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A SURVEY ON THE PERFORMANCE-RISK RATING INDEX FOR BUILDING PERFORMANCE ASSESSMENT IN HIGHER EDUCATION BUILDINGS

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Graphical abstract

Abstract

Higher education institutions (HEI) buildings are considered as key functional, as it generates environment, human and economic resources. The growing population of students in HEI is increasing year by year; therefore, it is important to optimize the building performance by conducting a proper performance assessment tool. Inevitably, growing students' population with various learning activities has constituted risk emergence, green issues, inefficient of energy use and climate discomfort. However, concerns on the prevalence of risk towards occupants are still deficient in assessing building performance. This paper presents the result of rating index for a construct of performance criteria, namely Building Performance-Risk Indicators (PRI). Questionnaire survey involving Analytical Hierarchy Process (AHP) is used to generate the weightings for each indicator. There were 12 experts from the leading facilities management (FM) industry involved in the survey and rating process. The experts' subjective weightings of the different attributes are extorted using the AHP computer software Expert Choice 11.

Keywords: Building performance evaluation, performance indicator, health and safety risk, Analytical Hierarchy Process (AHP), rating index

Abstrak

Bangunan institusi pengajian tinggi (IPT) merupakan lambang fungsi intelektual yang menghasilkan perkembangan ilmiah dan ekonomi. Terdapatnya peningkatan populasi pelajar di IPT dari masa ke semasa, oleh yang demikian, prestasi bangunan perlu dioptimumkan bagi mengekalkan kelestarian serta fungsi yang memenuhi kehendak pengguna. Perkembangan aktiviti pembelajaran di IPT sedikit sebanyak mewujudkan pelbagai isu bangunan seperti ketidakselesaan persekitaran, ketidakcekapan tenaga serta risiko pengguna. Di dalam konteks penyenggaraan dan penilaian prestasi bangunan, penekanan terhadap aspek risiko pengguna masih kurang diberi perhatian. Oleh itu, kertas kerja ini membentangkan skala pemberat bagi pembinaan kriteria prestasi yang dipanggil penunjuk prestasi-risiko (PRI). Kaji selidik melibatkan Analytical Hierarchy Process (AHP) ini digunakan untuk menjana pemberat bagi setiap petunjuk. Kaji selidik ini juga melibatkan 12 pakar dari sektor pengurusan fasiliti (FM) di Malaysia dan perisian komputer Expert Choice 11 digunakan bagi menganalisis data kajian.

Kata kunci: Penilaian prestasi bangunan, risiko kesihatan dan keselamatan, *Analytical Hierarcy Process (AHP),* petunjuk prestasi

1.0 INTRODUCTION

The development of higher education institutions (HEI) buildings including expanding facilities is spirally a welcoming sign on the growth of tertiary educational programmes. However, like other buildings, university buildings built for learning are also susceptible to the forces of change by various factors. Growing student populations with various learning activities have constituted risk emergence, green issues, inefficient of energy use and climate discomfort [1]–[4], thus, may decrease the total performance of the buildings. Performance failure not only affects the building's sustainability, but the users are also prone to be affected by the performance of the building [5].

It was revealed that performance optimisation in HEI buildings must avoid putting occupants, visitors and passers-by at risk [6]. Several studies have shown that inefficiency of energy in buildings presents vulnerability of risk towards the safety and health of building users [2], [7]–[13]. This demonstrates the significance of addressing risk in building performance evaluation that has the potential to jeopardise the building's users.

Most of the university buildings in Malaysia are constructed in the 1960s. Nevertheless, all buildings deteriorate and decay with age as a result of various factors, including poor quality materials, bad workmanship, excessive usage, abuse as well as inadequate and poor maintenance. As buildings become larger and house more people, political and societal issues have become more complex, which in turn change the risks associated with occupying buildings [14]. Proper building performance assessment through benchmarks and indicators can thus help organisations to reduce the operation cost.

2.0 CONCEPTUAL REVIEW OF BUILDING PERFORMANCE

Building performance studies have been emerged into numerous objectives and aspects. The evolution of performance in building is growing due to many factors, such as environment change and shifting of building needs. The prospective of building performance in fulfilling the expectations of owners, designers, building operators and the occupants is enormous [15]. Hence, it is crucial to understand the term "building performance". Inevitably, there is no single definition of terms accepted for building performance. Even though the term "building performance" is simple, the specific definition depends upon differing interests and widely requirements in buildings [16]. Building performance has been defined in BS 5240 as "behaviour of a product in use" [7], [17]. It is also described as the ability of the building to contribute in fulfilling the functions of its intended use [18].

Building performance is also a process of assessing progress towards achieving goods and services efficiency, quality of building outputs and effectiveness of building operations [19]. While, performance of a building simply as accomplishment, fulfillment, and achievement of a building in meeting the emergence objectives [20]. This refers to comprehensive features of a building including structural, architectural, surroundings, environmental issues and building services. From the above definitions, the monotonous norms that can be found in building performance are related to ability, function, operations, and services. Hence, it can be summarized that the definition of "building performance" is the ability of building to be operated in the best function, the best services and deliver the best quality throughout the building life cycle.

2.1 Rationale of Risk in Building Performance

Building performance deals with the physical aspects of the building and risk is described as the social factor that is derived from performance failures. Risk is associated with the unintended consequences of building performance and the primary cause of these risks may be lack of measured performance data [21]. Risk approach advocates principles on the level of building performance and predicts impact on society that is ultimately affected by the sources of risk. Therefore, benchmarking risks in building performance can be framed as health risk, safety risk, environmental risk, economic risk as well as political risk and others [7], [11], [22]. To suit the aspects in building performance in HEI building, health risk and safety risk become the main focus in this research. As supported that health, safety, security and sustainability have all been integrated into the lexicon of building performance and it requires accountability for these factors during each phase of the building's life [21]. The following provide the description of health risk and safety risk:

a) *Health Risk:* Associated with human health effects; either direct or indirect exposure of building factors that can cause health risks. Sick Building Syndrome (SBS), Indoor Air Quality (IAQ) and environmental quality are often related to the causes of health risks in buildings during occupancy period [8]. Besides that, building facilities [2] and post-construction activities such as demolition, salvage, maintenance, or renovation of structures are also allied to human health impacts [8].
b) *Safety/Security Risk:* In building context, users' safety is regularly permitted in buildings during construction and post construction stage; this risk includes injury, death. [11], [14], [23], [24], building defects, deterioration, building facilities, means of fire escape, [12], [24], crime, theft, nuisance, burglary [25].

2.2 The construct of Performance-Risk Indicators (PRI)

The initial step in developing a new rating index is to select the assessment areas that should be included and next, determine the parameters, attributes or indicators that can be used to measure the selected aspects [26], [27]. To recap, an analysis of the established building performance evaluation (BPE) schemes is reviewed and the review is considered by far the most comprehensive, including methodological tools developed to examine sustainability issues [27]. Therefore, the performance element is focused to three (3) main headings, which are functional performance, technical performance, and indoor environmental performance. These performance elements are further divided into several criteria; named as Performance-Risk Indicators (PRI). The construct indicators are relatively compiled and characterized from previous established rating tools such as Building Research Establishment's Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Building Safety Condition Index (BSCI), etc and also prior research [2], [7], [8], [10]–[12], [14], [23], [24], [28], [29].

A qualitative approach is used to identify the concept of building performance and risk approach, preliminarily compiled from various literatures and previously established building performance rating schemes. Indicators or variables for building performance and risk criteria are then validated through preliminary survey, using semi-structured interview technique. Eighteen (18) building managers and operators in local university buildings were involved in the interviews and their input is needed to obtain suitability of the listed indicators for building performance rating assessment to be used in the local HEI. Table 1 presents the construct of PRI that should be incorporated to establish the building performance-risk rating index, with 26 indicators categorised under the performance elements of functional performance, technical and indoor environmental performance.

3.0 METHODOLOGY

To determine the weightage score for the construct of performance-risk indicators (PRI), the survey adopts quantitative approach using questionnaire as the instrument. The questionnaire form comprises Section A: Demographic Background and Section B: The Analytical Hierarchy Process (AHP) for the Performance-Risk Indicators (PRI). The type of questions consists of multiple choice questions and also comparison pair-wise of indicator for AHP application. The questionnaire form begins with a cover stating the purpose of survey and definition of key terms that were used frequently in the research. This is to enhance the understanding of the means of research area towards the experts, thus help to obtain more reliable answers from the experts.

Table 1 The construct of PRI based on the result of preliminary survey

Performance Elements (PE)	Performance-Risk Indicators (PRI) *(associated to the user's health and safety risk)*
Functional Performance	Spaces (area) Orientation (direction, layout) Infrastructure (parking, landscape, etc) Access/entrance Circulation area (corridor, lobby, yard, etc) Ergonomic building facilities Adequacy of building signage Emergency exits Building-related illnesses/sick building syndrome Construction Signage
Technical Performance	Design of building fittings/fixtures (door, window, ironmongery, sanitary, etc) Structural stability (column, beam, slab, staircase, etc) Information Technology systems operations Electrical services Plumbing services Fire Prevention Services Materials & Internal Finishes (floor, wall, ceiling) Roof
Indoor Environmental Performance	Cooling (Thermal comfort) Artificial lighting (Visual comfort) Natural lighting (Visual comfort) Waste reduction Building ventilation Acoustic comfort (Noise) Level of cleanliness

3.1 The Expert Panels and the Sampling Method

Since the AHP method relies on experts to moderate feedback throughout the process, hence, the panel of experts that will participate in this main survey are predetermined with certain criteria. A careful selection of participants is important since the quality and accuracy of responses are only as good as the expert quality of the participants who are involved in the process [30]. The targeted respondents for this survey comprise the professionals from the leading public and private organizations related to facilities management (FM) industry. This is due to the familiarity and the general practice of the building performance audit or assessment in FM fields. The sampling frame comprises a list of experts and professionals, with the help of Malaysian Association of Facility Managers (MAFM) that has recorded the experience and involvement in building performance evaluation (BPE) of all professionals. Purposive sampling is used to obtain the number of experts as the potential respondents. Based on the pre-determined criteria of the experts and with the help from MAFM list of members, the list is shortlisted to 22 numbers of experts. The experts are from different fields such as architecture, engineering, surveying, academicians, facilities management and business studies. For this process, it requires the experts to provide justification on the importance of the construct indicators and also the rating process of weightage for each parameter. After the judgement is completed, the ranking of indicators are arranged according to the highest order of importance to the lowest order of importance. A final set of weightage assigned for each indicator is presented at the end of stages.

3.2 Analytical Hierarchy Process (AHP)

Although the attribute weighting can be determined by synthesizing the opinions gathered from an expert panel, consistent results cannot be readily obtained when there are a large number of attributes to be considered in the weighting process. In dealing with such a multi-criteria decision-making process, the Analytic Hierarchy Process (AHP) developed by Dr. Thomas L. Saaty in 1977 is recommended [31], [32]. This is because the AHP allowed experts to evaluate the attribute weightings with greater consistency through pairwise comparisons. The AHP is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales [33]–[36]. In AHP, all criteria or parameters are assigned with the weightage score that shows the importance of each criteria. The criteria with highest weightage score is clearly illustrated as the most important factor. In short, it is a method to derive ratio scales from paired comparisons. The AHP approach has been widely adopted in the built environment fields as decision making tool [27], [37]–[39]. It was also found that the previous building performance schemes such as Leadership in Energy and Environmental Design (LEED), Building Health and Hygiene Index (BHHI), Building Safety Condition Index (BSCI), etc, adopt the process of AHP to develop hierarchy or rating tool [32], [38]. AHP has also been used to assess risk in a supply chain, as mentioned by [40]. A set of weightings for building attributes and parameters can be generated in a more scientific manner based on the results of the opinion survey with the application of AHP [31]. AHP can also help decision makers compare the relative importance of the factors in a systematic and quantitative manner. Therefore, the application of AHP for this survey is robust and do not constitute any bias result as the judgment on the weightage is depends on the experts' decision. Moreover, the methodology of the AHP allows for the internal consistency of the respondent's results to be checked, which is essential for the identification of any illogical set of responses.

4.0 RESULTS AND DISCUSSION

4.1 Administration of Survey

A letter of invitation and the sample sets of questionnaire are firstly distributed to the shortlisted respondents, following a telephone conversation to confirm on their agreement to set a date for this survey. Out of total 22 experts, 12 experts are willing to participate in the survey and the rate of response for this survey is 54.6%. The percentage of response rate is acceptable, hence the data obtained from the experts are considered valid and sufficient. It was decided that the usual administration of AHP using a one-day workshop is not consider for this survey, since it is difficult to gather all the experts in the same day and time. Hence, a focus-group approach is used to obtain the data from the respondents. The focus-group approach is carried out in four (4) stages where the first stage involves 3 experts in the first and the second stage, 4 experts in the third stage and the last stage involve 2 experts. Before beginning with the survey, the researcher introduced the purpose of the survey to the respondents and showed all sections involved in the survey forms. A detail explanation was conveyed to the respondents for the application of Analytical Hierarchy Process (AHP) as the process is not aware by most of the respondents. The weightings of the building factors were assessed using nine (9) scales of importance [33], [34], as shown in Table 2. The respondents' weightings of the different factors were extracted from a pairwise comparison of the relative importance of all pairs of factors using the AHP computer software package Expert Choice 11 version 3.01.

Table 2 AHP Scale of Importance [33], [34]

AHP SCALE OF IMPORTANCE	DESCRIPTION
1	Equal Importance
2	Equally to Moderately
3	Moderate Importance
4	Moderately to Strong
5	Strong Importance
6	Strongly to Very Strong
7	Very strong Importance
8	Very strong to Extremely
9	Extreme Importance

4.2 Demographic Background

General demographic data were compiled from the experts, which include their academic background and working experience. Table 3 presents the summary of the respondents' demographic background. A majority of the respondents, which represents 50% out of total respondents, are from different background such as facilities management and business studies. All of the respondents affirmed that their working experience is above 10 years, where majority of them have experience between 16 to 20 years in the field. It is found that the respondents are designated in a higher position, i.e. from senior level to director level. It can be summarised that all respondents fit the identified criteria as the experts for the AHP survey.

Table 3 Demographic background of the experts

Items	Sub-Items	Frequency (N)	Percentage (%)
Gender	Male	9	75
	Female	3	25
Academic Background	Civil & Structural Engineering	4	33.33
	Mechanical Engineering	1	8.33
	Building Surveying	1	8.33
	Others: (Facilities Management and Business Studies)	6	50
Years of experience	11 to 15 years	4	33.33
	16 to 20 years	7	58.33
	More than 20 years	1	8.33
Level of position (in the current organisation)	Director Level	2	16.67
	Manager Level	6	50
	Senior Level	4	33.33

4.3 Result of Weightings for Assessment Items

The experts are required to compare the importance between two pair-wise indicators and rate the scale of importance for the chosen indicator. Comparison of importance for each indicator is rated using the values of importance 1–9 scale (as previously shown in Table 2). The rating of importance and internal consistency ratios are calculated by using the computer package Expert Choice 11 version 3.01. The relative importance (relative weight) of each category and each indicator within each category was established using square matrix structure. For each category and indicator, the weight was calculated by the geometric mean of values of questionnaires filled by experts who participated in the survey. The final step in the process combined the ratings of the criteria to form an overall rating for each decision alternative. The numerical pair-wise comparison of all indicators by combining overall judgment from the experts and the priorities of indicators are shown in Figure 1 and Figure 2 respectively. The distributive mode is chosen as it normalizes alternative scores under each criterion so that they sum to one. The internal consistency ratio (CR) must be less than 0.1 (10%) [34], hence, by using the Expert Choice, the computer package will locate the possible sources of inconsistency. It shows that the internal consistency for the combined instance for the overall indicators is .04 hence, the result is reliable and achieves consistency.

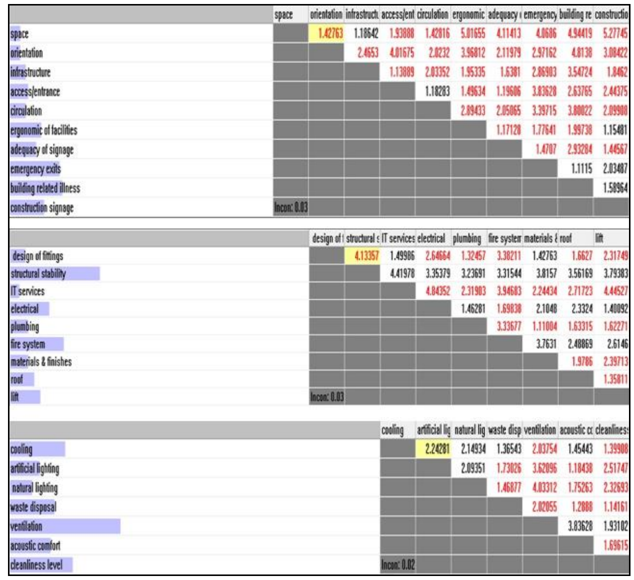

Figure 1 Numerical pair-wise comparison of indicators from Expert Choice 11

Figure 2 shows that *structural stability* is ranked as the most important indicator, with a global weight 14.9%, and followed by *fire prevention services* (9.1%), *building-related illnesses* (7.4%), *emergency exits* (6.8%) and *electrical services* (6.3%). This suggests that these five (5) indicators become the top important factors to be well performed in building performance, as it may generate larger impact towards the users'health and safety risk. To ease the calculation of weight for each performance element, the result from the combined synthesis of each indicator is illustrated into Table 4.

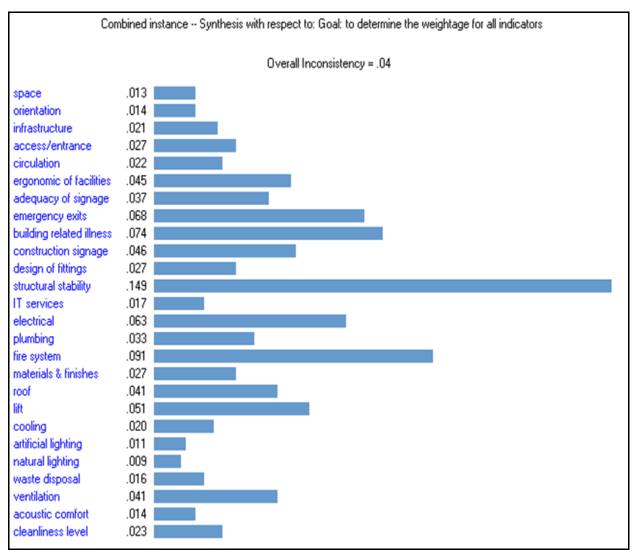

Figure 2 Priorities of indicators with respect to the goal – weighting of assessment items (distributive mode)

In respect to the result from the Expert Choice, it shows that the weightings for functional performance, technical performance and indoor environmental performance are 36.7%, 49.9% and 13.4%, respectively. This insinuates that technical performance was little bit more important than functional performance and indoor environmental performance. The performance elements are measured by placing a comparison against a standard for a criterion (or for a number of criteria) during the performance assessment process. The indicators of building performance are aspects of facilities that are measured, evaluated and used to improve buildings [41]. Hence, the structure of performance elements are ranked and described as follows:

a) *Technical Performance*: concerns on the elements can be categorised as the background environment that allows the operation of buildings and normally deals with electrical and mechanical services including heat and fire, etc.
b) *Functional Performance*: concerns on performance elements that directly support the function of building and activities within the building; much related to the building physical attributes
c) *Indoor Environmental Performance*: concerns on the performance elements that are able to control building physical and operation; such as air movement, visual, ventilation, acoustic, etc

5.0 CONCLUSION

By integrating criteria from different assessment methodological frameworks, this research builds on the strengths of each and provides a more holistic assessment approach among careful attention to local context. The next step in the development of the tool was the stage for defining the evaluation criteria and performance grade for measuring the degree or level in which the performance indicators are met. Performance grades were established to measure the degree, and the evaluation criteria were defined by relating the characteristics of the performance indicators with the degrees in the performance grade. By initiating a new perspective in optimizing the building performance and mitigating the user's health and safety risk, the proposed performance rating tool can play a significant role in the building industry.

Table 4 Summary of Relative Weights for Performance Elements (PE) and Performance-Risk Indicators (PRI)

PERFORMANCE ELEMENTS (PE)	PERFORMANCE-RISK INDICATORS (PRI)	GLOBAL WEIGHT (%)	RANKING
Functional Performance 36.7%	Spaces	1.3	23
	Orientation	1.4	24
	Infrastructure	2.1	18
	Access/entrance	2.7	14
	Circulation area	2.2	17
	Ergonomic building facilities	4.5	8
	Adequacy of building signage	3.7	11
	Emergency exits	6.8	4
	Building-related illnesses/ sick building syndrome	7.4	3
	Construction Signage	4.6	7
Technical Performance 49.9%	Design of building fittings/fixtures	2.7	15
	Structural stability	14.9	1
	Information Technology systems operations	1.7	20
	Electrical services	6.3	5
	Plumbing services	3.3	12
	Fire Prevention Services	9.1	2
	Materials & Internal Finishes	2.7	13
	Roof	4.1	9
	Lift	5.1	6
Indoor Environmental Performance 13.4%	Cooling (Thermal comfort)	2.0	19
	Artificial lighting	1.1	25
	Natural lighting	0.9	26
	Waste disposal	1.6	21
	Building ventilation	4.1	10
	Acoustic comfort	1.4	22
	Level of cleanliness	2.3	16

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