance, Visual performance, and lastly Acoustic Performance. These results corroborate with the results obtained from the content analysis where IAQ Performance and Safety and Security were ranked the first and second. Thermal and Spatial performance were only ranked number four and five on the list.

The importance and desirability of the basic attributes and features within each performance mandate are also examined and the top basic attribute and feature within each performance mandate are identified and discussed. One sample t test was also conducted to sieve out the attributes and features that are not rated significantly important or desirable so that they may be excluded. The results revealed almost 50% of the top basic attributes and features among the performance mandates are categorized under Safety & Security. This further affirms that Safety & Security is very important in a high performance building.

The results of the Tukey Kramer Procedure are generated by PHStat2 in Microsoft Excel based on the above statistical inputs. Table 8 lists the pairs of mandates that are identified by the statistical procedure to be significantly different from each other in terms of its overall importance in total building performance.

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Table 8: Pairs of mandates identified to be significantly different in overall importance

Performance Mandates	Absolute Difference
Thermal to Visual	12
Thermal to Acoustics	17
Thermal to Spatial	1
Visual to IAQ	30
Visual to Building Integrity	29
Visual to Safety & Security	74
Acoustics to IAQ	35
Acoustics to Building Integrity	34
Acoustics to Safety & Security	79
IAQ to Spatial	19
Spatial to Building Integrity	18
Spatial to Safety & Security	63
Building Integrity to Safety & Security	45

Table 8 shows that Safety & Security is significantly more important than Visual Performance, Acoustic Performance, Spatial Performance and Building Integrity in total building performance. However it is noted that the disparity in absolute difference between Safety & Security and Building Integrity is not very big at 45. The result justifies greater priority to be allocated to Safety & Security performance of the building with respect to the other four mandates in total building performance evaluation. It also further affirms the findings from previous section where Safety & Security has been shown to receive comparatively higher mean importance ratings than other mandates.

It is also seen from the table that Building integrity is significantly more important than Visual Performance, Acoustic Performance and Spatial Performance in total building performance. The absolute difference between the overall importance rating of Building integrity and the three mandates are rather large in magnitude. This result indicates that greater emphasis is placed on Building integrity over Visual Performance, Acoustic Performance and Spatial performance in total building performance evaluation. Likewise, it can be concluded from the results that IAQ is rated to be significantly more important than Visual Performance, Acoustics Performance and Spatial Performance by the experts in a high performance building. This signifies that in a high performance building, IAQ would be given a greater relative priority over these three mandates.

On the whole, the results indicate that Safety & Security, Building integrity and IAQ are the three most important performance mandates in a high performance building especially with respect to Visual Performance, Acoustic Performance and Spatial Performance.

Developing a total building performance framework for assessing office buildings

As the performance of a mandate is dependent on the corresponding performance of those

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relevant attributes and features, the Overall Weighted Attribute Score and Overall Weighted Feature Score were used to determine the performance index of each mandate. These two constituent scores of each mandate were totalled and divided by the maximum total score which sums up to 100 for both categories to arrive at the performance index for the respective mandate. In cases where the Overall Weighted Feature Score is equivalent to 0, only the Overall Weighted Attribute Score is divided by the maximum total score (120) to determine the performance index.

The performance index is the ratio of aggregated overall weighted scores of both attributes and features to the maximum total score and the maximum value of the index is 1. The performance index derived serves as an indicator of the level of performance achieved by each mandate hence the higher the index, the better the performance of a particular mandate. It is useful to derive individual performance index for each mandate so that the performance of each mandate can be examined separately to identify problems which may exist in each mandate.

As mentioned, the maximum value of a performance index is 1. This indicates that all attributes within the mandate are performing at the optimum/maximum level with an Overall Weighted Attribute Score of 100 and all the desirable features identified are present in the building with an Overall Weighted Feature Score of 20. On the other hand, when optimum/maximum performance is achieved by all attributes but no features are present in the building, the corresponding performance index achieved will be $100/120 \approx 0.8$. . If all the attributes have just met the minimum acceptable thresholds but there are no features present, then the performance index will be $50/120 \approx 40$. The lowest value of the performance index is -0.4 and this corresponds to the failure of all attributes within the mandate with an Overall Weighted Attribute Score of -50. The Overall Weighted Feature Score is not included because the prerequisite of meeting the basic requirements of the attributes has not been met. Thus the performance index is derived by taking $-50/120 \approx -0.4$.

It is assumed that Total Building Performance can be assessed by aggregating the individual performances of the seven mandates as the satisfactory performance of the seven mandates is the determinant of the overall building performance. As the role each mandate plays in the contribution towards total building performance varies, the weights of the performance mandates must be factored in to reflect the relative importance of each mandate. In view of this, a linear function to integrate the weighted performance indices of all seven mandates to arrive at the TBP index is proposed as follow in Equation 1.

Table 9: Mean performance mandates and acoustic performance

	Architects	Builders	Estate surveyors	Mechanical engineers
Φ* Ɣ	31.67	36.67	22.92	23.33
Ɣ* φ	63.33	28.33	60	78.33
Ω* Ɣ	54.44	69.17	49.17	58.33
ω * Ɣ	42.5	33.33	51.25	43.33
Ψ* Ɣ	61.94	57.5	73.54	71.67
Ð* Ɣ	57.22	53.33	50.83	28.33
Ŋ* Ɣ	38.89	71.67	42.29	46.67

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Table 10: Weight of all the performance mandates against acoustic performance by professionals

	Architects	Builders	Estate surveyors	Mechanical engineers
Φ* Ɣ	9.05%	10.48%	6.55%	6.67%
Ɣ* φ	18.10%	8.10%	17.14%	22.38%
Ω* Ɣ	15.56%	19.76%	14.05%	16.67%
ω * Ɣ	12.14%	9.52%	14.64%	12.38%
Ψ* Ɣ	17.70%	16.43%	21.01%	20.48%
Ð* Ɣ	16.35%	15.24%	14.52%	8.10%
Ŋ* Ɣ	11.11%	20.48%	12.08%	13.33%

Table 11: Mean score of each mandate in relation to their weight

	Mean score	% contribution	Rank
ψ	64.04	18.30	1
φ	54.54	15.58	2
ω	53.69	15.34	3
ð	46.77	13.36	4
ŋ	44.01	12.57	5
Ɣ	43.62	12.46	6
ɸ	43.33	12.38	7

Hence,

TBP Index = 13.36ð+12.57ŋ+12.46Ɣ+15.34ω+12.38ɸ+15.58φ+18.30ψ Equation 1

Where:

ð= Thermal Performance,
ŋ= Visual Performance,
Ɣ= Acoustic Performance,
ω= Indoor Air Quality,
ɸ= Spatial Performance,
φ= Building Integrity, and
ψ= Safety and Security.

The above function is based on the assumption that the individual performances of the seven mandates can be assessed independently and aggregated linearly to evaluate the total building performance. The individual performances of the seven mandates are measured by the performance index obtained for each mandate. The values of the performance indices of

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the seven mandates are substituted into the proposed function to derive the TBP index. Hence the magnitude of the performance indices will affect the result of the TBP index.

It is also assumed that total building performance can be measured along a linear scale where a value of 100 represents the maximum TBP index achievable. The lowest TBP index derivable is -40 where all the seven performance mandates have failed corresponding to the failure of all 38 attributes with calculated values at the extreme limits. In this case, the performance index is -0.4 for each mandate which is the lowest possible index as mentioned earlier. If all 38 attributes just fulfilled the minimum acceptable requirements corresponding to a score of 50 each (with no features present), the performance index of each mandate is approximately 0.4 and the TBP index derived is 40.

It is noted that it might be possible for a building that does not have all the attributes meeting the acceptable criteria to have a higher TBP index than another which has all the attributes meeting the acceptable criteria. This scenario is possible in the event that one building has most attributes achieving optimum performance and a few performing poorly outside the acceptable range but on the average still achieved a very high TBP index. On the other hand, another building that meets all the criteria albeit just marginally will achieve a lower TBP index in comparison. In this case, it is difficult to tell from the TBP index at first glance which building is better than another if the definition of a good building is one that has at least met all the acceptable requirements, i.e. the performance of all attributes are within the stipulated acceptable range.

However, it is presumed that most buildings are deemed to meet the acceptable requirements and even if not, should not deviate from the acceptable limits too drastically because of codes, standards and guidelines in place for compliance. Assuming that this holds true, then the higher the TBP index the better a building because it is very unlikely to have a building that has many attributes performing exceptionally well and some performing extremely poorly. This is further supported by the fact that the attributes within each mandate are usually interdependent, so the performance of one attribute is likely to have an impact on the performance of another.

In view of the above considerations, it is justifiable to say that a building with a higher TBP index is better than another with a lower TBP index even if the one with the higher TBP index has a few attributes performing slightly outside the acceptable limits. For example, say Building A has a higher TBP index than Building B. Building A has all attributes performing at optimum level except for thermal comfort with PPD at 22% which is only marginally below the minimum acceptable value of 20%. Building B on the other hand, has all attributes performing within the acceptable range but just meeting the threshold level. In this case, it is reasonable to conclude that Building A is on the whole a better building than Building B despite not meeting all stipulated acceptable performance requirements because the deviation of performance from the acceptable limits is marginal.

CONCLUSION

The weights of the seven performance mandates computed from experts' ratings reflect the relative importance of each mandate in total building performance. Performance indices were also derived for the seven performance mandates which served as an indication of the performance level of each mandate in the assessed building. The performance index of each

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mandate was taken from the aggregation of Overall Weighted Attribute Score and Overall Weighted Feature Score. The weighted performance indices of the seven mandates were then substituted into the above function to derive the overall TBP index which serves as an indicator of overall building performance. The maximum value of the TBP index was 100 and the lowest value was -40 which corresponds to the failure of all attributes, with measured values at the extreme limits. The proposed TBP assessment framework provides an opportunity for important performance requirements of office buildings to be assessed comprehensively along a common set of performance dimensions. This assessment framework ensures the total needs of a building to be examined together in an integrated manner which does not result in promotion of a single performance area at the expense of another.

Secondly, the assessment framework is not only capable of assessing the current capability of the occupied building in use, it can also be used for periodic check-ups, troubleshooting when problems occurs as well as an aid to building operation and maintenance.

Thirdly, as professionals in different disciplines working in different organizations tend to see the same problem from different viewpoints, it is beneficial to be able to integrate these viewpoints in a systematic manner which would serve as invaluable information. The expert survey conducted makes it possible to take advantage of the vast body of knowledge and expertise created in a variety of separate disciplines and enable different priorities to be focused on different performance issues in the building.

Lastly, the TBP index can be used to evaluate and compare building performance. It can be used to facilitate the benchmarking of total building performance of office buildings in Nigeria and thus may pave the way to the development of a labelling system.

Implications of the study

The findings of this study implies that the government should demand for TBP index of office buildings before issuing building permits for the construction of office buildings in Nigeria. This is necessitated by the need for security of buildings, especially in the wake of terrorists' attacks that are targeting office buildings. Also, the construction professionals that are involved in building design are required to incorporate the analysis of buildings for total building performance during the function analysis of buildings at the conceptual design stage.

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