INCORPORATING RISK MITIGATION INTO BUILDING PERFORMANCE RATING TOOLS (BPRTs) FOR MALAYSIA'S HIGHER EDUCATION BUILDING

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ABSTRACT

Higher educational buildings (HEB) are believed to have a key function that affects not only the environment, but also human and economic resources. Inevitably, the growing student population with various learning activities in public university buildings has exacerbated space inefficiency, ventilation discomfort and inadequacy of facilities. These malfunctions not only affect the buildings and sustainability, but in addition the users are also likely to be directly impacted in terms of health and safety risk. In accordance with the Government's instruction on the holistic management of assets through General Circular (No.1) dated 27th March 2009, all managements should undertake a systematic approach to achieve building performance optimization. However, a proactive tool to measure performance and users' risk is still lacking in the current assessment or maintenance of HEBs. Therefore, this research set out to develop a building performance risk rating tool, as a performance assessment measure concerning users' health and safety risks in HEBs. The research has four objectives: i) to identify the current concept of building performance assessment used for HEBs, ii) to identify the indicators that contribute to the performance requirement and the users' health and safety risk, iii) to determine the relative importance score as a weightage/rating in the construct of performance-risk indicators, and iv) to develop a building performance rating tool covering both building performance level and users' risk level. This study adopted a mixed-mode approach that involves both quantitative and qualitative methods. To achieve the first and the second research objectives, the determinants of the indicators were initially compiled from the literature and the previous building assessment tool. They were further confirmed through semi-structured interviews involving 18 building managers in Malaysia's public HEBs. The findings identified 26 indicators to be incorporated into the list of assessments. They were categorised as functional, technical and indoor environmental performance indicators. In the next stage, questionnaires and the Analytical Hierarchy Process (AHP) method was used to achieve the third research objective. Twelve experts from the leading facilities management organisation agreed to participate in the survey rating process. The weightings of the indicators were extracted using the computer software, *Expert Choice 11*. The AHP results ranked five indicators as the most important indicators; structural stability (14.9%), fire prevention services (9.1%), building-related illnesses (7.4%), emergency exits (6.8%) and electrical services (6.3%). The total weightings from overall indicators also summed up the weights for technical performance (49.9%), functional performance (36.7%), and indoor environmental performance (13.4%). From this result, the proposed tool was developed based on the previous rating tool, and it comprised three steps of assessment. The first and the second steps evaluated each indicator, using the AHP weights and the performance assessment score. The third step summarised the assessed building by signifying a rating classification of "Excellent", "Good", "Medium", "Low" or "Poor", that suggests further action to improve performance and mitigate users' health and safety risk. The proposed Building Performance-Risk Tool (BPRRT) has a significant contribution to make as an improved proactive measure for performance assessment in HEBs. The establishment of the BPRRT was successfully employed as an aid of improvement towards the current performance assessment of HEB by emerging the concept of building performance and risk into a numerical strategic approach. With this tool, explanatory studies of building performance and users' risk can be conducted with more reliable data.

ABSTRAK

Bangunan institusi pengajian tinggi (IPT) merupakan lambang fungsi intelektual yang menghasilkan perkembangan ilmiah dan ekonomi. Peningkatan populasi pelajar di IPT awam dari masa ke semasa sedikit sebanyak mewujudkan permasalahan seperti ketidakcekapan ruang, ketidakselesaan pengudaraan serta kegagalan fungsi fasiliti bangunan. Isu ini bukan hanya memberi kesan terhadap kelestarian bangunan, tetapi pengguna bangunan turut mengalami impak permasalahan dari aspek risiko keselamatan dan kesihatan. Seiring dengan arahan kerajaan melalui Pekeliling Am (Bil.1) bertarikh 27 Mac 2009, pengurusan aset kerajaan perlu dilaksana secara sistematik dan holistik supaya mencapai faedah aset yang optimum. Namun demikian, tiada langkah proaktif yang menekankan aspek risiko pengguna digunakan di dalam konteks penilaian prestasi bangunan IPT. Oleh itu, kajian ini bermatlamat untuk membina alat pengukuran prestasi bangunan-risiko dalam mencapai matlamat pengurangan risiko kesihatan dan keselamatan pengguna bangunan IPT. Terdapat 4 objektif dalam kajian ini; i) untuk mengenal pasti konsep semasa penilaian prestasi bangunan IPT, ii) untuk mengenal pasti kriteria atau penunjuk berkaitan risiko kesihatan dan keselamatan pengguna bangunan IPT, iii) untuk menentukan skor kepentingan relatif sebagai pemberat petunjuk, dan iv) untuk membina penilaian prestasi bangunan-risiko (BPRRT). Kajian ini mengguna pakai kaedah kuantitatif dan kualitatif sebagai metodologi kajian. Bagi mencapai objektif kajian pertama dan kedua, petunjuk prestasi-risiko dibina secara awalan melalui kajian literatur serta skim penilaian prestasi terdahulu. Ia kemudiannya melalui proses pengesahan secara temubual separa berstruktur yang melibatkan 18 pengurus penyenggaraan bangunan IPT awam di Malaysia. Hasil kajian temubual telah mengesahkan bahawa terdapat 26 petunjuk penilaian prestasi dikategorikan di bawah elemen prestasi kefungsian, teknikal dan persekitaran dalaman. Seterusnya, instrumen secara soal selidik dan proses analisis hierarki (AHP) digunakan bagi mencapai objektif ketiga. 12 pakar pengurusan fasiliti telah turut serta di dalam soal selidik dan proses penilaian kajian. Pemberat bagi setiap petunjuk telah dianalisa menggunakan perisian komputer, the Expert Choice 11. Dapatan analisa menunjukkan bahawa lima petunjuk telah disenaraikan sebagai petunjuk kepentingan utama mengikut pemberat, iaitu kestabilan struktur (14.9%), kelengkapan rintangan api (9.1%), penyakit berkait bangunan (7.4%), ruang keluar kecemasan (6.8%) dan kelengkapan elektrikal (6.3%). Jumlah pemberat bagi setiap petunjuk juga mendapati bahawa kedudukan pemberat bagi setiap elemen prestasi ialah prestasi teknikal (49.9%), prestasi kefungsian (36.7%) dan prestasi persekitaran dalaman (13.4%). Objektif akhir kajian telah dicapai berdasarkan analisa dan keputusan instrumen temubual, soal selidik dan kaji selidik AHP. Penilaian prestasi bangunan-risiko (BPRRT) telah dibina sebagai alat pengukuran prestasi bangunan IPT di Malaysia dan ia mencadangkan 3 langkah penilaian. Langkah pertama dan kedua memaparkan penilaian bagi setiap petunjuk yang menggunapakai pemberat AHP dan skor penilaian prestasi. Langkah ketiga di dalam BPRRT pula mengklasifikasikan bangunan yang dinilai di tahap "Cemerlang", "Baik", "Sederhana", "Rendah" atau “Lemah”. Klasifikasi akhir ini telah mencadangkan tindakan selanjutnya dalam meningkatkan prestasi bangunan bagi mengurangkan risiko kesihatan dan keselamatan pengguna bangunan. Pembinaan BPRRT yang dicadangkan di dalam kajian ini merupakan satu langkah proaktif dalam peningkatan prestasi penilaian bangunan IPTA di Malaysia. Hasil penilaian menggunakan BPRRT telah membantu dalam meningkatkan penanda aras penilaian prestasi bangunan IPTA ke arah pendekatan numerikal berbanding skim penilaian sedia ada. Dengan aplikasi penilaian BPRRT, kajian prestasi bangunan dan risiko pengguna mampu dilaksanakan secara empirikal dan lebih bersistematik.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
BARIS	Building Assessment Rating System
BCA	Building Condition Assessment
BHHI	Building Health and Hygiene Index
BPE	Building Performance Evaluation
BPRT	Building Performance Rating Tools
BPRRT	Building Performance-Risk Rating Tool
BQA	Building Quality Assessment
BREEAM	Building Research Establishment's Environmental Assessment Method
BSCI	Building Safety Condition Index
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CEPAS	Comprehensive Environmental Performance Assessment Scheme
GBCA	Green Star by Green Building Council Australia
GBI	Green Building Index
HEB	Higher Education Buildings
HK-BEAM	Building Environmental Assessment Method
LEED	Leadership in Energy and Environmental Design
MKN	National Security Council of Malaysia
MySPATA	Malaysia's Government Immovable Asset Management System
PRI	Performance-Risk Indicators
PROBE	Post-occupancy Review of Buildings and their Engineering
PWD	Public Works Department
SABA	SABA Green Building Rating System
TBP	Total Building Performance

LIST OF EQUATIONS

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Sustaining the performance of the lifespan of higher educational buildings has become a focal point and a global issue. According to Altan (2010), the with the rapid expansion of the higher education sector, institutions and, in particular, universities, have become large employers and major poles of economic and social growth. Inevitably, sustainability of buildings in universities is vital to support the adequacy of educational activities. Higher educational buildings (HEBs) generally occupy large land areas and accommodate populations that grow year after year. As stated by Olanrewaju (2010b), transmitting knowledge and culture is one of the business agendas of universities. Various activities, which are not limited to education and research activities alone, and involving students as the dominant occupants of HEBs, are conducted in the campus. Therefore, the academic and non-academic activities have two significant effects on buildings; direct impacts and indirect impacts on the conditions, environment and sustainability.

Sustainability can be achieved by maintaining the performance of a building. Building performance has the potential to play a major role in articulating the expectations of owners and occupants, and the fulfilment of them by designers and building operators (McDougall et al., 2002; Pati et al., 2006; Pati et al., 2009). Building performance, as defined in British Standard (BS) 5240 is the behaviour of a product in use (Almeida et al., 2010; Amaratunga & Baldry, 1998; Douglas, 1996). To sustain this performance and anticipate long-term performance, building diagnostics have the potential to rapidly become a major tool in building appraisal in order to evaluate the suitability of the building and to assess risk (Almeida et al., 2010). Wong and Jan (2003) state that building evaluation is the first priority before one can effectively predict future building performance, because it is imperative to know the status quo of the building. As stated by Douglas (1996), a more holistic approach is needed in order to assess how well a building is behaving overall and to predict its performance in the long term. Given the importance of building evaluation, the evaluative criteria derived from the occupants in educational buildings need to be taken into account, in terms of quality of the general condition of the building's facilities and its suitability for education.

Sapri and Muhammad (2010) state that the presence of diverse types of buildings in HEB makes the process of building evaluation time consuming and tedious; hence, there is a need to enhance the process of monitoring and benchmarking. People are currently concerned about building performance and sustainability, as the occupants place priority on comfort and fitness for purpose. Educational process and learning activities may be interrupted due to the tendency of risk occurrence, and dilapidated building conditions. Hence, there is a need to establish criteria for evaluating performance for HEB.

There are various performance mandates that can be evaluated depending on the evaluation objectives. The benefit of evaluating building performance is primarily conveyed to the building's occupants or the users (Bordass & Leaman, 2005; Cohen et al., 2001; Lützkendorf & Lorenz, 2007, 2006; Pati et al., 2009; Pitt & Tucker, 2008; Vischer, 2008; Woods, 2008). However, with respect to building safety performance, building occupants may not know what level of risk mitigation is being provided and what the hazards are that may imposed on them (Meacham, 2010). Meacham observed that the concept of risk tolerance is used to accept that risks associated with building performance are tolerated.

The risk factors that can have a direct impact on buildings' users are lacking and have not been considered as a priority in assessing the total building performance in previous studies (Almeida et al., 2010; Hassanain, 2007; Hirning et al., 2012; Riley et al., 2010; Sapri & Muhammad, 2010; Wong & Jan, 2003; Zalejska-Jonsson, 2012). Risk is significantly related to building performance (Meacham, 2010). This is supported by Altan (2010) who has revealed that carbon emissions and unsuitable allocation of equipment in HEBs contribute to the occurrence of building risk. By considering the potential impact of risk of each aspect, attention can be focused on controlling the most severe risks first. Therefore, the identified risk should have a proper assessment and adequate provision should be made to ensure a building's sustainability (Meins et al., 2010). Appropriate approaches for identifying risks allow the relevant stakeholders to collaboratively address the risks and to assign responsibility for risk mitigation to the most appropriate individuals.

Therefore, this study is conducted to develop a rating tool that can serve to evaluate building performance of HEBs. The study focuses on the public university buildings in Malaysia; specifically, it addresses building performance issues and the risk imposed on the buildings' users in the university buildings. The discussion of the performance mandate is extended in the literature review chapter, where the elements and the criteria are thoroughly explored to determine the most suitable elements for further performance evaluation. Among the performance aspects that are addressed in this study are the functional performance requirements, the technical performance requirements and the environmental performance requirements. As stated by Amaratunga and Baldry (1999), functional performance requirements deal with the fit between the building and its activities, and how well the building directly supports the activities within it, whilst being responsive to the specific needs of the organisation and its occupants, both qualitatively and quantitatively.

1.2 Background and Justification of the Research

The learning environment in higher educational buildings (HEB) is generally differs from that in primary or secondary education. Every higher learning institution is built to provide tertiary education to the students, based on the various programmes offered, and therefore the design and facilities provided in higher institutions must match the objectives of the education programmes. However, building condition assessments do not explicitly address the educational adequacy of academic buildings; that is, the relationship between the physical condition of the school and the various educational goals and activities that take place within the building (Doidge, 2001). Increasing numbers of students and learning activities in HEBs has contributed to risk occurrence, inefficient use of energy and climate discomfort (Altan, 2010; Gillen et al., 2011; Hassanain, 2007; Sapri & Muhammad, 2010) and these may diminish the total performance system of the building, year by year. Thus, it may impart more problems to the HEB, including various aspects, such as building design, technical building elements, room spaces, facilities, safety aspects, indoor and outdoor environmental problems, and noise pollution.

According to a study by Olanrewaju et al., (2010a), the current function of maintenance management systems in HEB is mainly corrective and cyclical; they depend on the complaints made by the users. This reactive approach to maintenance has been criticized for various inadequacies as it leads to maintenance backlogs and poor user satisfaction (Olanrewaju et al., 2010a). The study also suggested that facility management (FM) organization in local university buildings need to develop or adopt a performance metric that could be used to benchmark their service. It was assumed that there is no proactive approach being carried out in addressing risk towards the building users in HEB. Olanrewaju (2010b) argued that it is no longer acceptable for a university to invest only in improving methods of teaching and learning without improving the performance of the building assets.

Marzuki (2015) strongly recommended that facilities management (FM) experts in Malaysia should incorporate a summary of risk report in the result of building performance assessment. The report of building performance assessment generally presents the financial cost to the building owner, as the owner requires a summary of budget involved to prolong the sustainability of the building. However, in terms of risk, whether risk towards the building's stability itself or to the users, the owner is not made aware of the consequences of not executing a performance audit on the building. Marzuki further suggested that the result of the risk assessment should be incorporated into the performance assessment, to determine a more pro-active strategy for maintaining the stability and sustainability of buildings on the part of the owner and the stakeholders.

Amaratunga and Baldry (1999) in their study found that 100% of staff (4.71 mean score, 0.49 standard deviation) and 70.1% of students (4.02 mean score, 1.08 standard deviation) agreed that functional performance in an HEB must avoid putting occupants, visitors and passers-by at risk. This demonstrates the significance of addressing the risk impact that can potentially jeopardize building users by having an optimization of building performance. Mat et al. (2009) in their study suggested that universities must preserve the environment, stimulate economic growth, and improve the well-being of the surrounding community.

Ideally, the existence of building begins with the concept of design and the provision of building elements, not merely concern for the environment. Hence, the suitability of delivering the best performance requirements in an HEB also needs to be captured in the early design stage. Many building practitioners are not aware of the requirement for a building evaluation after it is occupied. The lack of awareness is clearly highlighted by O'Sullivan et al. (2004) who state that there is little or no assessment carried out in the operation and maintenance phase of a building's lifecycle. According to the authors, most building performance assessment is done at the building design stage and some assessment is carried out at the construction and commissioning stage.

Despite much previous research carried out on building performance (for example: Almeida et al., 2010; Hassanain, 2007; Hirning et al., 2012; Riley et al., 2010; Sapri & Muhammad, 2010; Wong & Jan, 2003; Zalejska-Jonsson, 2012), evaluations using a developed rating tool that emphasized both performance and users' is lacking. A survey of outcomes from previous studies for HEBs (Cupido, 2011; Hassanain, 2007; Mat et al., 2009; Najib et al., 2011; Olanrewaju et al., 2010; Olanrewaju et al., 2010a, 2010b; Olanrewaju, 2010; Sapri & Muhammad, 2010; Wong & Jan, 2003) also shows that users' severity or risks are not prioritised in assessing building performance. Table 1.1 summarises the findings from several leading articles with regard to the building performance framework studies and rating tools and identifies the gaps in the research that the present study is designed to fill. It can be seen that there remains a lack of building performance studies that emphasize the risk issues and their impact on building users.

Table 1.1: Findings and Gaps from Pilot Articles of Precedent Research

AUTHOR/ YEAR	PAPER TITLE/ JOURNAL	TYPE OF BUILDING	COUNTRY	ISSUE	AIM / OBJECTIVES	FINDINGS	RESEARCH GAP
Lee & Hensen, 2015	Developing a risk indicator to quantify robust building design (*Energy Procedia,* 78, pp. 1895 – 1900)	Industrial halls	Netherlands	Ratings for green buildings are only based on the predicted performance and not considers the actual performance	Proposes a design approach that incorporates a risk indicator into the existing energy performance evaluation process	The result suggests nine different operating scenarios as risk indicators in energy design solutions for industrial halls.	The indicators are not suggested for university buildings
Almeida, et al, 2010	A framework for combining risk-management and performance-based building approaches (*Building Research & Information,* Vol. 38(2), pp. 157-174)	Commercial buildings	Portugal	The majority of construction-related organizations do not interact directly with end-users.	Develop RM-PBB framework	The proposed framework relates mainly to the interaction of performance, risk and quality in building and construction projects.	The framework is not developed for university buildings
Hirning, et al, 2012	Post occupancy evaluations relating to discomfort glare: A study of green buildings in Brisbane (*Building and Environment,* pp. 1-9)	Office buildings	Australia	No effective method to predict discomfort glare within open plan offices.	Explore the building performance of current glare prediction models	The findings provide a platform for further research to fully develop a suitable glare metric.	No risk impact on occupants
Zalejska-Jonsson, (2012)	Evaluation of low-energy and conventional residential buildings from occupants' perspective (*Building and Environment,* Vol.58, pp. 135-144	Residential housing	Sweden	Consider the consequences of occupants' discomfort in the context of building performance.	Investigate building performance from the occupants' perspective	The "green" profile of the building has a positive impact on the occupants' environmental awareness.	No risk impact on occupants
Riley et al., (2010)	Assessing post occupancy evaluation in higher education facilities (*Journal of Facilities Management,* Vol. 8 (3) pp. 202 – 213)	Higher educational buildings (HEBs)	UK	Process of implementing POE as performance evaluation tool in HEB is the ownership issue	Illustrate most appropriate method as performance enhancement tool for HEB facilities.	Only a few suited to evaluate the building performance of educational facilities to maximise student success and productivity.	No risk impact on occupants

Table 1.1 continued

(Sapri & Muhammad, 2010)	Monitoring energy performance in higher education buildings for sustainable campus (*Malaysian Journal of Real Estate,* Vol. 5 (1) ,pp.1-25	Higher educational buildings (HEBs)	Malaysia	Issue of energy consumption and carbon dioxide emission in higher educational institutions	Develop a comprehensive building energy performance information system	Overall energy management function would be greatly enhanced.	Not related on any performance aspects to the probability of risk occurrence
Mat et al. (2009)	Managing Sustainable Campus in Malaysia - Organisational Approach and Measures (*European Journal of Social Sciences,* Vol. 8(2), pp. 201-214)	Higher educational buildings (HEBs)	Malaysia	Environmental pollution and degradation due to campus activities have raised serious concerns	To highlight the importance of having a sustainable campus	Enormous opportunities can be gained in adopting systems based integrated approach	Not related on any performance aspects to the probability of risk occurrence
(Hassanain, 2007)	Post-Occupancy Indoor Environmental Quality Evaluation of Student Housing Facilities (*Architectural Engineering and Design Management*,Vol.3,pp. 249–256)	Students' housing in HEBs	Saudi Arabia	Major areas of complaint and discomfort of the occupants in the building unit concern poor indoor environmental quality.	Determine design decisions provide the performance needed by the student residents.	The study has determined the degree of satisfaction obtained for the identified performance elements	Performance elements not related on any performance aspects to the probability of risk occurrence
(Najib et al., 2011)	Student residential satisfaction in research universities (*Journal of Facilities Management,* Vol.*9*(3), pp. 200–212)	Students' housing in public universities	Malaysia	Student housing offers limited security of ownership and freedom if compared to family housing.	Investigate the level of student satisfaction with campus student housing facilities	A significant relationship between overall satisfaction and loyalty behaviour.	The proposed model does not relate on any performance aspects to the probability of risk occurrence
(Wong & Jan, 2003)	Total building performance evaluation of academic institution in Singapore (*Building and Environment,* Vol. 38, pp. 161 – 176)	Secondary schools	Singapore	The TBP is not yet tested to optimize students' comfort learning environment	Involves the implementation of TBP evaluation on a typical school, since has not been explored yet.	The impact of a decision made based on all six mandates and any inter-relations between the mandates	The established tool does not relate on any performance aspects to the probability of risk occurrence

1.3 Research Questions

The introduction and the problem statement outlined above led to the formulation of the following research questions:

i. What is the current concept of building performance assessment used for higher educational buildings (HEBs)?

ii. What indicators have been identified that contribute to the performance requirement and users' health and safety risk in HEBs?

iii. What relative importance score will be a weightage/rating for each performance-risk indicator?

iv. What will be the characteristics of the rating tool that can include both the building performance level and the users' risk level?

1.4 Research Aims and Objectives

The main aim of this research is to develop a building performance risk rating tool, as a performance assessment measure assessing users' health and safety risk in higher education buildings (HEBs). The objectives outlined for this study are:

i. To identify the current concept of building performance assessment used for higher education buildings (HEBs)

ii. To identify the indicators that contribute to the performance requirement and the users' health and safety risk

iii. To determine the relative importance score as a weightage/rating in constructing performance-risk indicators

iv. To develop a building performance rating tool that includes both building performance level and users' risk level

1.5 Significant Contribution of the Research

By providing opportunities for improvement of building performance and combining it with relationships with behaviours among the users, the proposed building performance risk rating tool (BPRRT) can play a significant role in the industry. Since the proposed BPRRT in this study focussing the both technical aspect (performance elements) and the social aspect (the users' health and safety risk), this differentiates the main concerns from those of the previous rating tools that are more focused on green issues and energy efficiency. It is hoped that the tool developed from this study would make a significant contribution in terms of the following:

i. Introduce an improved performance evaluation approach using the building performance rating tool as a proactive measure in HEBs, replacing the current assessment or maintenance procedures
ii. Integrate the aspect of user's risk in building performance assessment for local HEBs
iii. Employ improved steps and processes to optimize the building performance aspects and requirements in HEBs
iv. Enhance sustainability in Malaysia's university buildings throughout the building delivery process and the building's lifecycle
v. Support continuous assessment of building needs at regular intervals

1.6 Research Methodology

A mixed-method approach was used to achieve the study objectives and answer the research questions. In general, this research approach utilizes the strategies related to relationships between the concept of building performance and the risk criteria by means of both qualitative and quantitative approaches. Such an approach can help achieve the main aim of the study: that is, to develop the proposed building performance rating tool for HEBs.

A qualitative approach was used to identify the concept of building performance and risk approach, primarily compiled from various articles in the literature, and from previously established building performance rating schemes. The performance elements, the risk frames, and the indicators for building performance and risk are then further confirmed through semi-structured interviews. The interviews were held building managers and operators in Malaysian universities. Inputs from the building operators were needed to obtain from professionals assessments on the suitability of the listed indicators for building performance rating assessment to be used in local HEBs. The transcription and interpretation from the interviews were carried out using *Atlas.ti* qualitative software.

Next, the identified indicators for building performance and risk, termed *performance-risk indicators* (PRI), were included to establish a questionnaire for the main survey. At this stage, the Analytical Hierarchy Process (AHP) method was used to determine the weightage or ranking of the indicators in a hierarchy. As part of the AHP method, experts from the leading facilities management (FM) organisations in Malaysia acted as respondents for the survey. Experts are needed to determine the relative importance of indicators, and their collective wisdom thus provides a weightage for each indicator. A quantitative approach was used to determine the impact of risk on building users. Descriptive analysis and non-experimental research methods such as mean rank and reliability tests (Cronbach alpha) were used to present the analysis of results from the questionnaire. The Statistical Packaging for Social Science (SPSS) version 16 was used to perform the data analysis for the main survey. The computer package, the *Expert Choice* 11, was used to present the result and analysis for the AHP survey. The research framework is summarized in Figure 1.1:

Intensive Reading from Leading Journals:

RESEARCH GAP:

- Mostly, the existing building performance rating tools are only concerned with green aspects, energy efficiency, environmental aspects, etc.
- Concerns about risk towards occupants is still deficient in assessing building performance
- Lack of a building performance rating tool associated with risk for building performance in

Foundation to write LR/theoretical framework:

- Building performance concept and rating tool
- Risk assessment theory
- Higher educational buildings (design, facilities, occupants, population, etc)

Research Objectives:

- To identify the current concept of building performance assessment used for higher education buildings (HEBs)
- To identify the indicators that contribute to the performance requirement and the users' health and safety risk
- To determine the relative importance scores as weightage/ratings in the construct of performance-risk indicators
- To develop a building performance rating tool consisting of both the building performance level and users' risk level

Problem Statement:

- Current assessment or maintenance management in HEBs is still reactive – depends on complaints, no specific ratings are used to assess performance of building and the users' risk in local HEBs
- Riskcriteria to occupants is not prioritised in assessing building performance, especially in HEBs

RESEARCH QUESTION	INSTRUMENT	ANALYSIS
What is the current concept of building performance assessment used for higher educational buildings (HEBs) What indicators have been identified that contribute to the performance requirement and users' health and safety risk in HEBs?	• Literature review • Preliminary survey: semi-structured interviews to local building operators	• Analytical review and synthesis • Interpret findings from interviews with building experts (using *Atlas.ti* qualitative software)
What relative importance score will be a weightage/rating for each performance-risk indicator?	• Main survey: Questionnaire survey • AHP method • FM professionals/ experts	• Pilot survey - Reliability test • Descriptive analysis – mean rank, standard deviation • The relative importance score as weightage/ratings – using AHP method (computer software *Expert Choice*)
What will be the characteristics of the rating tool that can include both the building performance level and the users' risk level?	• Results from all surveys and the indicators are credited with weightage from AHP method rating tool	Validate the proposed tool by validation interview and testing it on one Malaysian university building

Research design:
Semi-Structured Interviews, Questionnaire Survey (AHP survey)
Sampling frame/technique:
Building operators and FM professionals/experts (purposive sampling)

Figure 1.1: Research Framework

A strategy chart was used to achieve all the research objectives that were developed from the research questions, as illustrated in Figure 1.2. In general, this research strategy is divided into three (3) phases (as shown on Figure 1.2). The following describes the phases and their associated activities:

1.6.1 Phase 1: Literature Review and Preliminary Survey

In the first phase, a comprehensive literature was conducted to identify the current concepts of building performance assessment used for higher education buildings (HEBs). An extensive literature review also explored the indicators of building performance and the risk factors relating to building performance in HEBs. The review included several building performance rating schemes that have already been established. A preliminary survey was initiated to identify and further validate the indicators of building performance and risk for users of HEBs, using semi-structured interviews as the instrument. The interviews were conducted with the operators of local university buildings so as to ensure the validity of the indicators. Qualitative analytic software (*Atlas.ti*) was used to analyse and interpret findings from the interviews. This phase formed the foundation for subsequent phases and assisted in the design of the main survey for this research. Objectives 1 and 2 were achieved in this phase.

1.6.2 Phase 2: The Main Survey

In the second phase, the analysis and findings obtained in the previous phases were used to accomplish the main survey stage. The identified indicators for building performance and risk, performance-risk indicators (PRI), were incorporated into the questionnaires as survey questions. The Analytical Hierarchy Process (AHP) method was adopted in this stage, and a purposive sample of respondents was drawn from facilities management (FM) professionals and experts, based on predetermined criteria. The experts were required to rank the relative importance of the indicators and to provide a weightage for each indicator. The Statistical Packaging for Social Sciences (SPSS) version 16 was used to perform the data analysis of the demographic data and the level of risk impact on the users.

AHP was also used to indicate the weightage rating or index for each indicator. AHP is a mathematical decision-making technique, developed by Dr. Thomas L. Saaty in 1980, that provides an effective means to deal with complex decision-making. AHP allows consideration of both qualitative and quantitative aspects of decisions; it can reduce complex decisions to a series of one-on-one comparisons by assisting with identifying and weighting selection criteria, analyzing the data collected for the criteria and expediting the decision-making process. Computer software *Expert Choice 11* version 3.10 was used for the AHP process. Therefore, the third objective is achieved in this phase.

1.6.3 Phase 3: The Development of a Building Performance Risk Rating Tool (BPRRT)

In the third phase, the results from the preliminary survey and main survey were analysed to assist in the development of the building performance-risk rating tool (BPRRT), an improved measure of assessment relating to building performance, risk, and impact on the building's users. The discussion and interpretation of the results justify the used of mixed methods that facilitated the development of the framework.

Interviews were held with industry experts to validate the applicability and reliability of the proposed rating tool, to ensure face validity. The proposed rating tool was further tested by applying it to an assessment of a higher educational building (HEB). Objective 4 is achieved in this phase. The following actions were carried out in the process of developing the rating tool:

- Identification of the current building performance assessment used in local HEBs
- Identification of the building performance elements and risk frames, as the main indicators
- Identification of the level of risk impact on building users
- Identification of weightage or relative importance score of each indicators, using the AHP method
- Development of performance risk hierarchy consisting of the weightage, as the fundamental basis, from the survey results
- Calibration of the assessment score, weightings, components and classification of rating tool

All findings were then concluded with the aim of answering all the research questions and achieving the research objectives. Recommendations for further research are also provided to expand elements of the study to a broader context.

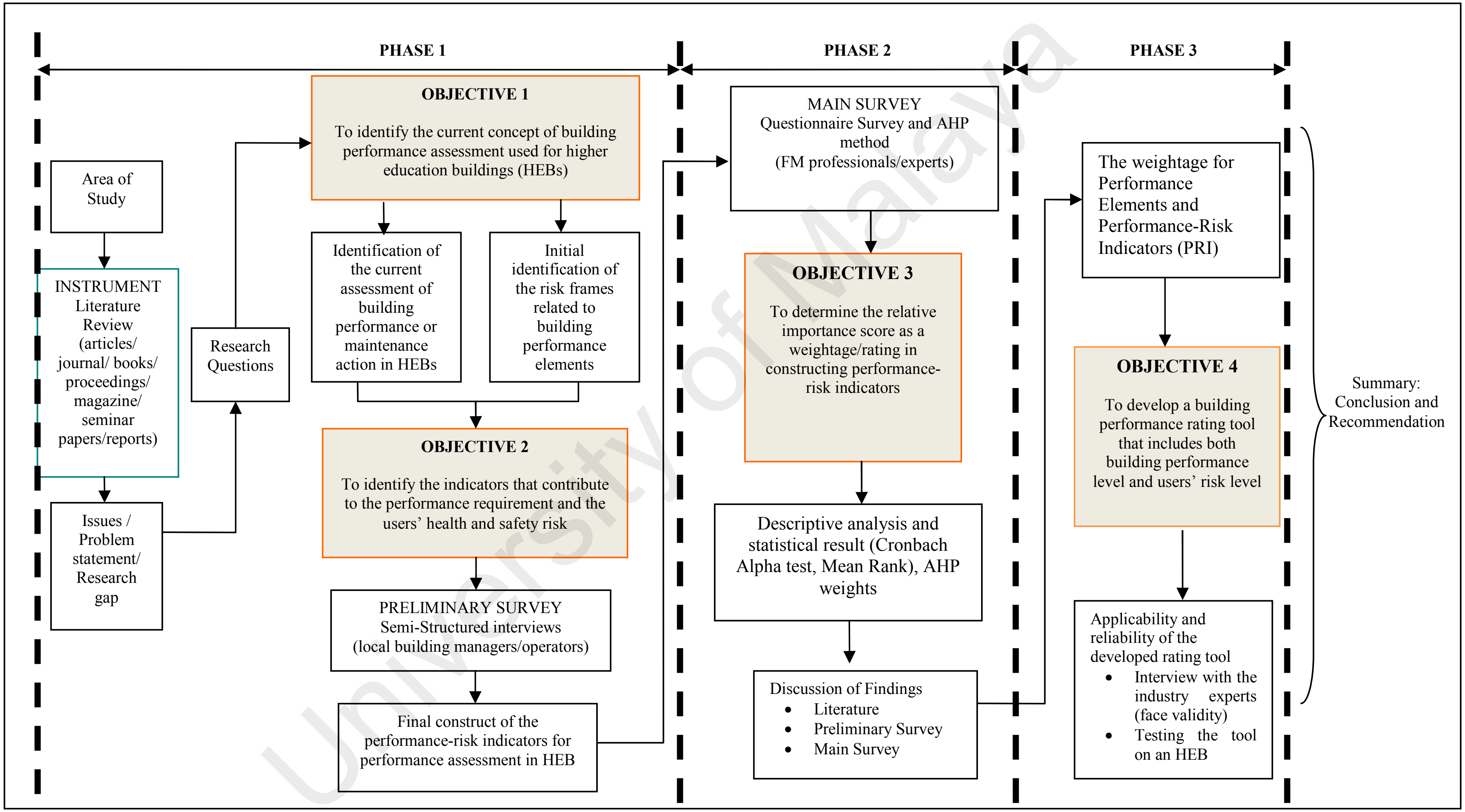


Figure 1.2: Research Strategy Chart

1.7 Scope of the Research

In Malaysia, HEBs are divided into buildings used in public, private and polytechnic/colleges institutions. To narrow the scope for this study, the research focuses only on Malaysian public universities. This takes into consideration the existing and general procedures of maintenance for government buildings, accessibility to the buildings, and also time constraints. In 2010, the Ministry of Higher Education (MOHE) listed twenty (20) public universities in Malaysia (see Table 1.2). Purposive sampling was used as the method for sampling the building operators in public university buildings. Building operators from HEBs were the experts needed to construct the performance-risk indicators (PRI) as the basis of the rating tool for performance assessment measure. Further explanation of the method of sampling is described in Chapter 3 (Research Methodology).

Table 1.2: List of Malaysia's Public Universities

No.	Name Of Institutions	Location	Year Of Incorporation
1.	Universiti Malaya (UM)	Lembah Pantai, Kuala Lumpur	1961
2.	Universiti Sains Malaysia (USM)	Minden,Pulau Pinang	1969
3.	Universiti Kebangsaan Malaysia (UKM)	Bangi,Selangor	1970
4.	Universiti Putra Malaysia (UPM)	Serdang,Selangor	1971
5.	Universiti Teknologi Malaysia (UTM)	Skudai,Johor	1975
6.	Universiti Islam Antarabangsa Malaysia (UIAM)	Gombak,Selangor	1983
7.	Universiti Utara Malaysia (UUM)	Sintok, Kedah	1984
8.	Universiti Malaysia Sarawak (UNIMAS)	Kuching, Sarawak	1992
9.	Universiti Malaysia Sabah (UMS)	Kota Kinabalu, Sabah	1994
10.	Universiti Pendidikan Sultan Idris (UPSI)	Tanjung Malim,Perak	1997
11.	Universiti Sains Islam Malaysia(USIM)	Nilai, Negeri Sembilan	1998
12.	Universiti Teknologi MARA (UiTM)	Shah Alam, Selangor	1999
13.	Universiti Malaysia Terengganu (UMT)	Kuala Terengganu, Terengganu	1999
14.	Universiti Tun Hussein Onn Malaysia(UTHM)	Batu Pahat, Johor	2000
15.	Universiti Teknikal Malaysia Melaka (UteM)	Durian Tunggal, Melaka.	2000
16.	Universiti Malaysia Pahang (UMP)	Kuantan, Pahang	2001
17.	Universiti Malaysia Perlis (UniMAP)	Kangar, Perlis	2001
18.	Universiti Sultan Zainal Abidin (UniSZA)	Kuala Terengganu, Terengganu	2005
19.	Universiti Malaysia Kelantan (UMK)	Pengkalan Chepa, Kelantan	2006
20.	Universiti Pertahanan Nasional Malaysia (UPNM)	Kem Sungai Besi, Kuala Lumpur	2006

(Ministry of Higher Education, 2011)

In order to determine the weightings for the PRI, Analytical Hierarchy Process (AHP) was adopted to incorporate the ratings of the experts or professionals from the facilities management (FM) organisations in Malaysia. The experts included a group of stakeholders from different academic background fields such as architecture, facility managers, engineers, business and marketing, and others. The sampling frame for the experts was established with the help of the Malaysian Association of Facility Managers (MAFM) that has recorded the experience and involvement in building performance evaluation (BPE) of all professionals. Purposive sampling techniques were employed to select the respondents from different fields of expertise. According to Palys (2008), purposive sampling is a sampling technique where the researcher relies on the experts' judgment and knowledge. Also know as judgment, expert or selective, purposive sampling is used when the research needs to glean knowledge from individuals that have specific expertise.

1.8 Structure of the Thesis Chapters

This thesis is divided into seven (7) chapters, and it is outlined according to the phases of the research. Each chapter provides an introduction at the beginning of chapter and ends with summary of the chapter. A brief description of the content of the thesis chapters follows.

a) Chapter 1: Introduction

Chapter 1 provides the introduction and background to the area of study: building performance and its relation to users' risk. This chapter provides the justification for conducting this research by highlighting the current practices of maintenance action in higher educational buildings, including performance and risk impact on the buildings users. Based on the gap identified, research questions, research aim and objectives were developed and are also presented in this chapter. The chapter also includes a brief explanation of the methodology and scope of the study.

b) Chapter 2: Literature Review

Chapter 2 reports on an in-depth review of the literature related to three areas of the study; they are: building performance evaluation; risk; and the background to higher educational buildings. This literature includes a more detailed discussion on the central concepts of the study, a definition of key terms, the performance and risk issues, and the rationale for incorporating users' risk as social aspect in building performance. A review of existing building performance rating tools is also provided in this chapter in order to distinguish those aspects that need to be improved. The initial construct of the performance-risk indicators is also provided in this chapter, as a conceptual framework and initial basis to develop the final building performance-risk rating tool. Thus, this chapter reports the plans for achieving the first and the second objectives of this study. Actual achievement of the first and the second research objectives were confirmed through the preliminary survey.

c) Chapter 3: Research Methodology

Chapter 3 describes the methodology in depth, which includes the research design, instrument and techniques used to collect data, and the analytical techniques used. There are three main phases involved: i) literature review and the semi-structured interviews (preliminary survey), ii) the questionnaire survey (main survey), using the AHP method, and iii) the development of the rating tool. A summary of the research design used is also provided in this chapter.

d) Chapter 4: Analysis and Discussion of Findings for the Semi-Structured Interview

The findings from the semi-structured interviews (preliminary survey) are presented in this chapter. The analysis includes an interpretation of the interviews and an analysis of data from the survey, according to the separate sections of the interview form. The interpretation of the interviews was analysed using qualitative data software, *Atlas.ti.* Discussion of the results is also included, based on the study and survey analysis. Since the research survey (preliminary survey and main survey) was carried out in two stages with different instruments, a discussion of the findings from the interviews is included in this chapter. The discussion of findings is incorporated after the section on the analysis of the interviews. This chapter aims to achieve the first objective and the second objective of the study, which were introduced in Chapter 2.

e) Chapter 5: Analysis and Discussion of Findings for the Questionnaire Survey

Chapter 5 presents the results for the subsequent stage of the survey, the questionnaire survey, or main survey. The analysis of results for the questionnaire survey is reported according to the sections in the questionnaire form. The results are derived from a descriptive analysis using quantitative data software, the *Statistical Package for the Social Science (SPSS)*. For the analysis of pairwise and weightage score comparisons, the Analytical Hierarchy Process (AHP) method was used to present the result of weightings. Discussions of the analysis for the main survey are included in this chapter, due to the different instrumentations used in each of the research method. This chapter aims to achieve the third objective of the study.

f) Chapter 6: Development of The Building Performance-Risk Rating Tool

Chapter 6 presents the development of the rating tool that incorporates the elements of health and safety risk to building users. The main phases in the development of the rating tool consisting of the indicators, the proposed steps for assessment, the potential application, and the validity of the tool are discussed in this chapter. This chapter explains the development of the performance assessment score and the rating classification, that includes the list of PRI and the weightage derived from the preliminary survey and main survey. The fourth objective of the study is achieved in this chapter.

g) Chapter 7: Conclusion and Recommendations

Chapter 7 presents the conclusions and recommendations of the study. The conclusion is based on the findings, related to the study objectives and answering all the research questions. The recommendations are provided in detail, based on general findings from literature, the problem statement, survey findings and overall findings of the study. This chapter also discusses some limitations of the study, and ends with several recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reports a literature review undertaken to provide an overview of the conceptual framework underlying the study. As mentioned by Boote and Beile (2005), a literature review encompasses an evaluative report of studies and provides a conjectural basis of argument for the research. The literature review is also able to demonstrate the ability of the researcher to identify relevant scholarly information as well as to synthesize the information to align with the scope of research. Thus, for the purpose of this study, the fundamental theoretical elements of the literature review discuss the concept and requirements of building performance. The concept of building performance is explored and addresses the purposes of building performance, the link between performance and users, the significance of feedback, and also of performance mandates. These are thoroughly explained so as to achieve the first objective of this research study.

In this chapter, it begins with a discussion of the design and planning requirements in higher education buildings (HEBs), which include addressing the performance factors and issues that arise in a building. Each section starts with a number of definitions and an explanation of vital keywords relating to the studies. Previous research on building performance is highlighted to explore previous findings and strengthen the gap that the present study seeks to fill.

The discussion continues with academic theories and an exploration of building performance evaluation (BPE) as practiced. It is followed by an argument for the relevance of risk mitigation in building performance and the context of both in HEBs. A description of relevant keywords is enhanced by a comprehensive review of the concepts and an overview regarding building performance and risk mitigation in HEBs.

The chapter also explores the requirements and indicators related to building performance, risk, and HEB users, as society perceives the impact of risk from the failure of building performance. To relate the sequential of the study area to one another, the literature is therefore critically reviewed, analyse and synthesis into one (1) chapter. The literature review ends with a summary overview.

2.2 Background to Higher Educational Buildings

The higher education sector is currently undergoing a large building programme. The development of educational institutions, including expansion of facilities and spaces, is a sign of the growth of tertiary educational programmes and student numbers. According to James and Hopkinson (2004), if the expansion initiatives are based on principles of sustainable construction, the higher education sector should be able to reduce operating costs over the building's lifetime. Ideally, to ensure the benefits of initiatives to ensure that higher education is sustainable, development planning and management of higher education buildings (HEB) must be scaled over the life spans of buildings.

Apart from being the centres of learning, many HEBs also supplement their income by hosting conferences and attracting business clients. For this reason, the character of campus has an economic significance as well as an educational one (Edwards, 2000). At the same time, universities are able to enhance their reputations amongst students, staff, communities and other stakeholders by exhibiting environmental and social responsibility (James & Hopkinson, 2004).

Since HEBs host a large number of users with a variety of needs, they generate a feeling of community, in whole and in part. Edwards (2000) claimed that the criteria for a university building transcends its function and identity, thus it needs to reflect academic aspirations. In an attempt to understand the conduciveness of educational buildings for learning, the total performance of the building in a holistic sense must be considered (Wong & Jan, 2003). Therefore, the definition of HEB is further explored in the next section to attain a better perspective of the impact upon building risk and performance factors.

2.2.1 Definition of "Higher Educational Buildings"

Defining a university typically focuses on the function of education and academic services. As pointed out by Edwards (2000), even though a university is constructed of concrete, steel and glass, it is more easily defined in academic rather than social or architectural terms. Disseminating knowledge is the main purpose for constructing an HEB, as it is the symbol of physical and intellectual replenishment. In relation to the performance of buildings in this study, an appropriate definition concerns "university buildings" or "higher educational building". According to Edwards (2000), HEBs are defined as places for teaching and learning, engaging a community of scholars in the pursuit of knowledge, with social and cultural connotations. Meanwhile, in the Free Dictionary (2014), an HEB is defined as a building designed for various activities in a higher educational system, often including living areas for students. In general, without a building to cater for tertiary education, the dissemination of knowledge among researchers and scholars may be impeded. Further descriptions of what constitutes an HEB are summarised in Table 2.1:

Table 2.1: Definitions of Higher Educational Buildings (HEB)

AUTHOR (YEAR)	DEFINITION / DESCRIPTION
Chapman (2006)	A collection of buildings that belong to a given institution, either academic or non-academic
Sapri & Muhammad (2010)	Higher education institutions are organisations that provide substantial services
Olanrewaju et al. (2010a)	A factor of production; they are used to produce future leaders, captains of industry, entrepreneurs, scientists, engineers and managers
Dyer & Andrews (2012)	Serve as 'hubs' in their local communities for creating, testing, and disseminating knowledge

The word "campus" has been applied to European universities, although most such institutions are characterized by ownership of individual buildings in urban settings rather than park-like lawns in which buildings are placed. A university building is a unique building as it able to form its own world and own identity. From the various definition as listed in Table 2.1, it can be summarised that the best definition of "higher educational building" is a place for tertiary programmes of teaching and learning activities, engaging community of scholars.

2.2.2 Review of the Higher Education Sector in Malaysia

The higher education sector in Malaysia is growing rapidly as various programmes and grants being offered to Malaysian citizens increase. According to Olanrewaju et al., (2010a), there has been an expansion of more than 420% in allocation to the education sector over the last 20 years. The 2012 Malaysian budget, for example, affirmed that the Government of Malaysia sees higher education as an essential element in the success of the country's Economic Transformation Programme (ETP). This is continuously addressed in the recent 2016 Malaysian budget where empowering human capital in higher education sector is described as critical issues (Ministry of Finance Malaysia, 2016).

The budgetary allotment for higher education has been increasing on an annual basis under the Tenth Malaysia Plan from year 2011 to year 2015 and the National Education Strategic Plan. For 2012 alone, the budget for higher education amounted to MYR12billion (USD3.75billion). Out of the total budget, MYR10billion (USD3.1billion) was allocated to operating expenditures, whereas the remaining MYR2billion (USD650million), was allocated to development expenditures (Tenth Malaysia Plan, 2011). In the years to come, there will be further increases in the budgetary allotment for higher education as the main aim of the National Education Strategic Plan is to produce world-class higher education institutions in the country (The Prospect Group, 2012).

The education sector continues to receive the biggest allocation with RM800 million provided in the Malaysian budget 2015 for the development and maintenance of education facilities (Ministry of Finance Malaysia, 2015). The Government announced the allocation as an effort to ensure a safe and conducive learning environment. For the higher education sector alone, RM288 million was allocated through Ministry of Education in the recent 2016 Malaysian budget (Ministry of Finance Malaysia, 2016). The allocation has proved the government's commitment in accelerating academic achievement and focus on strengthening public and private higher learning institutions.

According to a study by Najib et al., (2011), Malaysia has targeted that 40 per cent of its population acquire a tertiary education by the year 2020. New education policies and strategies have led to the establishment of HEBs (public and private), to meet the access and other demands (Fahmi, 2004). By 2011, these objectives had resulted in the establishment of 20 public universities, 33 private universities, four branch campuses of highly reputable foreign universities, and more than 500 private colleges (Najib et al., 2011). Most of the public universities are governed by the Universities and Universities Colleges Act 1971, while technical education is provided by the Education Act 1996 and funded by the government (Fahmi, 2004). Table 2.2 lists the total number of all public and private universities and colleges in Malaysia, as at 2016. The rapid expansion of universities and colleges in recent years shows the success of efforts by the national higher education sector to make Malaysia a hub of higher education regionally and internationally.

Table 2.2: Number of Higher Education Institutions in Malaysia

CATEGORY OF INSTITUTION	TOTAL
Public university	20
Private university	33
Branch campuses	4
Private colleges	532
Polytechnics	26*
Community colleges	94*

** statistic until June 2016*

(Source: Ministry of Higher Education, 2016)

As with other buildings, university buildings are considered to have key functions, as they generate environment, and human and economic resources. Therefore, to truly provide ‘value for money’ in the development of an HEB needs a better understanding of how the interactions among people, buildings and the organisation influences the delivery of organisational goals (Amaratunga & Baldry, 1999).

HEBs or university buildings are symbols of academic replenishment. Therefore, a well maintained building is critical to delivering a university's core business objectives and thus requires a more sophisticated performance assessment (Amaratunga & Baldry, 1999). Since HEBs often occupy large land areas with various building centres, the delivery of building performance may differ in each building, and it is necessary to know what are the general facilities and physical elements in HEBs.

2.2.3 The Development and Physical Elements of HEBs

The elements and characteristics of an HEB are based upon its function and services. The creation of the main physical elements becomes the primary consideration when developing a master plan for any university buildings. As Edwards (2000) points out, the advantages of a master plan is that it has a sense of aesthetic qualities and represents a practical and functional solution to campus growth. The most frequently considered matters when developing an HEB are questions regarding the design of learning spaces, with service and operational considerations (Bennett, 2006). The basic physical elements in an HEB often require spatial precepts, as it reflects the mission and objectives of the university in the widest sense. Table 2.3 lists several of the physical elements present in general HEBs, compiled from previous studies (Amaratunga & Baldry, 1998; Bennett, 2006; Edwards, 2000; Riley et al., 2010; Roxå & Mårtensson, 2008):

Table 2.3: General Physical Elements in HEB

ITEM	TYPE/ UNIT
1	Academic Buildings • Lecture halls, classrooms, studios, faculty blocks, departmental buildings, language centre
2	Library and learning resource centres
3	Administration Offices
4	Laboratories and research buildings
5	Amenities and special functions • Congregation/senate hall • Sports halls, stadium and physical recreation • Teaching hospital, clinics • Refectory (dining halls, cafeteria) • Bookshops, Bank, Religious amenities • Art and design gallery
6	Students housing and staff housing • Hostels, Apartments, Halls of residence
7	Infrastructure • Parking and amenities, Landscape, Pedestrian walkways

Therefore, the development of HEBs requires master plans and development frameworks. Without a long term plan, the potential of creating richness and character of an HEB is not high (Edwards, 2000). Generally, because the building is large and complex, the master plan needs to correspond to the physical plan attributes and other key ingredients as a formal centre. However, unlike most land developers, university authorities need to have a long-term view of operations. Edwards (2000) points out that many university buildings today are already more than a decade old. The issues are more likely to concern matters such as the preservation of the building operations and systems that are fundamentally changed due to physical requirements (Olanrewaju et al., 2010). If the rate of change in an HEB is well managed, the longevity of the campus provides opportunities to create places of strong identity and environmental richness (Edwards, 2000). Therefore, in order to truly provide value for money, those responsible for building and managing HEBs need a better understanding of how the interaction between people, buildings and the organisation influences the delivery of organisational goals (Amaratunga & Baldry, 1999).

In Malaysia, the space requirements and dimension regulations for public HEBs is based on guidelines issued by the Malaysian Economic Planning Unit (EPU), under Section B5. The guidelines are, however, not considered as mandatory for approval by the Ministry but, as explained by EPU (2008), for the building stakeholders to plan and develop government building projects. Generally, developing an HEB concerns a range of building types and building units involving academic buildings and non academic buildings. Given the wide diversity of functions, the present research therefore focuses on the provision of performance specifically in academic buildings. The next section explains the units in the category of academic buildings, and also the space requirement for each unit of academic buildings, according to the EPU guidelines.

2.2.3.1 The Economic Planning Unit (EPU) Guidelines for Academic Buildings

The Economic Planning Unit of the Prime Minister's Department, Malaysia has issued a standard guideline and regulations for all public buildings in Malaysia: "Rules and Guidelines for Building Design Standards Committee and the Economic Planning Unit Cost". According to the EPU (2008), the guideline was issued to supersede the previous guidelines provided by the Committee of Standards and Cost (previously known as Sub-Committee on Standards and Cost) in 2005. The guideline is intended to be a reference for all stakeholders to develop public buildings, before obtaining the endorsement and approval from the Committee of Standards and Cost (JSK). This is also in line with the criteria and general standards to develop government and public buildings cost effectively and fit for their functions (EPU, 2008). Table 2.4 lists the general building category of public buildings that were regulated under the space provision and requirements by EPU:

Table 2.4: Division and Category of Malaysia's Public Buildings

SECTION	DIVISION/SECTION	BUILDING CATEGORY
A	Offices	Admin/Office
		Ministers' offices
		Auditorium/Halls
B	Education	Schools (preschool, primary, secondary)
		Boarding schools
		Workshop
		Higher Education Institutions (academic and non-academic buildings)
C	Health	Hospital
		Treatment Centre
		Health Clinic
		Laboratories
		Training College
		Health Office
		Rural Clinic
		Hostel/Quarters
D	Security	Royal Malaysia Police Building
		Military Forces Building
		Prison Department Building
		Fire and Rescue Department Building
E	Quarters	Residential Quarters
F	Hostel	Students/Trainers/Staffs' Hostel
		Officers' Hostel
G	Library	State Library
		Metropolitan Library
		Regional Library
		Branch Library
		City Library
		Village Library
H	Mosque	Mosque
		Prayer room (*surau*)
I	Sport facilities	
J	Diplomatic facilities	
K	Courts of Law	

(EPU, 2008)

Therefore, it is mandatory for building stakeholders to refer to the stated guidelines when developing the above buildings. The EPU provision includes requirements on dimensions of space, building materials and finishes, internal building services (mechanical and electrical), energy efficiency, Industrialised Building System (IBS) technology and provisions for people with disabilities. For the purposes of this research, since the development of building performance risk-rating tool (BPRRT) focuses on academic buildings, the EPU regulations on space and other requirements for these buildings are described in the next paragraph. The brief explanation is sufficient to justify the need for a BPRRT for academic buildings in local HEBs.

2.2.3.2 Academic Buildings: Significance and Function

Public HEBs are required to have academic buildings in order to support the learning process and the learning environment. Academic buildings normally consist of faculty buildings that are separated into several units; lecture halls, classrooms, studios, workshops, libraries and laboratories. For these units, the allowance of gross floor area (GFA) for the academic buildings provided under the 2008 EPU guideline is shown in Table 2.5. The given GFA does not include other isolated buildings such as administration offices, library, lecture halls, language centres, computer labs, facility and development offices, mosque, sport centres or guest houses.

Table 2.5: Allowance of Gross Floor Area for Building Units under the Academic Buildings of Public HEBs

ITEM	BUILDING UNIT	GFA (M^2 / STUDENT)
1	Lecture Halls	0.90 m^2 - 1.00 m^2
2	Lecture rooms	0.95 m^2
3	Tutorial rooms	1.90 m^2
4	Seminar rooms	1.90 m^2
5	Laboratories	General lab: 7.90 m^2
		Research lab: 11.0 m^2
6	Architecture Studio	7.50 m^2
7	Engineering Drawing Studio	5.90 m^2
8	Library (reading area only)	Open area : 1.90 m^2
		Cubicle area : 2.30 m^2
		Carrel area : 2.80 m^2

(Source: EPU, 2008)

Hence, the function of academic building relies on the provison of educational programmes involving and teaching and learning activities. As described by Edwards

(2000), since teaching space covers 50 to 60 per cent of a university, the area is therefore significant where the concept of functional change through the provision of structured and services to be found.

2.2.4 Building Performance Issues in University Buildings

Buildings are identified as the most significant asset of a university organization, considering the investment a university makes to development and operate their building facilities (Olanrewaju, 2010a). Although there is a need for expansion of university building facilities, there is a corresponding need to optimize the performance of existing buildings. The economic plan to develop HEBs is based on the programmes offered by the university. Delivery of knowledge to students, their learning process and activities through face-to-face interactions are generally conducted in lecture halls or lecture rooms (Khalil et al., 2010). Therefore, the majority of HEBs must provide lecture halls, class/lecture rooms, library, studios, computer labs and other facilities.

In underlining the crucial aspect of performance assessment, the Government of Malaysia under the maintenance division issued General Circular (No.1), dated 27th March 2009, which states that all managements should undertake a holistic management of assets using a systematic approach to achieve building performance optimization. As described in the Guideline for Building Condition Assessment (BCA) for existing government and public buildings (Public Works Department, 2013) the assessment of a building is essential not only for building repairs and improvement, but it must also include the aspect of safety and risk of building. Government of Malaysia General Circular No. 2 (1995) also clearly states the responsibility of each head of department to prepare an effective and systematic plan to maintain and assess government and public buildings. Since public university buildings are categorised as government public buildings, it is therefore essential to execute effective measures or tools that can improve the performance and conditions of the building from time to time.

According to Sapri and Muhammad (2010), in order to deliver the core mission of university, which is its teaching and research mission, higher education institutions need to main substantial infrastructures. This often consists of an extensive estate and buildings, which include not only laboratories, lecture theatres, and offices, but also residential accommodation, catering facilities, sports, and recreation centres (Sapri & Muhammad, 2010). The rapid increase in the number of people using HEBs has therefore come to incorporate issues of cleanliness, noise and air pollution. Pollutant emissions from human activities, building materials and air handling units in the form of both living and dead material take place continuously in any type of buildings, including in an HEB. It has been found that chemical pollutants, volatile organic compounds, noise pollution or pollutant contaminants are among the factors that can have an impact on the quality of the indoor environment (Khalil & Husin, 2009), thus affecting the optimization of building performance in university buildings.

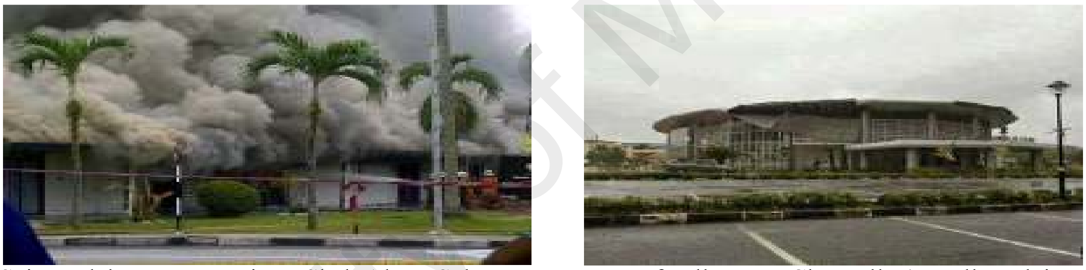
Like other buildings, university buildings as places created for learning become stressed by the forces of change released by various factors. Edwards (2000) stated that handling the forces of change within buildings requires a distinction to be made between various elements of construction, so that parts can be replaced or changed without distorting the whole. Olanrewaju (2010a) stresses that the operating cost of a building is very large in relation to the cost of construction. Growing number of students, diversification of academic activities with increasingly sophisticated equipment and the increase in complexity of research activities that has raised the energy cost also contribute to a higher operational cost in HEBs (Altan, 2010).

Failure to ensure the supply of services in an HEB is a loss. It not only impacts the value of the building, but also the university institution, the community, the students, staff, and other stakeholders (Olanrewaju et al., 2010a). For this reason, allocating proper monitoring assessment for the building should be critically allied to the changing needs of operations and expansive functions. The issue is how to ensure that the building, as the main asset of university, is able to face the challenges that arise in meeting the growing demands from its users.

Amaratunga and Baldry (1998) pointed that the university system is trying to improve its efficiency in the face of rising operating costs and increasing user expectations. When a particular HEB is analysed, it may be found to have a wider range of differing building types with more diverse operational needs than most organisations (Amaratunga & Baldry, 1998). Proper building performance assessment through benchmarks and indicators thus can help organisations to significantly reduce the operation costs. It is suggested that the development of building performance evaluation in HEBs would not only enable more efficient resource allocation in universities but also to lead to development of approaches for commercial competitive advantage. Wong and Jan (2003) claim that building assessment helps to facilitate the provision of a healthy studying environment and facilities that are better customized to the needs of students and teachers in educational buildings.

According to Gupta et al., (2005), HEBs require a number of support services in order to achieve their primary missions of research and teaching. Both of these missions must be integrated to maintain a sustainable environment and ensure an optimum delivery of building performance throughout the building lifecycle. Figure 2.1 shows evidence of several incidents in local HEBs that seriously jeopardized the safety of occupants and users.

Collapsed Walkway at Universiti Kebangsaan Malaysia (UKM), Bangi
Date: 13/11/2013



Science laboratory at UiTM Shah Alam, Selangor destroyed by fire
Date: 15/7/2013

Roof collapse at Chancellor's Hall, Kolej Universiti Tati (TATIuC) Kemaman, Terengganu
Date: 2/12/2013

Facilities and Development Unit at UiTM Shah Alam, Selangor destroyed by fire
Date: 3/4/2013

Chancellery Building of Universiti Malaysia Terengganu (UMT) destroyed by fire
Date: 21/3/2013

Figure 2.1: Reported Cases of Serious Incidents in Malaysia's Higher Education Buildings

From Figure 2.1, it can be summarised that even though unpredictable *force majeure* is among the causal factors of the events, nevertheless potential causes could be identified or prioritized earlier. Various activities which are not limited to education and research activities alone are conducted in the campus involving students, who are the predominant occupants of higher institutions. Therefore, academic and non-academic activities have both direct and indirect impacts on the conditions, environment and sustainability. Amaratunga and Baldry (1998) revealed that assessment of the building performance of institutions delivering higher educational services has become a matter of particular interest to the government seeking to increase the effectiveness of educational provision and to maximise value for money.

HEBs constitute an important part of a university's facilities and considerable resources are committed to their design, construction and maintenance (Olanrewaju et al., 2010b). Human resources, materials and financial resources are devoted for the acquisition, operation and management of the facilities (Sapri & Muhammad, 2010). It is imperative for institutions to manage their facilities well by adopting good practices in various aspects of their operations. However, the challenges and inspiration that can be sparked by commitments to a full suite of environmental performance variables have been missing in both education and practice (Loftness et. al, 2005). The focus in HEBs seems more narrowed to the university's policy and research in energy usage, maintenance management, and the students' learning efficiency. There is an absence of an holistic approach in the management of HEBs, that would be beneficial not only for the building itself, but also for its users.

Crucially, performance failure of a building also creates various risk issues in HEBs. As stated by Beicher (1997), universities should take a more progressive commercial approach to resource allocation than has been the case in the past. Dyer and Andrews (2012) revealed that HEBs face direct risks to their operations and infrastructure from the impacts of climate disruption. Other than that, disruption to energy systems (fuel and electricity) and water systems are among the issues that can lead to indirect impacts and risks for institutions in all regions. Within the higher education sector in Malaysia, other challenges include ensuring that students get a good education, equality of access, funding, strengthening internationalization initiatives and dealing effectively with issues of recognition, consolidation the quality assurance system and the higher education structures with the establishment of the Malaysian Qualifications Agency (MQA). On the other hand, the universities are also trying to improve their efficiency in the face of increasing operating costs and increasing users' expectations (Olanrewaju, 2010a).

It is foreseeable that campus operations and infrastructure are facing risks and vulnerable to various factors and one of the factors is derived from the poor performance of buildings in terms of functional, technical and environmental integrity. As stated by Dyer and Andrews (2012), relevant stakeholders in HEB need to be familiar with the financial and safety risks posed. By identifying the potential risk that is impacted from the building performance, HEBs potentially have opportunities to incorporate adaptation and solutions for the rest of society in their campus operations.

2.2.5 The Impact of Risk in Performance of University Buildings

The importance of maintaining and developing both the existing building stock and the already existing buildings is commonly recognized (Lützkendorf & Lorenz, 2006).

Within this context, the necessity to develop new tools (or to adjust and extend existing tools) for the description and assessment of existing buildings is being addressed. However, a number of methodological problems remain unsolved, as pointed out by Lützkendorf and Lorenz (2006):

- potential hazardous substances within the building require identification and assessment procedures
- determining an existing building's useful life span requires an appropriate assessment methodology

The above point concerning potential hazards that could lead to building performance failure critically needs to be identified. The potential of hazard or risk identification can only be applied through proper assessment procedures, risk management and building performance assessment. The risk issues in HEB are not new, but until today they have not been prioritised as important aspects to address among previously established criteria in HEB performance assessment, such as maintenance, energy issues, environmental issues, and facilities management. Building users are likely to be affected by the performance of the building, and the building is also affected by the activities of its users (Olanrewaju et al., 2010b). Therefore, in response to building performance aspects and requirements of users, the risk issues that need to be challenged in HEBs are delineated as follows:

- *Operational Risks*: more related to the processes within the organization than the functioning the university's goals. As noted by Whitfield (2003), operational risks potentially arise in HEBs when the ability to anticipate and manage risks is critical to maintaining on-going operations.
- *Financial Risks*: these are related to the institution's assets and safeguards. Failure in building performance includes a range of indicators, including energy

and environmental management. Whitfield (2003) described financial risk in HEB as the potential loss of physical assets or financial resources represents areas traditionally subjected to more focused risk management.

- *Reputational Risks*: correlated with the risk to image and reputation of the universities. A university's image may be tarnished when there is potential loss on performance failure. As pointed by Olanrewaju et al., (2010b), a failure in the supply of the required services is a loss in value to the university institution, the community, the students, staff and other stakeholders.

Since risk is also associated with social factors such as crime and nuisance, it is vital to create a secure and safe learning environment so as to limit the risk in HEBs. Edwards (2000) suggested that the management and policing of buildings and spaces should complement design-based crime prevention measures. The common crime problems in university buildings include theft from facilities, sexual offences, theft of vehicles, burglary (residences and academic buildings) (Edwards, 2000; Said & Juanil, 2013; Whitfield, 2003). These are risks that are likely to jeopardise the building's users wholly or partially. Edwards (2000) shows the importance of restricting entrance points and identifying crime hazards (Figure 2.2). This demonstrates that design can help define territories, as the buildings may be granted the ability to control spaces and limit movements and direct flows. Most universities have a security strategy, but only rarely does it influence campus planning or building design (Edwards, 2000). Therefore, the risk impact is not only derived from the poor performance of the building element itself, but also other from elements of design such as building orientation, building access, parking space, and entrance points.

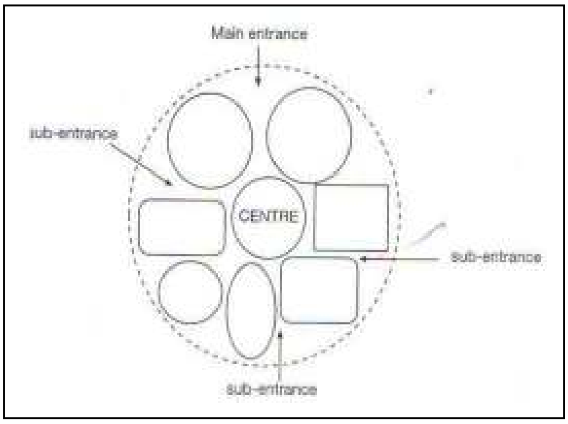


Figure 2.2: The Importance of Design Layout on Restricting Entrance Points and Identifying Territories for a Campus/University Building
(Edwards, 2000)

Users have the potential and capability to take action or make a decision if their value system is not adequately met. It is the correct functioning of the building that the users desire, not the physical condition of the building. As stated by Olanrewaju (2010a), building users are identified as the entity or group of individuals or organization, who are interested in the adequate functioning of the building. Most university buildings in Malaysia have been constructed since 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, and inadequate and poor maintenance.

Although it has not been stated unequivocally, it is possible that occupants or users suffer from the failure of adapting risk mitigation into building performance evaluation. A number of studies have revealed that poor performance of educational buildings has a significant impact on the building users, including students' performance and staff's productivity (Altan, 2010; Amaratunga & Baldry, 1999; Amole, 2008; Harb & El-Shaarawi, 2006; Hassanain, 2007; Khalil et al., 2010; Mat et al., 2009; Najib et al., 2011; Olanrewaju et al., 2010a, 2010b; Olanrewaju, 2010a; Sapri & Muhammad, 2010;

Shabha, 2004; Shafie et al., 2011; Wong & Jan, 2003). Although new buildings help to upgrade educational facilities and provide better quality education, buildings do not remain new throughout their life span. In response to the inevitable changes that will occur, university buildings in Malaysia are required to incorporate risk elements in building performance management that will support and facilitate learning, teaching and research activities (Olanrewaju et al., 2010).

Due to inconsistencies in assessment criteria and indicators within existing tools, there is a need for standardization and the transparent description of assessment tools and methods (Lützkendorf & Lorenz, 2006). Thus, the next section explores the academic theories in risk and building performance and integration of both aspects as the main focus of this study.

2.3 The Concept of Building Performance Evaluation

As described in the introduction, the overview in this chapter reveals the concept of building performance and risk in higher educational buildings (HEBs). According to Parmjit et al., (2006), difficulties can arise when certain key terms are interpreted differently with different meanings and contexts by different people, that may lead to confusion. Therefore, defining vital keywords that appear in the concept articulates a better understanding of the theories.

2.3.1 Definition of "Building Performance"

Building performance studies have emerged with numerous objectives and aspects. The evolution of performance in building develops over time due to many factors, such as environment change and shifting building needs. Pati et al., (2006) explained that the prospects for building performance in fulfilling the expectations of owners, designers, building operators and the occupants is vast. Hence, it is crucial to understand the term "building performance", because there is no single definition for it.

As asserted by Cole (1998), even though the term "building performance" seems straightforward, the specific definition depends upon differing interests and widely varying requirements in buildings. Khalil (2008) defined performance of a building simply as accomplishment, fulfilment, and achievement of a building in meeting the emergent objectives. This refers to comprehensive features of a building, including structural, architectural, surroundings, and environmental issues and building services. This is supported by William (1993) who described building performance as the ability of a building to contribute in fulfilling the functions of its intended use.

To gain a better understanding of the term, descriptions and definitions of building performance have been compiled and summarised as shown in Table 2.6. The definitions were based on general types of buildings and do not specifically address only one type of building. The summary definitions provide the fundamental keywords for the term "building performance". A number of common elements can be identified in definitions of building performance which are generally related to efficiency, function, fitness, and fulfilment. In summary, the definition of "building performance" is the ability of a building to be operated at optimum efficiency and fulfil its function throughout the building life cycle.

Table 2.6: Summary of the Definition of "Building Performance"

AUTHOR (YEAR)	DEFINITION / DESCRIPTION
Abaza (2012)	A permanent improvement in standard design practices among building designers and owners that results in higher efficiency and lower utility costs.
Woods (2008)	A set of measured responses of the building, as a system, to anticipated and actual forcing functions
Khalil (2008)	An accomplishment, fulfilment, and achievement of a building in meeting the emergence objectives
Foliente et al.,(2005)	"..what building process (e.g. mutual agreement/ interaction of interested parties), product (e.g. the output of a design or construction process) and/or service (e.g. asset in support of business) are required to achieve – the 'end' – and not on how they should be achieved – the 'means'
Amaratunga & Baldry (2003)	A process of assessing progress towards achieving goods and services efficiency, quality of building outputs and effectiveness of building operations.
McDougall et al., (2002)	...the measurement involves the efficiency and effectiveness of an action. Efficiency and effectiveness relate, as concepts, to Best Practice (efficiency) — the pursuit of perfection of a given approach, and Best Value (effectiveness) — the pursuit of the most economic (in the widest sense) approach
Eley (2001)	"......future expectations of the organization and its users......design/ build which uses the concept, akin to product provision, of fitness for purpose"
Clift & Butler (1995)	"....denotes the physical performance characteristics of a building functioning as a whole and of its parts"
William (1993)	A building's ability to contribute to fulfilling the functions of its intended use.

2.3.2 The Concept and Requirements of Building Performance

Generally, a building is a structure that provides basic shelter for people to conduct general activities. In common usage, the purpose of buildings is to provide people with a comfortable working and living space and protection from the extremes of climate. A building not only provides structures to live in, but it is supposed to address other key aspects (Khalil, 2008). Each building is unique and distinctive since it was constructed and developed based on various purposes, dealing with many objectives in terms of operation and management, and accommodates different occupancy patterns. As Douglas (1996) noted, even two buildings of the same design at one location may have varying exposures, dissimilar subsoil conditions, and different access provisions. The building may not in itself add value to the process, but it facilitates the process, and has the potential to cause process problems. To that end, cost reduction is a primary consideration for many building owners and occupiers (McDougall et al., 2002). Buildings, therefore, are important as they are the durable fixed assets enabling potential activities and tasks to be carried out.

However, a building's usage depends on the lifespan and the change of rate effected on their impact on efficiency of use. Hence, more attention needs to be given to the change rate and performance of buildings as the changes are not static over time. The emergence of these changes are allied to the building's response towards internal and external factors such as climate, exposure and, more significantly, internal factors such as use and maintenance (Douglas, 1996). As a commodity, a building is not only an asset for investment and financial purposes, but also reflected in functional terms as an enabler to the core business. In financial terms, for many organizations more than thirty per cent of their total asset value is related to their business premises (Amaratunga & Baldry, 1998).

Since not all buildings change in the same rate, the relevant building stakeholders must focus on how buildings were designed, built and whether operations are fit for purpose, as mentioned by Haapio and Viitaniemi (2008). The fact is that most buildings are too complex to be evaluated on various aspects and characteristics, so the question arises of how to ensure that buildings are able to be sustained throughout their life span. Building experts are unable to agree on the answer to this question. To assess how well a building is performing overall and in the long term, a more holistic approach is needed. This is where building performance evaluation (BPE) can play an important role.

According to Amaratunga and Baldry (1998), building performance is an attractive concept which not only benefits the designers and users, but also works for the long term benefit of those concerned with the built environment. The basic concept of building performance has been immersed in various issues, characteristics with various objectives. The performance concept involves BPE that combines with recommendations for improvement and is used for feedback and feed forward regarding the performance of similar buildings (Amaratunga & Baldry, 1998). It denotes the comparison of a client's goals and performance criteria against actual building performance, measured both subjectively and objectively.

As depicted in Figure 2.3, the performance concept is an act of evaluation, performance measures are compared with appropriate performance criteria and a conclusion is reached on how successful the building performance has been (Preiser et al., 1988). The following figure illustrates the benefit and values of building performance concept behind the goals and objectives of clients.

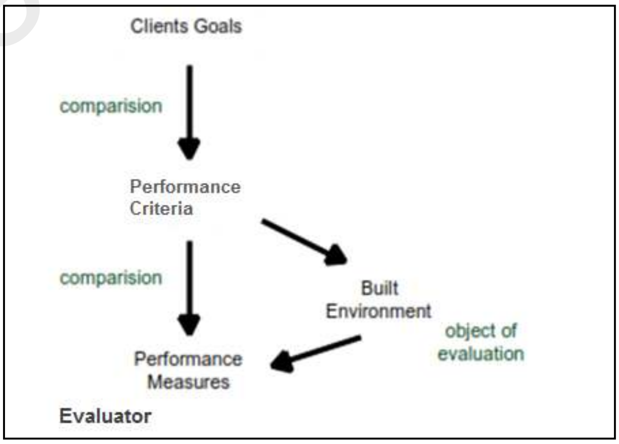


Figure 2.3: Building Performance Concepts
(Amaratunga & Baldry, 1998; Preiser et al., 1988)

The notion of assessing building performance is to understand how the building meets design, function, capability and technical objectives. As stated by McDougall et al., (2002), the performance measurement of a building is firstly summarised in terms of the background of the building and the scope of performance assessment. Building performance is an important aspect that reflects the issues arising in building operations and addresses varying uses placed on all buildings.

Amaratunga and Baldry (1998) stated that the performance concept in the building process views buildings as dynamic entities and indicates a comprehensive attitude towards the management of buildings. Therefore, the assessment of building performance serves as a valuable tool that has great potential for decision makers at both strategic and operational levels. As illustrated in Figure 2.4, the concept of building performance addresses a comprehensive evaluation that is closely related to the operational level, which can feed forward as a decision making tool for stakeholders (Amaratunga & Baldry, 1998).

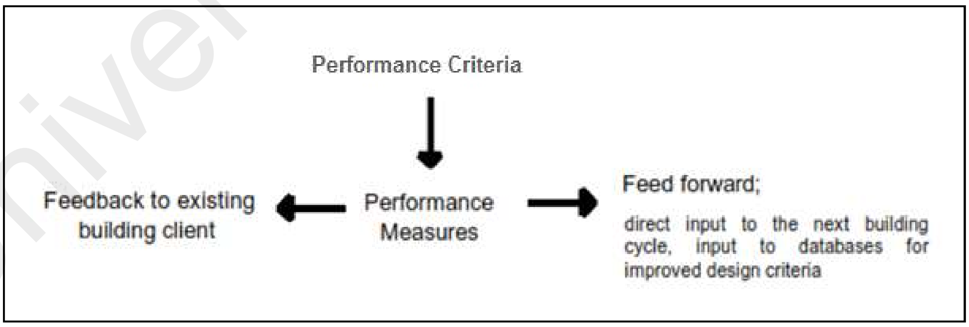


Figure 2.4: Building Process and the Performance Concept.
(Amaratunga & Baldry, 1998)

Figure 2.4 shows how performance is measured and compared to criteria, thus the valuation results are used as feedback to improve the evaluated building performance. Hence, the planning, programming, design and construction of future buildings can be improved through the feed forward of evaluation results. This depends on the requirement and purposes of evaluating the building's performance.

In the context of facilities management (FM), performance measurement has significantly become an important exercise and practice of organizations to create a greater awareness amongst managers of the important role facilities. As described by Pitt & Tucker (2008), there is a wide range of choices in FM for measuring performance, reflecting the varied nature of the field. Therefore, there is a need to assess performance in order to guide management decision-making, and performance measurement applies to management in the FM context (Amaratunga, 2000).

Building performance is evaluated for many reasons and purposes. Ideally, the aspects that need to be thoroughly assessed depend on the evaluation purposes. The following reasons listed by Douglas (1996) outline some of the uses of evaluating building performance in buildings:

- For property portfolio review, acquisition or disposal purposes
- To highlight where a building is lacking in performance
- To help prioritize maintenance or remodelling works
- To provide identification or early warning of obsolescence in buildings; and
- To assist in achieving value-for-money from building assets by aiding identification of performance achievements as well as failures.

The above purposes are angled towards achieving sustainable buildings and prolonging the optimization of their provision of service operations. Preiser and Nasar (2008) stated that the key issues to cover in building performance also include health, safety, security; issues addressed by building codes; functionality and guideline materials; and the social, psychological, cultural aspects of building performance. To assist the understanding of the concept of building performance and its requirements, Table 2.7 summarises several works that have expressed the requirements and purposes of evaluating building performance, generally applied to all types of buildings.

Table 2.7: Summary of Concept/Requirements and Purposes of BPE

	ITEMS	**AUTHOR(s)/YEAR**
Concept/ Requirements in BPE	• Building Users/ Occupants • Users' benefit • Users' feedback	Amaratunga & Baldry, (1998); Amaratunga, (2000); Augenbroe & Park, (2005); Baird, (2009); Bordass et al., (2001); Bordass & Leaman, (2005a), (2005b); Bordass, (2003); Clift & Butler, (1995); Cohen et al., (2001); Douglas, (1996); Lützkendorf & Speer, (2005); Mcdougall et al., (2002); Pati et al., (2009); Pitt & Tucker, (2008); Preiser, (2001); Preiser et al., (1988); Vischer, (2002), (2008); Woods, (2008)
	• Client's goal • Performance Criteria/Factors/ Attributes/Indicators • Performance measures/evaluation	Amaratunga & Baldry, (1998); Bordass et al., (2001); Bordass & Leaman, (2005a), (2005b); Bordass, (2003); Cohen et al., (2001); Douglas, (1996); Mcdougall et al., (2002); Pati et al., (2006), (2009); Preiser et al., (1988); Vischer (2008)
Purposes of BPE	Efficiency and effectiveness	Mcdougall et al., (2002)
	Help to fine tune building performance and reduce energy consumption	Nevill (2007)
	Explore design changes that provide incremental improvement measured against single criteria such as reduced energy consumption and or improved thermal comfort.	Soebarto & Williamson (2001)
	As an integral part of the planning and controlling cycle - it is among essential issues for the effective implementation of a facilities strategy.	Alexander (1996)
	For better matching of supply and demand, improved productivity within the workplace, minimisation of occupancy costs, increased user satisfaction, certainty of management and design decision making, higher returns on investment in buildings and people.	Baird (2009)
	As negotiating instruments among stakeholders at various phases of the building procurement process.	Pati et al., (2006, 2009)
	To solve problems on "real-world research" such as predicting effects, robust results and developing services towards client orientation	Robson, C. (2002) as cited in Leaman et al., (2010)
	To credibly account for how well a building achieves its purpose at any time during its useful life	Woods (2008)

The overall performance includes the building's appearance, evaluative quality, the meanings and evaluative responses that may be conveyed by the users. As a summary, the building performance concept has been an evolutionary process. Therefore, all relevant stakeholders need to understand the key performance factors in a building.

2.3.3 Users' Benefits in Building Performance Evaluation (BPE)

The goal of building evaluation is to ascertain how well the building serves the needs of the occupier. At the same time, identification of any major deficiencies based on the performance factors in its overall performance can be collected. As summarised by McDougall et al., (2002), key performance factors can be attained by obtaining accurate measures and recording the findings as a lesson learned to adjust the relevance of certain aspects. Lessons learned are generally obtained from mistakes, issues arising and problems that appear in buildings, so that those mistakes are not repeated by current management or in future developments. The question is how to acquire the "lesson-learned" and what will be the suitable medium to carry out actions from "lessons learned"?

According to Zimmerman and Martin (2001), lessons learned are retrieved from the building users or occupants and could be used to improve the fit of the existing building and act as feed back into design research and programming for subsequent buildings. Lessons-learned can be established from an assessment that involves the benefits of assessment for the building users. Users are the most knowledgeable people who experience the impact from occupied buildings. Therefore, the performance assessment should be thoroughly conducted for the users' benefit.

Sinopoli (2009) states that experience and responses from people using a building. Whether they are office workers, shoppers or teachers, are invaluable inputs to building operations or the design of future buildings. Typically, the criteria for judgement are the fulfilment of the functional programme and the occupants' needs (Zimmerman & Martin, 2001). This has been gradually expanded to incorporate the changing needs of the users and does not only depend on the suitability of the building orientation and facilities towards the users.

The responses from the users on how well the buildings performed are considered to be feedback. As defined by Bordass (2003), 'feedback' is a process of learning and understanding from valuable information and responses in a current building situation. In simple words, the understanding is gained from information people have provided, thus facilitating actions based on the information that will improve the situation. Without a feedback loop, every building and its systems will be put together in new ways, with potentially unpredictable outcomes (Zimmerman & Martin, 2001). In building performance, it is vital to incorporate the users' benefits and responses to propose feasible improvements that can be instituted for the building.

According to Leaman et al., (2010), feedback potentially falls into four types, as listed below, which represent the requirements of building performance being applied from users' feedback:

- making the case: the project objectives and the brief
- the design and building process: including appointments, design, project management, construction, coordination, cost control, build quality, commissioning and handover

- the building as a product, the outputs: what it is like, what it costs, its fitness for purpose, and how professionals and public react to it
- the building's performance in use, the outcomes: technical, for the occupier, for users, financial, operational and environmental

To improve building performance overall in a changing market, the industry and its clients need to identify opportunities and pitfalls by means of rapid feedback (Cohen et al., 2001). This is allied to the concept of building performance in which feedback in the occupancy stage is able to meet client's goal and objectives in the preliminary stage of building development. As stated by Lützkendorf and Lorenz (2006), feedback derived from occupants' satisfaction represents a key performance indicator that may replace some other partial building indicators. Significantly, this indicator (occupants' satisfaction) reveals a very close relationship between the social aspects of sustainable development (in terms of health, comfort and well-being) and economic or financial considerations. As described by McDougall et al., (2002), in the development of performance measurement systems, the importance of a feedback loop has long been established. Many studies have shown an increasing awareness of the direct impact of responses gathered from the experience of building users.

The above statements were based on research findings showing that there is a direct link between the building and its users as factors in building performance (Amaratunga & Baldry, 1998; Douglas, 1996; Karemera et al., 2003; Khalil & Husin, 2009; Pitt & Tucker, 2008). The results tend to indicate that the occupants' comfort and productivity performance are correlated with the performance of building. An extreme example of the effect of poor building performance on building users is "sick building syndrome" (SBS), which illustrates how a building can have an adverse effect on its occupants.

The user-centred theory introduced by Vischer (2008) asserts that the relationship between users and buildings changes over time, and that each situation must be studied and assessed on its own merits. The theoretical polarity is illustrated in a diagram in Figure 2.5. The figure supports the extreme cause-effect perspective based on the premise that what is built, and the environments thereby created, cause users to behave in certain ways, many of which are predictable.

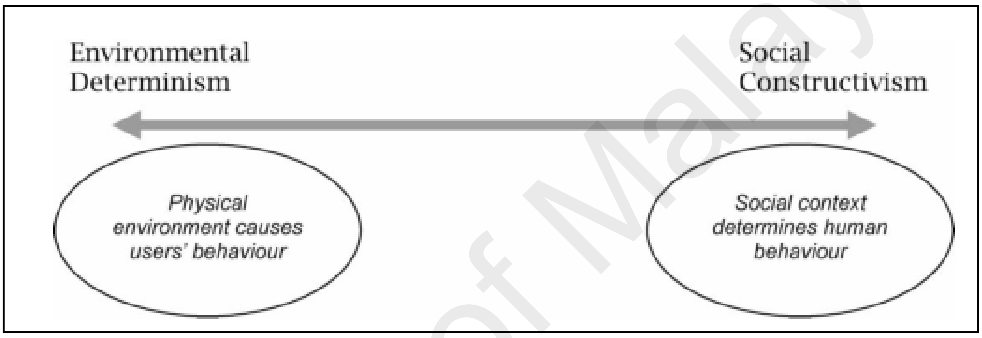


Figure 2.5: The User-Centered Theory in Built Environment (Vischer, 2008)

However, learning from feedback is not yet embedded in many processes affecting the procurement and use of buildings (Way & Bordass, 2005). In building performance, one of the barriers to performing such an evaluation includes reluctance of occupants to participate, which strengthens the need for feedback. Hence, effective feedback needs to be addressed so as to ensure that the information obtained is comprehensive and relevant to the performance criteria. According to Leaman et al., (2010), effective feedback needs to provide objectivity, and lead to action and insight where it should incorporate all the following:

- improve the performance of the studied building: this is nearly always possible, but needs motivation and commitment

- improve the services of those who provided it: this is always possible, but needs connection, motivation and knowledge management at the organizational level
- contribute to a wider knowledge base so that insights are disseminated and are more than anecdotal

In Malaysia, collecting feedback in completed and occupied buildings is not a routine activity, especially when questions arise about the cost and time that will imposed to obtain such information. As stated by Bordass (2003), feedback is not routine in the industry because there are many barriers and not enough drivers. Similar experiences have been found in developed countries such as US and UK; the presence of some barriers not only relates to time and cost, but also to other factors such as management, client and users' participation.

To overcome the barriers, the priority of evaluation must be enhanced with suitable performance criteria, suitable techniques and appropriate methods that enable the resulting improvement to be successful. It is encouraging that the relevant stakeholders are now becoming aware that it is in their interest to ensure that feedback systems are in place (Bordass, 2003). Therefore, an improvement of performance assessment addressing the users' benefit should be emphasized. For this research, the proposed tool has been developed not only to optimise the performance of building, but at the same time to benefit and satisfy the building users in terms of social aspects.

2.3.4 Requirements of the International Standards Organisation (ISO)

The requirements of the International Standards Organisation (ISO) regarding building performance and the users' requirements on performance improvement is reviewed in this section of the chapter. ISO is a global organization coordinated in Geneva, Switzerland that is responsible for developing new standards for products and services. The purpose of ISO is to help governments around the world create environmental, health and safety policies. According to Ahmad Kamil (2009), ISO occupies a special position as a bridging organization in meeting both the requirements of business and the needs of the society. There are two types of ISO being reviewed that relate to building performance; i) ISO9000:2015 – Quality Management, and ii) ISO9836:2011 – Performance Standards in Building. As the main concept in this study is delineated to building performance, hence, both ISO was reviewed in order to relate the importance of fulfilling the customer's need in building performance.

2.3.4.1 ISO 9000:2015 – Quality Management

The issuance of ISO9000 is to fulfil the customers' quality requirements, while aiming to enhance customer satisfaction and achieve continual improvement of performance. Based on the latest issuance of ISO 9000:2015, the standard describes the fundamental concepts and principles of quality management which are universally applicable to the following (The International Standards Organisation, 2015):

- organizations seeking sustained success through the implementation of a quality management system;
- customers seeking confidence in an organization's ability to consistently provide products and services conforming to their requirements;
- organizations seeking confidence in their supply chain that their product and service requirements will be met;
- organizations and interested parties seeking to improve communication through a common understanding of the vocabulary used in quality management;

- organizations performing conformity assessments against the requirements of ISO 9001;
- providers of training, assessment or advice in quality management; and
- developers of related standards.

The ISO9000 standard is intended for use in any organization which designs, develops, manufactures, installs and/or services any product or provides any form of service. It sets out a number of requirements which an organization needs to fulfill if it is to achieve customer satisfaction through consistent products and services (The International Standards Organisation, 2015). In relation to building performance and users' benefit, this standard signifies the importance of fulfilling the customer's need or the building users' requirement in delivering the operation and services of a building.

2.3.4.2 ISO 9836:2011 - Performance Standards In Building

The ISO 9863:2011 is a revised version from the previous 1992 standards, which specifies how to determine functional performance requirements for buildings and building-related facilities. According to the International Standards Organisation (2011), this standard provides information on how to check the capability of buildings and facilities to meet the identified requirements, which is the building users' need. The standard is particularly useful for the relevant stakeholders to have control or occupancy of a building's assets that can benefit the owners and managers, occupants, tenants, or other users or stakeholders. The standard is also intended to be used in establishing evaluations that include comparing and controlling the properties of a building that are related to its geometric performance (The International Standards Organisation, 2011).

Based on the review of this standard, the following is a summary of the requirements for defining the performance standards in buildings:

- The standard provides the indicators on the relationship between the area taken up by the building and usable area, indicating whether the building costs and materials have been used to their best advantage.
- The standard provides a basis for minimising running costs by limiting the amount of space and the cost of individual materials by calculating and comparing the area and volume indicators.
- The standard provides a relationship between the area of the building envelope and the usable area (functional use of a building), showing the extent to which basic savings have been made on the envelope and the running cost of services items.
- The standard provides several examples of using building loss factors (the percentage difference between rentable and usable area) when setting requirements for new construction.

Hence, the standard furnishes comparability of measurements that assist in calculations of costs and benefits of buildings. Since space functionality is also one of the criteria that can contribute to the aspect of building performance, this shall act as a basis for measuring various aspects of the performance of buildings or as a planning aid.

2.3.5 Review of Established Building Performance Evaluation (BPE) Tools

Building performance studies are not a new issue and many building performance tools exist that have emerged in diverse contexts. The only distinguishing features of the tools are the performance criteria, or aspects relating to the application of the tools. As described in previous sections, the objective of a building performance evaluation

(BPE) is to have a reliable list of aspects and criteria for the building. Determinants of the initial set of parameters or indicators for the rating tool are needed before any performance assessment can be carried out. Therefore, an exploration and analytical review of the established BPE tools was carried out to distinguish the items and also any quantification methods involved to determine criteria for measurement. The analysis of the established BPE schemes is also reviewed to act as a guide for the qualitative interviews, as recommended by Ali and Ali (2008), which is considered to be the most comprehensive and methodological tools developed to examine sustainability issues. Hence, the initial set of indicators were also used in the semi-structured interview sessions as part of the preliminary survey for this research.

A growing number of performance assessment tools have been developed for the building sector all over the world. Soebarto and Williamson (2001) stated that in several countries, rating schemes have been introduced in BPE tools that incorporate a variety of objectives forming part of the requirements for building planning code compliance. Hence, this review is limited to the leading industry tools for BPE that particularly incorporate the benefits of evaluation for the users and as lessons-learned that can contribute towards improved building performance. Conceptually, the exploration on the types of building performance evaluation is needed to address the nature and level of measurements they provide, their limitations, and the incorporated characteristics they attempt to measure.

2.3.5.1 Building Research Establishment's Environmental Assessment Method (BREEAM)

One of the leading globally recognised performance tools is known as the Building Research Establishment Environmental Assessment Method (BREEAM). BREEAM was established in 1990 in the UK (Baird, 2009; Cole, 2005; Haapio & Viitaniemi, 2008a; Poveda & Lipsett, 2011; Soebarto & Williamson, 2001; Yau, 2006; Yik et al., 1998) and it is the first commercially available performance assessment tool for buildings. Since then, the field of building environmental assessment has expanded rapidly and a number of performance methods/ tools have been developed with a correspondingly swift increase both in use and refinement worldwide.

BREEAM is best known as an environmental assessment method and rating system for buildings; however, the sets of its assessment are merely to establish the best practice in sustainable building design, construction and operation. Typically, BREEAM consists of weighted scores and sums from the scores of individual factors are used to arrive at an overall rating for a building (Brandon & Lombardi, 2011; Cole, 2005; Poveda & Lipsett, 2011). It contains nine different categories and each category has a pre-determined environmental weighting; Management (12%), Health & Wellbeing (15%), Energy (19%), Transport (8%), Water (6%), Materials (2.5%), Waste (7.5%), Land Use & Ecology (10%) and Pollution (10%).

Poveda and Lipsett (2011) explained that the performance assessment in BREEAM uses different environmental issues that are grouped in three main areas, as follows:

- global issues, which include CO2 emissions, acid rain, ozone depletion, natural resources and recyclable materials, storage of recyclable materials, and designing for longevity;
- local issues, which include transport and cycling facilities, noise, local wind effects, water economy, overshadowing or other buildings and land, reuse of derelict/contaminated land, and the ecological value of the site;
- indoor issues, involving hazardous materials, natural and artificial lighting, thermal comfort, and overheating and ventilation

The strength of this assessment lies in its quantification scheme. As described by Soebarto and Williamson (2001), it provides a tool and authoritative assessment procedures for a quantitative evaluation of the environmental impacts of a building. Credit points are accumulated against the various performance requirements and these are summed to a total score to define "*fair", "good", "very good*" or "*excellent*" overall performance (Papadopoulos & Giama, 2009; Soebarto & Williamson, 2001; Yau, 2006). Table 2.8, shown below, is extracted from Larsson and Cole (2001); it summarises the application of BREEAM according to building types, performance criteria and weighting scores:

Table 2.8: Summary Overview of BREEAM

BUILDING TYPES	CRITERIA	SCORING/WEIGHTING/REPORTING RESULTS
Commercial or office (new and existing) Residential (EcoHomes) Retail superstores, supermarkets Industrial units	Management (policy, procedures) Energy (operational use, CO_2) Health and well being (indoor and external issues) Pollution (air, water) Transport (CO_2, location factors) Land use (greenfields, brownfields) Ecological value of site Materials Waste Water consumption and efficiency	Credits awarded for each criterion Weightings applied to produce overall score Score translated into rating of fair/pass, good, very good, excellent, or a sunflower rating Certificate awarded Updated regularly 25% of new offices have been assessed for certification since inception

(Source: Larsson & Cole, 2001)

2.3.5.2 Building Quality Assessment (BQA)

Building Quality Assessment (BQA) is a computerized system of building appraisal that is used to obtain the score of building performance. According to McDougall et al. (2002), the BQA is a tool for assessing building performance in terms of the facilities available. It is closely related to the actual performance of the building (Baird, 2009; Clift, 1996; McDougall et al., 2002; Yau, 2005). The initial version of BQA was developed by Ryder Hunt in Australia, in conjunction with Victoria University of Wellington (VUW), under the umbrella company, Quality Assessment International, and it covered a range of building types (Clift, 1996). The term "quality" in BQA defines the degree to which the design and specification meets the requirements for that building (Clift, 1996).

Theoretically, BQA can be used in any type of buildings and it identifies the user's requirements based on a number of groups. McDougall et al., (2002) state that the BQA provides a fairly comprehensive set of 138 assessment factors, under 9 categories, as described in Table 2.9. Each category is further divided into four or five sections, generally representing the effects of each category on building users (Clift, 1996; Yau, 2006).

The evaluator then needs to determine the factors that should be included under each section. These factors are outlined by assuming that if the user experiences quality problems in terms of particular section, it may occur due to several factors. Clift (1996) added that each factor derived from the user's experience of having quality problems needs to be scaled. The scoring scales provide a common basis for scoring the factors so that variability of scores, with regard to the same factor by different assessors or in different buildings, can be minimized (Yau, 2006). Scoring criteria for a sample development (car park) are shown in Table 2.10.

Table 2.9: Categories, Description and Sections in BQA System

CATEGORY		DESCRIPTION	SECTION
1	Presentation	Appearance of the building and impression created	1. External attributes 2. Common space 3. Space for retailing 4. Office space
2	Space functionality	Factors that determine operation of spaces	1. Floor construction 2. Subdividability 3. Retail space
3	Access and circulation	Access of people and goods, security	1. People access 2. Vehicles 3. Goods 4. Security
4	Amenities	Facilities or spaces for people	1. Hygiene facilities 2. Hydraulics 3. Catering 4. Staff facilities
5	Business services	Electrical services and IT	1. Telecommunication services 2. Electrical services
6	Working environment	Environmental conditions	1. Acoustic conditions 2. Lighting 3. Thermal environment 4. Temperature and humidity 5. Ventilation
7	Health and safety	Mandatory and other health and safety issues	1. Construction 2. Fire safety
8	Structural	Building structure and condition	1. Structure 2. Construction 3. Condition
9	Building management	Short and long term	1. Cleanability 2. Maintainability 3. Building manageability 4. Future

(Source: Clift, 1996; Yau, 2006)

Table 2.10: Scale of Scores for Factors in Car Park Layout

SCORE	DESCRIPTION
10	Wide aisles, angled bays for large cars, way finding easy
8	Wide aisles, 90-degree bays for large cars, way finding easy
6	Adequate aisle and bay width, bays easy to move in and out of, good signage and way finding assistance
4	Shape of parking area makes way finding difficult, and/or narrow aisles and bays, poorly located
2	Shape of parking area makes way finding difficult, and/or narrow aisles and bays, poorly located, with blind or difficult corners to negotiate
0	No car park

(Source: Yau, 2006; Clift, 1996)

BQA, therefore, can be used to compare the performance and quality attributes at all levels by obtaining the total overall BQA score, the category totals, and down to the individual factor levels (Clift, 1996). It thus provides a direct benefit not only to facility and asset managers, but it also benefits tenant groups and consultants as it is able to measure and judge alternative design options or competitions.

2.3.5.3 Total Building Performance (TBP)

Total Building Performance (TBP) appeared in the USA during the 1980s and 1990s (Hartkopf et al., 1986). Recently, this concept has gained much interest in maintaining the sustainability prospects of buildings in Singapore (Low et al., 2008; Wong & Jan, 2003). There is a joint venture between the Building and Construction Authority (BCA) and the National University of Singapore (NUS) that emphasizes the TBP assessment. The TBP was established to addresses delivery of integrated and high performance buildings with respect to needs and resource availability (Low et al., 2008). TBP has many objectives and has developed complex methodologies, based on some results of systematic studies and research, for the application of TBP concepts in terms of indicators (mandates) of performance and their integration into the building system.

According to Low et al., (2008), the TBP framework incorporates six performance concepts which relate to: i) spatial performance, ii) acoustic performance, iii) thermal performance, iv) indoor air quality, v) visual performance and vi) building integrity. TBP has been applied to commercial and residential buildings and, in particular, to the issue of sick office buildings and intelligent buildings (Wong & Jan, 2003).

In short, all of the performance mandates and concepts comprise a framework or guideline that is used to measure building performance. The performance mandates can be divided into two areas (Hartkopf et al., 1986; Wong & Jan, 2003):

- Building enclosure integrity – deals with protection of the building's visual, mechanical, and physical properties from environmental degradation.
- Interior occupancy requirements and the elemental parameters of comfort – addresses thermal, acoustic, visual, air and spatial comfort, that are dependent on physiological, psychological, sociological and economic values.

TBP is better known as a framework than a tool. As described by Wong and Jan (2003), it makes comprehensive use of both objective and subjective field evaluations in all performance areas simultaneously. It generally serves to understand the critical balance needed to simultaneously ensure all building performance mandates. Table 2.11 illustrates some data measurements and evaluation assessments that can be carried out using TBP (Hartkopf et al., 1986; Wong & Jan, 2003):

Table 2.11: Selected levels of data measurement and evaluation assessment

DIAGNOSTIC MEASUREMENT	REQUIREMENTS/REASONS FOR USE
Plan/archive analysis	Plans, specifications, building budgets, occupancy management records, photos,. Documents are available and used to ascertain if the mandates are assured for the building occupants and activities
Occupancy and use analysis	Behavioural mapping, observations, physical trace records , interviews and questionnaires
Expert walk-thorough analysis	Listening, seeing, smelling, touching, tasting
Simple instrumentation analysis	Measuring instruments and method of assessment
Selected levels of evaluation assessment and Statistical assessment	Thresholds compared to Codes/standards and Guidelines

(Source: Hartkopf et al., 1986; Wong & Jan, 2003)

Therefore, both objective and subjective methods of measurement are taken in an attempt to challenge the current set of local standards for a better building performance.

2.3.5.4 Post-occupancy Review of Buildings and their Engineering (PROBE)

Post-Occupancy Review of Buildings and their Engineering (PROBE) studies are renowned as landmarks in the development of the British Construction Industry (Derbyshire, 2001). Bordass et al., (2001a) stated that PROBE has undertaken post-occupancy studies of a total of 16 UK buildings and the tool is emerging as a systematic effort to make public the performance of buildings. PROBE's initial purpose was to provide feedback to building services engineers with generic and specific information on factors for success, and areas of difficulty and disappointment (Cohen et al., 2001). The establishment of PROBE was inspired by the pressure to produce buildings which save energy and at the same time are healthier and more comfortable for their occupants. It thus motivated building services engineers to try innovative ways, ranging from novel technology to integrated design, to provide a good internal climate under the new constraints (Derbyshire, 2001).

As described by McDougall et al., (2002), the PROBE study covers 43 variables, which may be adapted to specific circumstances if necessary. The variables mainly emphasize environmental comfort issues such as noise, temperature and glare. In its entirety, it also covers technical and energy performance issues, that focus on the following elements (McDougall et al., 2002) :

- The technical performance reports - Focus on how the building services interact with the users, and on manageability, maintenance and control issues.

- The energy performance report - Provides a comparison of systems using a breakdown of energy consumption and estimated CO2 emissions. By using objective data in the technical and energy performance reports, a number of useful benchmarks have been created that provide some assessment of the efficiency of various energy consuming systems.

Theoretically, the results have proved useful in identifying issues that require continued review throughout the procurement process. Eley (2001) observed that the PROBE approach to things that matter to the user must be explored, measures developed, tested and used. The main focus in PROBE is the occupants (Bordass et al., 2001; Leaman, 2001; Leaman et al., 2010) and the occupants' survey is its main strength (Hewitt et al., (2005). Questions in PROBE surveys are enhanced or changed only when absolutely necessary, as this can have serious implications for cost, quality, consistency and comparability (Cohen, et al., 2001a). The licensed questionnaire survey used in PROBE, namely Building Use Studies (BUS) Occupant Survey, is commonly used to find out what occupants think about a building before alterations, relocation or new construction is planned. Figure 2.6 shows a sample of the overall summary results of a BUS survey for a case study of an office building involving twelve key variables, as extracted from Baird (2009):

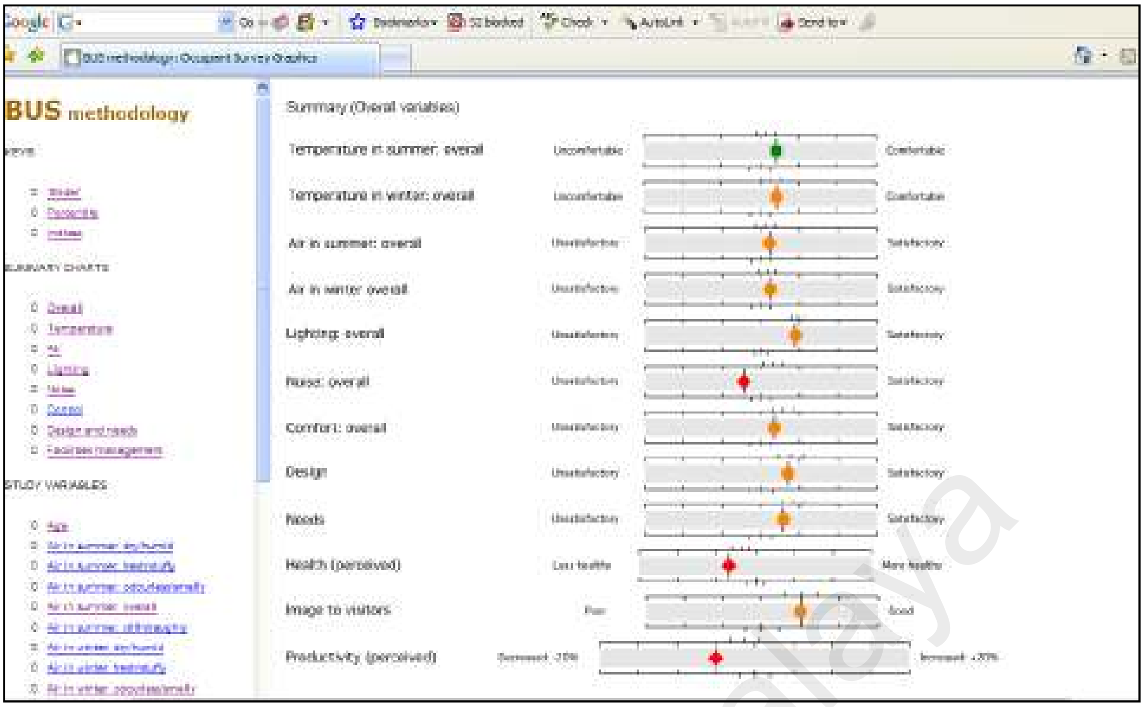


Figure 2.6: Screenshot of Sample BUS Survey
(Baird, 2009)

The BUS survey in PROBE had previously been used for the investigation of sick building syndrome (SBS) in the 1980s (Baird, 2009; Derbyshire, 2001). The respondents are required to rate their level of satisfaction for certain aspects of a building on a 7-point scale; typically from "unsatisfactory" to "satisfactory" or "uncomfortable" to "comfortable". The survey covers the following aspects (Baird, 2009):

- Operational – space needs, furniture, cleaning, meeting room availability, storage arrangements, facilities, and image;
- Environmental – temperature and air quality in different climatic seasons, lighting, noise, and comfort overall;
- Personal Control – of heating, cooling, ventilation, lighting, and noise;
- Satisfaction – design, needs, productivity, and health

Preiser (2001) considered that PROBE could be an enormous factor in moving from highly subjective aesthetics-based evaluations of buildings to more objective and quantitative building evaluations. However, Bordass and Leaman (2005a) maintained that the PROBE package was in effect a method of POE, that is relevant when the building is completed but most appropriate when the building has settled into routine operation. According to Hewitt et al., (2005), PROBE designers deemed that the surveys could be used to ascertain a number of difficulties with building performance that might be more expensive to find out in other ways. Thus, the PROBE approach marks a major cultural change in the building industry, to place emphasis on green and sustainable buildings.

2.3.5.5 Leadership in Energy and Environmental Design (LEED)

Another performance tool that emphasized environmental issues is the Leadership in Energy and Environmental Design (LEED). This tool was established and developed by the U.S. Green Building Council (USGBC). Klotz et al. (2010) remarked that this tool is the most widespread green building rating system for new construction and major renovations after the establishment of BREEAM. Since its inception in 1998, LEED has been accorded strong credibility among experts and has also increased the number of its affiliates (Langston et al., 2008).

The LEED rating system is based on credits and points and it sums the weighted scores of individual factors to arrive at an overall rating for a building (Pathak et al., 2011). Generally, the level of assessment in LEED is graded as “Certified”, “Silver”, “Gold” or “Platinum”, and the levels of certification are based on the total points earned by the assessed building (Baird, 2009; Klotz et al., 2010; Pathak et al., 2011; Soebarto & Williamson, 2001). The five major categories in LEED comprise: i) Sustainable sites credits; ii) Water efficiency credits; iii) Energy & atmosphere credits; iv) Materials & resources credits; and v) Indoor environmental quality credits (USGBC, 2013). There are two further bonus categories which are: Innovation in design or innovation in operations credits; and Regional priority credits, giving a total of seven categories. Figure 2.7 illustrates the certification score points for all seven categories, which sum up to a final score out of 100 points.

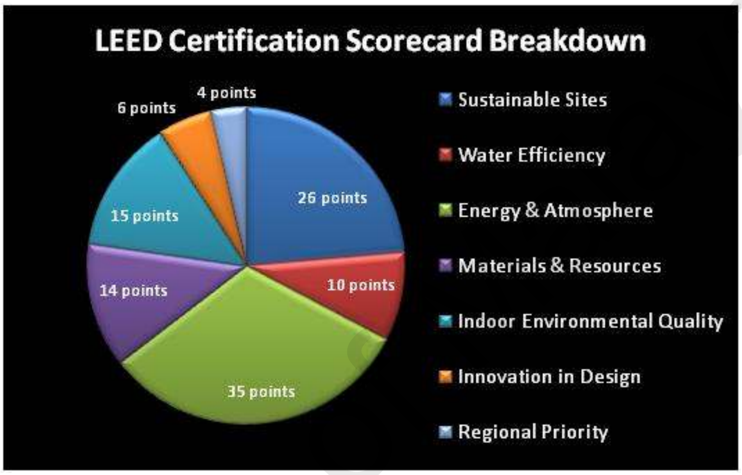


Figure 2.7: LEEDS scorecard
(U.S. Green Building Council, 2013)

Larsson and Cole (2001) summarised that credits are specified for each criterion in LEED and users select criteria for scoring, which are updated every three years. The final score that determines the level of certification of the assessed building depends on the following score, as listed in Table 2.12 (USGBC, 2013):

Table 2.12: LEED's Scoring for Certification

BUILDING CATEGORY	**LEED'S LEVEL OF CERTIFICATION**			
	Certified/ Bronze	**Silver**	**Gold**	**Platinum**
For other building and project types	40-49 points earned	50-59 points earned	60-79 points earned	80+ points earned
For Home	45+ points earned	60+ points earned	75+ points earned	90+ points earned

(Source: USGBC, 2013)

It can be seen that, compared to BREEAM, the assessment in LEED is not limited and it is able to cover various building types, including for renovated buildings and neighbourhood development.

2.3.5.6 Comprehensive Assessment System for Built Environment Efficiency (CASBEE)

The Comprehensive Assessment Scheme for Building Environmental Efficiency (CASBEE) is a Japanese rating tool that was initiated in 2001 for assessing and rating the environmental performance of buildings and the built environment (CASBEE, 2013). Poveda and Lipsett (2011) noted that CASBEE assesses buildings using environmental efficiency and impact on the environment. The assessment tool uses two factors:

- Building Environmental Quality and Performance (Q) - covers the indoor environment (including acoustics, lighting, thermal comfort, and air quality), service quality (including adaptability, flexibility, and durability), and outdoor environment
- Loadings (L) - relates to Building Environmental Loadings that cover energy, materials, and the off-site environment

In CASBEE, the assessment employs an additive/weighting approach, for each of the above factors; i.e. Q and L. The final determination is arrived at by scoring them separately to determine the Building Environmental Efficiency; that is, the ratio of Environmental Quality and Performance to Environmental Loading (Ali & Al, 2008; Cole, 2005; Haapio & Viitaniemi, 2008b; Papadopoulos & Giama, 2009; Poveda &

Lipsett, 2011). Therefore, building assessment is presented more explicitly as a measure of the environmental implications associated with providing a set of 'services' (Cole, 2005).

Generally, the assessment of factor Q (building environment quality and performance) is broken down into three categories: Q-1 (indoor environment); Q-2 (quality of service); and Q-3 (outdoor environment on site). While, LR (reduction of building environmental loadings) is sub-grouped into LR-1 (energy); LR 2-2 (resources and material); and LR-3 (off-site environment) (Poveda & Lipsett, 2011). To reach the final score, BEE (building environmental efficiency) is calculated as the ratio of Q to L. The result is a representation that can be shown according to a 'spider web' diagram, histograms and building environmental efficiency BEE graph (Papadopoulos & Giama, 2009). The overall setting of CASBEE is mainly to cover the following criteria as the main assessment fields: i) Energy efficiency; ii) Resource efficiency; iii) Local environment; and iv) Indoor environment.

2.3.5.7 Green Star by Green Building Council Australia (GBCA)

Green Star is a performance rating tool that certifies environmental design and achievements of buildings. This tool was established by the Green Building Council Australia (GBCA) in 2001 as a comprehensive and voluntary environmental rating system that evaluates the environmental design and construction of buildings and communities (GBCA, 2009). Green Star was developed for the property industry in order to achieve the following (Baird, 2009; GBCA, 2009; Klotz et al, 2010):

- establish a common language
- set a standard of measurement for built environment sustainability

- promote integrated, holistic design
- recognize environmental leadership
- identify and improve life-cycle impacts; and
- raise awareness of the benefits of sustainable design, construction and urban planning.

Like most other rating tool schemes, this tool sums the weighted scores of individual factors to arrive at an overall rating for a building. The scores depend on the list of performance aspects that were drawn up for performance evaluation. Larsson and Cole (2001) list the performance aspects in Green Star as follows:

- Resource consumption - energy, land, water, materials
- Loadings - greenhouse gases, ozone depleting substances, acidification, solid waste, liquid effluent, impacts on site and adjacent properties
- Indoor environmental quality
- Quality of service - flexibility, controllability, maintenance of performance, amenities
- Economics - life cycle, capital, operating/ maintenance
- Pre-operations - construction management, transportation

Green Star ratings are determined by comparing a project's overall score with the following rating scale, as shown in Table 2.13 (GBCA, 2009):

Table 2.13: Rating Determinants in Green Star

POINT SCORE	GREEN STAR RATING	OUTCOME
45-59	4 star	Best Practice
60-74	5 star	Australian Excellence
75+	6 star	World leader

(Source: GBCA, 2009)

2.3.5.8 Green Star New Zealand (Green Star NZ)

Green Star New Zealand (Green Star NZ), which was modelled to a large extent on its Australian counterpart, was first released in New Zealand in April 2007 (Baird, 2009; NZGBC, 2007). Its initial objectives, outcomes and the final rating star determinants were similar to those of Green Star Australia. The difference between Green Star NZ and Green Star Australia is in the listing of the performance categories. According to Baird (2009), Green Star NZ evaluates building projects against eight (8) environmental impact categories, as follows:

- Management (10%)
- Indoor environment quality (20%),
- Energy (25%)
- Transport (10%),
- Water (10%),
- Materials (10%),
- Land use and ecology (10%),
- Emissions (5%).

Within each category, points are awarded for initiatives that demonstrate that a project has met the objectives of Green Star NZ and the specific criteria of the relevant rating tool credits. Points are then weighted (in accordance with the above percentages) and an overall score is calculated, determining the project‘s Green Star NZ rating (NZGBC, 2007). The tool specifically addresses the needs of specific building types, such as office buildings, industrial buildings and education buildings, in the design phase and following construction, especially in the Built phase. However, the application has been extended to assess the environmental impact that is a direct consequence of a building's site selection, design, construction, and maintenance (NZGBC, 2007).

2.3.5.9 Building Health and Hygiene Index (BHHI) and Building Safety Condition Index (BSCI)

In mid 2003, a research team from the Faculty of Architecture, University of Hong Kong launched a project called the Building Health and Hygiene Index (BHHI). The BHHI covers the health and hygiene performance of apartment buildings in Hong Kong. According to Ho et al., (2008) and Yau (2006), the motivation for the project was the outbreak of Severe Acute Respiratory Syndrome (SARS) in Hong Kong in early 2003, which aroused people's concerns about the potential impact of the living built environment on their well-being.

The scheme of the Building Safety and Condition Index (BSCI) introduced by Ho et al., (2008) is an extension of the theoretical assessment framework to be used for high-rise apartments in Hong Kong. BSCI was introduced to examine the seriousness of the high-density problem. The scheme is aimed at surveying the health and safety performance of apartment buildings in the densely populated city of Hong Kong by means of a simplified assessment scheme.

There are 25 building factors for BHHI and 19 building factors for BSCI (Ho et al., 2008). Each factor is weighted by building safety experts who were able to give their perceptions of the relative importance of the building factors and provide the weightings for each factor. Two expert panels were selected; one panel consisted of 35 experts in building health, and the other panel consisted of 23 experts in building safety.

The weighting of each factor was finally computed by averaging out the weightings obtained from the consistent responses, using the Analytical Hierarchy Process (AHP) method. To compute the rating of each building factor in the assessment scheme, one would normally use a continuous scale ranging from the best practice (*rating = 1*) to the worst practice (*rating = 0*). Table 2.14 and Table 2.15 show the overall building factors assessed under the BHHI and BSCI, respectively, with their relative weightings.

Table 2.14: Building Factors and Weightings in BHHI

LEVEL 1		**LEVEL 2**		**LEVEL 3**	
Performance Indicators	**Weight (%)**	**Category**	**Weight (%)**	**Building Factors**	**Weight (%)**
Design	53.6	Architecture	18.5	Size	2.5
				Plan shape	3.5
				Headroom	2.0
				Windows	5.7
				Noise reduction	3.4
				Open space	1.4
		Building services	19.3	Water supply	5.6
				Drainage	6.8
				Refuse disposal	4.7
				Lift	2.2
		External environment	15.8	Density	1.9
				Adjacent use	1.7
				Air quality	5.2
				Aural quality	2.6
				Visual obstruction	1.6
				Thermal comfort	2.8
Management	46.4	Operations & maintenance	27.1	Cleaning	5.1
				Pest control	3.1
				Refuse handling	4.6
				Drainage condition	4.6
				Unauthorised alteration	4.0
				Water quality	5.7
		Management approaches	19.3	Owners' duty	7.9
				Documentation	6.8
				Emergency preparedness	4.6

(source: Ho et al., 2008)

Table 2.15: Building Factors and Weightings in BSCI

LEVEL 1		LEVEL 2		LEVEL 3	
Performance Indicators	**Weight (%)**	**Category**	**Weight (%)**	**Building Factors**	**Weight (%)**
Design	47.0	Architecture	22.1	Height and disposition Means of escape Means of access Amenities	3.8 9.3 6.3 2.7
		Building services	16.6	Fire service installations Electrical installations Fuel supply	8.3 4.3 4.0
		External environment	8.2	Proximity to special hazards Proximity to fire station	6.4 1.8
Management	53.0	Operations & maintenance	33.5	Structural condition Building services condition Exit routes condition Fire compartmentation Illegal appendages	8.6 5.3 8.4 4.3 6.9
		Management approaches	19.5	Owners' duties Documentation Emergency preparedness Financial arrangement	4.3 3.5 7.8 3.9

(source: Ho et al., 2008)

Both schemes have similar performance indicators and categories; however the building factors are different in each scheme. The weightings for the performance indicators are also different; for BHHI the design is more important than the management; on the other hand, for BSCI, management is more important than design. The details of each *Category* in Level 2 of both BHHI and BSCI (as shown in Table 2.14 and Table 2.15), are as follows (Ho et al., 2008):

- Architecture: refers to the layout and elevation design of a building (e.g. plan shape, height, and disposition).
- Building services: service components added onto a building's fabric to provide functionality. Water supply, drainage, refuse disposal, fire services, electrical systems, etc. are included under this category.
- External environment: the immediate external environment of a building, which can affect the health and safety of its occupants. For example, green parks are regarded as amenities, whereas street wet markets and petrol stations increase the health and safety hazards to a building.

- Operations and maintenance: concerns operational issues in building management, which include the daily management tasks (e.g. cleaning and refuse disposal) and maintenance standards for a building.
- Management approaches: the strategic issues in building management that include the delineation of responsibility among owners, documentation, emergency preparedness, and the provision of feedback systems.

2.3.5.10 Building Environmental Assessment Method (HK-BEAM)

The Building Environmental Assessment Method (HK-BEAM) was developed by the Centre for Environmental Technology in Hong Kong and launched in December 1996. It was adopted from BREEAM, UK (BEAM Society, 2011; Yik et al., 1998). This assessment was introduced to measure, improve and label the performance of buildings over their whole life cycle; that is, from planning, design, construction, commissioning, management and operations, to deconstruction. According to Yau (2006), HK-BEAM has become an industry-led scheme owned and being implemented by the HK-BEAM Society, a non-profit-making and member-based association comprising more than 160 individual and corporate members. The latest version of HK-BEAM, which was issued in December 2004, attempted to cover assessments for all types of buildings (Yau, 2006).

In terms of structure, HK-BEAM has five performance inputs; namely Site Aspects, Materials Aspects, Energy Use, Water Use, and Indoor Environmental Quality (Table 2.16). Under each category, specified criteria that have an impact on the quality of the respective input are listed. In respect of each of these criteria, there is a set of factors that facilitates the assessment of building performance.

Table 2.16: The Structure of HK-BEAM for Assessment of Residential Buildings

PERFORMANCE INPUT	CATEGORY
Site Aspects	Site Location Site Design Emissions from site Site Management
Material Aspects	Efficient of the materials Selection of materials Waste Management
Energy Use	Annual energy use Energy efficient system Energy efficient equipment Provision of Energy management
Water Use	Water quality Water conservation Effluent
Indoor Environmental Quality	Safety Hygiene Ventilation Thermal Comfort Lighting quality Acoustic and noise Building amenities

(source: Ho et al., 2008; Yau, 2006)

HK-BEAM is a private sector initiative and a voluntary scheme. Criteria adopted in HK-BEAM have been set at levels over the legislative and code requirements (Yik et al., 1998). Even though it is described as a building performance scheme, HK-BEAM focuses more performance on the environmental aspects in buildings, and it is considered to be an environmental assessment method. According to Cole (1998), the notion of 'environmental labelling' is often used in conjunction with environmental assessment as a logical outcome. Hence, the labelling or the grades in HK-BEAM is as shown in Table 2.17:

Table 2.17: Rating classification for HK-BEAM

GRADES	CREDITS FOR OVERALL GRADES
Excellent	75% and above
Very Good	65% to 74%
Good	55% to 64%
Fair	40% to 54%

2.3.5.11 Comprehensive Environmental Performance Assessment Scheme (CEPAS)

The Comprehensive Environmental Performance Assessment Scheme (CEPAS) is the first building performance assessment scheme developed in Hong Kong. It was initiated in 2006 by the government under the 2001 Government Policy Objectives (Building Department HKSAR Government, 2006). According to Ho et al. (2008), CEPAS seeks to measure and label a green building, with a labelling performance scheme over the whole life cycle of the building, from the planning stage, through design, construction, commissioning, operation, maintenance, management stages and finally to deconstruction. The ultimate goal of implementing CEPAS is to create a positive shift in the current environmental performance of buildings in Hong Kong, as well as to keep in line with the global trend of building sustainability (Building Department HKSAR Government, 2006).

This performance evaluation scheme endeavours to address both physical and human-related issues, amongst the core aspects of sustainability (Ho et al., 2008). CEPAS also considers other social-economic factors, including impacts on surroundings, joint interactions, building economics, transportation, and heritage conservation, while placing much emphasis on traditional environmental performances, such as energy, indoor air quality and the maintenance of building services installations.

There are eight (8) performance categories in CEPAS, and several building factors need to be assessed under each category (shown in Table 2.18). Each category is allocated a specific weighting, which directly influences the cumulative performance scores. Some of the categories are relevant to the building itself, while others are related to the user context or neighbourhood. The structure of CEPAS consisting of the building factors, parameters, and the building factors are tabulated in Table 2.18, below:

Table 2.18: The categories and building factors in CEPAS

PERFORMANCE CATEGORIES	WEIGHT (%)	BUILDING FACTOR
Indoor Environmental Quality	0.960	Health and hygiene Indoor air quality Noise and acoustic environment Lighting environment
Building Amenities	0.875	Safety Manageability Controllability Maintainability Living quality
Resources Use	1.00	Energy conservation Energy efficiency Use of renewable energy Water conservation Timber use Material use
Loading	0.850	Pollution Waste management
Site Amenities	0.810	Inclusion Landscape Cultural character Security
Neighbourhood Amenities	0.820	Provisions for community Transportation
Site Impacts	0.810	Site environment
Neighbourhood Impacts	0.850	Environmental interactions

(Source: Building Department HKSAR Government, 2006; Yau, 2006)

According to the guidelines issued by the Building Department, HKSAR Government, (2006), a CEPAS performance label will be issued by the CEPAS administrator after a completed building environmental performance assessment process for the relevant stage. The scores shall be achieved in accordance to the stages of building development; depending on whether the assessment is performed during the design stage, construction stage, or operation stage. Table 2.19 shows the performance grading and the minimum scores required to achieve each label in CEPAS:

Table 2.19: Performance Grades, Interpretation and Minimum Scores for CEPAS

GRADE	INTERPRETATION OF GRADES	MINIMUM SCORE REQUIRED TO ACHIEVE EACH GRADE (based on 100 full marks)			
		Design Stage	Construction Stage (Construction Works)	Construction Stage (Demolition Works)	Operation Stage
Bronze	• Equivalent to above average building environmental performance standard of existing buildings • Compliance of current environmental-concerned standards	28	29	29	29
Silver	Equivalent to good building environmental performance standard according to current building standards and local conditions	45	50	50	48
Gold	Equivalent to very high building environmental performance standard according to current building standards and local conditions	57	62	67	64
Platinum	• Establishes a new standard to create a positive paradigm shift to the building industry in the forthcoming years • For building with outstanding performance • Encourages research works on innovation • Buildings adopted many genuine innovative and additional building environmental performance	77	79	78	85

(Source: Building Department HKSAR Government, 2006)

Similar to HK-BEAM, CEPAS was formulated to promote green schemes and focus on current environmental performance. Hence, it can be considered to be an environmental assessment method even though it is termed as a building performance scheme.

2.3.5.12 Green Building Index (GBI) for Non-Residential Existing Building (NREB)

In terms of local context, Malaysia introduced the Green Building Index (GBI) in 2011. It is an environmental rating system for buildings developed by the Greenbuildingindex Sdn Bhd (GSB), Malaysian Institute of Architects (PAM) and the Association of Consulting Engineers Malaysia (ACEM). GBI is the first comprehensive rating system for evaluating the performance and the environmental design of Malaysian buildings. There are several categories of certification GBI in accordance with the type and function of the building assessed. Therefore, the GBI Assessment Criteria for Non-Residential Existing Building (NREB) is reviewed in this section as the most appropriate for a higher educational building. Buildings that are included under the GBI NREB are factories, offices, hospitals, universities, colleges, hotels and shopping complexes. GSB (2011) has outlined the following objectives for introducing GBI NREB:

- To define a green building by establishing a common language and standard of measurement
- To promote integrated, whole-building design
- To recognise and reward environmental leadership
- To transform the built environment to reduce the environmental impact of development; and

- To ensure new buildings remain relevant in the future and existing buildings are refurbished and thereafter sustained properly to remain relevant.

According to the guidelines issued by GSB (2011), GBI has six (6) main criteria that consist of: i) Energy Efficiency; ii) Indoor Environment Quality; iii) Sustainable Site Planning & Management; iv) Materials & Resources; v) Water Efficiency; and vi) Innovation. It is adapted from existing rating tools (Singapore Green Mark and the Australian Green Star system) and modified to suit the Malaysian context in terms of tropical weather, environmental context, cultural and social needs. Table 2.20 shows the score or relative weight for each criteria of GBI:

Table 2.20: GBI Rating Score

PART	ITEM	SCORE
1	Energy Efficiency	38
2	Indoor Environment Quality	21
3	Sustainable Site Planning & Management	10
4	Materials & Resources	9
5	Water Efficiency	12
6	Innovation	10
TOTAL SCORE		**100**

(source: GSB, 2011)

From Table 2.20 it can be seen that the criteria *energy efficiency* is allocated more points than any other criteria. Achieving points in these targeted areas will mean that the building is likely to be more environmentally friendly than buildings that do not address the issues. Under the GBI assessment framework, points will also be awarded for achieving and incorporating environmental friendly features which exceed the current industry practice in Malaysia. Once the assessment is completed, the total score is summed and the building is classified in accordance to the GBI classification, as shown in Table 2.21.

Table 2.21: The GBI Classification

POINTS	RATING/ CLASSIFICATION
≥ 86 points	Platinum
76 to ≤ 85 points	Gold
66 to ≤ 75 points	Silver
50 to ≤ 65 points	Certified

(source: GSB, 2011)

Hence, higher scores will greatly impact the classification of the "greenness" of the building for the assessed building. This scheme is therefore more focused on the environmental aspects of a building, even though the criteria are meant to be relevant to the performance of buildings, as a whole. To initiate the process to determine whether the building is categorised or awarded as "green", the building developer needs to make a formal application for the rating procedure. Hence, achieving GBI certification is not a mandatory process for all NREBs.

2.3.5.13 Building Assessment Rating System (BARIS)

In Malaysia, the division of the Government Asset Management Committee (JPAK) and Integrated Asset Planning Branch (CPAB), under the Public Works Department (PWD) has initiated a standard procedure for maintenance and assessment of building defects and conditions, known as Building Condition Assessment (BCA). The BCA was introduced after a JPAK meeting held in February 2009 decided that the Malaysian Administrative Modernisation and Management Planning Unit (MAMPU) should develop a system for all government immovable assets (Yusof, 2013). Under the BCA, a Building Assessment Rating System or BARIS was introduced as a scheme or a tool to assess the condition and defect occurrences of all existing government buildings.

BARIS is suggested as a method to facilitate the process of action after a building has been inspected for failure or defect occurrence.

Information and guidance on the methodology of assessment for all existing government immovable assets is documented in the *Guideline on the Assessment for Existing Building* (ref: JKR 21602-0004-13) (Public Works Department, 2013). The guideline was issued to ensure more consistency in the execution of building assessment and the preparation of reports after the assessment process. The guideline is to be referred to by JKR building inspectors, according to the General Instruction Chapter E Clause 27 that states JKR is responsible for inspecting the condition of government buildings annually. The objectives of BARIS under the BCA are as follows:

- To enable the building inspectors or evaluators to collect data within the shortest possible time by avoiding descriptive assessment and documentation.
- To record the existing defects of the building by assessing the condition and assigning the priority of each defect recorded.

According to the guideline JKR 21602-0004-13 (Public Works Department, 2013), the procedures of BCA requires the building inspector to inspect the conditions of a building based on the schedule and ratings attached in the guideline. The aspects that need to be assessed are listed in Table 2.22 and are as follows:

Table 2.22: Aspects of Assessment for Defects

SCHEDULE NO.	ASPECT OF ASSESSMENT	ITEMS (GENERAL)
1	Examine the type of defects/damages of building	Cracks, Damp, Broken, Peeling, Condensation, Removable, Disconnect, Does Not Fulfil Specifications, Missing, Fungi, Mosses, Insect Attack, Surrogate, Bend, Sagging, Loose, Rocking, Leakage, Moisture content, Degrading, Faded, Torn, Broken, Clogged, Rusty, Leaning, Perforated, Collapse, Decay, Stale, Distorted, Dirty, Cracked, Swelling, Fibrous, Rust
2	Examine defects/damage of mechanical and electrical items	Clogged, Leaning, Skews, Cracked, Broken, Missing, Bent, Broken, Damaged, Not functioning, Collapsed, Broken, Sagging, Peeling, Bent, Loose, Burning Effects, Smelling, Condensation, Removable, Unplugged, Leakage, Shaken, Torn, Expired, Rusted
3	List of factors contributing towards defects/damage	Design, Construction, Building materials, Environment, Human use, insects, natural disasters

(Integrated Asset Planning Branch (CPAB), 2015; Public Works Department, 2013)

After the building element is assessed according to the above list of defects, the building inspector shall rate each of the assessed elements based on two variables: i) the level of building condition assessment, and ii) priority of maintenance action. Under these variables, there is a numerical score (*score 1 to 5*) that is accompanied by a scale value and description incorporated as the building rating scale. This helps the evaluators to rate the building's defects and determine the exact condition implied by the scale values. The scale values and their descriptions depend on the maintenance standard of the building being evaluated, as shown in Table 2.23 and Table 2.24.

Table 2.23: Level of Building Condition Assessment

GRADE	SCALE	REF.	DESCRIPTION
1	Very Good	SB	• No Defects • Excellent performance condition • Functioning well
2	Good	B	• Minor defect or damage • Good performance condition • Functioning good
3	Medium	S	• Major defect or damage • Medium performance condition • Still functions but needs monitoring
4	Critical	K	• Major / minor defect or damage • Critical condition • Not functioning in accordance to the accepted level of services
5	Very Critical	SK	• Very critical condition; • Not functioning • At risk which could cause death and/or injury

(Integrated Asset Planning Branch (CPAB), 2015; Public Works Department, 2013)

Table 2.24: Priority of Maintenance Action

PRIORITY ASSESSMENT	SCALE VALUE	REF.	DESCRIPTION
Normal	1	N	• No sign of defect or damage • Components/elements are well maintained, no repair requirements
Routine	2	R	• Damage/defect minor • Needs monitoring, repair and replacement in order to avoid defects/damage becoming more serious
Repair	3	PB	• Damage/defect major • Needs significant repairs, (needs to be repaired/replaced)
Refurbish	4	PM	• Damage/defects are serious • Need urgent repairing works (need to be urgently and immediately repaired)
Replace	5	PG	• Very serious damage/defects • Necessary to redefine replacement/repair (should be carried out urgently and immediately) • Requires a detailed examination from experts

(Integrated Asset Planning Branch (CPAB), 2015; Public Works Department, 2013)

After each failure or defect is assigned a numerical scale of its condition and priority rating, both numerical assessments are multiplied to determine the total score for each defect. The scores range from *1* to *25* and are indicated by a coding colour (*green, blue, grey, yellow or red*). The colours determine the level of seriousness of the defects, as shown in Table 2.25 and Table 2.26.

Table 2.25: Matrix of Scale of BARIS

SCALE		**PRIORITY ACTION**				
		5	**4**	**3**	**2**	**1**
CONDITION ASSESSMENT	**5**	25	20	15	10	5
	4	20	16	12	8	4
	3	15	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

Table 2.26: Classification of Building Rating

COLOUR CODE	**ACTION**	**MATRIX OF ACTION**	**SCORE**
	Very Good	Scheduled Maintenance	1 to 5
	Good	Condition Based Maintenance	6 to 10
	Medium	Repairing	11 to 15
	Critical	Refurbishment	16 to 20
	Very Critical	Replacement	21 to 25

Therefore, the ratings in the BARIS scheme are based on the result of assessment of the buildings by Public Works Department (PWD) assessors or officers. The extent to which rating results can be accepted with confidence depends on the frequency of maintenance. Hence, appropriate measures should be taken to ensure that the rating made can be used for more comprehensive decision-making, especially during maintenance work at the planning stage.

Based on the above diagnostic review of BPE tools, it is found that the primary concepts of the tools are similar in several aspects. Discrepancies between the tools is generally allied to the approach taken towards the evaluation and the building users: whether the assessment is regarded as a matter of serious concern or it is likely to be ignored. Table 2.27 provides a detailed summary of the performance indicators, with several items and sub-items that relate to established assessment tools.

Table 2.27: Classification of Performance Indicators in Established Building Performance Evaluation (BPE) Tools

BUILDING PERFORMANCE TOOL	BUILDING/ PROJECT TYPES	PARAMETERS/ ELEMENTS/ INDICATORS
BREEAM (UK)	Commercial office (new and existing), Residential (EcoHomes), Retail superstores, supermarkets, Industrial units	Management - policy, procedures Energy - operational use, CO2 Health and well being - indoor and external issues Pollution - air, water Transport - CO2, location factors Land use - green fields, brown fields Ecological value of site Materials Water consumption and efficiency
BQA (NEW ZEALAND & AUSTRALIA)	All types of buildings	Presentation - Appearance of the building and impression created, Space functionality - Factors that determine operation of spaces, Access and circulation - Access of people and goods, security Amenities - Facilities or spaces for people Business services - Electrical services and IT Working environment - Environmental conditions Health and safety - Mandatory and other health and safety issues Structural - Building structure and condition Building management – Short and long term
TBP (USA – extensively used in Singapore)	All types of buildings	Spatial performance Acoustic performance Thermal performance Indoor air quality Visual performance Building integrity.

Table 2.27 continued

PROBE (UK)	All types of buildings	Environmental comfort, technical and energy performance issues: • Operational – space needs, furniture, cleaning, meeting room availability, storage arrangements, facilities, and image; • Environmental – temperature and air quality in different climatic seasons, lighting, noise, and comfort overall; • Personal Control – of heating, cooling, ventilation, lighting, and noise; • Satisfaction – design, needs, productivity, and health
LEED (USA)	• New commercial construction and major renovation projects, • Existing building operations and maintenance, • Commercial interiors projects, • Residential, • Educational buildings • Healthcare buildings.	• Site • Energy • Water • Materials • Indoor environmental quality

CASBEE
(JAPAN)
	• Pre-design
	• New Construction,
	• Existing Building,
	• Renovation
	Specific Purposes:
	• For Detached Houses
	• Temporary Construction
	• Brief versions
	• Local government versions
	• Heat Island effect
	• Cities
		• Q (Quality): Built Environment Quality
		  • Indoor environment (including acoustics, lighting, thermal comfort, and air quality),
		  • Service quality (includes adaptability, flexibility, and durability),
		  • Outdoor environment
		• L (Load): Built Environment Load
		  • Energy
		  • Materials
		  • Off-site environment

GSNZ (NEW ZEALA D)	• Commercial buildings • Office buildings • Industrial buildings • Education buildings	• Management • Indoor environment quality • Energy • Transport • Water • Materials • Land use and ecology • Land emissions • Innovation

Table 2.27 continued

BHHI & BSCI (HONG KONG)	• High-rise apartments • Apartment buildings	Design: • Architecture • Building services • External environment Management: • Operations & maintenance • Management approaches
HK-BEAM (HONG KONG)	All types of buildings	• Site Aspects • Material Aspects • Energy Use • Water Use • Indoor Environmental Quality
CEPAS (HONG KONG)	• Residential buildings • Non-residential buildings (offices, commercial, institutional buildings, mixed-used buildings, etc)	• Indoor Environmental Quality • Building Amenities • Resources Use • Loading • Site Amenities • Neighbourhood Amenities • Site Impacts • Neighbourhood Impacts
GBI (MALAYSIA)	• Residential buildings • Non-residential building	• Energy Efficiency • Indoor Environment Quality • Sustainable Site Planning & Management • Materials & Resources • Water Efficiency • Innovation
BARIS (MALAYSIA)	All existing government assets and government buildings	The elements of assessment are not fixed (depends on the building), however the assessment shall covers: • Architecture & civil • Electrical condition • Mechanical assets • External work

As depicted in Table 2.27, the elements in building performance are benchmarked on various aspects and further divided into sub-elements. Bordass and Leaman (2005a) contend that methods like BREEAM in the UK and LEED in USA are often started very much as design assessments, but are evolving to take more account of what is actually built and how it is used and managed.

In general, it can be seen that all of the above performance tools comprehensively cover most issues related to sustainable buildings and green issues. However, a compilation that summarises possible indicators for these performance rating tools conducted by Malmqvist (2008) has revealed that identification of risk construction and installations were lacking in several of the BPE tools. The listed performance elements are not thoroughly enhanced on risk as the prevalence factors that could lead failure to all of the above characteristics. For instance, BREEAM is found to be more concerned with sustainability issues, but the apparent weakness of this tool is it that it does not address the social aspects in regard to the building users. As Dewlaney and Hallowell (2012) revealed, recent studies have found that LEED buildings have a higher injury rate than traditional non-LEED buildings, and that 12 of the LEED credits increase risks for construction workers.

According to Lützkendorf and Lorenz (2006), the application of many existing assessment tools does not provide the building stakeholders with appropriate information on the impacts of their decisions on building users' health and well-being. It has been debated that there is possibility of risk that could jeopardize the users caused by the failure of building performance aspects. As an example, McDougall et al. (2002) pointed that the BQA is silent on the intrinsic quality of the items that are being assessed and, therefore, the results could be quite misleading. Baird (2009) also argues that the current set of building rating tools such as LEED, CASBEE, BREEAM , GBCA, tend to focus more on technical aspects such as green building aspects, energy consumption, water use or materials. The argument is raised due to actual performance in operation that can severely compromise the specification, and technical performance that may fail to take into account the users' need.

Even though safety is typically related to risk and it is addressed in BARIS, BQA and PROBE, in general there is an absence of indicators to establish the risk basis for occupants and how risk relates to all other performance indicators. It has also been found that health aspects for the users are not rated accordingly in the performance scale of BARIS. As mentioned by Woods (2008), under this more comprehensive definition of measurable building performance, an owner needs to assess what indicators of the building affect the primary business function. Hence, it is crucial to identify possible indicators for this study instead of using the listed criteria from the existing rating systems. Unfortunately, many stakeholders could not identify risk as the main susceptibility that could trigger the failure of a building's function. As a consequence, it may affect the whole performance of building if it is not addressed in the early stage of building development.

2.3.6 Performance Elements in Assessing Building Performance

According to Poveda and Lipsett (2011), variables related to performance improvement are identified and data are collected and analyzed with technically appropriate methods. Hence, assessment of a building's performance is a practical undertaking in evaluation and decision making, with expected participation by stakeholders. The performance is measureable by placing a comparison against a standard for a criterion (or for a number of criteria) during the performance assessment process.

Generally, performance dimensions may have one or more indicators, and could be influenced by various performance indicators and characteristics of the building. Inevitably, there are many terms reflected as the "performance element", apart from “performance indicators” (Ho et al., 2008; Pati et al., 2009). Several commentators have used the term “performance criteria” (Amaratunga & Baldry, 1998; Douglas, 1996; Preiser et al., 1988; Sinopoli, 2009) as well as the term “performance mandates” (Gill et al., 2010; Hatrkorf, 1996). Pati et al., (2006) explained that expressions of building performance are required based on the idea of impartially quantifiable performance measures, or “performance indicators”. Some studies have regarded building performance in terms of the relationship between embodied energy and operational energy (Scheuer et al., 2003).

However, in meeting the current changing needs in a building, performance is not restricted only to energy. Augenbroe and Park (2005) state that the criteria for building performance deal with the following:

i. Architectural/ engineering procurement

This deals with the way services are procured by the design team to engineer building systems that meet functional needs and client expectations.

ii. Tenant/ facility manager

Generally, this deals with the proper maintenance and management of the facility in a way that expectations of the occupant, owner or portfolio manager are met, and maximum value from the facility is provided and maintained for all stakeholders.

Therefore, the actual objective of evaluating building performance must be predetermined and this can be identified by classifying the suitable performance criteria of a building. According to Sinopoli (2009) the performance criteria of a building should exemplify how well it succeeds in enabling its occupants. The metrics and methodology of evaluating the satisfaction and productivity of building occupants has been developed; at its core it is a survey of people that use the building. Figure 2.8 depicts a framework of performance aspects that are able to be addressed as a holistic approach in BPE. Lützkendorf and Lorenz (2006) proposed the framework as an integrated assessment tool that has the potential to capture all dimensions of sustainable development throughout the whole building's life cycle. This enhanced the aspects of building performance to be extended into a superior approach in performance management.

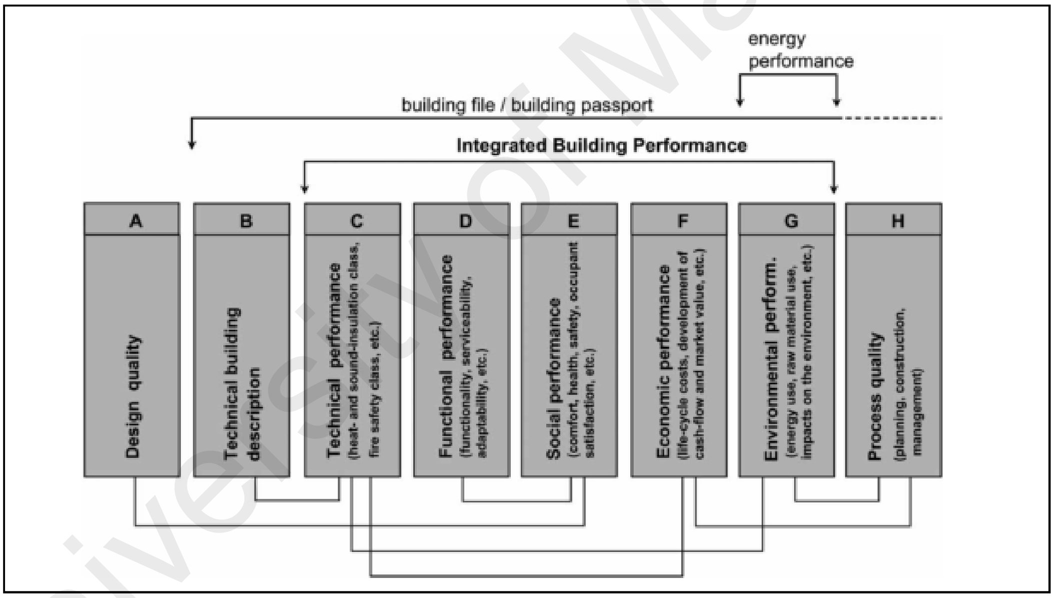


Figure 2.8: Performance Aspects in Integrated Building Performance
Source: Lützkendorf & Lorenz (2006)

It is not easy to measure comprehensive building elements in the evaluation of building performance. Douglas (1996) stipulates that when understanding of total building performance increases, the list of mandates employed can be refined. To ensure success in outlining the criteria of building performance, more details should be narrowed down by highlighting major issues affecting occupants in the building; for example, safety issues, comfort issues, or ergonomic usage. Lützkendorf and Lorenz

(2006) listed several issues that require detailed consideration, which includes the assessment object, the purpose of the assessment, the extent of the assessment, and the duties of the assessors. It is recommended that a clear distinction be made between the following:

i. Attributes of the building performance (e.g. the appropriateness of available space and rooms, thermal and acoustic comfort, the manifestation of building-related illness, cultural value)
ii. Quality of design, operating and management processes (e.g. stakeholder participation during the planning stage, the quality and appropriateness of the available services)
iii. Building's location (e.g. the characteristics and conditions of inclusive environments, access and/ or distance to other facilities)

Based on the recommendation above, prototyping the building indicators may require a long list for evaluators. For that reason, the listed indicators may be categorised under broader issues. Thus, a comprehensive issue is able to be assessed indirectly at the same time, even though it is sub-headed under one or two headings. This situation has been found through the analysis carried out in the review of the established BPE tools.

According to Chen et al. (2006), one problem of current building rating methods is that they pay less attention to functional variation in different types of buildings, which influence not only the emotional as well as the physical well-being of human beings, but also the design and the management of buildings. In other words, each assessment procedure conducted under each rating method actually uses a generic platform of indicators applied to all kinds of buildings. Therefore, it does not differentiate one building from another, regarding their various features. As a consequence, assessment results of different kinds of buildings actually lack the power of comparability.

The term building performance also emphasizes the function of a building; it is understandable that if the building fails in function, that failure will also influence performance too. If an important function of the building is for it to be occupied by employees, workers or visitors, the owner should consider how to minimize the residual risks and maximize the resiliency of such a building (Woods, 2008). Building performance generally deals with the physical aspects of the building, and risk has been addressed as the social factor that results from performance failure.

Therefore, as argued by Woods (2008), both the physical and social factors of a building must be addressed to properly fulfil the requirements in assessing a building's function. Preiser et al., (1988) pointed out that the indicators of building performance are those aspects of facilities that are measured, evaluated and used to improve buildings. For the purposes of the present research, performance elements are categorised into three types: functional performance, technical performance and indoor environmental performance, as recommended by Lützkendorf and Lorenz (2006). A detailed justification on these performance elements is given as follows:

2.3.6.1 Functional Performance

According to Pitt and Tucker (2008), functional performance concerns the relationship of the building with its occupiers and embraces issues such as space, layout, ergonomics, image, ambience, communication, health and safety, and flexibility. In general, functional aspects are often related to the physical aspects of a building.

Hashim et al, (2012) described that functional performance includes areas of space design, security and safety, comfort, strategic value and operational cost. This supports the view that functional aspects do not only affect the physical aspects of the building, but also affects the building financial aspects and capability.

Preiser (1995) states that the functional elements of the building directly support the activities within it; therefore the aspects must be responsive to the specific needs of the organisations and occupants. The activities should be supported by the performance of various functional building indicators such as access, parking, spatial capacity, utilities, communications, change/growth/ circulation and equipment (Amaratunga & Baldry, 1998; Lützkendorf & Lorenz, 2006). It can be concluded that functional elements are the building's physical aspects, provided for its intended use, that directly support the function of building and activities within the building. Without functional aspects, the building may not be fulfilling its main function. As Amaratunga and Baldry (1999) stress, the functional elements deal with the fit between the building and its activities, and how well they directly support the activities within it.

2.3.6.2 Technical Performance

It is important to measure the technical performance in a building Because, as Augenbroe and Park (2005) pointed out, buildings undergo drastic changes over time so there is an obvious need for continuous monitoring of their technical performance over their lifespan. Technical elements in a building performance are generally consist of the building's structural (Preiser, 1995), electrical and mechanical services (Lützkendorf & Lorenz, 2006; Preiser, 1995), including heat and fire. Ali et al., (2010) summarised that items in the building services include ventilation, lighting and power supply, water supply, sanitation, transportation, communication and other systems.

Preiser et al., (1988) commented that technical elements can be categorised as the background environment, a kind of “stage off” for activities. Technical aspects in a building complete the functionality aspect; therefore, a building may succeed in achieving a high level of functionality if it is able to meet prescribed technical standards. Alternatively, the building may conform to the highest technical standards but have been so inadequately conceived that it fails to deliver the functional satisfaction which stimulated the original need (Amaratunga & Baldry, 1998). Ideally, the technical performance elements are provided to allow the effective operation of buildings. According to John et al., (2005), building services systems are generally installed in buildings to provide a healthy and safe living environment for the occupants or residents.

2.3.6.3 Indoor Environmental Performance

Many tools have been developed to assess indoor environmental issues, including BREEAM, LEED and CASBEE. Theoretically, elements of the indoor environment in building performance have a more instant and direct impact on building users, compared to items in the external environment. They are often related to safeguards for the health of the building and also the building’s users. Energy efficiency, raw materials, thermal comfort (consisting of heating, ventilating, air conditioning - HVAC), visual comfort, acoustic comfort and indoor air quality (IAQ) are among the parameters highlighted in indoor environmental performance assessments (Fabi et al, 2012; Heerwagen, 2000; Khalil & Husin, 2009; Lützkendorf & Lorenz, 2006; Malmqvist, 2008; Woods, 2008).

Generally, aspects of the indoor environment are closely related to the building's functional aspects such as space, design, and orientation. They are also related to the provision of physical and technical aspects in a building such as openings (doors and windows), building materials, and finishes. Pollutant emissions from human activities, building materials, and air handling units in the form of both living and dead material take place continuously in any type of buildings (Khalil & Husin, 2009). Therefore, the possible synergy effects of criteria in the performance elements may affect to one another. Hence, it can be summarised that aspects in a building's indoor environmental performance help to control its functional and technical operation.

A summary of description for each of the performance elements mentioned above is shown in Table 2.28. The description provides a better understanding of the performance elements incorporated in this study. It also helps to identify the indicators or further criteria that should be constructed as an initial conceptual framework for a building performance-risk tool.

Table 2.28: Descriptions for Functional, Technical and Indoor Environmental Elements

PERFORMANCE ELEMENTS	DESCRIPTION
Functional Performance	Performance elements that directly support the function of the building and activities within the building; much related to the building's physical attributes
Technical Performance	Performance elements that allow the operation of buildings; normally deal with building services
Indoor Environmental Performance	Performance elements that are able to control building's physical and operational conditions; such as air movement, visual, ventilation, acoustic, etc

The above performance elements are appropriate for assessing both technical and social aspects of buildings in meeting demands for comfort and safety from building users. Inevitably, if the building's performance is assured during normal conditions, its preparedness for safe and secure performance during and after extraordinary conditions is likely to be enhanced, and the residual risk is likely to be diminished. Hence, the next section discusses the significance of risk in a building's performance; it begins with an explanation of the basic principle of risk mitigation.

2.4 Risk Mitigation in Building Performance Evaluation

Typically, buildings must provide physical protection for their occupants and assets. This includes protection from crime, vandalism, terrorism, fire, accidents and environmental elements. According to Sinopoli (2009), security threat measures and assessment of buildings are deployed to deter, detect, delay, mitigate, or notify any attempt to injure, damage, modify or remove an asset or person. This provides a structured mechanism to provide insights into threats to success in building function, as compared to the concept of risk management which merely depicts proactive action. Security and life safety are affected by many different factors such as location and age of the building, composition of the building's occupants, climate, economic conditions and education levels (Sinopoli, 2009). Therefore, before incidents occur, risk must be mitigated in a proper approach as exemplified through a building performance assessment.

Building performance assessment is carried out in the context of the facilities management phase. Therefore Wong et al., (2011) stressed that its implementation is able to mitigate the potential loss of building data over the life cycle of the building.

The ability of an emergency response team to attain information from such an assessment could substantially reduce risk to the responders, building occupants and the general public (Wong et al., 2011). This exemplifies the ability of a building performance assessment to reveal risk prevalence to be beneficial to its users at large.

Almeida et al., (2010) noted that, as with many other concepts in this field, the concept of risk has been used with a variety of meanings. Other related terms for risk, such as uncertainty, probability, event, source, factors, or consequence, may have different considerations and interpretations. Awareness of a wide range of risks makes it possible focus on controlling the most severe risks first, by considering the potential impact of each risk item. Appropriate approaches are needed to identify risks, to allow shared risks in a building, and to assign responsibility for risk mitigation to the most appropriate individuals. As stated by Meacham (2010), the use of risk makes it possible to establish "tolerable" performance that is associated with what society finds tolerable with respect to various performance factors, and requirements for the improvement of design and construction of buildings. Ideally, the initial understanding of risk must be focused on the definition and description of the term first, followed by the principles upon which the risk exposure in building performance is assessed.

2.4.1 Definition of "Risk"

The interpretation of the term "risk" depends on how the "risk" is categorised (Almeida et al., 2010), whether in organizational contexts, management, business operations or social aspects. Nevhage and Lindahl (2008) suggested that perception in risk is the way stakeholders view a risk based on a set of values or concerns. Hence, for in the context of the present research, risk is defined in the perspective of building management and the organizational perspective. According to Almeida et al. (2010), risk can be defined as "the effect of uncertainty (deviation from the expected either positive or negative)". It is much related to this study where risk is described as the perceived likelihood that the building users will receive negative impact due to poor building performance.

According to the Australian and New Zealand Standard (1999), risk is defined as the chance of something happening that will have an impact upon objectives, and it can be measured in terms of consequences and likelihood. Risk characterizes situations where the actual outcome for a particular event or activity is likely to deviate from the forecast value. As cited by Wolski et al. (2000), the Uniform Building Code (1994) categorised risk in terms of human factors, or risk factors such as `control' or 'volition' or 'severity'. Hence, risk can be perceived by describing risk factors and it can be associated with ordinary or small consequences. To develop a better understanding on the definition of risk, Table 2.29 summarises various definitions or descriptions of the term:

Table 2.29: Definition of Risk

AUTHOR (YEAR)	DEFINITION / DESCRIPTION
Abaza (2012)	The chance of an adverse event depending on the circumstances
Ahmed et al., (2007); Davidsson (2010)	Something that can be quantified by using probabilities
Cervone (2006)	A problem that has not yet happened
Hillson & Murray-Webster, 2004)	Uncertainty of such future events that might influence the achievement of one or more objectives such as the organisation's strategic, operational and financial objectives
Massingham (2010)	An unwanted event with negative consequences
Powers (2009)	A measure of the potential deviation of an outcome from its anticipated state,
Richardson (2010)	The potential for loss or gain
Sinnha et al., 2004)	A function of the level of uncertainty and the impact of an event
Susilawati (2009)	The uncertainty of outcome, which may have a positive opportunity or a negative effect on project objectives
Tchankova (2002)	Condition or circumstance that increases the chance of losses or gains and their severity

Although many different definitions of risk are being used in the field, nevertheless the main, underlying idea is similar; likelihood of occurrence. Despite commonly agreed definitions of the concept of risk, it is necessary to imply risk mitigation activities to direct and control an organization, with regard to risk. For a better understanding, mitigating of risk is described as an act of limiting the unwanted event through a systematic process of identifying, analysing and transferring the risk.

2.4.2 Theoretical Basis of Risk Management

Risk is something that is less than 100% certain; if it is 100% likely to occur, it becomes a certainty and a fact (Mulcahy, 2003). All risk can be managed through experience and knowledge; however, an appropriate and systematic approach is needed to ensure that all the risks that arise can be controlled and, probably, eliminated. Minimizing risk can be a design objective to facilitate the decision making process (Lee & Hensen, 2015). Every decision maker must take into account every risk that they may encounter to ensure that their operation is efficient and can be completed on schedule. When there is possibility of risk in a particular event, the basic process to handle the inherent risk is by applying a risk management approach.

The risk attitudes differ from personal characteristics in that they are situational responses rather than natural preferences or traits, and chosen attitudes may therefore differ depending on a range of different influences. Hence, it is important firstly to understand risk attitudes and the impact they can have on the risk management process if their presence and influence are not recognised or managed. According to Hillson & Murray-Webster (2004), it is inherent in the nature of risk management for it to be exposed to sources of explicit and implicit bias. Since all elements of the risk process are performed by individuals and groups of people whose risk attitudes affect every aspect of risk management (Hillson & Murray-Webster, 2004).

Risk Management (RM) principally deals with pure risk, involving steps to manage those risks and involves peering over the horizon at possible 'traps' (Davidsson, 2010; Pelzer, 2009; Richardson, 2010). Thus, RM allows a relevant stakeholder to take action to minimize the likelihood or impact of these potential problems. The definition of RM has expanded in various deviations, with authors endow various definition of RM in different terms. Table 2.30 listed several definitions of RM, which extracted from various sources:

Table 2.30: Definitions of Risk Management (RM)

Source(s)	Definition/description of RM
Ahmed et al., 2007)	The identification, measurement and control of hazards so that all controllable events have an action plan or a risk mitigation plan
Australian & New Zealand Standard, 1999)	The systematic application of management policies, procedures and practises to reduce either likelihood of an occurrence or its consequences, or both
Flanagan & Norman, 1993)	A system which aims to identify and quantify all risks to which the business or project is exposed so that a conscious decision can be taken on how to manage the risks
Massingham, 2010)	Determining risk, predicting the probability and the consequence and outcomes of that risk; deciding to avoid or take the risk; developing and implementing strategies to respond to the risk
Mulcahy (2003)	A systematic and proactive approach to taking control of projects and decreasing uncertainties, involving minimizing consequences of adverse events as well as maximizing the results of positive events

By referring to the above definitions, in general, RM is the application of appropriate tools and procedures to contain risk within acceptable limits. It is a general management function that seeks to identify, assess, and address the causes and effects of uncertainty and risk on an organization. RM entails the prediction of the future behaviour of systems, allowing humans to reduce the chance of unwanted events (de Wilde & Tian, 2012).

The purpose of RM enables the relevant organization to reduce different risks related to a pre-selected domain to a level tolerated by society and which enables an organization to progress toward its goals and objectives (its mission) in the most direct, efficient, and effective path (Cervone, 2006; Mills, 2001; Richardson, 2010). RM stands as a pro-active action that leads to reducing risk and accomplishing its goals and objectives efficiently and effectively. Ideally, it is vital to understand the hierarchy and components arrayed along this approach. Almeida et al. (2010) postulated the hierarchy RM approach as illustrated in Table 2.31:

Table 2.31: Components of risk management in ISO/FDIS 31000

HIERARCHY	DESCRIPTOR (ELEMENTS)
Principles	Principles for managing risk
Framework for managing risk	• Mandate and commitment • Design of framework for managing risk • Implementing risk management • Monitoring and review of the framework • Continual improvement of the framework
Process for managing risk	• Communication and consultation • Establishing the context • Risk assessment (risk identification, risk analysis, risk evaluation) • Risk treatment • Monitoring and review • Recording the risk management process

(Almeida et al., 2010)

It is clear that a formal RM process provides a number of benefits, because it gives a structured mechanism to provide visibility into threats to success. By considering the potential impact of each risk item, attention can be focused on controlling the most severe risks first (Mulcahy, 2003). Therefore, formal application of RM could greatly improve the likelihood of successful building operation and reduce the potential negative consequences of those risks that can be avoided. The significance of this process is that it can be used to improve building performance by identifying the root of performance failure. Tere are three fundamental steps to implement RM procedures, which are: risk identification, risk analysis, and risk control (Ahmed et al., 2007; Cervone, 2006; Davidsson, 2010; de Wilde & Tian, 2012; Emblemsvåg, 2010; Miller et al, 2012; Mills, 2001; Pelzer, 2009; Powers, 2009; Richardson, 2010; Susilawati, 2009; Tchankova, 2002; Williams et al., 2006). Figure 2.9 depicts the typical flow chart representing the risk management process:

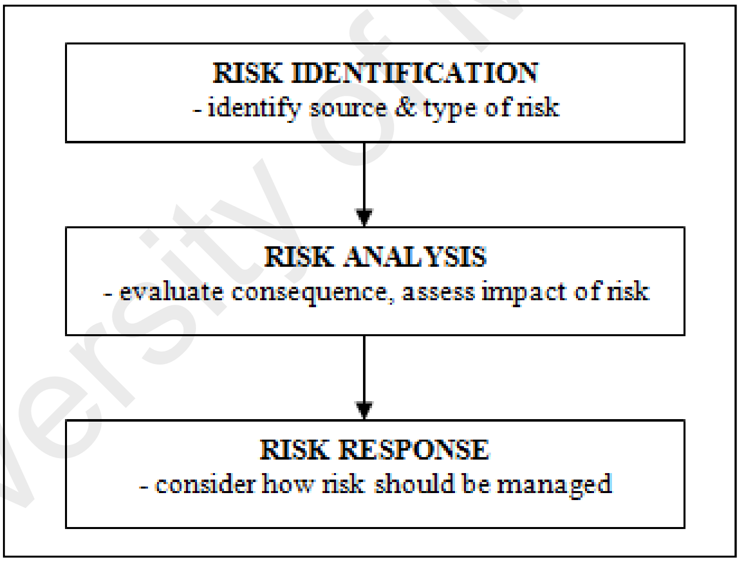


Figure 2.9: Components of Risk Management

Risk management begins with the establishment of context, proceeds to risk identification, and then to risk assessment or analysis, and finally, to risk response and mitigation (Cervone, 2006; de Wilde & Tian, 2012; Mills, 2001; Susilawati, 2009). To reduce the impact of risk in various aspects it is necessary to have contingencies for risk mitigation. Susilawati (2009) revealed that areas of impact can include risks associated with finance, human performance, tenancy management and reputation. Such risks may impact on the organisation, staff, tenants and/or on various stakeholders (Spence, 2004). In the context of the present research, a basic understanding is needed that covers each of the above processes to associate the concept of risk into evaluations of building performance. The following section explores the steps in the process.

2.4.2.1 Risk Identification

According to Bajaj (1997), if risk is not identified, it cannot be controlled transferred and managed. Therefore, identifying relevant knowledge on the prevalence of the risk situation is very important. By identifying which information and data are missing, it is possible to determine early in the process whether to pursue better information and data (Emblemsvåg, 2010). Risk identification is the process of identifying the potential possible risk source or origin of a component and ranking the major processes, or components of a project. It reveals and determines the possible organisational risks as well as conditions, giving rise to risk (Tchankova, 2002; Williams et al., 2006). Ahmed et al. (2007) reported that risk identification involves studying a situation to realize what could go wrong in the product design and development project at any given point of time during the project. Sources of risk and potential consequences need to be identified before they can be acted upon to mitigate them (Ahmed et al., 2007). The identified risk source could then be discussed and recorded according to its priority to decide whether and what actions should be taken.

All possible risks must be systematically identified and classified, treating risks of all types on an equal basis, with causes and effects from the occurrence of risk mapped out (Ahmed et al., 2007; Mills, 2001). This sets the groundwork and benchmarks for better risk decision-making and risk assessment for any objectives, including a building operational mission. As summarised from the existing risk literature (for example, Cervone, 2006; Flanagan & Norman, 1993; Mills, 2001; Williams et al., 2006), the purpose of the risk identification is as follows:

- To create a logic-based model of the operation's activities and possible mishaps/deviations.
- To identify the most significant participants in the RM and to provide the basis for subsequent management. (e.g. who are the core, senior management, the expert/s, the client/s).
- To study the component, the elements of the system or project to find out the possible risk source; to understand the component, goals and risk confronting the project.
- To identify the risk inherent in the component or project.
- To group the items and risks into structural or functional categories.

Hence, the identification process can form a good basis for eliminating barriers to resources that will be affected and also the complexity of managing risk itself (Tchankova, 2002). Those risks will then be able to be categorised and mitigated in accordance to a systematic process. It is possible to determine any internal and external factors that may influence the prevalence of risk, not only at the organizational level, but also in business operations and activities. Tchankova (2002) reported that, by having access to this information about the internal and outside environment of the organization, the relevant building stakeholders will be able to see virtual risks that challenge current problems in building operation.

Tchankova (2002) commented that risk identification is a continuous process; therefore an in-depth investigation on the problem of the risk identification may need a classification that can cover all types of risk. If a risk is related to one or more other risks (that is, if risks have dependencies) good practice dictates that the related risks should be evaluated together as one unit (Cervone, 2006). Therefore, risk identification is the basic stage in mitigating risk occurrence for any potential losses and events, including performance failure for building operations. Ideally, the importance of identification is determined by knowing the risks that face the organisation and thus reveals the cause and effect of the event.

2.4.2.2 Risk Analysis

Risk analysis is the sequel of the risk identification process, and a significant part in the analysis part of the risk management process. When risk identification is complete, risk analysis is subsequently used to identify the likelihood that the risks that have been identified will occur and, if so, when they are most likely to occur in the overall project timeline (Cervone, 2006). Generally, the aim of risk analysis covers the following (from (from Flanagan and Norman, 1993)**:**

- To capture all feasible options and to analyse the various outcomes of any decision
- To explore the consequences of the decision and the chance of the decision being implemented.
- To explore the implications of various possible futures.
- To quantify the possible outcomes of the various limitations

Once it is decided that a risk event needs analysis, it must be determined whether the risk event information can be acquired through quantitative or qualitative means

(Ahmed et al., 2007; Cervone, 2006; Chicken, 1994; Flanagan & Norman, 1993; Thompson & Bank, 2007):

- Qualitative Risk Analysis - a process where all the identified risks are evaluated subjectively on the probability and impact of each risk. This type of analysis requires a real understanding of the risks in order to measure them effectively.
- Quantitative Risk Analysis - focuses on a numerical analysis of the probability and impact of each risk and analysis of the extent of overall project risk. Quantitative risk analysis is an attempt to determine how much risk the project has, and where, so that limited resources of time and effort can be focused on the areas of greater risk, which subsequently decrease the overall risk of the project.

Because qualitative measurements of risk may produce a biased result, quantitative implementations appear to have a better diagnosis of risk mitigation, as the risks are quantified to estimate loss frequency and severity distributions or amount lost when a loss occurs. Most quantitative analyses produce matrix relationships and weighted attributes according to the predominance of the predefined criteria (Ahmed et al., 2007). Cervone (2006) explained that risk factors can then be ranked by severity of risk and, therefore, overall potential impact on the project. Thus, the results of the analysis must be interpreted in order to develop a strategy to deal with the risk and decide what risk to retain or to allocate to other parties. The following flow-chart (Figure 2.10) extracted from the Australian and New Zealand Standard (1999), emphasizes that risks are not only highlighted to be analysed in RM process, but also need to be thoroughly evaluated.

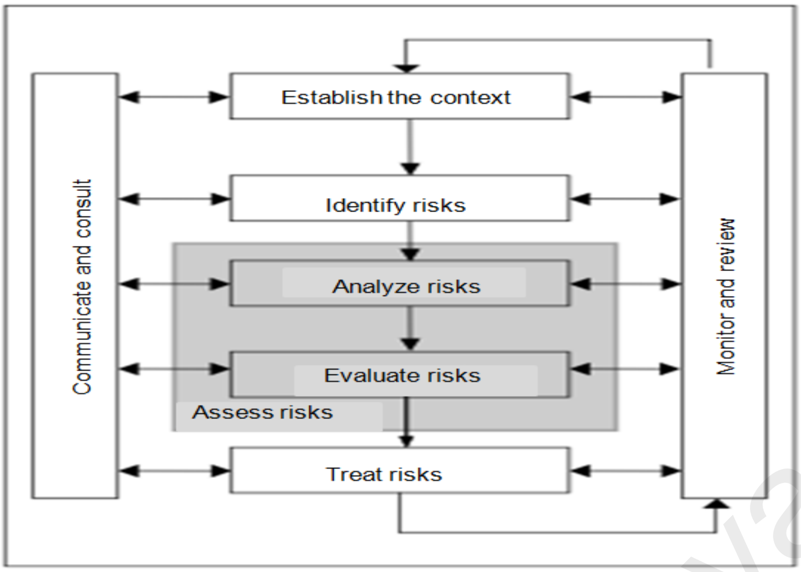


Figure 2.10: Representation of the Risk Management Process (Australian & New Zealand Standard, 1999)

Thus, risk analysis is generally based on likelihood and consequences that depend on the probability of occurrence and the frequency of activity. The next stage is risk evaluation, where each risk is evaluated against an appropriate risk-acceptance criterion to give a ranking on the consequential impact from the risk exposure (Williams et al., 2006). According to Yang et al., (2015), risk analyses are important not only for recognising the causes of risks, but it also leads to to effective decision-making and efficient communication among building stakeholders. Therefore, the process of risk analysis is important because it provides an understanding and awareness of the impact of risk on decision making. It depicts the scale and complexity of risks being faced in building operations and illustrates a representation of the risk exposure of the organisation. Without a thorough analysis, the possibility of random emergence of risk is higher.

2.4.2.3 Risk Response/Control

Risk control or, as it is sometimes termed, risk response, risk resolution, or risk transfer, is the sequel to the risk analysis process. In this stage, the risks are ranked in order of importance and impact of the occurrence. Cervone (2006) proposed that each risk be assigned a risk factor value and that contingency plans be developed only for the tasks that have the highest risk factor. In dealing with risk response, a thorough, holistic understanding of the issue is required. This is where managers and relevant stakeholders mitigate the inherent risk by making the right decision in allocating the risk to the right party, so that risk is best managed. Ranking and prioritizing the risk in risk control is necessary because they facilitate the formulation of an effective plan for dealing with every possible risk, and thus the resolution may need to be more extensive than initially conceived (Cervone, 2006).

The purpose of this risk response stage is to handle risks in a manner that could achieve project goals efficiently and effectively. This stage also allows the management to respond and mitigate the risk by introducing several actions or a response plan which can be implemented by the stakeholder. According to Mills (2001), there are different ways to respond to the risk and some may be used in a combination of techniques to mitigate and control the likelihood of the risk. The following actions to mitigate risk that can be taken in risk response are summarised from the literature (Ahmed et al., 2007; Emblemsvåg, 2010; Flanagan & Norman, 1993; Mills, 2001; Susilawati, 2009; Williams et al., 2006):

- *Remove* - Risk that can be eliminated from the Project and therefore no longer poses a threat

- *Reduce/Risk reduction* - Risk that can be reduced by taking certain actions immediately
- *Avoid/ Risk avoidance* - Risk that can be mitigated by taking contingency action should it occur.
- *Transfer/Risk transfer* - Risk can be passed to other parties such as designers, contractors, sub-contractors and insurers
- *Acceptance/Risk retention or absorption* - The cost of accepting the risk should be balanced against the other actions (removing/reducing/avoiding/transferring). These may be small or repetitive risks.

Emblemsvåg (2010) pointed out that the development of a specific plan to mitigate the risk depends on the chosen risk management strategy. Hence, the suggested plans in risk response need to be implemented in the initial stage as a proactive action towards mitigating risk occurrence. This is supported by Ahmed et al. (2007) who suggest a pro-active approach or a feed forward approach, referring to actions initiated based on chance of a risk event occurring. Figure 2.11 illustrates the context establishment function of risk management tools that can be developed in relation to the risk management process. Risks worth investigating further are those with a high chance of occurring, or high potential impacts, or leading to new opportunities; these are then pursued leading to being treated (Ahmed et al., 2007).

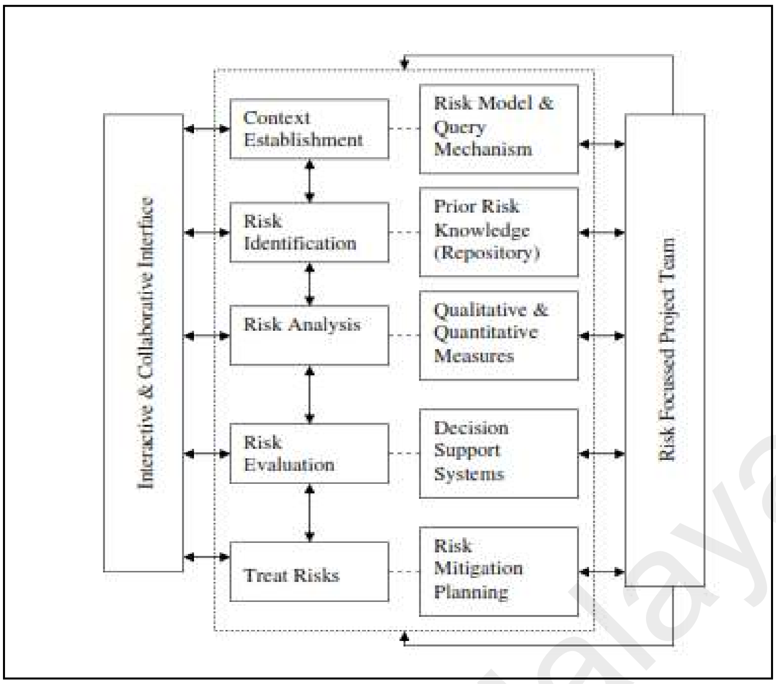


Figure 2.11: Framework for risk management tools (Ahmed et al., 2007)

To summarise, it should be understood that the purpose of risk management is not to remove or expel the risk; its principal aim is to ensure that risks are properly managed. In the end, the burden of responsibility to deal with the risk remains with the party that carries the risk (Mills, 2001). It therefore benefits the building users who are most severely impacted by the occurrence of risk, as the operational activities in building are continuous and are not undertaken only within a specified duration. Furthermore, risk management can open the way to finding innovative solutions that may otherwise not have been considered.

2.4.3 The Rationale of Risk in Building Performance Evaluation

Many studies (for example, Lee & Hensen, 2015; Almeida et al., 2010; Lützkendorf & Lorenz, 2007, 2006; Lützkendorf & Speer, 2005; Meacham et al., 2005; Meacham, 2010; Thompson & Bank, 2007; Wolski et al., 2000; Woods, 2008; Zalejska-Jonsson,

2012) note that principles of building performance have been incorporated into sustainable buildings, by emphasizing the vulnerability of risk in building performance. Awareness of the need to prioritize the comfort and safety of occupants is much concerned with the risk aspects perceived towards them. This illustrates how aspects of allocating the susceptibility of risk have expanded more broadly into building performance, and this can be applied in the context of Malaysia. Bordass and Leaman (1995) state that the critical parameters for real measurements in a representative number of buildings are planned to include:

- Occupants' behaviour – relatively to be changed in view of needs and their requirements
- Risk recognition – within the modelling regime there is a need to quantify the risk to building performance of deviation of people's behaviour from the norm

In any building, the occupants will find ways of operating their parts of it with the least effort, for a reasonable result in terms of comfort, service and convenience, but with little regard for efficiency (Bordass & Leaman, 1995). Thus buildings must deal with risk issues in various ways and aspects. As stated by Thompson and Bank (2007), as buildings have become larger and house more people, political and societal issues have become more complex, and risks associated with occupying buildings have changed. Even though risk is difficult to remove or even to reduce, it can be mitigated with proper management and a suitable approach. Building performance promises measureable expectations and if the promises are not achieved, adverse consequences are likely to lead to increased risks to occupants and tenants (Woods, 2008).The concept of incorporating risk into building performance evaluation (BPE) could be applied not only to mitigate the risk, but to reduce costs of operation, or to increase the level of productivity in a building.

Risks might only arise if attempts are made to realize a sustainable building by using inappropriate, experimental, and/or untested construction products and technical buildings solutions (Lützkendorf & Lorenz, 2007). While the physical attributes of the built environment are the key to preparing for the risks associated with climate change, the way in which it is managed and used is an essential component of risk management. Buildings and infrastructure should be able to withstand environmental climate change while maintaining the comfort and safety of their occupants/users (White, 2004). The delineation needs to be updated to account for the 'business-as-usual' climate change scenario. Almeida et al. (2010) revealed that quality, performance, and risk approaches have the potential to improve end-user satisfaction as well as the potential for disclosing vital building-related information (for example, quality or performance labels for end-users, risk related information for banks and insurance companies). Sustainability concerns also prompt the development of information management frameworks and tools that require a combination of quantifiable economic, environmental, and social criteria (Almeida et al., 2010).

According to Woods (2008), accountability for the performance of a building is not a new issue, but it has become an ill-defined function not only during the construction stage, but also during occupancy or operations of buildings. Therefore, accountability is required during the building stages, since the aspects of health, safety and security have been incorporated into the ambit of building performance. Woods (2008) described that the primary causes of risks may be lack of measured performance data and the means and methods to collect them. Valuable data and input on risk is appropriate to be collected during the occupancy stage, as the building users are able to provide credible data for further assessment.

According to White (2004), many emergency systems in buildings failed because they were not well-maintained. Therefore, relevant stakeholders that deal in building performance during both normal and extraordinary conditions must be able to verify quantitatively that the buildings are performing in accordance with the appropriate criteria. Unfortunately, such criteria may not yet be developed and this is supported by Woods (2008). Given this situation, the management should realise how important it is for risk to be allocated as the main criteria in BPE. The goal of BPE is not only to improve the performance aspects of buildings, but at the same time, it is also able to mitigate the occurrence of risk that may affect the building's stakeholders.

With existing building performance regulations, occupants are not aware of what level of risk mitigation is being provided for them, so they do not actively think about identifying and assessing the related risks in a building (Meacham, 2010). Assessment in building performance, therefore, should incorporate a flexible and efficient evaluation process into daily activities. It should support all stages of the building delivery system such as the facilities plans, design, construction and operations including improvement for users' productivity and efficiency.

According to Meacham (2010), many countries, including Australia, Canada, Japan, New Zealand, the USA and the 27 Member States of the European Union, are already using risk-informed criteria in some aspects of building regulations and standards. It should be possible to expand the concept and create performance-risk criteria in BPE that focus on the benefits of building users. Major focuses of risk in BPE are for better understanding of the context of building delivery processes and decisions on customer response, both initially and over the life cycle of the building. The perspective of risk in building context is shown in Figure 2.12:

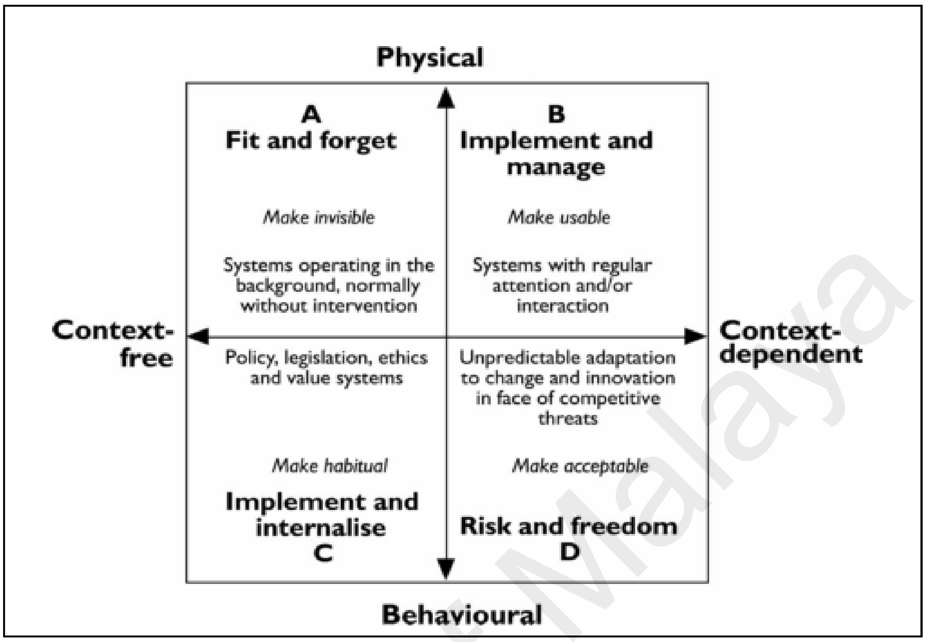


Figure 2.12: Perspectives on Context of Risk in Building Performance (Leaman et al., 2010)

It can be seen that the context of risk is allied to the activities conducted by the building users and Figure 2.12 illustrates four directions of perspectives:

i. 'Context free' - refers to principles, rules and processes that may be applied anywhere, irrespective of location
ii. 'Context dependent'- factors locally determined
iii. 'Physical' - represents the features of a building's physical form
iv. 'Behavioural' - user activities within a building.

The perspectives in Figure 2.12 are divided into four quadrants (A,B,C and D). Leaman et al. (2010) explained that a perspective of risk in a building relating to things that emerge from existing use and situations as they develop should be classified under

‘Risk and freedom’, as depicted in Quadrant D. Buildings that can be said to be truly ‘flexible’ and ‘adaptable’ will have included consideration of each of the four strategies at some point in the briefing, design and fit-out processes. This is likely depicted the importance of risk incorporation in assessing building performance.

As stated by Woods (2008), a comparison of aspects in BPE indicates that risks are inherent in promising building performance that cannot be objectively measured and evaluated for compliance with established criteria (e.g. building codes and standards, contract requirements, owner and tenant policies). Some of the risks are associated with the unfulfilled promises of achieving high-performance green buildings during the design process. Similar risks are also expected as a result of unfulfilled promises made to justify modifications, renovations, or changes in operations within existing buildings (Woods, 2008). Lawrence (1976) as cited in Wolski et al. (2000) affirmed that risk problems are filtered through human perceptions. A risk, therefore, can be perceived to be associated with ordinary (small) consequences. For example, an ordinary risk may entail minor injuries to one person. The relative differences of how people feel about these risk factors explain why people desire more or less safety (Wolski et al., 2000).

Significantly, risk can be categorised into different aspects of impact, which depend on the severity, analysis and response taken in mitigating the risk. Wolski et al. (2000) asserted that a given risk could be perceived as having the potential for catastrophic consequences. For example, the likelihood of risk for buildings constructed on a hilly site may potentially be perceived as catastrophic compared to buildings that are constructed on flat ground. Thus, risk factors can also be combined to describe a risk-problem: a risk-problem can involve catastrophic and voluntary factors, or involuntary and ordinary factors (Wolski et al., 2000).

Cole (2000) noted that health risks to building occupants are normally a concern during construction, which emphasizes the significance of workplace safety regulations. However, in completed and occupied building, the vulnerability of building users to health risk should never be neglected. Typically, safety and security risk factors in buildings are associated with crime and vandalism, but risk could also be generated by poor building morphology, deterioration and poor design orientation. Recently, several studies have shown that inefficiency of energy in buildings increases the vulnerability to risk in the safety and health of building users (Almeida et al., 2010; Altan, 2010; Cole, 2000; Lützkendorf & Lorenz, 2007, 2006; Meacham, 2010; Wolski et al., 2000; Zalejska-Jonsson, 2012). This suggests that prioritizing risk as the main constituent that could initiate a failure of other performance factors needs careful consideration.

In his research, Altan (2010) found that heating and lighting requirements of vast estates, reliance on and heavy use of computers and research equipment have affected the comfort and health of building users. Thus, inappropriate provision of facilities in buildings can also prompt risk. Therefore, risk frames that are constituted as social factors, can be categorized as follows:

Table 2.32: Categorization of Risk Frames

RISK FRAMES	DESCRIPTION
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 is often related to the causes of health risks in buildings during occupancy period (Cole, 2000). • Building facilities (Altan, 2010) and post-construction activities such as demolition, salvage, maintenance, or renovation of structures have also been allied to human health impacts (Cole, 2000)
Safety/Security Risk	• Health and safety risk is consistently termed as having similar risk impacts • However, in a building's context, users' safety is regularly permitted in buildings during construction and post construction stage; injury, death • The tendency of safety risk is consistently associated with natural disasters, seismic building movement (Meacham, 2010; Meins et al., 2010; Spence, 2004; Thompson & Bank, 2007), building defects, deterioration, building facilities, means of fire escape, (Meins et al., 2010; Wolski et al., 2000), etc. • The tendency on security risk : crime, theft, nuisance, burglary (Edwards, 2000)
Economic Risk	• The economy and related business environment risk is associated with the leaders and management of an organisation. • For example, the potential loss of physical assets or financial resources represents areas traditionally subjected to more focus as an economic risk (Whitfield, 2003) • Hence, businesses generally acquire insurance to protect against potential or unanticipated asset and/or financial losses
Environmental Risk	Associated with the potential of failure or loss of building performance in meeting indoor and outdoor environmental factors, such as: • Visual comfort, thermal comfort, noise level, ecological building materials and ventilation comfort (Camilleri et al, 2001; Meins et al., 2010) • Flooding, storms or earthquakes (Lützkendorf & Lorenz, 2006)
Comfort Risk	• Comfort aspects often related to the needs of users and regularly derived from holistic building aspects. • Failure to meet users' comfort, creates risk that could lead to other risk aspects such as health and safety risk (Meins et al., 2010) • Comfort risk may include environmental performance factors, visual comfort, thermal comfort, noise level, ecological building materials and ventilation comfort (Meins et al., 2010), building quality (Almeida et al., 2010; Meacham et al., 2005; Meacham, 2010)
Political Risk	• Similar to economic risk in that it is likely to be associated with business activities and resources; political risk is thoroughly allied to image and reputational risks. • Reputation lies in the business organization and is guarded only by the policies and decisions made; wrong decisions may tarnish reputation by failure to effectively manage reputational risks (Whitfield, 2003)

Within this understanding of risk frames, it can be seen that the principles in risk tend first, to minimize the impact of building performance, and then control for the health, safety and well-being of the building occupants (Woods, 2008). Hence, any information concerning the performance impacts of building and particular risks for occupants/users will need to be described and assessed in the future. Some professionals argue that this assessment can be incorporated into post-occupancy evaluations.

However, many post-occupancy evaluations show that, for a variety of reasons, buildings frequently do not achieve their targets (Almeida et al., 2010). This can be explained by the fact that quality and performance approaches intend, but do not ensure, that the building product actually performs as promised. Therefore, this underlies the importance of the risk approach, as risk mitigation in building performance assessment. The incorporation of a risk management approach is able to contribute to the improvement of performance as well as to the demonstrable achievement of product quality, as described in ISO/FDIS 31000 (Almeida et al., 2010). An example of the risk management and investment dilemma that must be resolved periodically throughout the lifetime of the building is shown in Figure 2.13 (from Woods, 2008).

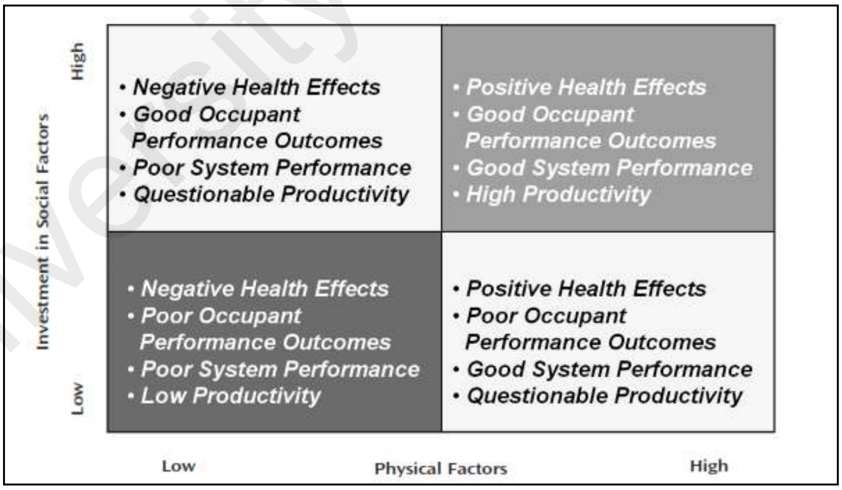


Figure 2.13: Matrix of risk aspects (social and physical factors) and their consequences to be addressed in the whole building life-cycle (Woods, 2008)

The above figure shows the differential outcomes that result if little is invested or much is invested in both the physical and the social factors,. However, if the investment must be limited and non-uniformly distributed among the choices, it is important to know which set of measurable factors incur the highest risks (high motivation and low physical performance; or low motivation and high physical performance).

Meacham (2010) states that without an understanding of delivering the building performance assessment, the occupants may simply expect that regulations provide them a level of safety and they tolerate the risk levels imposed to them. The probability of risk towards building performance failures may occur during the post construction phase and is likely to be more catastrophic during occupancy period. As supported by Almeida et al. (2010), the risk approach advocates similar principles because it is based on the presumption that individuals and society are ultimately affected by the various sources of risk. Woods (2008) raised several major issues that touch upon the accountability of designer, contractor, owner and tenant:

- Designers, contractors and building operators are not currently prepared to evaluate the health consequences of their decisions, although professional licensure requires this knowledge to protect the health and safety of the general public.
- Codes and standards seldom address “health” issues, and prescriptive formats of these documents are not consistent with evaluation of health consequences.
- Occupant health may be explicitly excluded from these contracts.
- Occupant health is generally avoided in project documentation.
- Insurance policies often have exclusion clauses on indoor environmental issues and health consequences or, if included, they are very expensive

Consequently, risk can have a direct impact on end users, society and individuals or the whole building itself. Benchmarking the risk in building performance can be framed as a health risk, a safety risk, an environmental risk, an economic risk, a political risk or other type of risk (Almeida et al., 2010; Meacham et al., 2005; Meacham, 2010). It can be seen that the risk approach advocates principles at the level of building performance and predicts its significant impact on individuals and society that are ultimately affected by those sources of risk. Therefore, the risk and the indicators are the predictor variables that can contribute to the level of building performance. The conceptual framework that relates building performance, risk and building users is depicted in Figure 2.14:

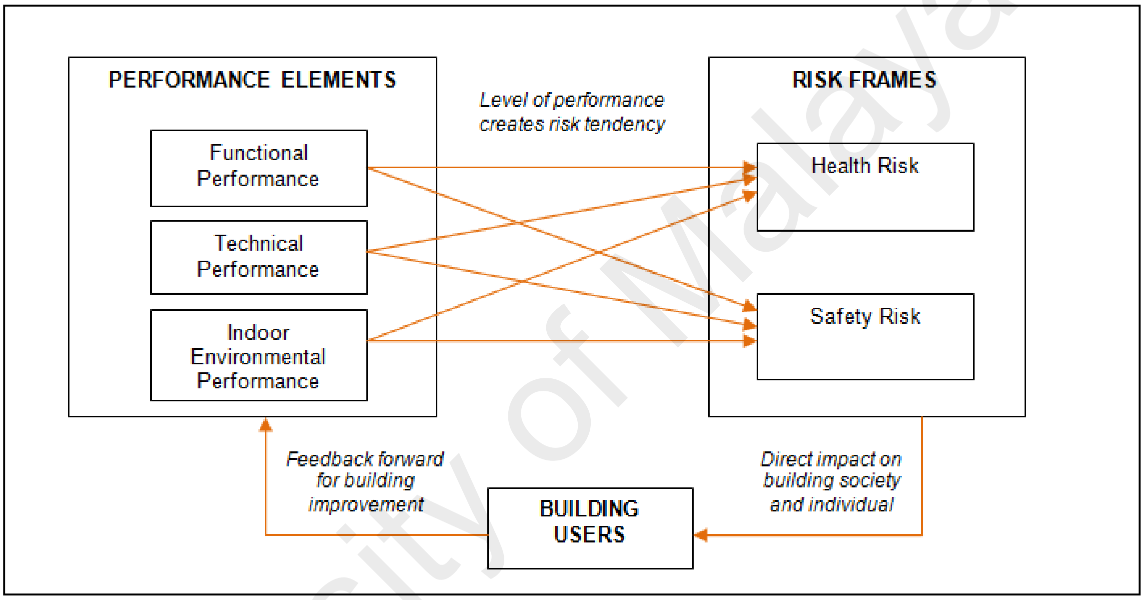


Figure 2.14: Schematic Relationship of Building Performance and Risk Frames feed-forwarded to Building Users

Figure 2.14 describes the fundamental concept that performance failure in buildings has increased the tendency of risk. The cycle is forwarded to the building occupants who perceive the risk created from building performance failure. It can be said that there is a significant benefit of providing a good quality of building performance that can incorporate the tendency of risk occurrence in buildings. In the context of the present research, the risk impact on building performance is focused on higher educational buildings in Malaysia. Since the elements of risk are focused on health risks and safety risks. An explanation of both risk frames in educational buildings is given below.

2.4.3.1 Health Risk

Since the concept of evaluation for building performance is conducted during occupancy or during post construction, human health issues are given greater coverage than other environmental issues. The prevalence of risk associated towards human's health includes indoor air quality (Cole, 2000), climate change (Dyer & Andrews, 2012), inefficient energy (Altan, 2010). The risk is highly associated towards human's health includes thermal stress, vector-borne diseases (Dyer & Andrews, 2012). Risks that associated to human's health include thermal stress, vector-borne diseases, eye irritation. According to Ho et al. (2008), building should minimizes the physical and mental health risk of its occupants, such as safeguarding against infectious diseases or chronic/mental illnesses found within the built environment.

2.4.3.2 Safety Risk

The creation of a secure and safe learning environment is essential for the efficient functioning of a university (Edwards, 2000). Crime, for instance, is costly to a university in a number of ways. The loss may include the replacement of equipment, the repair of buildings, and the additional cost for a surveillance service provider or security systems. Apart from crime, nuisance is also related to safety aspects that are a matter of concern for the building users. For this study, the context of safety is also extended to human injury that may have consequences for short or long terms suffering. Apart from injuries, the worst part of safety risk could lead to death.

2.4.4 Requirements of The Occupational Safety and Health (OSHA) 1994-Act 514

The requirement of health and safety risk mitigation at the workplace is not a new issue. In Malaysia, all workplaces are regulated under the Act of Occupational Safety and Health Association (OSHA) 1994. Even though compliance of OSHA is mandatory for all sectors, the requirements of health and safety as stated in the act are not aligned to the focus of health and safety risk for this study.

The Occupational Safety and Health Act (OSHA) was enacted on 25th February 1994 with the intent to ensure safety, health and welfare of all persons at all places of work (Ministry of Human Resources Malaysia, 2006). It was disseminated based on the concept of self regulation, with the primary responsibility of ensuring safety and health at the workplace lying with those who create the risks and work with the risks. The definition of OSHA as stipulated in the Act is as follows:

"An Act to make further provisions for securing the safety, health and welfare of persons at work, for protecting others against risks to safety or health in connection with the activities of persons at work, to establish the National Council for Occupational Safety and Health, and for matters connected therewith"

(The Occupational Safety and Health 1994-Act 514)

According to this Act, it shall apply throughout Malaysia to industries specified in the First Schedule including university buildings, which are categorised under the Public Services and Statutory Authorities.

Basically, there are four objects to ensure the safety, health and welfare of persons at work, as extracted from the Act (Ministry of Human Resources Malaysia, 2006):

- to secure the safety, health and welfare of persons at work against risks to safety or health arising out of the activities of persons at work
- to protect persons at place of work other than persons at work against risks to safety or health arising out of the activities of persons at work;
- to promote an occupational environment for persons at work which is adapted to their physiological and psychological needs
- to provide the means whereby the associated occupational safety and health legislations may be progressively replaced by a system of regulations and approved industry codes of practice operating in combination with the provisions of this Act designed to maintain or improve the standards of safety and health.

The first object is intended to protect persons at work against risks to their safety and health. Hence, the requirement is furnished to the employees in the building. For university buildings, the employees shall be the academic staff and also administration staff that are regulated under this requirement.

However, visitors and the students are regulated by the second object of this Act, which is intended to protect persons other than persons at work against risks to their safety and health. Persons who are authorized to enter the premises should be considered as visitors and are covered under this Act. It is mandatory to appoint safety and health officers for each university building, since the employer has an additional duty to ensure that so far as is practicable, a person other than his employees who might be affected is not exposed to any health and safety risk.

For public university buildings, the risk audit or assessment is conducted by Safety and Health officers once every 3 months. The items for audit are based on the list in the "Office Safety Checklist (KPKK 7A Form, Amendment 1/2006)" issued by the National Security Council of Malaysia (MKN). The aspects covered in the health and safety risk assessment include: officers' general requirements, physical safety, security of documents, and officers' private security. However for the aspects of physical safety, the checklist is limited to gate, lighting, alarm, access, exits, key systems, machinery and fire fighting systems.

Although a university building falls within the act of OSHA, recommendations for a more thorough list of risk assessment is acceptable, as way of improvement. As mentioned in the fourth object of the Act, associated occupational safety and health laws may be replaced by regulations and industry codes of practice in combination with the provisions of the Act.

Based on the above review on the OSHA act, the elements of health and safety risk that are included in this study are more comprehensive. The study includes items from the elements of the building performance, which include functional performance, technical performance and indoor environmental performance. Further sub-elements or indicators under the category of building performance elements need to be constructed in order to reduce users' health and safety risk from poor performance elements. Further validation on the rationale of risk incorporated into the concept of building performance evaluation is presented during the report of the preliminary survey of this research.

2.5 The Initial Construct Of Performance-Risk Indicators (PRI)

As an initial step in the development of a rating tool, sub-elements or indicators under the category of building performance elements are constructed based on the review of academic theories and previous reports of building performance and risk studies. The construct of indicators were compiled into a performance element that is subdivided under three main headings: functional performance, technical performance, and indoor environmental performance, as adapted from Lützkendorf and Lorenz (2006). As illustrated in Table 2.27 earlier, the description of the elements incorporates both technical factors and social factors. In order to identify the impact of poor performance on the users' health and safety risk, criteria or indicators from the performance elements need to be further identified and set in a comprehensive list. This also acts as the initial step in risk management procedure; that is, identification of risk sources. For this study, the risk sources are considered as the indicators or elements of performance-risk.

Identification of performance-risk indicators in buildings is critically needed to ensure that they meet the performance goals and objectives. Denoted as the first step in mitigating the likelihood of risk impacts to the building users, identifying risk sources and causes are essential in order to continuously achieve improvements in building performance (de Wilde & Tian, 2012; Lützkendorf & Lorenz, 2007). In this research, the determinants of risk criteria or factors are firstly grouped into categories according to performance elements and the type of risk impact on the user. As stated by Malmqvist and Glaumann (2009), in developing a new rating method, the initial step is to select the assessment areas that should be rated in the method. The next important step is to determine the parameters, variables, attributes or indicators that can be used for measuring the selected aspects (Ali & Al, 2008; Malmqvist & Glaumann, 2009). Therefore, in order to construct the parameters, determinants of the performance and risk indicators are developed to be used for the following:

- as the conceptual framework of this study
- as the evaluating items for performance-risk survey
- as initial parameters for the development of the final rating tool

The parameters for this study are known as Performance-Risk Indicators (PRI), and they were further divided from the category of performance elements. The PRI were compiled and characterized from the following:

a) criteria or sub-items included in the existing established rating tools
b) items categorised under the description of functional performance, technical performance and indoor environmental performance (in earlier studies and the literature)

2.5.1 Identification of Performance-Risk Indicators (PRI)

Since the benefits of building performance are conveyed to the building users, the selected risk frames in the context of this research context were allied to the impact on building users, as social factors. The entailing indicators are connected to the list of risk frames that focus on health and safety risks. Both health and safety risks are defined as the risk frames that have a major impact on building users. Literatures by Lützkendorf & Lorenz (2007), as well as Preiser (2005), showed that the mandates or the criteria in building performance depend on the objectives of evaluation. The elements can be technical performance (heat insulation, fire), functional performance (functionality, applicability, adaptability), social performance (comfort, health, safety), economic performance (LCC, cash flow, market value) or environmental performance (energy use, materials use). Based on the review, functional performance, technical performance, and indoor environmental performance had been found appropriate for assessing both technical and social aspects in meeting demands for reducing risk to building users.

From this division of elements, it was further divided to sub-items as the indicators might have an impact on building performance condition, as well as users' health and safety risks. Dividing the type of performance into three elements (functional, technical and indoor environmental) that can contribute to the health and safety risk of building users has made it possible to concentrate on the development of a standardised, well documented method and to validate the method. Table 2.33 lists the Performance Elements (PE) and PRI that were generally allied to both the health and safety risks of the building users.

Table 2.33: The Initial Construct of Performance-Risk Indicators (PRI) associated with Users' Health and Safety Risk

Performance Elements (PE)	Performance-Risk Indicators (PRI) *(predictor variables)*	Risk Frames
1. Functional Performance	1.1 Spaces (area) 1.2 Orientation (direction, layout) 1.3 Infrastructure (parking, landscape) 1.4 Access/entrance 1.5 Circulation area (corridor, lobby) 1.6 Ergonomic building facilities 1.7 Adequacy of building signage 1.8 Emergency exits 1.9 Building-related illnesses/sick building syndrome	• Health Risk • Safety Risk
2. Technical Performance	2.1 Design of building fittings/fixtures (door, window, ironmongery, sanitary) 2.2 Structural stability (column, beam, slab, staircase) 2.3 Information Technology systems operations 2.4 Electrical services 2.5 Plumbing services 2.6 Building integrity 2.7 Fire Prevention Services 2.8 Materials & Internal Finishes (floor, wall, ceiling)	
3. Indoor Environmental Performance	3.1 Heating (Thermal comfort) 3.2 Cooling (Thermal comfort) 3.3 Artificial lighting (Visual comfort) 3.4 Natural lighting (Visual comfort) 3.5 Waste disposal 3.6 Building ventilation 3.7 Acoustic comfort (Noise) 3.8 Level of cleanliness	

The listed indicators are the predictor variables that can contribute to performance level and to users' health and safety risk. In general, the list covers the overall aspect of performance indicators that mainly concern the risk criteria and their impact on the occupants. The coverage of the social aspects, health risk and safety risk, are influenced by the listed indicators. Definitions and detailed explanations of the PRI in terms of performance issues in regard to the impact on building users or the occupants' risk are set out in the following section.

2.5.2 Description for the Performance-Risk Indicators (PRI) and Performance Issues

A definition and a description are provided for each of the indicators to better understand the context of this study. They also help to clarify the terms during the survey stage. The performance issues were also described to clarify the impact of the indicator's performance on users' health and safety risk.

i. Spaces

- *Description* – Space is defined as the amount of an area, room, surface, etc., that is empty or available for use (Merriam-Webster Dictionary, 2014). It is understood that certain spaces in any facility are significantly more important to overall facility performance (Pati et al., 2006). Hence, for this study, the aspect was the measured area as allocated in the plan.
- *Performance Issues and Impact on Users* – The issues are addressed on the improper or inadequate size, density problems, spatial deficiencies in the buildings (Ibem et al, 2013). As Pati et al. (2006) stated, such high-importance spaces determine to a large extent how the facilities perform as a whole in a particular building; for example: educational building, courtrooms, hospitals, etc. An improved use of spaces reduces the risk and the perception of risk for users as well-planned spatial relationships may improve profit and productivity (The AIA, 2007).

ii. Orientation

- *Description* – Building orientation refers to the way a building is situated on a site and the positioning of windows, rooflines, and other features (NJ Green Building

Manual, 2011), orientation is the positioning of a building in relation to seasonal variations in the sun's path as well as prevailing wind patterns.

- *Performance Issues and Impact on Users* – According to Papadopoulos and Giama (2009), the building forms and orientation are decisive factors for energy use and costs. Hence, a good orientation can increase the energy efficiency of a building, and thus be able to boost the performance level of the building. The orientation of rooms is important, as some rooms are more likely to be ventilated for longer periods than similar rooms orientated in other directions (Fabi et al., 2012). It seems most likely that it is the effect of solar radiation and temperature, rather than the orientation itself that affects occupants' window opening behaviour (Fabi et al., 2012), which may thus affect the occupants' safety or health aspects.

iii. Infrastructure

- *Description* – Infrastructure is defined as the basic physical and organizational structures and facilities needed for any area development. According to Edwards (2000) in the context of academic buildings, ideally the infrastructure comprises vehicle parking, landscape, walkway and pedestrian areas.
- *Performance Issues and Impact on Users* – Generally, the aspects are concerned with users' safety due to crime cases when the provision of infrastructure is neglected. For instance, research on space efficiency by Space Management Group (2006) for UK higher education building projects revealed that parking problems were the only serious complaint made by the users. BQA tools described that the shape of parking areas makes way finding difficult (narrow aisles and bays) and they are often poorly located (Clift, 1996). Hence, it may encourage crime, nuisance or car stealing.

iv. Access/entrance

- *Description* – In general, any building requires an access or entrance that allows the users to enter the enclosed building area. It is described as the point that the users may go into a building or enclosed area.
- *Performance Issues and Impact on Users* – The building should be designed to be easily accessible by occupants and visitors. Lack of surveillance, or hidden entrances, may increase opportunities for crime, as mentioned by Edwards (2000). Campus buildings must recognise the importance of restricting entrance points and identifying territories early in the development of the building masterplan (Edwards, 2000). Hence, considerations for this aspect include ease of locating the building and clearly visible entrances to the building.

v. Circulation area

- *Description* – In the context of this study, circulation area is extended to the provision or allocation of corridors, lobbies and staircases. A stairwell enclosure is a term used to mean the area occupied by stairs and landings and any part of a horizontal circulation area not separated from them by doors (Hassanain, 2007).
- *Performance Issues and Impact on Users* – Vertical segregation in the circulation area in campus buildings can become alienating and sometimes dangerous (Edwards, 2000). In a study of fire safety in university students' housing by Hassanain (2007), it was found that common violations in stairwell enclosures included stairwell enclosures that were not fire-rated, broken closers and latches and doors propped open. Such conditions may facilitate the spread of smoke and toxic gases to other floors in the building, as well as preventing the residents from using the stairwell to escape from the fire (Hassanain, 2007).

vi. Ergonomic building facilities

- *Description* – relation between the design of facilities fit to be used by the users (for example: table, chairs)
- *Performance Issues and Impact on Users* – Ergonomic hazards refer to workplace conditions that pose the risk of injury to the musculoskeletal system of the worker. According to Badayai (2012), functional comfort refers to the ergonomic support for users' performance of activities. Hence, ergonomic furniture or facilities size might help to ensure functional comfort. When functional comfort is not achieved, the building users may have tendency to suffer health problems, such as back pain, body injury or muscular disorders. Thus, health risk may arise from unsuitable facilities or furniture.

vii. Adequacy of building signage

- *Description* – Signage is defined in the Merriam-Webster Dictionary (2014) as an identification or direction used to show information about something. More simply, signage is generally located (indoors and outdoors) as a system to direct users for better way-findings.
- *Performance Issues and Impact on Users* – Improper allocation or poor signage in a building will have a negative effect on building users (Preiser, 1995; Riley et al., 2010). Any hazards should be identified, highlighted and described using clear building signage. According to Bordass (2003), assessment of building performance can be used to identify and remediate such problems associated with poor signage and lack of storage. Providing better interior signage/directories and colour coding is needed to assist people unfamiliar with the space and for better way-finding (Preiser, 1995; Space Management Group, 2006).

viii. Emergency exits

- *Description* – Extracted from UBBL (1997), an emergency exit is a mandatory requirement for any building as a fire prevention requirement and for the building to be certified as fit for occupation. It is a structure or an area that is allocated in a building for faster evacuation, especially in the event of fire.
- *Performance Issues and Impact on Users* – Safety and security measures relating to people are being given greater attention due to increasing awareness among the population; therefore suitable hazard prevention or escape routes and emergency exits need to be considered (Meins et al., 2010). As stated by Yau (2006), visibility of emergency exits with supplemental emergency lighting may help building users evacuate in case of an emergency

ix. Building-related illnesses/Sick Building Syndrome

- *Description* – The term "building related illness" (BRI) is used when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants. The World Health Organization (WHO) defines SBS as an excess of work-related irritations of the skin and mucous membranes. It can lead to other symptoms, including headache, fatigue and difficulty concentrating, reported by workers in modern office buildings. The reason this indicator is placed under functional performance is because the health suffered may derive from any specific area in the building (patent defects).
- *Performance Issues and Impact on Users* – The consequences of poor performance of buildings are manifested in building related illness (BRI) and sick building syndrome (SBS), as revealed by Ibem et al. (2013). According to Zamani, et al. (2013), SBS was a major concern as many people were potentially at risk. It was also reported by Brooks and Davis (1991, as cited in Yau (2006)

that occupants increasingly began to suffer from SBS and other BRI when the building overly emphasized energy issues, with airtight windows and doors, and insulation. Failure to identify the SBS resulted in poor performance of a building, thus, affecting users' health and safety.

x. Design of building fittings/fixtures

- *Description* – This deals with the design of the openings, i.e. doors, windows, ironmongery, door fittings and window glass (opening accessories) (Goh & Ahmad, 2012).
- *Performance Issues and Impact on Users* – Damaged windows will leave the occupiers unprotected from burglars, rapists and other criminals. Faulty windows could allow entry to dangerous insects like mosquitoes, which can cause dengue fever, in the buildings (Olanrewaju et al., 2010b).

xi. Structural stability

- *Description* – Stability of structural items; columns, beams, floor slabs, concrete walls or roof slabs.
- *Performance Issues and Impact on Users* – According to Ali et al. (2010), the structural stability of a building must be inspected and maintained from time to time in order to ensure the occupants' safety. Hazards in the built environment have been closely related to accidents occurring in buildings; thus, occupants must be safeguarded against hazards arising from structural failure.

xii. Information Technology systems operations

- *Description* – any operations in a building involving technology services such as public address (PA) system, door access card, Building Automation System (BAS).
- *Performance Issues and Impact on Users* – The automation system ensures that the operational performance of a building runs smoothly as well as to raise comfort and safety of the building's occupants. Dysfunctional or improper installation of an automation system in a building may reduce the safety of occupants in many ways. In the context of building performance, using advanced automation systems also makes it possible to optimize energy efficiency, as recommended by Dewlaney and Hallowell (2012).

xiii. Electrical services

- *Description* – Electrical services deals with the functioning of power - used to provide light, to heat buildings, or to power devices.
- *Performance Issues and Impact on Users* – Faulty electrical systems are a very serious defect as they can lead to death. In their research, Olanrewaju et al., (2010b) revealed that urgency of identifying defects in university buildings is needed because faulty electrical equipment was rated as the second most frequently rated defect. Their findings showed that user safety and user well-being is of paramount consideration due to faulty electrical services.

xiv. Plumbing services

- *Description* – In general, it refers to the functioning of piping; arrangements of pipes, fixtures, fittings, valves, and traps, in a building which supply water and remove liquid-borne wastes.

- *Performance Issues and Impact on Users* – Corrosion, leaking which is due to improper installation or aged plumbing and drainage systems in buildings involves a higher remedial cost (Wong; 2002 as cited in Ali et al., 2010). Performance failure in plumbing systems (corrosion or leaking) can lead to more serious defects, thus affecting the safety of the building users. Optimisation of access to the plumbing equipment for inspections and maintenance could help to mitigate these risks (Dewlaney & Hallowell, 2012).

xv. Building integrity

- *Description* – Building integrity is related to the characteristic or stability of a building; in terms of its ability to hold together under a load, including its own weight, resisting breakage or bending.
- *Performance Issues and Impact on Users* – Inevitably, the issues become relevant to the safety of the building users if the stability of the building is not guaranteed. This factor is likely to be similar to structural stability.

xvi. Fire Prevention Services

- *Description* – A mandatory system installed in buildings to reduce fire emergency and damages such as allocation of smoke detectors, sprinklers, fire extinguishers, hose reels.
- *Performance Issues and Impact on Users* –Improper installation, poorly maintained or dysfunctional fire fighting systems create safety risks to the building users in educational buildings. Statistics show that many students have died in fires in student housing, and many more have been injured from burns, smoke inhalation and jumping from windows (Bruno, 2006). Hassanain (2008) suggested that frequent maintenance of fire protection and safety equipment is

needed to improve the level of safety and to mitigate risks in students' housing in university buildings.

xvii. Materials & Internal Finishes

- *Description* – The type of interior materials on exposed surfaces of a building, i.e. floor finishes, wall finishes, ceiling finishes
- *Performance Issues and Impact on Users* – High performance buildings will use less material more effectively, and ensure that they are durable and require less maintenance (Abaza, 2012). Shabha (2003) revealed that incompatible and poor quality materials used in construction have caused deterioration or defects to occur in building components. Therefore, awareness of the need to use materials which do not emit any harmful substances inside the building must be increased.

xviii. Heating (Thermal comfort)

- *Description* – Heating is one of thermal systems installed in buildings for maintaining temperatures at an acceptable level, especially during cold or winter weather. As found in several established rating tools, heating is included as parameter of indoor environment, energy or thermal comfort.
- *Performance Issues and Impact on Users* – As indicated by Pati et al. (2009), thermal comfort performance is delivered by the ''comfort control system'', composed of the heating. Ideally, failure in the heating system may cause noise, gas leaks, unsafe furnaces or even building fires due to overheating boilers. It constitutes a further impact to the building users in terms of health and safety.

xix. Cooling (Thermal comfort)

- *Description* – for the purposes of this study, it is generally concerned with the level of air cooling. Air cooling is a standard method of cooling used to dissipate heat.
- *Performance Issues and Impact on Users* – Olanrewaju et al. (2010b) noted that faulty air conditioning systems could lead to discomfort, the growth of mould leading to sick building syndrome, pathogenic diseases and also facilitate water seepage. Poor performance of thermal comfort can have serious consequences for users' health and safety.

xx. Artificial lighting (Visual comfort)

- *Description* – Visual comfort is a subjective condition of visual well-being induced by the visual environment (Frontczak & Wargocki, 2011). For this study, artificial lighting is generally concerned with the adequacy and the level of lighting for electric lightings system.
- *Performance Issues and Impact on Users* – Issues affecting building users due to artificial lighting in buildings is often related to its adequacy, control and level of brightness. A study by Hassanain (2007) revealed that students of King Fahd University in Saudi Arabia were dissatisfied with the adequacy of artificial lighting at study areas and the lighting control levels in the room. It was revealed that artificial lighting alone does not provide for comfortable reading conditions at the desk, and that task lighting at the desk level is essential. Heerwagen (2000) reported that glare from electric lighting is associated with headaches, muscular skeletal problems, and eyestrain. According to the Canadian Centre for Occupational Health & Safety (2013), poor lighting can be a safety hazard resulting in misjudgements about the position, shape or speed of an object, which

can lead to accidents and injury. It can also cause health hazards: too much or too little light strains the eyes and may cause eye discomfort (or burning) and headaches (Canadian Centre for Occupational Health & Safety, 2013).

xxi. Natural lighting (Visual comfort)

- *Description* – Refers to the adequate penetration of natural daylight into the building, that may be enhanced by the inclusion of atriums, curtain glass walls, bigger window openings, etc
- *Performance Issues and Impact on Users* – As described by Meins et al. (2010), a building design that ensures sufficient daylight is increasingly important not only due to rising health awareness, but also because of rising costs for lighting (electricity).

xxii. Waste disposal

- *Description* – Refers to practices and management of general and solid waste within buildings. The type of solid waste can be categorised as organic, paper, plastic, glass, metals, and others (textiles, leather, rubber, multi-laminates, e-waste, appliances, ash, other inert material) (Hoornweg & Bhada-Tata, 2012).
- *Performance Issues and Impact on Users* – Waste is one of the environmental concerns (Kowaltowski et al., 2006). Improper disposal of waste or poor management of waste can lead to leakage of hazardous substances and indoor air pollution (Wang et al., 2005). Thus, it can cause health problems among the building's users, such as respiratory problems and other effects, as contaminants are absorbed from the lungs into other parts of the body, including in HEBs. A clear example was evidently shown in the operating procedure book for general waste in the campuses of The University of Queensland Australia, where the main

objective of the procedure is to avoid risk to health and safety (QUT Facilities Division, 2011).

xxiii. Building ventilation

- *Description* – Circulation of air throughout a building that removes air either naturally (windows) and/or mechanically.
- *Performance Issues and Impact on Users* – Inadequate ventilation in a building leads to sick building syndrome (Zamani et al., 2013), thus affecting air quality, and consequently the health of occupants. Hassanain (2007) suggested that poor air quality in a university could affect the health of students, resulting in higher rates of absenteeism and lower productivity.

xxiv. Acoustic comfort

- *Description* – As defined by Low et al., (2008), acoustic concerns relate to noise and vibration and the performance refers to how well noise is being managed in a space.
- *Performance Issues and Impact on Users* – Noise is sound that is unwanted in one context; that is annoying to the (unwilling) hearer. This aspect of the limits of acceptability aims to ensure the physical health and safety of building occupants. The built environment needs to be free from excessive noise so as to protect occupants from potential hearing damage (Low et al., 2008). Lower levels of noise that are not physically dangerous can, however, distract people from their work and is an additional stressor.

xxv. Level of cleanliness

- *Description* – Refers to a scale of cleanliness level that ensures the building is free from dirt and dust, and is related to hygiene and disease prevention.
- *Performance Issues and Impact on Users* – the level of cleanliness in buildings is often related to the impact of indoor air quality (IAQ) (Frontczak & Wargocki, 2011; Kavgic et al, 2008). The causes may derive from many factors such as improper waste disposal, moisture or dirt in HVAC systems, contaminants from building materials. The consequences for users' health include respiratory health effects and other severe effects such as rashes, eye irritation, and headaches.

The above list forms the basis of questions in the interview survey. The final list of indicators was constructed as a result of consensus among the experts who acted as participants for the interview. At this stage, the compilation of the indicators is based on previously established BPE schemes and the literature of BPE and risk studies. It has yet to be validated by reliable experts in terms of its suitability for the Malaysian context.

2.6 Summary

Building performance and risk management is an emerging field of academic enquiry. It intergrates elements from two broader fields – building performance and risk management – that were previously separated and self-contained, in terms of both concepts and principles. The above literature review has explored and contributed how risk management can help to boost building performance through linkages with performance optimization for the comfort and satisfaction of building users. It was found that an integrated risk-performance rating tool is needed to incorporate the social aspects of building performance evaluation (BPE) that are currently lacking. It would thus help provide opportunities for the improvement of building performance and highlight relationships with users' risk and satisfaction.

The above review also demonstrates that there is a plethora of risk factors with the potential to affect the different dimensions of building performance. It can be summarised that the first objective and the second objective for this research is partly achieved through this exploration and analytical review of literature. A full achievement of both objectives is dependent on the analysis of the preliminary survey reported in Chapter 4 of this thesis. The next chapter describes the methodology used to undertake this research and details the procedures followed to achieve all objectives and answer research questions.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The risk factors in building performance evaluation (BPE) explored in the previous chapter provide critical inputs to the development of a building performance-risk rating tool for higher educational buildings (HEB). To rationalize the statements and problems in this study, the nature of the methodology and procedures must be described clearly. Therefore, this chapter presents a detailed explanation of the research methodology to justify the methods used to collect and analyse the data to extract the findings for this study. It includes descriptions of the instrumentation for data collection, decisions on research design, and analysis procedures.

The methodology began with an analytical review of the literature of BPE and Risk to attain up-to-date perspectives of the main area of study. This was followed by a thorough review of existing research and practice in the study area to obtain key variables, relations, trends and gaps that gave rise to the formulation of the research problems. This chapter also describe all phases undertaken in the collection of data and findings, including the presentation technique and procedures for reporting the findings.

3.2 Research Methodology

In establishing the methodology of research, the type of research approach is determined by the problem statement of the study and the more specific research objectives. The objectives derived from the problem statement form the basis of the approach to the study of the research. Research strategy can be defined as the way in which research objectives can be questioned (Naoum, 2001).

The methodology of research can be either a qualitative approach or a quantitative approach, or a mixed-method strategy, when a combination of both approaches is used. The following section includes a brief explanation of qualitative and quantitative methods to provide a preliminary understanding on why both methods are used for this research.

3.2.1 Qualitative Approach

The characteristics in qualitative research differ from those in quantitative research. Not all research can be validated through numerical data and, in some cases the data can only be obtained through observations and exploration. Therefore, a qualitative approach is adopted in order to make the research viable and to generate better findings. According to Chua (2011), latent elements such as human emotions, motivations and empathy are more suitably studied through a qualitative approach as these elements are not able to be described in numerical forms. Creswell (2012) suggested that qualitative research is best suited to address a research problem in which the researcher does not know what the variables are and needs to explore the topic more widely. Although the literature may provide some information about the phenomenon under study, the research may need further exploration through information provided by participants.

The main purpose of the qualitative approach is to enable the researcher to add to the theory, In the present study, a qualitative approach is used to identify more clearly the indicators that constitute health and safety risks to HEB users. A semi-structured interview was the instrument used for the survey.

3.2.2 Quantitative Approach

According to Creswell (2012), a quantitative approach is typically used when the research needs to describe a research problem through a description of trends or seeks an explanation of the relationship among known variables. In quantitative research, the investigator identifies a research problem based on trends in the field or on the need to explain why something occurs. Describing a trend means that the research problem can be answered best by a study in which the researcher seeks to establish the overall tendency of responses from individuals and to note how this tendency varies among people.

Analyses in the quantitative method are based on tabulated and numerical data. In quantitative research, data are collected in numerical form, often with pre-coded categories. This data collection enables the researcher to generalize the findings from a sample of responses to a population. Creswell (1994) pointed out that experiments based on findings test cause and effect, in which the researcher randomly assigns subjects to groups. Questionnaires are usually administered to a large number of respondents; in the present study they included occupants of buildings and individuals. The steps taken in this research are described below.

3.2.3 Mixed method: Qualitative and Quantitative Approach

Many researchers believe that scientific research should merge both approaches, qualitative and quantitative (Chua, 2011; Creswell, 2012; Parmjit et al., 2006). According to Chua (2011), data triangulation using both approaches makes it possible to amplify the reliability and validity of data, where phenomena from a specific area are viewed in a holistic perspective. This statement emphasizes that a mixed method approach supports validity, thus helping to refine and strengthen the findings. Sequential methods and triangulation have been applied for instrument validation, when both quantitative and qualitative methods have been used for validation. As stated by Hyrkäs et al., (2003), the approach has been found useful for instrument validation and cultural adaptation since it also provides an opportunity to explore and discover what might undermine the validity and the biases of an instrument (Chua, 2011; Creswell, 2012). A brief review of the literature found that several researchers investigating assessment of the environment and building performance (for example, Gillen et al., 2011; Hendrickson & Wittman, 2010; Huisman et al., 2012; Raslan & Davies, 2012; Stevenson & Rijal, 2010; Teo & Lin, 2011) also adopted triangulation of data in their studies. Hence, using mixed methods for this study is appropriate and achievable.

This research therefore adopted a multi-dimensional design strategy that involved both approaches; quantitative and qualitative. The approaches included interviews (semi structured), a questionnaire survey and a decision making approach. In other words the research is based on an interaction between an archival ethnographic approach and qualitative interviews. This research is a non-experimental design, hence the terms *dependent variable* (DV) and *independent variable* (IV) are not identified in this thesis. According to Simundić (2006), when following a non-experimental research design, DVs and IVs should not be used as there is no testing of relationships or causal effects on the variables. Instead, the indicators are termed as *predictor variables* that can contribute to performance level and can affect users' health and safety risks. The following describes the phases of methodology, from the identification of the research objectives and the methods used to answer the research questions.

3.3 Phase 1A: The Literature Review

A vital part in collecting data of research is a search and a review of literature. As described by Creswell (2012), it is important to know what earlier researchers who have studied a similar topic or area have studied and found in order to avoid replication of research aims and objectives. Therefore, the prior basis of methodology in conducting research is a literature review carried out at the beginning. According to Boote and Beile (2005), a literature review is an evaluative report of studies found in the literature related to the selected area. The review should describe, summarize, evaluate and clarify the literature that provides a theoretical basis for the research and help the researcher to determine the specific focus of the study.

Literature can be considered as a summary and synopsis of a particular area of research. A good literature review expands upon the reasons behind selecting a particular research question (Chua, 2011; Creswell, 2012; Shuttleworth, 2009). In addition, a literature review goes beyond the search for information and includes the identification and articulation of relationships between the literature and the selected field of research. Among the information that needs to be obtained from a reading of the literature are matters relating to research theory, research design, instrumentation, research procedure, data collection and findings from previous research. The review involves a wide range of secondary data comprising of articles from leading journals, books, seminar papers, reports, legal regulations and unpublished doctoral and master theses from local and international universities. Summarizing the literature into a written report (Creswell, 2012) will help steer the researcher to the research problem, the questions and the appropriate methods to be applied in the new study.

For the present study, the literature search began by reviewing the background of higher educational buildings (HEBs) as the main subject of building samples. The first objective of this study was partly achieved in this stage. Full achievement of Objective 1 was obtained in the next phase, the preliminary survey.

3.4 Phase 1B: The Preliminary Survey (Semi-Structured Interviews)

The next phase of methodology was the preliminary survey stage. The preliminary survey was initiated as a step toward identifying the criteria or indicators that have a potential impact on users' health and safety. This stage is also important as the first step in identifying the hazards or risk factors listed in the risk management (RM) process, at the risk identification stage. The initial set of parameters or indicators that would form the basis for the qualitative interviews, an analysis of the established building performance evaluation (BPE) schemes, were reviewed as recommended by Ali and Al (2008).

Generally, there are two purposes for conducting a preliminary survey:

i. to elicit respondents' views and judgments on the incorporation of users' health and safety risk in building performance evaluation

ii. to suggest and support the construction of performance-risk indicators (PRI) that have an effect on users' health and safety risk, in higher educational buildings

Therefore, this phase produces the basis for the next phase, which is the main survey. The findings from this preliminary survey also help to fully achieve Objective 1 and Objective 2 of this study. The following section provides details of the scope and administration of the preliminary survey.

3.4.1 Criteria for selecting respondents

Use of performance lists, criteria or indicators is closely related to the responsibility of building management or the development division for building inspection purposes. Since the construct indicators (as outlined in Chapter 2) are to be used for the performance context of HEBs, therefore the sample identified respondents as professionals who are working in the division of building facility management in Malaysian HEBs. From a review of established rating tools like BREEAM, LEED, HK-BEAM, it can be concluded that these tools assist the building operators to measure impacts and encourage the adoption of "green" practices in the buildings' performance (Neida & Hicks, 1998; Papadopoulos & Giama, 2009; Soebarto & Williamson, 2001; Summerfield, Lowe, & Summer, 2012). As a consequence, building operators are selected as the respondents who can support the construct of performance-risk indicators in HEBs, as recommended by previous studies (Janda, 2011; Lützkendorf & Lorenz, 2006; Maile, Bazjanac, & Fischer, 2012). Yik et al. (1998) emphasize that the performance assessment or criteria should be set at such levels that they can be used by the building operators. Hence, the operators are likely to be reliable respondents due to their familiarity, knowledge and expertise on the suitable criteria for assessment of HEBs.

To select the respondents, certain criteria were predetermined in order to achieve better and more appropriate participants for this survey. The respondents were identified in accordance with the following criteria:

- Designated in the position of professionals with a building background (senior levels, with designation grade J44 and above)
- Work in the division of building maintenance management or maintenance services
- Possess knowledge of technical elements, building elements and facilities management based on their academic background and professional working experience
- Have at least five years' working experience, including in previous organisations

3.4.2 Administration of the interviews

The management of the semi-structured interviews began by short listing potential participants based on the stipulated criteria. Screening forms were distributed earlier via email to potential participants to obtain demographic details of the participants, including their designation, academic background, years of working experience and current responsibility/duty. The interview forms were also distributed to the participants via email, along with the screening form. Potential participants were given ample time to review the interview questions in order to gain a better understanding of the research area and for validation purposes.

The participants were then further contacted to set a date for an interview. After the date and time were agreed by both participant and researcher, the participants were asked about their preferences for the interview mode; that is, whether it should be conducted via telephone conversation, or in a face-to-face situation. Both methods are oral conversations that enable the researcher ask further questions during the interview, or the respondents to ask for clarification. For this reason, oral interviews rather than a written questionnaire-type format was used.

3.4.3 The interview question form

To ease the semi-structured interview process, the questions were prepared in an interview form. As described earlier, this interview form was distributed to the potential participants via email, for their preliminary review. Basically, the interview form consisted of a cover and three sections and a copy of the form is attached in Appendix A:

- Section A : Particulars of Interviewee
- Section B : Rationale for Risk in Building Performance
- Section C: Indicators of Performance and Risk for Academic Buildings in HEBs

The main cover of the interview form included a reference number for each participant and briefly explained the main purposes for conducting the interview. Definitions and descriptions of several key terms were also highlighted on the cover of the form. This was to assist participants to understand the terms in a more uniform way, to relate them to the research area and also to act as a reference for them.

On the next page, Section A, the participants were required to fill up their demographic details. As mentioned above, a screening form containing details of the participants had been distributed earlier. This explains the brief information required in the first section of the interview form. Section B comprised five open-ended questions, relating to building performance in general, users' risk and also the current evaluation adopted by the management in the respondent's department. Since the interview session was a semi-structured type, simple unstructured questions were asked thereafter, where necessary. Table 3.2 shows the questions that were prepared for the interview session:

Table 3.1: Semi-structured interview questions (Section B) for the Preliminary Survey

NO.	INTERVIEW QUESTIONS
1	Can you briefly describe the building items that are generally managed/audited/serviced in this building?
2	Based on your experience, what are the identified risks that you have encountered when the building experienced poor performance?
3	During building audit/management/services, do the items assessed in the building checklist incorporate users' health and safety risks?
4	In relation to question B3, do the assessed items include the building physical structure (Functional Performance), building services (Technical Performance) and indoor environmental items (Indoor Environmental Performance)? *(Please state others, if any)*
5	What is the current instrument/unit/rating system used to evaluate the performance and users' risk in this building? *(Please state if any)*

In the last section of the interview form, Section C, the initial construct of performance-risk indicators (PRI) that were associated with HEB users' health and safety risks were listed for the participants. The initial construct was intended only as a guide for participants. This follows the suggestion by Ali and Al (2008) that an initial set of variables to identify the categories, indicators and parameters that could be involved in the assessment system should be provided to help and inform the qualitative interview guide.

In this section, 25 indicators were identified as having a potential impact on users' health and safety risk if their performance was reported as poor. The 25 indicators were listed in the form of a table and the participants were asked to rate "*Yes*" if they thought the indicator had an impact on users' health and safety risk, or "*No*" if they thought the indicator was irrelevant. At the end of the table, the participants were given the opportunity to offer suggestions for any other indicators that were not listed in the constructed PRI, based on their experience and also to seek other indicators that might be specifically suited for Malaysian HEBs.

3.4.4 Sample selection for the interviews

At the time this study was conducted, there were 20 public universities in Malaysia (MOHE); thus, 20 facility management departments were involved, representing all public universities. The total population for potential participants was drawn from each department, based on the stipulated criteria to qualify them as "experts". Generally, each university has one department that is responsible for maintaining and managing the academic buildings, in terms of physical facade and building services. In this department, the physical facade and building services management is carried out by four divisions; i) Architecture, ii) Civil Engineering, iii) Mechanical Engineering, and iv) Electrical Engineering. Each division is led by their head personnel, together with several assistants and technicians.

Based on the listed criteria and samples from each development department in the universities, 58 potential participants were identified to constitute the sample for this interview. Table 3.3 shows the details of each division and department at all universities. The selected sample of the population fulfilled the criteria as interviewees. Collectively, they covered a variety of tasks, duties and responsibilities, but their academic background, knowledge and working experience was sufficient to provide the information required. Because of their knowledge and experience, they were also highly eligible to verify and validate the preliminary data obtained by the researcher.

Table 3.2: Sample of potential participants in building maintenance divisions

Item	List Of HEB	Department/ Division	No. of Participants
1	Universiti Malaya (UM)	Department of Development and Asset Management (JPPHB)	3
2	Universiti Sains Malaysia (USM)	Development Department Engineering Campus	3
3	Universiti Kebangsaan Malaysia (UKM)	Division of Development and Maintenance Department	3
4	Universiti Putra Malaysia (UPM)	Development and Asset Management	4
5	Universiti Teknologi Malaysia (UTM)	OSHE Division, Development Division	2
6	Universiti Teknologi MARA (UiTM)	Department of Development and Facilities Management	4
7	Universiti Islam Antarabangsa (UIAM)	Facilities Monitoring Unit	1
8	Universiti Utara Malaysia (UUM)	Development and Maintenance Unit	4
9	Universiti Malaysia Sarawak (UNIMAS)	Division of Development and Asset Management	2
10	Universiti Malaysia Sabah (UMS)	Development and Maintenance Unit (Research & Innovation)	1
11	Universiti Pendidikan Sultan Idris (UPSI)	Facilities Management Division	2
12	Universiti Sains Islam Malaysia (USIM)	Department of Development and Facilities Management	4
13	Universiti Malaysia Terengganu (UMT)	Development and Property Management Office	3
14	Universiti Tun Hussein Onn (UTHM)	Development Office (Maintenance Division)	3
15	Universiti Teknikal Melaka (UtEM)	Department of Development and Asset Management (Maintenance Division)	2
16	Universiti Malaysia Pahang (UMP)	Development Department	4
17	Universiti Malaysia Perlis (UNIMAP)	Department of Development (Maintenance)	3
18	Universiti Sultan Zainal Abidin (UNISZA)	Department of Development and Facilities Management	3
19	Universiti Malaysia Kelantan (UMK)	Centre of Services and Infrastructure Development (Maintenance and Services Division)	3
20	Universiti Pertahanan Nasional (UPNM)	Development and Maintenance Department	4
Total No. of Potential Participants			**58**

3.5 Phase 2: The Main Survey (Questionnaire, and the Analytical Hierarchy Process)

The next stage in the methodology was the main survey. This stage requires more comprehensive criteria and assignment of a numerical weightage factor for each indicator. The objective of the main survey is to determine the level of risk impact on users' health and safety from possible defects or poor performance of the indicators in higher educational buildings (HEB), and also to determine the weightage or ratings for each indicator. The outcome of this survey is the information needed to develop the performance rating tool. Since each indicator is to be assigned with weightage factors, the ratings require knowledge from people who understand the building performance issues, the meanings of the indicators and also the significance of the risk impact on the users. Therefore, the ratings can be expected to be more valid and dependable if they are determined by experts in the field. Therefore, the Analytical Hierarchy Process (AHP) application was adopted for this main survey, which can help to answer the study questions more appropriately.

3.5.1 Design and Administration of the Main Survey

A questionnaire survey was used as the main instrument for the main survey. A set of indicators, called Performance-Risk Indicators (PRI), was constructed based on the findings of the semi-structured interviews conducted at the preliminary survey stage. The list guided the design of the questionnaire for the main survey. To derive the weighting as systematically as possible, the PRI in the proposed rating tool was initially established in collaboration with the identified building operators in all HEBs.

A sample set of the questionnaire accompanied by a letter of invitation were distributed to the shortlisted respondents, following a telephone conversation to confirm their agreement to set a date for this survey. The invitation was also necessary because the main survey involves AHP. The invitation stated that the experts will meet in a focus-group approach, since the researcher needs to clearly explain the application of AHP to the respondents. It was decided not to administer the AHP during a one-day workshop, as is frequently the way it is managed, because of problems gathering all the experts together on the same day and at the same time. Hence, a focus-group approach was used to obtain the data from the respondents.

Before beginning the survey, the respondents were introduced to the purpose of the survey to and shown all sections involved in the survey forms. A detailed explanation was conveyed to the respondents about the application of the Analytical Hierarchy Process (AHP), as most of the respondents were not familiar with the process.

3.5.1.1 The Expert Panels and the Sampling Method

Since the AHP method relies on experts to moderate feedback throughout the process, the panel of experts participating in this main survey was selected following the application of certain criteria. According to Taylor-Powell (2002), 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. The targeted participants for the main survey comprised professionals from the leading public and private organizations related to the facilities management (FM) industry, given their familiarity with the building performance audit or assessment in FM fields.

The sampling frame comprised a list of experts and professionals registered with the Malaysian Association of Facility Managers (MAFM), which records the experience and involvement in building performance evaluation (BPE) of all professionals. Purposeful sampling was used to obtain the required number of experts to act as the potential respondents. The experts to form the panel were shortlisted according to the following criteria:

- Designated in the position of manager or director level or senior academician
- Works in the division of building/facilities audit, BPE or operation and management. For academicians, they must lead in research of and various publications of BPE
- Have experience or involvement in any project related to the educational buildings; currently or previously
- Possess knowledge in the area of risk, health or safety aspects
- Have at least 10 years' working experience, including in previous organisation

Based on the pre-determined criteria of the experts and with help from MAFM's list of members, the initial list included 22 experts. The experts were from different fields including architecture, engineering, surveying and business studies. However, there are no general rules for determining the size of a sample of experts for AHP (Qureshi & Harrison, 2003; Saaty & Özdemir, 2014). The number of participants depends upon the purpose of the survey, the nature of problem, the availability of experts and the diversity of the targeted population.

This process required the experts to provide their justification for the importance of each the construct indicators and also the rating process or weightage for each parameter. After the judgement is completed, the indicators are ranked from the highest order of importance to the lowest order of importance. A final set of weightages assigned for each indicator is presented at the end of stages. As recommended by Cuhls (2003), it is sufficient for the experts to finalise the parameters and help to generate the relative importance score.

3.5.1.2 Objective of the Main Survey

The objective of the main survey is as follows:

i. To determine the level of risk impact on users' health and safety risk, from the possibility of defects, or poor Performance-Risk Indicators (PRI) in higher education buildings (HEBs)

ii. To determine the relative importance score in the construct PRI, using AHP rating scale

The result of the risk impact helps to strengthen the significance of incorporating the users' risk in the assessment of building performance. Lastly, the survey is also conducted to determine the relative importance score in the construct of PRI, using the AHP rating scale. This is also in line with the third objective of this research; to determine the relative importance scores as weightage/ratings in the construct performance-risk indicators. Thus, the result of this survey helps to achieve the main aim of this research which is to develop a building performance risk rating tool, as a performance assessment measure concerning users' health and safety risk in HEBs.

3.5.1.3 Design of Questionnaires

The questionnaire was designed in accordance with the aim and objectives of this research. Questions consist of multiple choice questions, Likert-scale type questions and also comparison pairwise indicators for application of AHP. The questionnaire form begins with a cover stating the purpose of survey and definitions of key terms that were used frequently in the research. This is to enable the experts to better understand the scope and purpose of the research, thus helping to obtain more reliable answers from them. A sample of the questionnaire form is attached in Appendix B. The survey form comprises three (3) main sections and the details of each section are described below.

a) Section A: Demographic Background of the Respondents

In this section, the general demographic questions are divided in two parts; i.e. part A1 and part A2. Part A1 includes five (5) questions that consist of the respondents' gender, academic background, working sector, years of experience and the level of their position (in the current organisation). In part A2, the questions concern the respondents' tasks in the organisation, and there are four multiple choice answers to choose from. The demographic questions in part A1 and part A2 were designed in accordance to the criteria for respondents that were predetermined during the early stage of the experts' selection.

b) Section B: The Level of Risk Impact on the Users' Health and Safety

In this section, the respondents are required to rate the level of risk impact on the users' health and safety, resulting from poor levels of performance of each PRI. This section is also divided into two parts: Part B1 is the rating of risk impact on health risk and Part B2 is the rating of risk impact on safety risk. The PRI consists of 26 indicators that were derived from the results of the preliminary survey. There are five (5) scales for the risk rating that describe different levels of impact; i.e. little, minor, moderate, major and catastrophic. The scale for the risk rating was adopted from the assessment description in BARIS and risk precedence by Massingham (2010); Whitfield (2003) and Zou et al. (2008). (A table of definitions of risk impact is attached to the survey form as an appendix.)

c) Section C: The Analytical Hierarchy Process (AHP) for the Performance-Risk Indicators (PRI)

Section C in the survey form is further divided into three sub-sections: i) Section C1: Functional Performance, ii) Section C2: Technical Performance, and iii) Section C3: Indoor Environmental Performance. Section C requires the respondents to compare the importance between two pairwise indicators and rate the scale of importance for the chosen indicator. The rating process for this section is parallel to the process of AHP, where each of the indicators needs a pairwise comparison of its importance. Following Saaty (1990, 2008), there are nine (9) scales of importance and the description of the scale is Shown in Table 3.4. The data obtained from this section are crucial for this survey, and for the study. Hence, each respondent was briefed on the procedure for rating the importance scale of AHP by the researcher. A detailed explanation of the application and strength of the AHP method is given in the next section.

Table 3.3: AHP Scale of Importance

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

Source: Saaty (1990, 2008)

3.5.2 Overview of Analytical Hierarchy Process (AHP) method

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, Ho et al. (2008) and Yau (2006) recommended using the Analytic Hierarchy Process (AHP) developed by Prof. Thomas L. Saaty in 1977. 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 (M. Alexander, 2012; Bunruamkaew, 2012; Saaty, 1990, 2008). In AHP, all criteria or parameters are assigned with a weightage score that shows the importance of each criterion. The criterion with the 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 disciplines as a decision making tool. It was also adopted by previous building performance schemes such as LEED, BHHI, BSCI to develop a hierarchy or rating tool (Ho et al., 2008; Poveda & Lipsett, 2011). AHP has also been used to assess risk in a supply chain, as mentioned by Pujawan and Geraldin (2009). As recommended by Yau (2006), 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, and Yau (2006) comments that the AHP can 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 eliminates any biassed result as the judgment on weightage depends on the experts' decision. Moreover, the methodology of AHP allows for the internal consistency of the respondents' results to be checked, which is essential for the identification of any illogical set of responses.

3.5.2.1 Computation Details of AHP

The detail of computations of factor weights and consistency ratios using the AHP is explained as follows:

a) ***Matrix of pairwise elements (reciprocal matrix)***

A matrix of pairwise criteria is needed before a reciprocal matrix can be calculated. For example, there are three criteria given as A, B and C. The scale of importance is summarised in a matrix table, as shown in Table 3.5:

Table 3.4: Comparison matrix of criteria in AHP

Criteria	A	B	C
A	1	5	7
B		1	6
C			1

The above table interprets the scale of importance as follows:

- A is more important than B, with importance scale of 5.
- A is more important than C, with importance scale of 7.
- B is more important than C, with importance scale of 6

The lower triangular matrix is filled using reciprocal values from the upper diagonal. The equation is as shown in Equation 1;

$$a_{ij} \equiv \frac{1}{a_{ij}} \qquad \text{(Equation 1)}$$

Where,

a_{ij}= the element of row $_i$ and column $_j$ of the matrix

$$\begin{bmatrix} 1 & 5 & 7 \\ \frac{1}{5} & 1 & 6 \\ \frac{1}{7} & \frac{1}{6} & 1 \end{bmatrix}$$

Each column is summed up to obtain the reciprocal matrix. Hence, the example of reciprocal pairwise matrix with the sum of each column reciprocal matrix is shown as follows:

	A	B	C
A	1	5	7
B	0.20	1	6
C	0.1429	0.1667	1
sum	**1.3429**	**6.1667**	**14**

b) Normalised Pair-Wise Matrix

Before Eigen vector can be calculated, the matrix needs to calculate the normalised score of each element. To generate a normalised pairwise score, each element of the matrix a_{ij} is divided by the sum of each column (in the reciprocal matrix). The sum of column normalised pairwise must be equal to 1. Therefore, the normalised pairwise matrix is now illustrated with new score:

	A	B	C
A	0.7447	0.8108	0.5000
B	0.1489	0.1622	0.4286
C	0.1064	0.0270	0.0714
sum	**1**	**1**	**1**

c) Priority Vector

To determine the weightings, Eigen vector is calculated in accordance to each criterion. The normalised principal Eigen vector can be obtained by averaging across the rows at each criterion. The sum of normalised score at $_i$ is divided by the total number of criteria $_n$ to generate the weighted matrix. Therefore, the priority vector is now illustrated with the calculation of Eigen vector:

	A	B	C	Normalised Sum (each row)	Eigen Vector	Weight
	0.7447	0.8108	0.5000	2.0555	0.6852	68.52%
Priority Vector	0.1489	0.1622	0.4286	0.7397	0.2466	24.66%
	0.1064	0.0270	0.0714	0.2049	0.0682	6.82%
	1	**1**	**1**	**3**		**100.00%**

Through comparing the relative importance of every pair of attributes on the same level in the process of pairwise comparisons, the respondents' subjective weightings of the different attributes for this research is extracted using the AHP computer software *Expert Choice* 11 version 3.10.

3.5.2.2 Consistency and Reliability of AHP

According to Ho et al. (2008), the AHP procedure for weighting determination is often deemed more reliable than direct weighting allocation, because the former allows for the checking of internal consistencies in the answers from each respondent. Problems with weights and scores are overcome by using pairwise relative comparisons and incorporating redundancy, thus reducing errors and providing a measure of the consistency of judgments.

As suggested by Saaty (1990, 2008), the internal consistency ratio (CR) must be less than 0.1 (10%). By using *Expert Choice*, the computer package will locate possible sources of inconsistency. The internal consistency ratio at any level is not smaller than 0.1 (10%). Hence, a data item that indicates a consistency ratio greater than 0.1 is considered as reliable and acceptable.

3.6 Phase 3: The Development of The Rating Tool

The results from the preliminary survey and main survey are intended to provide a new insight into building performance, risk frames and the impact on the building users. Hence, in the third phase, the development of the building performance rating tool is suggested based on the results and analysis of the preliminary survey and the main survey. The discussion and interpretation of the results justify the used of mixed methods that facilitate the development of the rating tool. The reliability and validity of the developed rating tool is further tested on a building in one Malaysian university (i..e. a higher educational building or HEB), as a sample building for tool testing. The fourth objectives are achieved in this phase.

The procedures described above assisted in the establishment of the proposed framework. The Analytical Hierarchy Process (AHP) was used to provide the scale of importance for the PRI. The rating of AHP was carried out during the process of collecting data for the main survey. Therefore, the results from the survey were used for the initial development of the Building Performance-Risk rating tool. The data were analysed using the computer software *Expert Choice* 11 version 3.10. The software was appropriate as there is no limit for the number of criteria to be keyed-in. The software also makes it possible to combine all participants' pairwise comparisons, and it provides the result of priorities in a clear format.

A further development was extended by generating the performance-risk score and performance elements score with equations. Following established performance tools such as BREEAM, LEED, GBI, BHHI, and BSCI, the development of the score is needed for final classification of overall performance assessment of buildings. The weighting or index for each indicator is retrieved from the result of AHP. The classification shall be the benchmark for the performance of the building in regards to users' health and safety risks.

3.7 Statistical Analysis Technique

For this research, descriptive analysis was used to present the demographic data of all respondents from the preliminary survey and the main survey. Several statistical analyses were also used to determine the reliability of the data obtained, thus enhancing the robustness of the research objectives for this study.

3.7.1 Reliability Analysis

A reliability analysis for the questions in the main survey form was carried out using the Statistical Package for the Social Science (SPSS) version 16. According to Barua (2013) reliability tests are important when derivative variables are intended to be used for subsequent predictive analyses. If the scale shows poor reliability, then individual items within the scale must be re-examined and modified or completely changed as needed (Barua, 2013).

Hence, Cronbach's alpha was used as the reliability test statistic for this study. Cronbach's alpha is able to determine the internal consistency or average correlation of items in a survey instrument (Santos, 1999). It is also selected due to its widespread use and ease of understanding. The reliability test is carried out to test whether the questionnaire is measureable or not. Hence, for this study, the presentation of the analysis provides data tabulation of the alpha value obtained from the reliability test. A further analysis based on the perceived alpha value was also inserted after the tables.

3.7.2 Mean rank

Mean is used to present descriptive statistics by determining the centre of a value for which the observed data has the highest likelihood. This likelihood has to be calculated from a probability distribution for the deviations of the observed values from this hypothetical center. Mean rank helps to ease the result of data by presenting a specific data (Chua, 2012). Mean summarises the data and convey information in a concise way about distributions. Hence, it put the values in one numerical order and then denote where in the ordered set they fall rather than percentage distribution. There is no hypothesis testing carried out for this research, hence, mean rank is used to present the result. As supported by Lau et al. (2012), mean is not useful for hypothesis testing and forecasting.

3.8 Summary

The research methodology consists of a serial chronological process that requires a step-by-step approach. The methodology was systematically conducted based on three phases; i) Phase 1: the Literature Review and the Semi Structured Interview (preliminary survey), ii) Phase 2: The Questionnaire Survey (main survey), and iii) Phase 3: The Development of the Rating Tool. These phases are designed specifically to ensure the achievement of the research objectives and to answer all the research questions. The analysis of data using software such as *Atlas.ti*, Statistical Package for the

Social Sciences (SPSS) and the *Expert Choice* 11 helped to present a more robust and reliable analysis .

The next chapter provides the results from the preliminary survey to obtain the validity of the performance elements and performance-risk indicators based on the view and judgment from the operators/managers of university building. The analysis of semi structured interviews with the experts is also interpreted as the further findings of the survey to strengthen the validity of the elements and the indicators, and to provide an initial framework for the development of the building performance risk rating tool.

CHAPTER 4

ANALYSIS AND DISCUSSION OF FINDINGS FROM THE PRELIMINARY SURVEY (SEMI-STRUCTURED INTERVIEWS)

4.1 Introduction

This chapter presents an analysis of the findings from the semi-structured interviews, which were the main instrument in the preliminary survey. The objective of the preliminary survey is to identify the suitability of the construct performance criteria, namely Performance-Risk Indicators (PRI), that are associated with users' health risk and safety risk. To reiterate, these interviews were conducted for the following purposes:

i. to elicit respondents' views and judgments on the incorporation of users' health and safety risk in building performance evaluation

ii. to suggest and support the constructs of performance-risk indicators (PRI) that relate to users' health and safety risk, in higher educational buildings

A detailed explanation of the research approach, techniques for the survey and the interviews was provided in the previous chapter. The responses and results summarized from the preliminary survey provided evidence from the building operators, as the participants in the interview session. The results of interview questions were analysed using Atlas.ti qualitative software version 7.1.6, while demographic information and the suitability of indicators were analysed using the Statistical Package for the Social Sciences (SPSS) software, version 16.

4.2 Analysis Of The Interviews

The interview sessions were conducted from March to August of 2014, through face-to-face meetings and, in some cases, through telephone conversations. Each session lasted between 30 minutes and 1 hour. For the analysis of the interview, the findings were recorded in accordance to the sections of the interview form. The interview forms consisted of three sections, i) Section A: Demographic background, ii) Section B: Rationale of Risk in Building Performance and iii) Section C: Indicators of Performance and Risk in Higher Educational Buildings.

4.2.1 Section A: Particulars Of Interviewee

Fifty-eight (58) building operators were shortlisted as the potential participants for the interview survey. The samples were selected from personnel at the relevant department of each organisation and also their job designation and background. Screening forms were then distributed to the persons identified in order to obtain a formal agreement from them for the interview session and also to attain additional personal information. Based on the returned screening forms, 18 building operators agreed to participate in the interview survey. The rate of response for the interview survey (18 participants from a pool of 58) is 31.03%. Even though the response rate is small, it is sufficient as, according to Travers (2010), there are no pre-set rules on the number of interviews needed for a qualitative survey. For interviews, the sufficiency of response depends on the objective of survey. When the data from interviews has achieved saturation level (i.e. no new information is forthcoming), the interviewer may stop his or her survey (Travers, 2010). This is also supported by Chua (2011) who stated that as few as five participants are sufficient to validate the data if the demographic background of the interviewees is rather similar.

Table 4.1: Composition of interview participants according to HEB

ITEM	HEB	DEPARTMENT/ DIVISION	NO. OF PARTICIPANTS	REF.
1	Universiti Malaya (UM)	Department of Development and Asset Management (JPPHB)	1	#R2
2	Universiti Sains Malaysia (USM)	Development Department Engineering Campus	1	#R5
3	Universiti Kebangsaan Malaysia (UKM)	Division of Development and Maintenance Department	1	#R6
4	Universiti Putra Malaysia (UPM)	Development and Asset Management	1	#R7
5	Universiti Teknologi MARA (UiTM)	Department of Development and Facilities Management	2	#R1 #R3
6	Universiti Islam Antarabangsa (UIAM)	Facilities Monitoring Unit	1	#R8
7	Universiti Utara Malaysia (UUM)	Development and Maintenance Unit	1	#R9
8	Universiti Malaysia Sarawak (UNIMAS)	Division of Development and Asset Management	1	#R11
9	Universiti Malaysia Sabah (UMS)	Development and Maintenance Unit (Research & Innovation)	1	#R18
10	Universiti Pendidikan Sultan Idris (UPSI)	Facilities Management Division	1	#R12
11	Universiti Sains Islam Malaysia (USIM)	Department of Development and Facilities Management	1	#R15
12	Universiti Tun Hussein Onn (UTHM)	Development and Property Management Office	1	#R13
14	Universiti Teknikal Melaka (UtEM)	Development Office (Maintenance Division)	1	#R4
15	Universiti Malaysia Pahang (UMP)	Department of Development and Asset Management (Maintenance Division)	1	#R10
16	Universiti Malaysia Perlis (UNIMAP)	Development Department	1	#R17
17	Universiti Sultan Zainal Abidin (UNISZA)	Department of Development (Maintenance)	1	#R14
18	Universiti Pertahanan Nasional (UPNM)	Development and Maintenance Department	1	#R16
Total No. of Interview Participants			**18**	

For each of the HEB units in all 20 universities, at least one representative who met the selection criteria agreed to participate in the interview. Hence, the responses are likely to be more varied compared to responses from a larger number of participants but from a smaller number of units. However, representatives from three universities (Universiti Malaysia Terengganu – UMT, Universiti Malaysia Kelantan – UMK, and Universiti Teknologi Malaysia – UTM), could not be included for the interview due to failure of response and/or data miscommunication. Thus, the total number of participants was 18, with two representatives from Universiti Teknologi MARA (UiTM), and one from each of 16 other universities.

4.2.1.1 Gender of the Participants

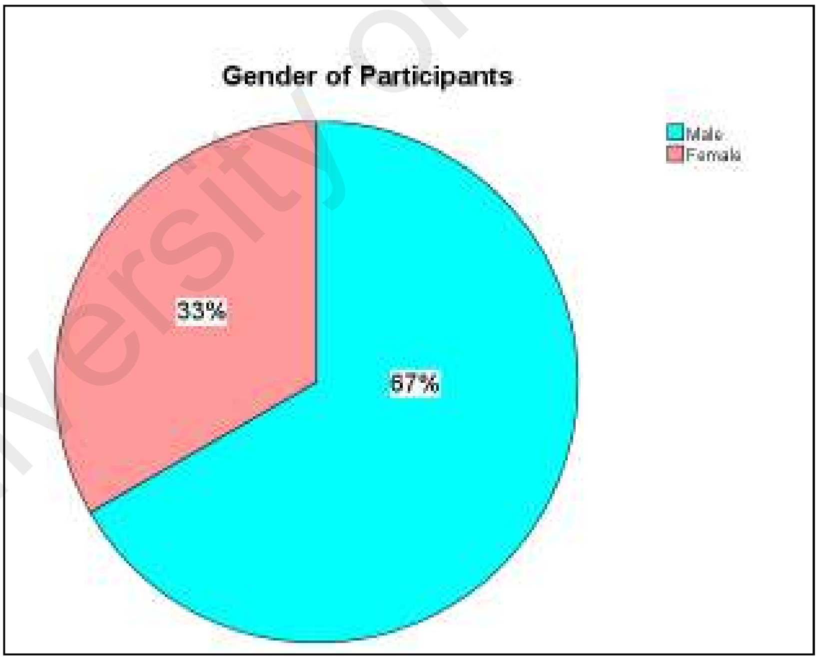


Figure 4.1: Gender of the interview participants

As depicted in Figure 4.1, 67% of the total of eighteen respondents were male and the remaining 33% were female. Thus, the majority of senior personnel in the maintenance management or facilities management organizations in public universities are male.

4.2.1.2 Academic Background

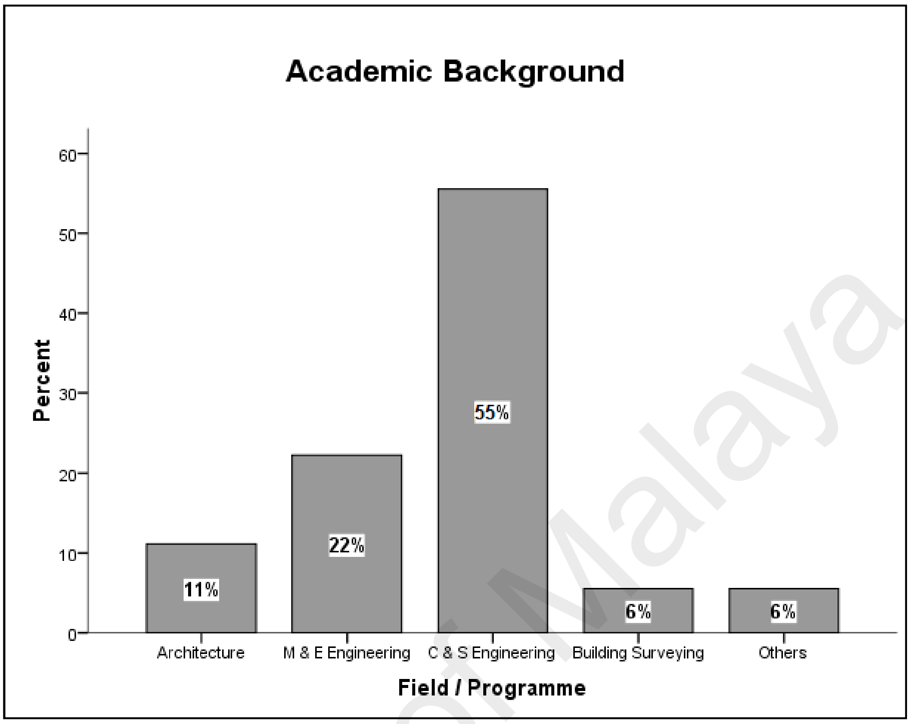


Figure 4.2: Academic backgrounds of the interview participants

The academic background of the majority (56%) of the participants is in civil and structural engineering, followed by mechanical and engineering (22%), architecture (11%), building surveying (6%) and others (6%). This is in line with the division within maintenance or facility management that basically has three (3) main divisions; civil works division, electrical and electronic works division, and mechanical works division.

4.2.1.3 Working Experience

Figure 4.3 shows that 56% of the participants affirmed that they have working experience of between 10 to 14 years in the field. The next largest group (28% of the respondents) have 5 to 9 years' working experience, and 17% have more than 15 years working experience. The result shows that all respondents met the identified criteria as participants for the interview survey.

Figure 4.3: Years of Working Experience for the Interview Participants

The participants were also asked about the length of time they have worked in the current organisation. From the results (shown in Table 4.2) it can be seen that their experience in their current organisation ranges from one year to 14 years. Even though several participants are still new staff in the organisation, their previous working experience is sufficient to provide the needed information.

Table 4.2: The Participants' Years of Experience (in the current organisation)

PARTICIPANTS' REFERENCE	ORGANISATION	YEARS OF WORKING (in the current organisation)	WORKING EXPERIENCE (including previous organisation)
R1	UiTM	13 years	More than 15 years
R2	UM	9 years	5 – 9 years
R3	UiTM	10 years	10 – 14 years
R4	UTEM	5 years	More than 15 years
R5	USM	7 years	10 – 14 years
R6	UKM	14 years	More than 15 years
R7	UPM	8 years	5 – 9 years
R8	UIAM	9 years	10 – 14 years
R9	UUM	13 years	10 – 14 years
R10	UMP	9 years	10 – 14 years
R11	UNIMAS	11 years	10 – 14 years
R12	UPSI	12 years	10 – 14 years
R13	UTHM	4 years	5 – 9 years
R14	UNISZA	3 years	10 – 14 years
R15	USIM	4 years	5 – 9 years
R16	UPNM	2 years	10 – 14 years
R17	UNIMAP	5 years	10 – 14 years
R18	UMS	1 year	5 – 9 years

4.2.1.4 General Task or Duty

The participants were required to provide information on their general task in the organisation. Five (5) duties were listed in the screening form and the participants were also free to state other tasks if their duty was not listed. Figure 4.4 shows the participants' general duty and responsibility.

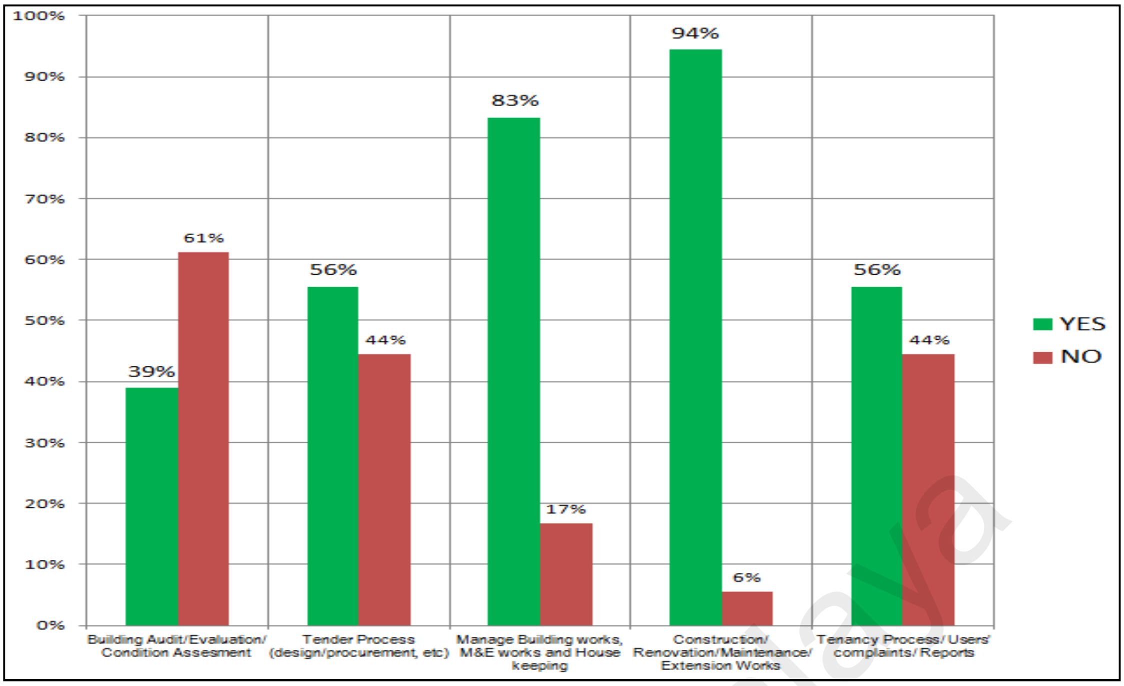


Figure 4.4: Participants' General Duty and Responsibility

Almost all participants (94%) stated that they are responsible for construction, renovation, maintenance and extension works. The next most frequently cited task was managing the building works, mechanical/ electrical works and housekeeping task, which was cited by 83% of the participants. A similar percentage, 56%, was reported for both the tasks of tendering process (design/procurement) and the handling of users' complaints/report, while only 39% of the participants reported being responsible for conducting building audits, evaluation or assessment. It can be summarised that building performance evaluation tasks are not a major element in the current management of university buildings in Malaysia.

4.2.2 Section B: Rationale of Risk in Building Performance

In this section, the analysis was carried out through content analysis and also qualitative software, *Atlas.ti*. For question one (Q1), question three (Q3) and question four (Q4), the interpretation of the answers is presented using a network generated by

Atlas.ti, since the coding and the nodes are able to be generated in a simple manner. For question two (Q2) and question five (Q5), the interpretation of the participant's responses was summarised through content analysis and presented in a tabular form. At the end of the interpretation of the findings, computer software *Atlas.ti* was used to present the relationship and associations of all coding and quotations, in accordance with the interview questions. Using this method, the answers could be connected to the set of coding, thus strengthening the justification of the research and the survey's objectives.

4.2.2.1 Analysis of Q1: The assessed building items

The first question asked the interview participants about the building items that are generally managed or maintained in the university building. The responses to the question are depicted in an *Atlas.ti* network using coding and quotations, as shown in Figure 4.5.

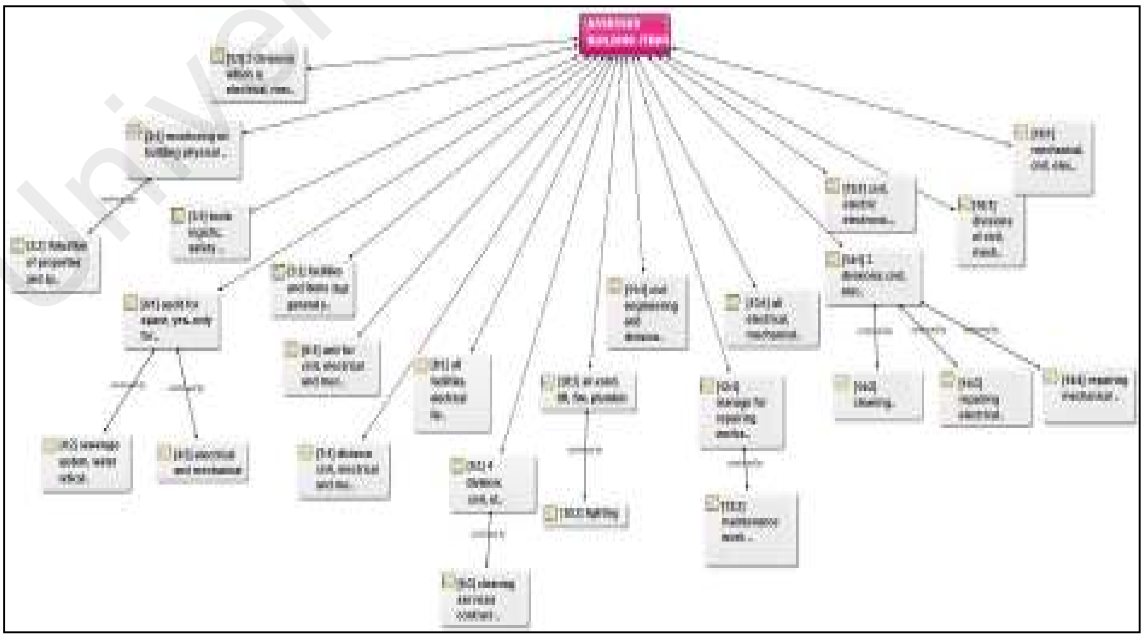


Figure 4.5: The participants' Responses on the Assessed Building Items

Based on the responses shown in Figure 4.5, it is revealed that the building items that are generally managed or maintained consist of three major components; electrical items, mechanical items, and civil/structural items. The coding was provided from Participant 1, Quotation 1 (p1:q1) and also by the other participants in their quotations (p2:q1, p3:q1, p4:q2q3, p5:q1, p6:q1, p7:q1, p8:q1, p9:q1, p10:q1, p11:q1, p12:q1, p13:q1, p14:q1, p15:q1, p16:q1, p18:q1) as shown in Figure 4.5. All of these components were then sub-divided into several items. The participants also explained that each division is led by the head of personnel and the tasks are allocated in accordance with campus zones. A probe question was asked on the assessment programmes used to manage the building items. Generally, the participants affirmed that their assessment programmes were based on scheduled programmes (certain items for electical and mechanical works) and ad-hoc programmes (for immediate action or repairing works). However, the frequency of scheduled assessment or maintenance programmes is not uniform, since some of organisations carried them out once every three months and several conducted them once a month.

4.2.2.2 Analysis of Q2: The risks encountered when the building experienced poor performance

Proceeding to the next question, the participants were asked about any risks that they have encountered or were aware of when the building experiences performance failure. The responses are presented in Table 4.3, as follows:

Table 4.3: Encountered risks due to the building performance failure

QUESTION	PARTICIPANT'S REFERENCE	ANSWER
What are the identified risks that you have encountered when the building experienced poor performance	P1	Safety and health risks, it is under my scope after all
	P2	Yes, there are a few risks, there is definitely a safety risk, security risk, the risk of deterioration
	P3	Yes, various risks. We've identified risk in terms of user's health (for example the usage of facilities is not suitable; some facilities do not meet the specifications).
	P4	Risk of building defects, safety and health risks to the user, but it is only recorded as remarks in the form (if assessed by outsourced contractors). We will ask them to rectify immediately
	P5	Indeed, we found many risks; for example, if the roof leaks, we are concerned with the risk of building structures being affected if it is not repaired. It could also lead to severe damage to property and harm the occupants
	P6	Many risks and the buildings will be more severely affected so we identify any emergence of risks. We also stress to the staff, if the damage occurs, the users' safety is our first concern.
	P7	Yes, common risks such as the risk of damages
	P8	Risk towards the building, economical risk, user's risk
	P9	No doubt that risk exists if the building is not repaired quickly. Risks to the public and users of the building as an example. In any case, the action should look into the serious level of the defects and also the needed budget.
	P10	The health risk to the occupants, yes, we've encountered and also safety/security risk. In terms of structure damage, I'm not very sure about it since I'm not in the building structure divisions.
	P11	The most important, building safety risks that will be affected, and certainly when the building is unsafe, it will jeopardize the users. Yes, I can say that there is also risk to occupants' safety and health
	P12	There are many risks that we've encountered. Usually like serious cases; leaking roof, leaking pipes, lift (not functioning), electrical damage. We emphasize that it will immediately affect safety. So, there is an emergence of safety risk.
	P13	Yes, a lot...safety risks, the risk of failure, the risk of safety to the users.
	P14	Safety risks
	P15	Safety, security risks, the risk of defects. Wide scope
	P16	Yes, safety risk especially. Others; comfort risk
	P17	The most major impact is a safety risk. Safety may include the building itself, the equipment, the occupants (the staff, the students), the passersby.
	P18	Risks to the building itself (the risk of deterioration, collapse) mostly involving mechanical and electrical compartments

It is revealed that most of the participants identified safety risk as the most important risk. The term of safety was extended to the integrity of the building, the user, the facilities; that is, it covered almost all aspects. Health risk was also highlighted by most of the participants. Another risk that they have encountered includes the risk of defects, the risk of building collapse and financial risks.

4.2.2.3 Analysis of Q3: The incorporation of users' health and safety risks in the assessment checklist

In the next question, the participants were asked whether their current assessment list incorporated the user's health and safety risk. The majority of the participants (14 out of 18 participants) responded that their assessment list does not include the risk aspects as criteria for assessment. The answer is supported from the quotations shown in Figure 4.6 (p4:q6q7, p5:q6 p7:q4, p8:q3, p9:q5, p10:q6, p11:q4, p12:q5, p13:q5, p14:q6, p15:q4, p16:q4, p17:q4, p18:q4). However, they are concerned with the risk aspects during the condition survey and it is normally recorded as a remark in the assessment list. The responses for this question are presented in Figure 4.6:

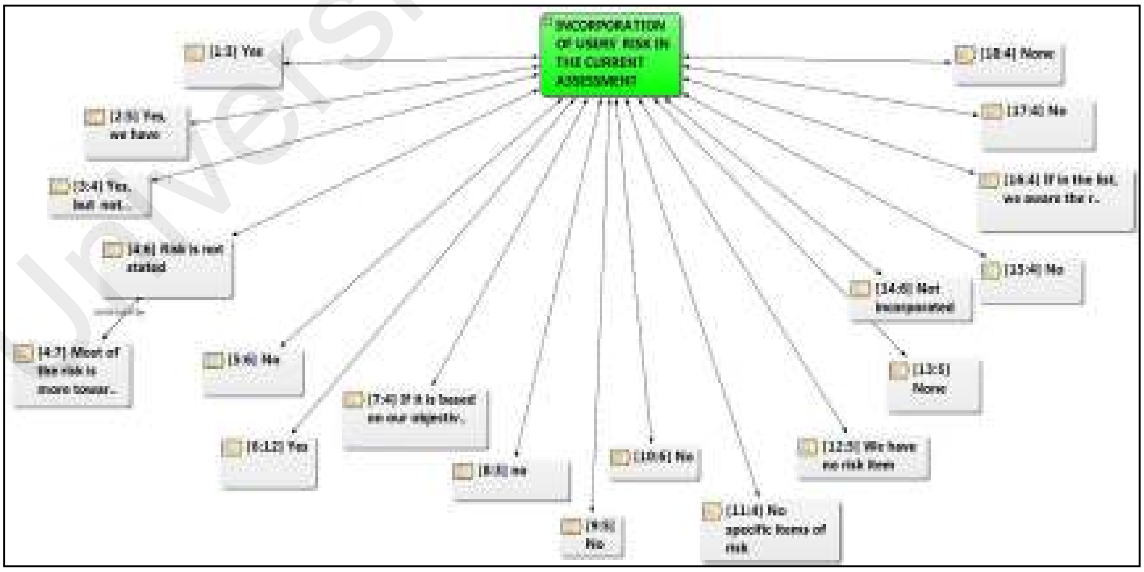


Figure 4.6: Participants' responses on the incorporation of users' risks in their building assessment

Based on the responses shown in Figure 4.6, only four (4) participants stated that their assessment list incorporated the aspect of users' risks, as quoted by participant 1, quotation 3 (p1:q3), participant 2, quotation 5 (p2:q5), participant 3, quotation 4 (p3:q4) and participant 6, quotation 12 (p6:q12). Probe questions were asked in order to figure out the building aspects that are associated with the stated risk. It was found that the risks are included in the standard form used by the government's organisation and the issuance of form is from the National Security Council of Malaysia (MKN). However, the form is too confidential to be revealed as the appendix to this chapter.

Based on the review of the form, the list of items is not comprehensive enough to cover all building aspects. The aspect of safety risks is much concerned with the handling personnel, confidentiality of documents, building access and entrance. Some participants also mentioned that the Occupational Safety and Health Administration (OSHA) division in the university is also associated with the assessment of users' health and safety risks. However, in accordance with the OSHA Act 514 (Laws of Malaysia, 2006), the concerned aspects are not into the building performance assessment, but the aspects are emphasized at the workplace, in occupational works and in handling task of the building facilities.

4.2.2.4 Analysis of Q4: The inclusion of functional, technical and indoor environmental elements into the assessed items

For question no. 4, the participants were asked to refer to the construct performance-risk indicator (PRI) in the interview form to determine whether the items are related to three aspects; functional, technical and indoor environmental aspects. The items are in line with the performance elements highlighted for the construct PRI; functional performance, technical performance and indoor environmental performance. The answers are shown and summarised in coding and quotations in Figure 4.7.

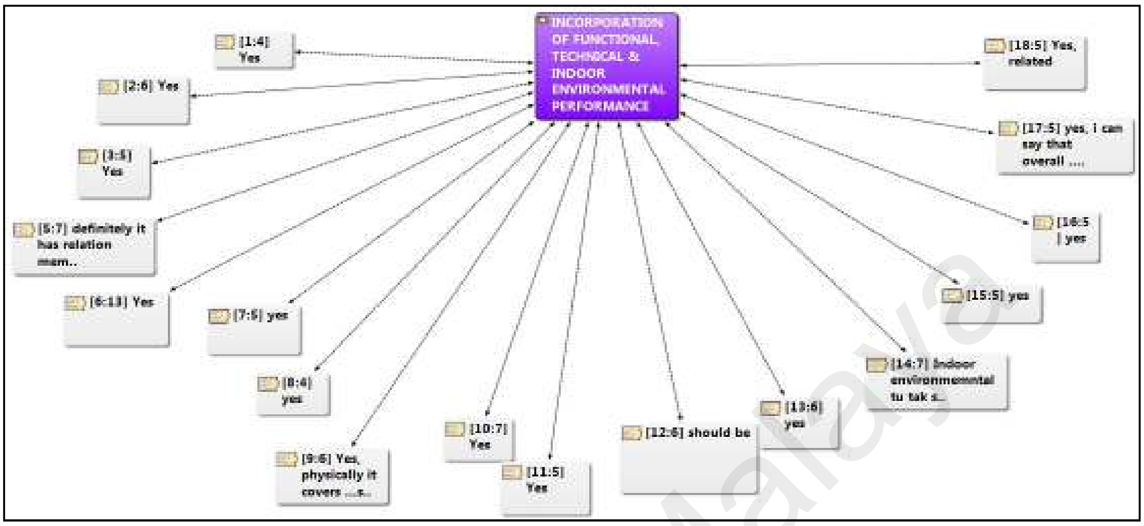


Figure 4.7: Participants' responses on the incorporation of the assessed items towards the building's physical, technical and indoor environmental performance

Based on the responses shown in Figure 4.7, all of the participants agreed that the construct PRI is incorporated and relates to the aspects of functional, technical and indoor environmental performance. The answer is supported from the quotations shown the network view of Figure 4.7 (p1:q4, p2:q6, p3:q5, p5:q7, p6:q13, p7:q5, p8:q4, p9:q6, p10:q7, p11:q5, p12:q6, p13:q6, p14:q7, p15:q5, p16:q5, p17:q5, p18:q5). Hence, the performance elements are accepted to be incorporated into the list for building assessment.

4.2.2.5 Analysis of Q5: Current rating or instrument used to evaluate the performance and users' risk

For the last question, the participants were asked about the current instrument or rating system that they use to assess the performance of the building items. A probe question was also asked about the system or actions towards the building user, if there are any damage that may be hazardous to them. The responses were divided into two groups; i) the participants' responses regarding their current assessment system, and ii) the participants' responses to the existence of a rating tool. Table 4.4 shows their answers for this question.

Table 4.4: Participants' responses on the current instrument or rating tool for building performance assessment

QUESTION	PARTICIPANT'S REFERENCE	ANSWER	
		CURRENT INSTRUMENT?	ANY DEVELOPED RATING TOOL?
What is the current instrument/ unit/rating used to evaluate the performance and users' risk in this building?	P1	We are using the standard form by National Security Council of Malaysia (MKN). It has hierarchy/rating but the items are not covered for the technical and indoor environmental aspects.	So far, no. It is not a comprehensive item.
	P2	We are using the Helpdesk System JPPHB starting 1st February 2012 in place of the previous "Sistem Aduan Penyenggaraan". It facilitates the user to make complaints on any defect occurrence that requires ad-hoc repairs	As far that I am concerned, no current ratings are used.
	P3	-	So far, no rating tool as the instrument. We may construct OSHCO hierarchy, but it will be decided in a future meeting.
	P4	Mostly, based on scheduled and ad-hoc programmes. We also have provided a form for users' complaints.	There is no rating, but is in discussions to build Hirac. So far this has not been adopted yet.
	P5	Current instrument is the CMMS-BEAM as I've described earlier.	In terms of rating or hierarchy, so far it is not yet developed (in this unit).
	P6	What we have now is Sistem Aduan Kerosakan (SAK).	We don't have hierarchy or rating to assess both performance and risk of the user.
	P7	We use a system I-SO (form SOK is used if there are complaints of damages). It can only be accessed by staff and students.	No ratings.
	P8	-	No rating tool at the moment.
	P9	Current instrument that we use is CMMIS (like I mentioned earlier), in addition to that we have also created a call centre to facilitate users to make direct complaints to the JPP unit.	No, we don't have.

Table 4.4 continued

	P10	We have a users' complaint system called CMMS (centralised monitoring management system).	No.
	P11	-	So far, we don't have any rating scheme.
	P12	We have a complaint system (System Aduan Kerosakan).	But there is no rating (you can refer to the guidelines given).
	P13	We have introduced a Facility Management (FM) Helpdesk. It is a system for handling complaints by our users (staff/students) in a more systematic manner.	No rating in this system.
	P14	-	No rating.
	P15	-	No.
	P16	All is based on users' complaint forms.	No ratings.
	P17	We have implemented a SEGAK System - Government Asset Maintenance System for managing the maintenance of buildings and infrastructure.	Curently, we have no rating.
	P18	We have provided "E-Aduan" in our website to make it easier for users to make their complaints	So far, no ratings.

Based on the findings as shown in the above table, all organisations have provided channels for users' complaint to allow any needed actions for immediate repair, for instance. It is revealed that all organisations are depending on the users' complaints or users' report to solve performance failure or issues that may jeopardise users. In the building performance concept, mitigating the risks towards the user needs pro-active actions, and ideally it should be identified before the incidents happen. It can be summarised that in the current system actions are reactive, which is contradictory to the concept of building performance evaluation. A further network by *Atlas.ti* is used to relate the participants' responses based on the coding and quotations. The network relationship is presented in Figure 4.8.

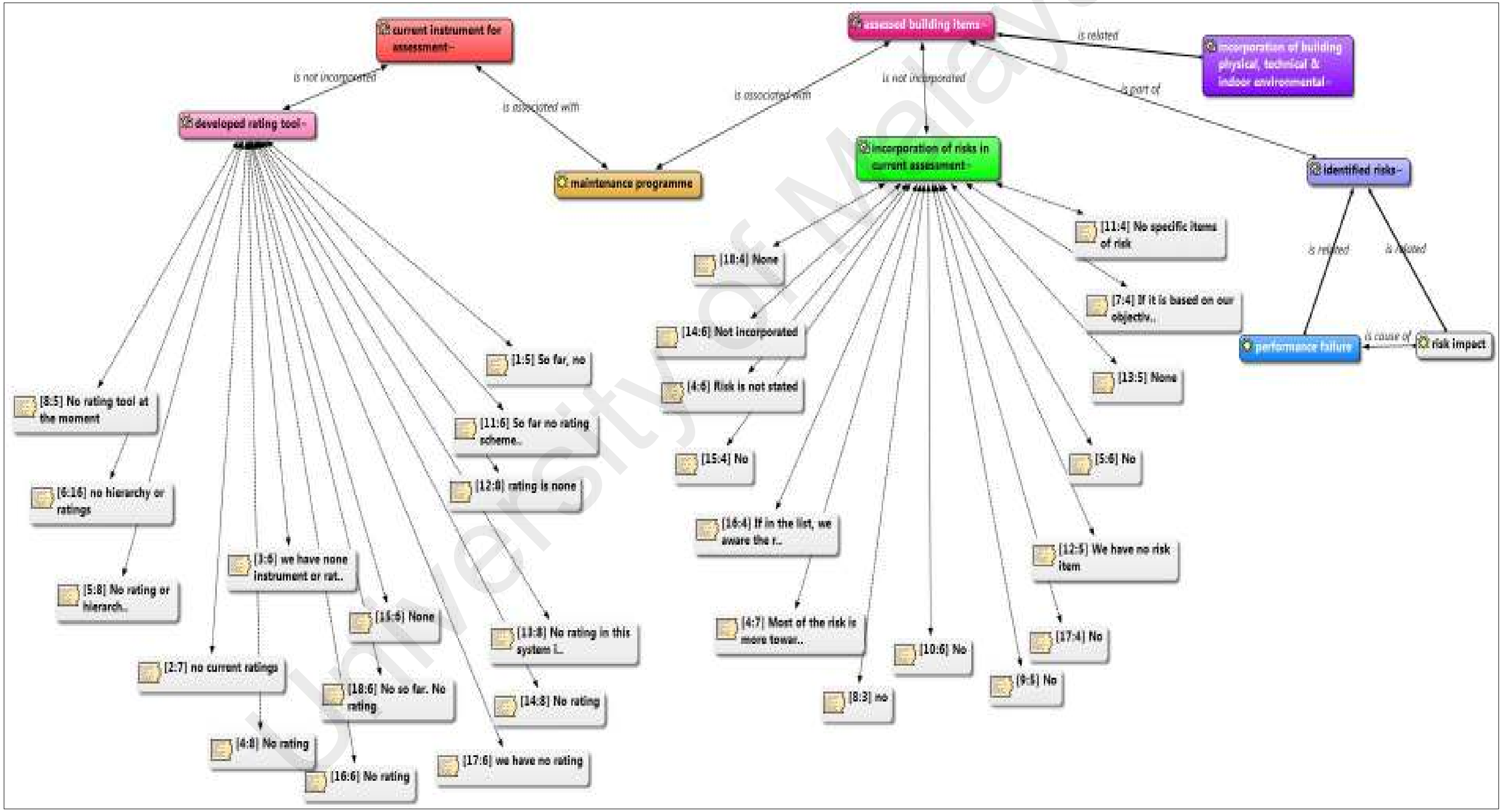


Figure 4.8: Network of main codings and quotations from the interview findings, using *Atlas.ti*

Based on the network of relationships shown in Figure 4.8, it is revealed that the maintenance programmes (*coded in yellow*) in the organisations are associated with the current instrument for assessment (*coded in red*) and they are also associated with the assessed building items (*coded in fuschia*) in the instrument. Most of the aspects of the building's physical, technical and indoor environmental performance (*coded in purple*) are related to the assessed building items (*coded in fuschia*). It is also found that there are risk identifications (*coded in blue*) encountered from the performance assessment of the building items. The responses have summarised that the identified risks are related to performance failure (*coded in teal*) and risk impact (*coded in white*) towards the building user.

However, there is no incorporation of risk aspects in their current assessment (*coded in green*) or into the list of assessed building items. The coding was provided from Participant 18, Quotation 4 (p18:q4) and also verified by the other participants in their quotations (p14:q6, p4:q6, p15:q4, p16:q4, p4:q7, p8:q3, p10:q6, p9:q5, p17:q4, p12:q5, p5:q6, p13:q5, p7:q4, p11:q4). It is also presented that no established rating tool (*coded in pink*) is incorporated into the current instrument or current assessment system. This answer was provided by Participant 8, Quotation 5 (p8:q5) and supported by the rest of participants in their quotations (p6:q16, p5:q8, p2:q7, p4:q8, p3:q6, p15:q6, p18:q6, p16:q6, p17:q6, p14:q8, p13:q8, p12:q8, p11:q6, p1:q5).

Hence, the building performance-risk rating tool requires a list of indicators that can be incorporated into the performance assessment. The list of indicators was initially constructed and shown in Section C. The next section provides the participants' views on the suitability of the indicators for the use of local HEBs.

4.2.3 Section C: Indicators of Performance and Risk for Academic Buildings in HEBs

The analysis of finding for this section begins with suitability of the indicators.

4.2.3.1 The relevance and suitability of the indicators

A list of performance-risk indicators (PRI) was shown to the participants during the interview. The PRI is associated with user's health and safety risks and it is initially constructed to provide guidance for the participants. The participants were asked to rate "*Yes*" if the indicator is suitable for the performance assessment of Malaysian HEBs, or "*No*" if the indicator is irrelevant. Table 4.5 presents the result for this section.

Table 4.5: Descriptive analysis result for the suitability of the performance-risk indicators (PRI)

Performance Elements	Performance-Risk Indicators *(predictor variables)*	Mode (Yes=1 ; No=2)	Frequency (N) Percentage (%) Yes	No
Functional Performance	1. Space	1	18 100%	- 0%
	2. Orientation (direction, layout)	1	18 100%	- 0%
	3. Infrastructure (parking, landscape)	1	18 100%	- 0%
	4. Access/entrance	1	18 100%	- 0%
	5. Circulation area (corridor, lobby)	1	18 100%	- 0%
	6. Ergonomic building facilities	1	18 100%	- 0%
	7. Adequacy of building signage	1	18 100%	- 0%
	8. Emergency exits	1	18 100%	- 0%
	9. Building-related illnesses/ sick building syndrome	1	10 56%	8 44%
Technical Performance	10. Design of building fittings/fixtures (door, window, ironmongery, sanitary)	1	18 100%	- 0%
	11. Structural stability (column, beam, slab, staircase)	1	18 100%	- 0%
	12. Information technology systems operations	1	17 94%	1 6%
	13. Electrical services	1	18 100%	- 0%
	14. Plumbing services	1	18 100%	- 0%
	15. Building integrity	2	8 44%	10 56%
	16. Fire prevention services	1	18 100%	- 0%
	17. Materials & internal finishes (floor, wall, ceiling)	1	18 100%	- 0%
Indoor Environmental Performance	18. Heating (Thermal comfort)	2	6 33%	12 67%
	19. Cooling (Thermal comfort)	1	17 94%	1 6%
	20. Artificial lighting (Visual comfort)	1	17 94%	1 6%
	21. Natural lighting (Visual comfort)	1	13 72%	5 28%
	22. Waste disposal	1	18 100%	- 0%
	23. Building ventilation	1	18 100%	- 0%
	24. Acoustic comfort (Noise)	1	15 83%	3 17%
	25. Level of cleanliness	1	16 89%	2 11%

Based on the result shown in Table 4.5, all 18 of the participants confirmed the relevance of the following 16 indicators, as follows:

- space
- orientation (direction, layout)
- infrastructure (parking, landscape)
- access/entrance
- circulation area (corridor, lobby)
- ergonomic building facilities
- adequacy of building signage
- emergency exits
- design of building fittings/fixtures (door, window, ironmongery, sanitary)
- structural stability (column, beam, slab, staircase)
- electrical services
- plumbing services
- fire prevention services
- materials & internal finishes (floor, wall, ceiling)
- waste disposal
- building ventilation

Subsequently, 94% of the participants have rated "Yes' for the indicators information technology systems operations, cooling (thermal comfort) and artificial lighting (visual comfort). While the other indicators that shows a higher percentage for "Yes" is, level of cleanliness (89%), acoustic comfort (noise) (83%), natural lighting (visual comfort) (72%), and building-related illnesses/sick building syndrome (56%). The indicator of *building-related illnesses* recorded the least difference between "Yes" and "No" responses by the participants, with 44% rating this item as "No". A probe investigation for this result revealed that several participants stated that the indicator is a not a specific building element, and thus it is not being observed as one of the "elements" or "assessed building items". However, since a higher percentage is perceived for its suitability, this indicator has been incorporated as relevant for the establishment of a building performance-risk rating tool. Therefore, 23 indicators were rated as suitable to be used in the context of Malaysia's HEBs.

Out of the 25 indicators that were initially outlined, only two (2) indicators; i) building integrity and ii) heating (thermal comfort), were removed from the list. Those two indicators were rated with a low percentage (less than 50%), and hence, both indicators are considered as not relevant to the Malaysian context of performance assessment in HEBs.

4.2.3.2 Suggestion on other relevant indicator

The participants were also asked to suggest any other indicators or criteria that are relevant to be incorporated into the list. Some of their suggestions and are shown in Table 4.6.

Table 4.6: Suggestions for other relevant indicators

NO.	NEW INDICATOR	PERFORMANCE ELEMENT	REF.
1	Roof	Technical Performance	R3, R16
2	Amenities	Functional Performance	R18, R4
3	Lift	Technical Performance	R10, R18

Three further indicators relating to the roof, amenities and lifts were suggested as additional items that should be incorporated into the building performance-risk rating tool. The participants argued that these items are also associated with the building performance items. Any damage or defects on these indicators will not only constitute failure of the building performance, but also represent an impact on the user's health and safety risk. All of the suggested indicators were accepted for incorporation into the list of PRIs. It is suggested that the indicators of *roof* and *lift* be incorporated under the performance elements (PE) of technical performance, while the indicator *amenities* be incorporated under the PE of functional performance. The justification for the inclusion of these indicators in the list of PRI is given below.

i. Roof

The performance of roof is related to its structural performance. As pointed out by Abdul-Rahman et al. (1999), structural degradation and deterioration may have an impact on the performance quantification of a building in terms of collapse safety. For this study, the aspect of performance for roof deals with the design, structure and function of roof system.

ii. Amenities

Amenities are categorised according to the criteria of building performance (Birt & Newsham, 2009; Hendrickson & Wittman, 2010; Preiser & Schramm, 2002; Preiser, 2002). They are also included in previous rating tools such as GBI, CEPAS, BQA and HK-BEAM. The performance of amenities should meet the requirement of the occupants as they facilitate the building's function: the occupants require basic amenities in a building such as toilets, gyms, cafeterias and pantries. Theories (from Ho et al., 2008; Kim et al., 2005; Liu, 2003; Wang et al., 2005; Yau, 2006) described that amenities with better ambience and open space should be free from crime and vandalism, thereby mitigating the health and safety problems of the users. For this study, the aspect of assessment for amenities is concern for poor access or space of basic amenities for the population of users in HEBs. Basic amenities covers toilets, cafes, pantry, *surau* and other relevant areas that support the main function of the HEB.

iii. Lift

Lifts are important vertical services that provide mechanical operations for buildings, and their performance must be continuously monitored. The provision of lift must incorporate suitable safety management to avoid poor installation and improper fixing of the services (Husin et al., 2012). For this study, the assessment of performance for lifts is related to the satisfactory functioning of the system with minimal problems.

The finding in Section C has contributed to the outcome of constructing the PRI, which is based on its suitability for local HEBs and also the judgments of experts. Hence, the final PRIs based on the results of preliminary survey are presented in Table 4.7:

Table 4.7: The construct of PRI based from the result of preliminary survey

PERFORMANCE ELEMENTS (PE)	PERFORMANCE-RISK INDICATORS (PRI) *(predictor variables)*	REMARK
1. Functional Performance	1.1 Spaces (area)	100% (based on findings)
	1.2 Orientation (direction, layout)	100% (based on findings)
	1.3 Infrastructure (parking, landscape)	100% (based on findings)
	1.4 Access/entrance	100% (based on findings)
	1.5 Circulation area (corridor, lobby)	100% (based on findings)
	1.6 Ergonomic building facilities	100% (based on findings)
	1.7 Adequacy of building signage	100% (based on findings)
	1.8 Emergency exits	100% (based on findings)
	1.9 Building-related illnesses/sick building syndrome	56% (based on findings)
	1.10 Amenities	New Suggestion
2. Technical Performance	2.1 Design of building fittings/fixtures (door, window, ironmongery, sanitary)	100% (based on findings)
	2.2 Structural stability (column, beam, slab, staircase)	100% (based on findings)
	2.3 Information technology systems operations	94% (based on findings)
	2.4 Electrical services	100% (based on findings)
	2.5 Plumbing services	100% (based on findings)
	2.6 Fire prevention services	100% (based on findings)
	2.7 Materials & internal Finishes (floor, wall, ceiling)	100% (based on findings)
	2.8 Roof	New Suggestion
	2.9 Lift	New Suggestion

Table 4.7 continued

3.	Indoor Environmental Performance	3.1	Cooling (Thermal comfort)	94% (based on findings)
		3.2	Artificial lighting (Visual comfort)	94% (based on findings)
		3.3	Natural lighting (Visual comfort)	72% (based on findings)
		3.4	Waste disposal	100% (based on findings)
		3.5	Building ventilation	100% (based on findings)
		3.6	Acoustic comfort (Noise)	83% (based on findings)
		3.7	Level of cleanliness	89% (based on findings)

The above table shows the PRI constructs to be incorporated in the building performance-risk rating tool, with 26 indicators. The PRI constructs constitute the preliminary basis of a framework for further development of the proposed building performance-risk rating tool. It will be developed further with relative importance and assigned weights for each PRI in the next stage (i.e. the main survey) using Analytical Hierarchy Process (AHP) as decision-making approach.

4.3 Discussion Of Findings From The Interviews

Qualitative data can be used for exploring the content validity of an instrument from another perspective and for providing experts with the chance, for example, to suggest rephrasing of items or to supply new items, if so required by the results of a quantitative survey. From the findings, the experts rate the suitability of the items. The discussion on the findings from the interviews is in accordance with the sequence of objectives for conducting the survey. The findings are also discussed to correlate with and validate the content obtained from the literature.

4.3.1 The current Assessment of Building Performance Evaluation

Maintenance programmes in organisations are carried out using the currently available instruments and also associated with the assessed building items in the instrument. Most of the aspects of building's physical, technical and indoor environmental aspects are related to the assessed building items. It was also found that risks identifications are encountered from the performance assessment of the building items. The responses have summarised that the identified risks are related to performance failure and risk impact on the building user, which supports the findings from previous studies (de Wilde & Tian, 2012; Ibrahim et al., 2012; Meacham et al., 2005; Meacham, 2010; Wolski et al., 2000; Yau, 2006).

However, it is concluded that there is no incorporation of risk aspects in the current assessment or in the list of assessed building items in local university buildings. It is also found that there is no established rating tool that focuses on the users' risk currently incorporated into the present maintenance or assessment systems. According to Olanrewaju et al. (2010a), there are no clear key performance indicators; thus, it is difficult to make improvements, since improvement in user satisfaction and productivity cannot be measured or monitored. This situation arises where maintenance systems in local university buildings are not systemic; where maintenance is considered as an operational issue and not, instead, as a strategic issue (Olanrewaju, 2010b). Hence, the findings from these interviews reflect the academic theories and the findings of previous studies. The interpretation of the interview findings further justifies the need for this research, on the grounds that there is currently no pro-active action in executing building performance assessment in order to mitigate risk towards users' health and safety. It also supported the conclusions of Olanrewaju et al., (2010); Olanrewaju

(2010a); and Olanrewaju et al. (2010a), and reveals the prevalence of the current situation in which only reactive action occurs in maintenance management or performance audit in local university buildings.

The interview findings also help to strengthen the aim of this research, which is to develop a building performance rating tool, incorporating risk mitigation concerning health, safety and environmental aspects towards the building occupants in higher educational buildings (HEB). Hence, the development of the building performance rating tool shall aid improvements in addressing users' risk in terms of health and safety aspects.

4.3.2 Rationality of Users' Risk in Building Performance Evaluation

The findings are in agreement with the literature that emphasizes the element of risk into Building Performance Evaluation (BPE) as pro-active measures. It is in line with the precedent studies carried out by Almeida et al., (2010); Lützkendorf & Lorenz, (2007), (2006); Lützkendorf & Speer, (2005); Meacham et al., (2005); Meacham, (2010); Thompson & Bank (2007); Wolski et al., (2000); and Zalejska-Jonsson (2012), that diverts the principles of sustainable buildings by underlining the vulnerability of risk in building performance.

The findings illustrate that performance issues in higher educational buildings require thorough improvement, as they may contribute to risk factors to the building's users. This is supported by Woods (2008) who argued that the principles in risk tend to firstly minimize the impact of building performance and then control for the health, safety and well-being of the building's occupants. According to Tchankova (2002), the idea of integrating new risks highlights a persistent approach in identifying the present and future risk to the organisation. In terms of identifying users' risk, it falls into the category of physical, operational and social environment risk that impact the well being of users due to failure of a building's physical structure and operation, as maintained by Tchankova (2002). Hence, it can be concluded that the incorporation of users' risk into the performance of a building is rational and necessary for continuous improvement in the building's sustainability.

4.3.3 Identification and Suitability of the Indicators

As an outcome of the preliminary survey, 26 indicators were identified as the elements capable of generating risk to users' health and safety. The listed indicators are confirmed as the predictor variables that can contribute to the performance level and the users' health and safety risk. The list of indicators differs from previous established performance rating tools, as it prioritises the elements of risk to the building users of health and safety aspects. However, the process of identifying risk sources is essential in order to continuously achieve improvements in building performance, as stressed by de Wilde & Tian (2012) and Lützkendorf & Lorenz (2007).

Therefore, a further risk analysis can be carried out to determine the level of risk impact on users, whether the risk is little, minor, major or catastrophic. Subsequent action is needed to mitigate the risk by improving the performance of the indicator that has a higher ranking of risk. The process of identification is consistent with the process of risk management that begins with risk identification, is followed by risk analysis and ends with risk response (Tchankova, 2002; Thompson & Bank, 2007). Hence, the result supports the justification to advocate the principles of a risk approach as it is based on the presumption that individuals are ultimately affected by the various sources of risk.

4.4 Summary

The research findings have confirmed that performance-risk can be appropriately categorised into functional performance, technical performance and indoor environmental performance. As the result from the semi-structured interview with the local building operators, each category was further divided, producing a total of 26 indicators. Each of the indicators represents a certain characteristic of the sector they describe, but they are all concerned with the goals and objectives of mitigating user's risk in terms of health and safety. This reinforces the work by Ali and Al (2008) that contended that the context within which indicators are developed should be defined in order to develop valid assessment indicators. Evaluating indicators is important to ensure their accuracy, reliability and sensitivity and this can be done using empirical or modelling techniques. The comprehensive description of the results from the preliminary survey made it possible to indicate the users' risk, in order to optimise the building performance in higher education buildings (HEBs). The interview findings have achieved the first and the second research objective; i) identifying the current concept of building performance assessment used for HEBs, and ii) identifying the indicators that contribute to the performance requirements and the users' health and safety risk. The performance and risk indicators identified are to be used as initial parameters for the final rating tool development. Hence, the next chapter provides the analysis of the results of the main survey, involving the questionnaire surveys distributed to experts and the AHP process as a mathematical decision making technique.

CHAPTER 5

ANALYSIS AND DISCUSSION OF FINDINGS FROM THE QUESTIONNAIRE SURVEY (MAIN SURVEY)

5.1 Introduction

This chapter presents the analysis of the findings from the questionnaire survey, which was the primary instrument for the main survey. The survey was carried out to determine the level of risk impact on users' health and safety. The impact is derived from the possibility of defects or poor performance of the Performance-Risk Indicators (PRI) in higher education buildings (HEBs). The outcome of this survey also provides input for the subsequent development of the performance rating tool. The demographic data from the survey were analysed using the Statistical Package for the Social Sciences (SPSS) software, version 16. The weightings or relative importance scores for the PRIs were obtained using the Analytical Hierarchy Process (AHP) computer package; *Expert Choice* 11 version 3.10. The results from the analysis of the survey achieve the third objective of this study: to determine the relative importance score in the PRI construct. The discussion of findings for this survey is also included in this chapter.

5.2 The Administration of the Questionnaire Survey

Before distributing the questionnaire, the respondents were short listed based on the stipulated criteria for respondents, as previously described in the methodology chapter. The list of experts was selected with the help from the Malaysian Association of Facility Managers (MAFM), which has records of the experience and involvement of all professionals in building performance evaluation (BPE). Hence, the list of experts was shortlisted to 22 experts. Of this number, 12 experts expressed their willingness to participate in the survey; thus the response rate for the survey is an acceptable 54.6%, and hence the data obtained from the experts are considered valid and sufficient. As recommended by Creswell (2012), a response rate of 50% for a questionnaire is considered adequate for most surveys.)

As described in the methodology chapter, a focus-group approach was adopted for the survey administration. The survey was carried out in four stages. The first stage involved 3 experts in each of the first and second stages, 4 experts in the third stage, and the last stage involved 2 experts. The surveys were conducted from February to May of 2015. Each focus group session took between 60 minutes to 90 minutes.

To review, the main survey was carried out i) to determine the level of risk impact on the users' health and safety from the possibility of poor performance, and ii) to determine the relative importance score for the PRI constructs, using the Analytical Hierarchy Process (AHP) rating scale, for the purpose of achieving the third objective of this study.

5.3 Reliability Analysis of the Survey Instrument

Before proceeding with the survey, a pilot study was carried out involving three respondents in order to test the reliability of the questionnaires. According to Hertzog (2008), a reliability test is sufficient if it involves at least 10% of total respondents in a survey. Since this survey involved a total of twelve (12) respondents, the reliability test was carried out on 3 respondents, or 25%. A Cronbach's coefficient alpha test was performed on the data from the pilot study. According to Creswell (2012), Cronbach's alpha is a specifically to measure internal consistency. Santos (1999) explained that alpha coefficients ranging in value from 0 to 1 may be used to describe the reliability of factors extracted from dichotomous or multi-point formatted questionnaires or scales. The higher the score, the more reliable the generated scale is. An alpha value which exceeds 0.70, indicates that the instrument has sufficiently good reliability or internal consistency (Hair, et al., 2006; Muhamad Ariff, 2011).

As previously described in the methodology chapter, the questionnaires were divided into three main sections: Section A (part A1 and part A2), Section B (part B1 and part B2) and Section C. However, for reliability test, only the questions in Section A and Section B were involved in the testing. Section C was not included in the reliability test as the result was not analysed using the *SPSS* software. The ranking of importance in Section C was carried out using the Analytical Hierarchy Process (AHP) computer package, *Expert Choice* 11. The consistency of variables in Section C were obtained through the internal consistency ratio as it appeared in the output of the *Expert Choice* software.

Table 5.1: Cronbach's alpha for the items in the questionnaire

SECTION	QUESTIONS	NO. OF ITEMS	CRONBACH'S ALPHA (α)
Section A, part A1	General Information	5	.745
Section A, part A2	Duty and Responsibility	4	.762
Section B, part B1	Level of Impact Upon Health Risk	26	.913
Section B, part B2	Level of Impact Upon Safety Risk	26	.945

The Cronbach's coefficient alpha values are presented for each section of the questionnaire. As shown in Table 5.1, the alpha values in the four subsections of Section A and Section B ranged from.745 to .945. Thus all questions in both Section A and Section B received coefficient alpha values above 0.7, which indicates good reliability. Therefore, the result of the reliability test is that all the variables demonstrate internal consistency and the main survey could be carried out on all respondents.

5.4 Analysis Of The Questionnaire Survey

The analysis begins with the result of demographic items in Section A (part A1) involving five (5) questions; the respondents' gender, academic background, working sector, years of experience and the respondents' current position in their organisation. For Part A2, multiple choice questions were asked about the respondents' duty and responsibilities. The results are shown below.

5.4.1 Section A: Demographic Background of Respondents

a) Part A1: General Information

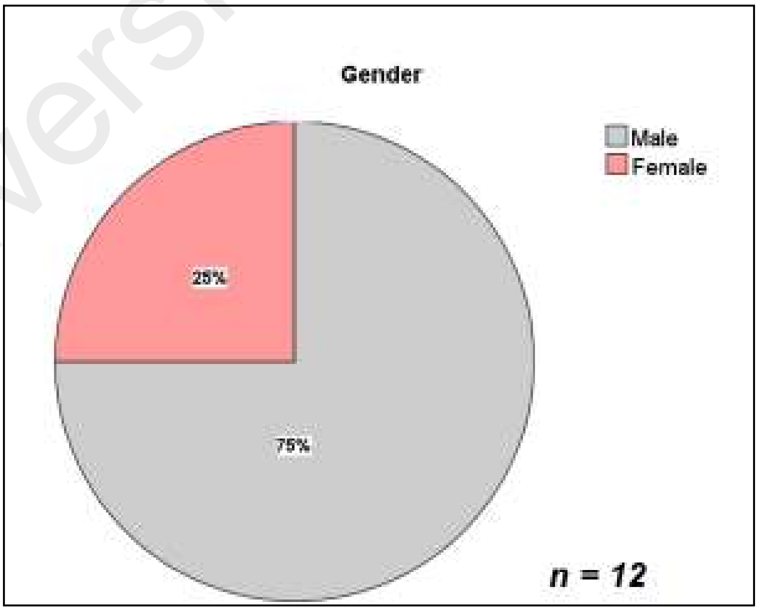


Figure 5.1: Respondents' gender

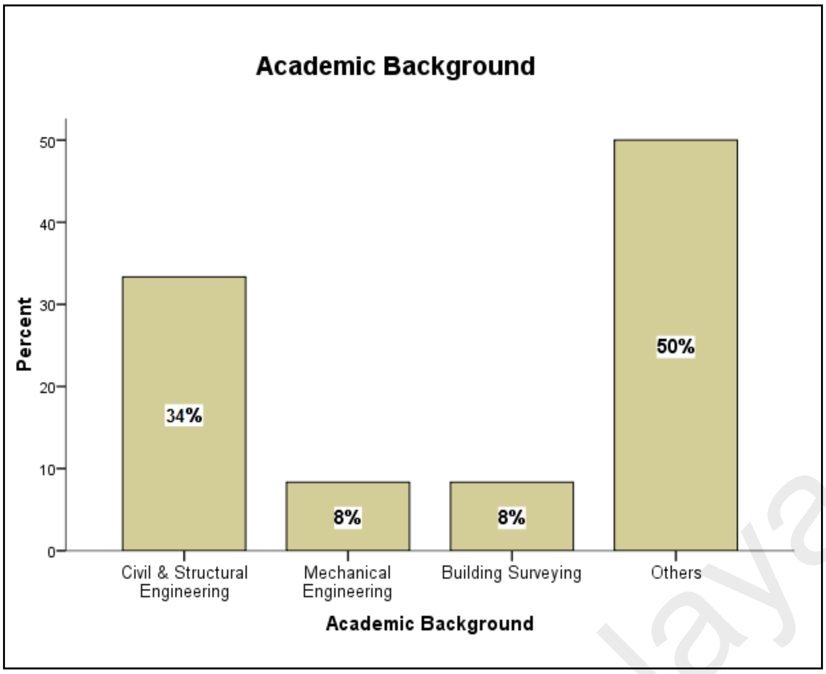


Figure 5.2: Academic Background of the Respondents

Figure 5.1 and Figure 5.2 show the respondents' gender and the academic background. Nine of the total 12 respondents were male, with the rest (25%) of the respondents female. In terms of academic background, half (*n*=*6*, 50%) of the respondents selected "Others" as the answer for their academic background. It was later found that these respondents were from different fields such as facilities management, science fields and international business studies. The second largest group (34%, *n*=*4*) of respondents were from civil and structural engineering backgrounds, while one respondent was from mechanical engineering and one respondent was from a building surveying background.

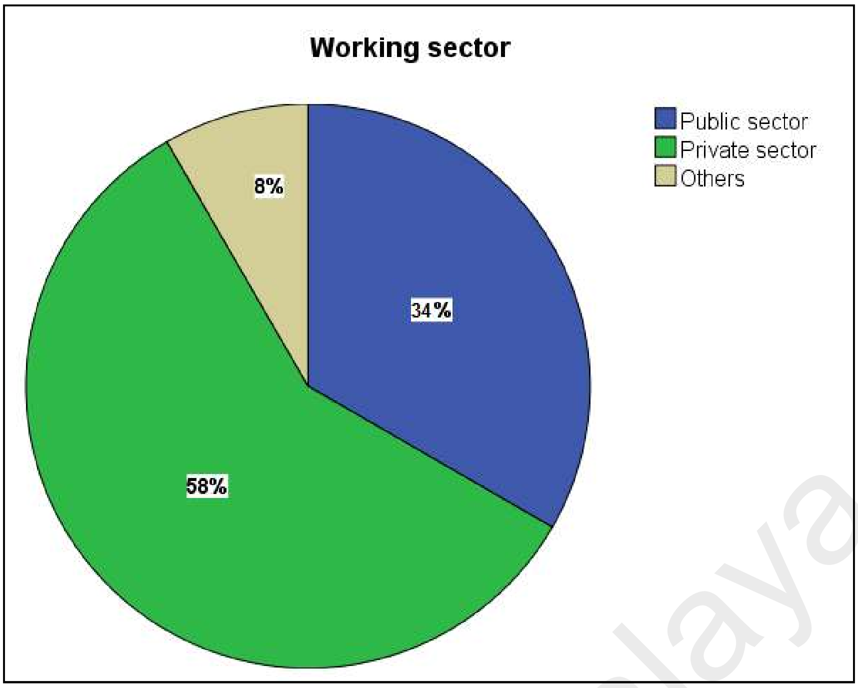


Figure 5.3: Working sector of the respondents

In terms of working sector, the majority 58% (*n=7*) of respondents worked in private sector organisations, as shown in Figure 5.3. Four respondents (34%) affirmed that they were from the public sector. Only one respondent chose "Others" in terms of working sector (semi-government organisation).

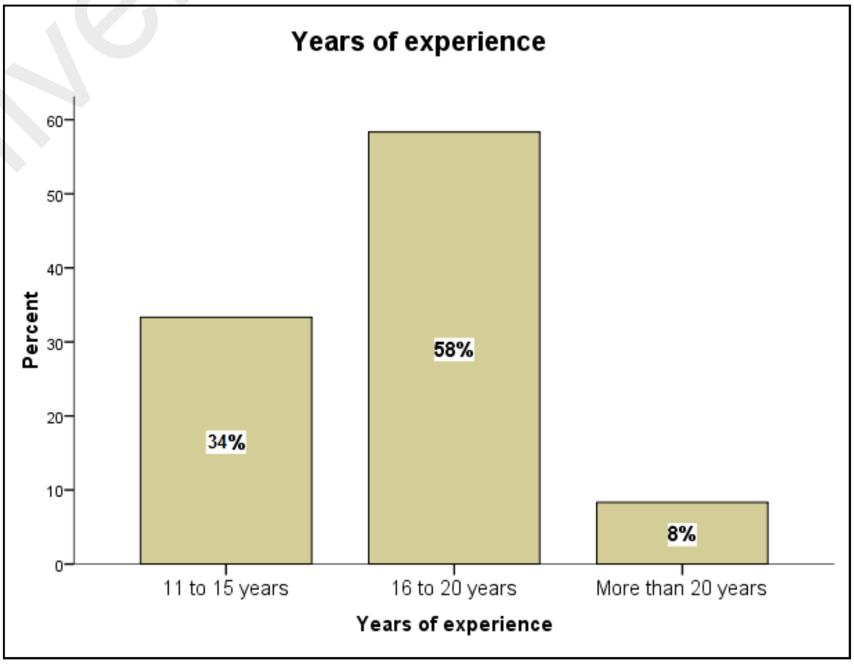


Figure 5.4: Respondents' Years of Experience

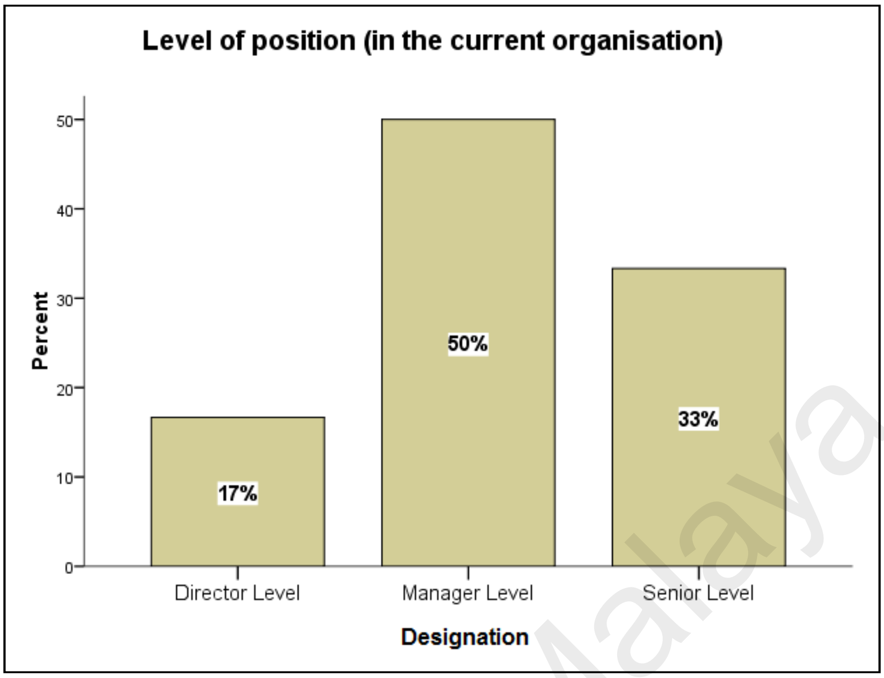


Figure 5.5: Respondents' Level of Position (in current organisation))

Figure 5.4 and Figure 5.5 shows the respondents' capability in terms of years of experience and their current position in their organisation. The majority (58%, *n=7*) of the respondents had between 16 to 20 years' experience, followed by 34% of the respondents (*n=4*) with between 10 to 15 years' experience. In terms of position in the organisation, half (50% *n=6*) of the respondents held managerial posts, followed by 34% of the respondents (*n=4*) are at senior levels, and two respondents were at director level in their current organisation. This result confirmed that all of the respondents qualified as "experts", and were fit and capable to take part in the survey.

b) *Part A2: Duties and Responsibilities*

In this part, the respondents were asked to affirm the duties that were assigned to their designation in the organisation. The question was a close-ended multiple-choice question with four options, including "Others". Respondents were able to select more than one answer. The question was included in the demographic section to ascertain the respondents' credentials as experts for this survey in relation to the predetermined criteria. The results are shown in Table 5.2

Table 5.2: Respondents' Duties and Responsibilities

No.	Duty and Responsibility	Yes		No	
		Percentage	**Frequency**	**Percentage**	**Frequency**
1	Safety and Health Risk	58%	7	42%	5
2	Building Performance Evaluation (BPE) or Building Audit	33%	4	67%	8
3	Operation Requirement Plan and Management	58%	7	42%	5
4	Others (*property development, building maintenance, fleet management, business development and continuity management*)	50%	6	50%	6

It was found that the majority of respondents (58%) were involved in managing safety and health risk and in operating plans in their organisations. Only 33% affirmed that they were involved in building performance evaluation or building audit tasks. Half of the respondents stated that they were also involved in other duties (property development, building maintenance, fleet management, business development and continuity management). Even though building performance evaluation or building audit tasks occupied a minority, the other duties are relevant to the objective of this survey and the general area of study.

5.4.2 Section B: The Level of Risk Impact on the Users' Health and Safety

Section B concerned the level of risk impact on the users' health and safety risk. It was divided into two parts: i) Risk impact on Health, and ii) Risk impact on Safety. This section listed the 26 performance-risk indicators (PRI) and the respondents were required to rate the impact from poor performance of each PRI on users' health and safety on a five-level numerical Likert-scale of risk impact, as shown in Table 5.3. The description of scale for the risk impact was adopted from the risk likelihood and consequences from the description of assessment in PWD's BARIS and Massingham (2010); Whitfield (2003); Zou et al. (2008). The description was adjusted to suit the context of users' health and safety aspects for higher educational buildings.

Table 5.3: Scale of Risk Impact and the Description

SCALE VALUE	**SCALE**	**DESCRIPTION OF SCALE**
"1"	Little Impact	The impact is insignificant; minimal impact or no apparent impact at all
"2"	Minor Impact	Minor physical discomfort to occupants or minor occupational illness/injury
"3"	Moderate Impact	Significant impact with minor injury or minor occupational illness/injury
"4"	Major Impact	Serious or fatal injury to occupants or major illness/injury
"5"	Catastrophic Impact	Results in multiple fatalities; may result in human death or serious illness/injury.

To simplify the interpretation of the results, the analysis is presented in descriptive statistics using mean score, as shown in Table 5.4. Mean rank can summarise overall data and convey information about distributions in a concise way. Hence, the PRI impact values are listed descending numerical order, rather than in percentage distribution.

Table 5.4: Mean Rank of the Risk Impact Level on Users' Health Risk

No.	Performance-Risk Indicators (PRI)	Mean	Standard Deviation
1	Building-related illnesses/ sick building syndrome	4.25	1.138
2	Waste disposal	4.00	0.603
3	Ergonomic building facilities	3.92	0.996
4	Level of cleanliness	3.82	0.603
5	Building ventilation	3.75	1.055
6	Cooling (Thermal comfort)	3.67	1.073
7	Acoustic comfort	3.67	1.073
8	Emergency exits	3.50	1.508
9	Amenities	3.50	1.243
10	Electrical services	3.50	1.243
11	Structural stability	3.42	1.505
12	Access/entrance	3.25	1.422
13	Adequacy of building signage	3.25	1.485
14	Fire prevention services	3.25	1.545
15	Artificial lighting	3.25	0.965
16	Orientation	3.17	0.718
17	Plumbing services	3.17	1.115
18	Natural lighting	3.17	1.030
19	Circulation area	3.08	1.240
20	Materials and internal finishes	3.08	0.669
21	Roof	3.08	1.165
22	Design of building fittings/fixtures	3.00	0.853
23	Lift	3.00	1.477
24	Spaces	2.92	0.996
25	Infrastructure	2.92	1.165
26	Information technology systems operations	2.33	0.651

Table 5.4 shows the analysis of risk impact of PRIs on building users' health risk, as assessed by the panel of experts. The mean values of all PRIs range from the highest mean (4.25) to the lowest mean (2.33). The standard deviation (*sd*) value shows a smaller dispersion on the distribution of data and the obtained *sd* score is less than the mean, that range from 0.603 to 1.508. The standard deviation indicates that the ratings are consistent among all respondents (12 respondents); hence, the data are considered reliable.

The results in Table 5.4 revealed that the indicator *building related illness* was ranked as a contributor to users' health risk, with a mean of 4.25 (*sd*=1.138). It is followed by the indicators *waste disposal, ergonomic building facilities, level of cleanliness* and *building ventilation*. Thus, these five indicators were identified as the main items that may generate greater risk towards users' health. Hence, if these items perform poorly, more thorough solutions are needed to mitigate the potential of health risk to the building users. The result also shows that the indicator *information technology systems operation* had the lowest mean, 2.33 (*sd*=0.651). However, even though it is ranked as the lowest mean, this indicator still poses a significant impact to users, according to the description of risk impact, with outcomes of minor injury or minor occupational illness.

The mean scores obtained (2.33 to 4.25) show that all of the PRIs listed are considered to have a medium to high impact on users' health risk. By referring to the mean value, it can be concluded that the impact on health risk ranges from moderate impact to catastrophic impact. None of the mean scores show that the impact falls in the category of little or minor impact. This provides robust data for justification of the construct of PRIs and their incorporation into the final rating tool. Apart from health risk, the impact of poor performance of the PRIs on the users' safety was also analysed, as shown in Table 5.5:

Table 5.5: Mean Rank of the Risk Impact Level on Users' Safety Risk

No.	Performance-Risk Indicators (PRI)	Mean	Standard Deviation
1	Structural stability	4.42	0.900
2	Fire prevention services	4.42	0.996
3	Amenities	4.25	0.866
4	Emergency exits	4.17	0.937
5	Ergonomic building facilities	4.00	0.739
6	Lift	4.00	1.206
7	Design of building fittings/fixtures	3.92	0.900
8	Electrical services	3.92	0.996
9	Access/entrance	3.75	0.087
10	Adequacy of building signage	3.67	1.073
11	Building-related illnesses/sick building syndrome	3.67	1.073
12	Roof	3.67	1.371
13	Plumbing services	3.58	1.165
14	Infrastructure	3.50	0.674
15	Circulation area	3.42	1.084
16	Orientation	3.25	1.215
17	Level of cleanliness	3.17	0.937
18	Building ventilation	3.08	1.165
19	Spaces	3.00	1.044
20	Acoustic comfort	3.00	0.953
21	Information technology systems operations	2.92	1.084
22	Materials and internal finishes	2.92	0.900
23	Waste disposal	2.92	1.084
24	Artificial lighting	2.58	0.900
25	Cooling (Thermal comfort)	2.50	0.798
26	Natural lighting	2.50	1.000

Table 5.5 shows the analysis of risk impact of PRIs on building users' safety risk. The mean values of all PRIs ranged from the highest mean (4.42) to the lowest mean (2.50). As in the analysis of impact upon the users' health risk, a relatively small dispersion of the standard deviation (*sd*) value is showed in the above table. All the obtained *sd* scores, which ranged from 0.674 to 1.371, were less than the mean score; hence, the data on the impact on users' safety risk are considered reliable.

The data reveal that the indicators *structural stability* and *fire prevention services* were ranked to have the highest impact on users' safety risk, with a mean score of 4.42 (*sd*=0.900, 0.996). This is followed by the indicators *amenities, emergency exits* and *ergonomic building facilities*. These top five indicators were identified as the main items that may generate greater risk to users' safety. It is revealed that further action is needed to improve the performance of these indicators, if they experience poor performance. According to the mean values obtained, the impact upon safety risk ranges from moderate impact to catastrophic impact (the mean scores obtained ranged from 2.50 to 4.42). Thus, it can be concluded that all of the PRIs contribute significantly to an impact on safety that may lead to minor or serious injury to the building users.

5.4.3 Section C: The Analytical Hierarchy Process (AHP) for Performance-Risk Indicators

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. As previously described in the methodology chapter, the Analytic Hierarchy Process (AHP) developed by Dr. Thomas L. Saaty in 1977 is used to deal with such a multi-criteria decision-making process. In Section C of the questionnaire, the list of performance-risk indicators (PRI) was compared to each criterion in the three separate areas of performance; i) functional performance, ii) technical performance, and iii) indoor environmental performance. The pairwise importance of the indicators is compared in accordance to the other indicators only for the same performance areas. Hence, there are ten (10) indicators for functional performance, nine (9) indicators for technical performance, and seven (7) indicators for indoor environmental performance.

5.4.3.1 Administration of the Steps for Analytical Hierarchy Process (AHP)

The administration of the AHP method begins by briefing the respondents on the process for rating the pairwise importance of the indicators. Before starting the AHP interviews, the experts were given clear instructions on the pairwise comparison process and furnished with a definition of the key terms used in the questionnaires. All participants were allowed to ask questions to clarify any ambiguities. This procedure is indispensable, as respondents need to have a common understanding of the questions before the results can be analyzed in a meaningful way. The researcher explained the purpose of the survey to the respondents and showed them all the sections in the survey forms. A detailed explanation was conveyed to the respondents for the application of AHP, as most of the respondents are unfamiliar with the process. This is an important step as it ensures that none of the indicators is left unattended and the rating of importance is thoroughly understood by the respondents.

It was decided that the usual administration of AHP by means of a one-day workshop was not feasible for this survey, since it is difficult to gather all the experts on the same day and at the same time. Hence, a focus-group approach was used to obtain the data from the respondents. Since 12 respondents are involved in the survey, four focus-groups were formed composed of three, three, four and two respondents, respectively. The steps necessary for performing the AHP survey are summarised in Figure 5.6:

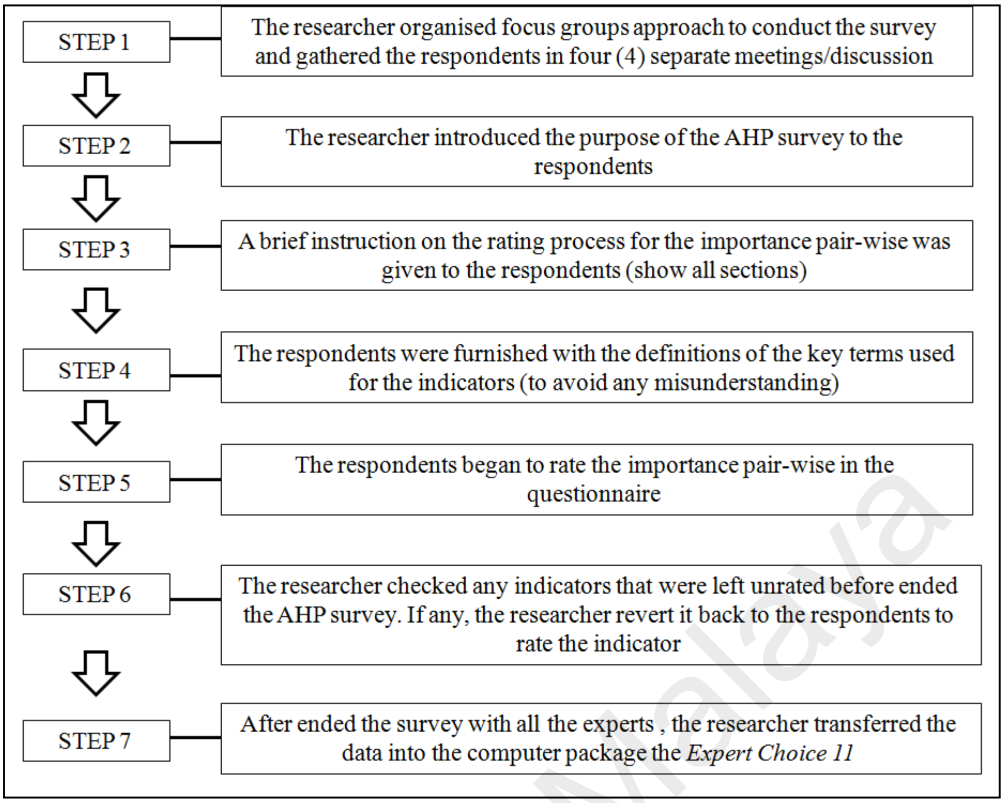


Figure 5.6: Steps for performing AHP for the main survey

The weightings of the building factors were assessed by 12 panel experts using nine (9) scales of importance (Saaty, 1990, 2008), as explained previously in the methodology chapter. 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 3.10.

5.4.3.2 Results of the Analytical Hierarchy Process (AHP)

The relative importance (relative weight) of each category and each indicator within each category was established using a square matrix structure. For each category and indicator, the weight was calculated by the geometric mean of values of questionnaires filled by the 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 pairwise comparison of all indicators obtained by combining the overall judgment from the 12 experts is shown in Figure 5.7. It shows that the indicators were keyed-in in accordance to their category of performance elements. From the numerical pairwise comparison, the priorities of indicators are then calculated by the *Expert Choice* 11 software and the results are shown in Figure 5.8.

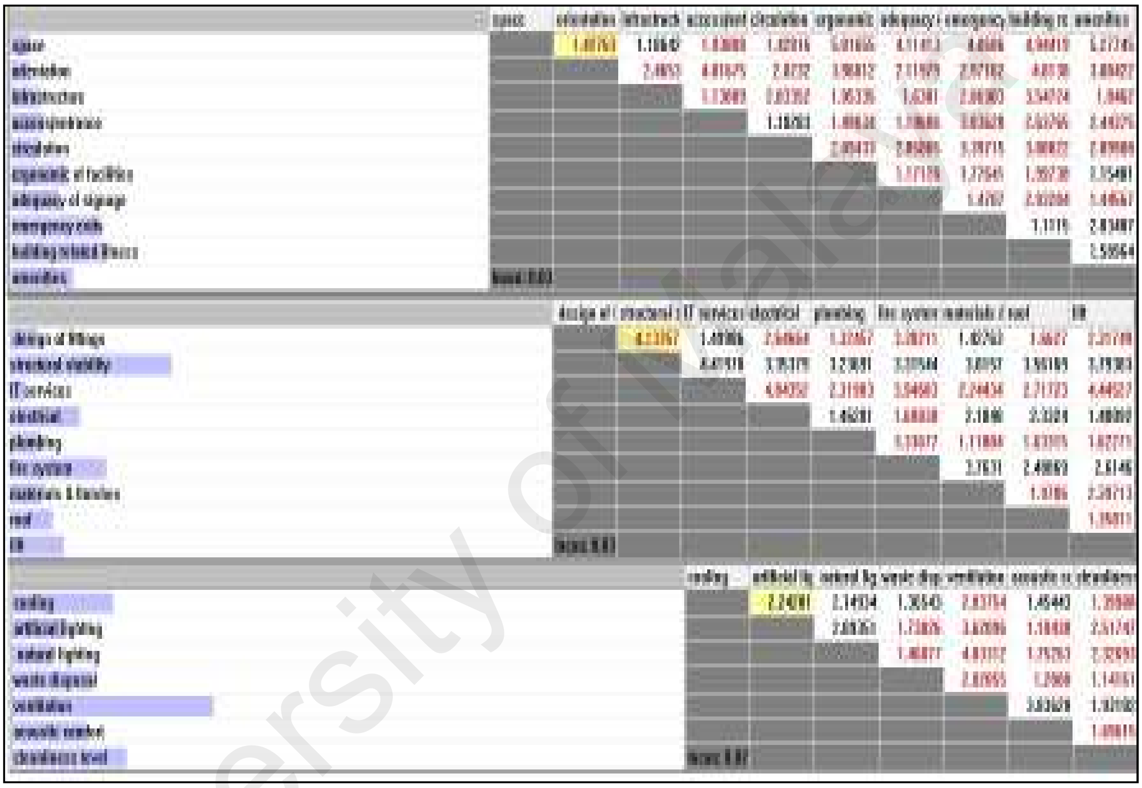


Figure 5.7: Numerical Pairwise Comparison of Indicators derived from *Expert Choice* 11

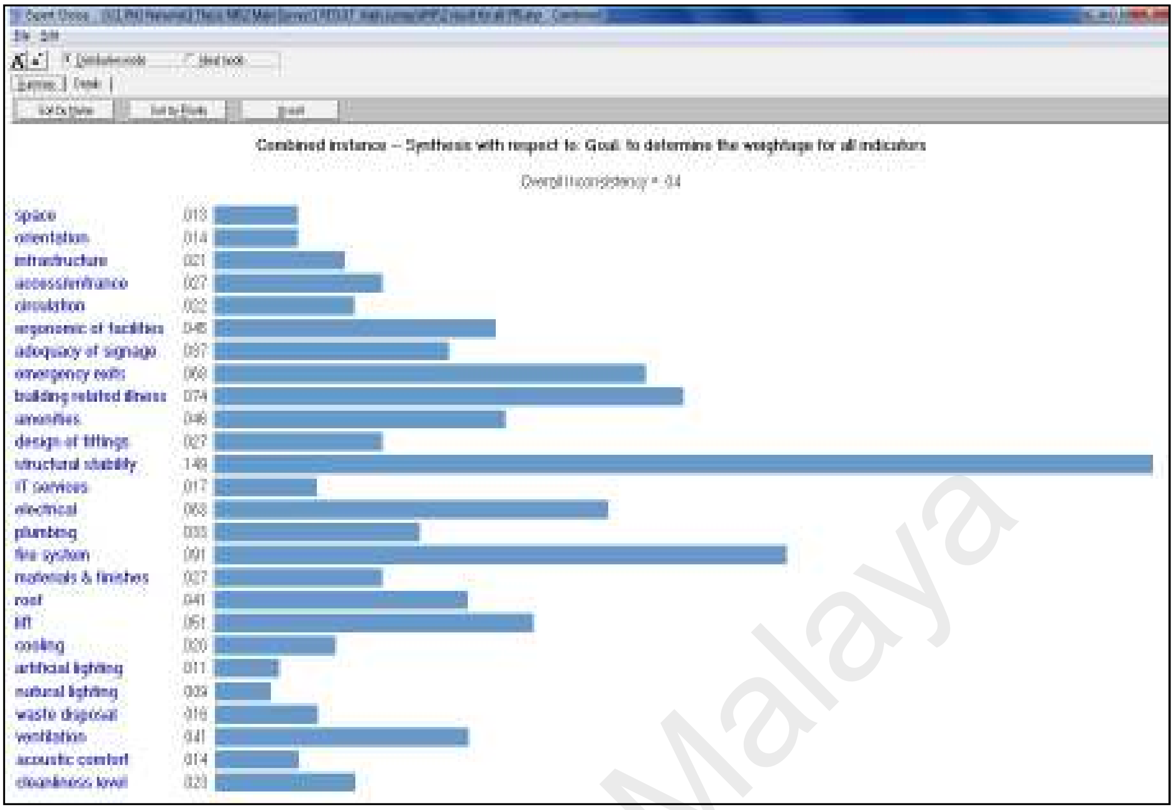


Figure 5.8: Priorities of Indicators with Respect to the Goal – Weighting of Assessment Items (Distributive Mode)

According to Saaty (1990), the internal consistency ratio (CR) must be less than 0.1 (10%). The computer package (*Expert Choice*) will locate the possible sources of inconsistency. The result in Figure 5.8 shows that the internal consistency for the combined instance for the overall indicators is .04; therefore, the data of this survey is reliable and meets the criterion for consistency. To obtain the priorities of indicators as shown in Figure 5.8, the distributive mode is chosen as it normalizes alternative scores under each criterion so that they sum to one (1.00). This creates a dependency on how well all other alternatives perform and hence the potential for rank reversal.

As shown in Figure 5.8, each indicator is assigned a final weight, resulting from the pairwise ratings of all the experts. The figures for the indicators are, however, not sorted in rank order. To ease the calculation of weight for each performance element, the result from the combined synthesis of each indicator is illustrated in Table 5.6. Each weight for the indicator is converted to a percentage mode (100%). Table 5.6 summarises the relative weight of each indicator in accordance to the category of performance elements; functional performance, technical performance and indoor environmental performance.

Table 5.6: Summary of Relative Weights for Performance Elements and Performance-Risk Indicators

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
	Amenities	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 and 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

The result in Table 5.6 showed that *structural stability* is ranked as the most important indicator, with a weight 14.9%, followed by *fire prevention services* (9.1%), *building-related illnesses* (7.4%), *emergency exits* (6.8%) and *electrical services* (6.3%). This result suggests that these five indicators are the most important elements that should perform well in building performance, as they may generate a larger impact on users' health and safety risk. The weightings also show that natural lighting obtained the lowest weight at 0.9%.

To determine the weightage for each performance element, the global weights are summated from each indicator in accordance to the category of performance elements. For functional performance, there are ten (10) indicators; *space, orientation, infrastructure, access/entrance, circulation area, ergonomic building facilities, adequacy of building signage, emergency exits, building related illness* and *amenities*. Meanwhile for technical performance, there are nine (9) indicators; *design of building fittings, structural stability, information technology systems operations, electrical services, plumbing services, fire prevention services, materials and internal finishes, roof* and *lift*. Lastly, there are seven (7) indicators for performance elements for indoor environmental performance; *cooling (thermal comfort), artificial lighting, natural lighting, waste disposal, building ventilation, acoustic comfort* and *level of cleanliness*.

With the total summation of the weights for the indicators, the result in Table 5.6 shows that the obtained weightings for functional performance are 36.7%, for technical performance 49.9%, and for indoor environmental performance 13.4%. This suggests that technical performance is more important than functional performance and indoor environmental performance. Hence, this suggests that the performance of indicators categorised under technical performance generate a larger impact of risk towards the users' health and risk. If these indicators show poor performance, the overall performance scale of the building is affected, even if other indicators (in the two other performance categories) had not deteriorated.

The obtained weightings achieved the third objective of this study; to determine the relative importance score as a weightage/rating in the construct of performance-risk indicators. The next section discusses the findings from the analysis and the result of the main survey. The purpose of the discussion is to amalgamate the results of the main survey with the conceptual framework and to compare the results with those obtained in other studies. Hence, the discussion shall provide a stronger link and justification of the data obtained to achieve the study's purpose.

5.5 Discussion of Findings for the Questionnaire Survey

For the discussion of findings, the structure of discussion is presented in accordance with the sequence of sections in the questionnaire survey. Comments are supported based on academic theories, the literature and findings from previous studies. The discussion in this section is divided into three main parts; i) the reliability of the experts, ii) the level of risk impact on users' health and safety, and iii) the relative importance score of the performance-risk indicators (PRI).

5.5.1 The Reliability of the Experts

To carry out the main survey, respondents were selected based on purposive sampling, with predetermined criteria. Since the Analytical Hierarchy Process (AHP) method is included in the questionnaire of the main survey, a panel of experts from different field backgrounds were the main respondents. As described earlier, the experts are from leading public and private organizations related to the facilities management (FM) industry. The experts were selected based on their knowledge and experience with building performance audits in the FM field. Twelve experts agreed to participate in the main survey, out of 22 experts who were identified and invited. The experts' knowledge and experience cover and reflect the needed criteria within the FM industry in Malaysia.

The selection of prominent experts who represent the FM industry is relevant and suits the objective of survey and the study area. This is supported by Amaratunga (2000) who stated that there is a trend in FM industries towards performance measurement, particularly for strategic development and the focus of this study provides a good setting for the study of performance measurement. According to Pitt and Tucker (2008) performance measurement in FM is important to contribute to organisational success, in terms of effectiveness, efficiency, and adding value. Hence, it is valid to enlist the services of experts with backgrounds in FM and FM organizations.

Since the AHP method is a major component of the main survey, the reliability of experts whose knowledge and experience are in the specific field and background is important. There are no pre-set rules to determine the acceptable sample size of experts for AHP survey, as expressed many previous studies (for example: Alexander, 2012; Frontczak & Wargocki, 2011; Ho et al., 2008; Ishizaka & Labib, 2009; Said & Juanil, 2013; Yau, 2006). As Saaty and Özdemir (2014) have emphasized, one needs to know the area of expertise needed to make that decision and to select a judge or judges who have both knowledge and practical experience with the matter. Depending on the objectives of the survey, one expert judge may suffice unless political expediency requires that several experts from different constituencies are necessary and therefore, several experts are needed if they are available (Saaty & Özdemir, 2014).

Based on the respondents' demographic information, the reliability of using expert judgement is also shown in other similar studies for the purpose of assessing weightage for the development of a building performance rating tool. Previously established building performance rating tools have used small samples to gain expert feedback to provide weightings for the development of the rating tool. For example, BHHI used 35 experts in building health to provide their perceptions of the relative importance of the building factors; and BSCI made use of 23 experts in building safety to provide such weightings (Ho et al., 2008). Another AHP analysis carried out by Fu and Lin (1988) used 32 experts to analyze the priority of performance criteria for Taiwan's energy projects.

The value of expert knowledge is also recognised as an opportunity for the experts to participate in in-depth comparisons for the importance of the criteria (Larsson & Cole, 2001). Previous studies validated the results that generate weightings for criteria by inviting a panel of experts using AHP surveys to complete a detailed questionnaire (Ali & Al, 2008; Frontczak & Wargocki, 2011; Fu & Lin, 1988; Ho et al., 2008; Kim et al, 2005; Yau, 2006; Yik et al., 1998). Hence, the experts' criteria, knowledge and experience ensure their judgments are reliable and justify acceptance of the subsequent results on risk impact and also on relative weightage of the PRIs.

5.5.2 The Level of Risk Impact on Users' Health and Safety

The results for the level of risk impact on users' health and safety were presented in the form of mean scores and standard deviations. They showed that the mean scores for the impact on health risk ranged from 2.33 to 4.25, while the mean scores for the impact on safety risk ranged from 2.50 to 4.42. Standard deviations of scores for both analyses ranged from 0.651 to 1.371. Even though several PRIs received standard deviations in scores that are larger than 1.00, this does not indicate whether the mean score is "good" or “bad” (Chua, 2008). The standard deviation is a description of the data spread and how widely it is distributed about the mean. Generally a smaller standard deviation indicates that more of the data is clustered about the mean and a larger one indicates the data are more spread out. Grosskopf and Moutray (2001) clarify that standard deviations that are smaller than the means suggests some degree of homogeneity within the sample.

For the analysis of risk impact on users’ health, it was revealed that *building related illness* obtained the highest mean score (4.25). For this mean value, the description of risk impact is “catastrophic impact that results in multiple fatalities; human death or serious illness/injury”. This result is in line with the studies and theories set out in previous studies (Hassanain, 2007; Heerwagen, 2000; Lützkendorf & Lorenz, 2006; Zamani et al., 2013) that described the issues of people suffering illness, injury or even death due to this factor. It is found that several studies are dedicated to identifying and finding ways to eliminate sick building syndrome (SBS) and building-related illness (BRI) (Malmqvist, 2008; Malmqvist & Glaumann, 2009; Salleh et al, 2013; Sulaiman et al, 2013; Zamani et al., 2013) relating to building performance. Among the performance issues relating to SBS and BRI are indoor environmental quality (IEQ), indoor air quality (IAQ) and building ventilation.

The occurrence of SBS or BRI can be very costly to an organization (Heerwagen, 2000). Poor maintenance of building systems, which can lead to build up of bacteria and other pollutants in the air ducts, or water leakages in walls or ceilings, are one of the building factors that lead to BRI and SBS. According to Malmqvist (2008), fatigue, headache, cough, skin irritation, running nose, eye irritation and sore throat are among the symptoms suffered by occupants due to BRI and SBS. These symptoms may cause occupants to suffer long term health problems and could lead to serious illness. For this reason, an improved performance assessment for the factors that are likely to contribute to the impact of SBS and BRI should be addressed as a priority.

For the analysis of impact upon the users' safety risk, it was revealed that the highest mean scores were for *structural stability* (mean=4.42, *sd*=0.900) and *fire prevention services* (mean=4.42, *sd*=0.996). In relation to safety, this result is in line with the issues raised by Yau (2006), who stressed that occupants must be safeguarded against hazards arising from structural failures and fires. Several studies support this result, that recognises the importance of structural stability in building performance that leads to people's safety (Dewlaney & Hallowell, 2012; Goh & Ahmad, 2012; Ho et al., 2008; Merkulov et al, 2014; Ng et al, 2005; Yau, 2006) and fire safety (Chow & Lui, 2002; Chow, 2002; Hassanain, 2008; Ho et al., 2008; Yau, 2006).

To ensure long-term structural stability and safe use of a building, the building needs to be examined to verify whether or not it poses any risks. As supported by Ali et al. (2010), the structural stability of a building must be inspected and maintained from time to time in order to ensure the occupants' safety. According to Smith and Willford (2008), structural risk and fire risk are among the performance challenges within the context of building design. Failures in structural stability may pertain to cracked or damaged concrete, sudden failure or risks from load, building physics, corrosion or cracking (Bazant, 2000). Hence, in-depth inspection during building performance assessment helps to mitigate safety hazards imposed on the building users. This includes visual inspection of the construction to verify compliance with the structural analysis and to detect visible damage.

The importance of fire regulation can never be underestimated, as it is a mandatory requirement for buildings to be awarded for certificate of fitness. Fire risk can be linked to the needs of health and safety of users or occupants (Ramly et al., 2006). Fire safety is much related to the design of building, where the focal point is delineated to the emergency exits, signage and the installation of fire fittings. According to Hassanain (2008), building factors that can lead to fire in a building include interior finishes, closed stairwells, unprotected vertical openings and violated fire doors. Such conditions may facilitate the spread of smoke and toxic gases to other floors in the building, as well as prevent the residents for using the stairwell for escaping from the fire (Hassanain, 2008). Hence, regular checking and inspection of these items are vital during performance assessment, as they present serious safety risks for the building users.

5.5.3 The Relative Importance Score of the Performance-Risk Indicators (PRI) using Analytical Hierarchy Process (AHP)

Section C of the questionnaire elicited the results of the AHP, with the aid of computer package *Expert Choice* 11 version 3.10. To reiterate, the obtained weightings achieved the third objective of this study, which was to determine the relative importance scores as weightage/ratings in the construct of performance-risk indicators. The results of the AHP survey specified that each indicator is assigned a relative weight. The obtained weight as the outcome result of this AHP survey has facilitated the development of the building performance-risk rating tool. Each of the indicators is weighted and then the weighted scores are summed to give total scores for the performance elements. This approach allows the system to be more easily refined by users, as suggested by Larsson and Cole (2001). According to Yau (2005), weightings represent the relative importance of a building factor to the overall goal of the assessment, as they affect the degree of influence of each building factor on the overall result. The result also reinforces Fu and Lin (1988) who pointed out that AHP is able to systematically organize complicated problems, and display the problems in a hierarchical context.

For this study, the weightings of building attributes represent their relative importance in respect of the users' health and safety risk in higher educational buildings. The performance elements are measured by placing a comparison against a standard for a criterion during the performance assessment process. As mentioned by Preiser et al. (1988) the indicators of building performance are aspects of facilities that are measured, evaluated and used to improve buildings.

From the AHP result, out of the total 26 indicators, the results have ranked five indicators as the most important factors; namely, *structural stability* (14.9%), *fire prevention services* (9.1%), *building-related illnesses* (7.4%), *emergency exits* (6.8%) and *electrical services* (6.3%). This suggests the indicator *structural stability* is more significant than the other 25 indicators, and that it should be prioritised in the focus on building performance and user's risk. This is supported by Abdul-Rahman et al., (1999); Baird et al., (1996); Clift, (1996); Goh and Ahmad, (2012) and Liu (2003) who stated that structural degradation and deterioration have impacts on performance quantification in terms of collapse safety and health of the users. A study by Husin et al., (2012), also shows that structural elements are among the important safety factors for performance assessment. The structural stability of a building must be inspected and maintained from time to time in order to ensure the occupants' safety (Ali, et al., 2010). Hazards in the built environment are closely related to accidents occurring in buildings; therefore the occupants must be safeguarded against hazards arising from structural failure. As described by Meacham et al. (2005), buildings should provide socially acceptable levels of health, safety, welfare and amenity for building occupants and this has to be accomplished through regulatory controls on the operation of buildings, which includes structural stability. Therefore, the result of AHP for this study supports the importance of the indicator of structural stability on the impact on users' health and safety.

The summation score from the indicators in each performance category has identified that the top priority is ranked for technical performance (49.9%), followed by functional performance (36.7%) and indoor environmental performance (13.4%). The significant finding based on the summated score is that technical performance is considered as including the most critical performance elements that have greater impact in the context of building performance and users' risk. Inevitably, the performance assessment for technical performance in a building becomes a crucial measure. As mentioned by Augenbroe and Park (2005), the need for continuous monitoring of the technical performance of buildings over their lifetime is obvious because buildings are not operatively static. Technical performance aspects in a building complete the functionality aspect; therefore, a building may succeed in achieving a high level of functionality if it is able to meet prescribed technical standards. The performance requirements for a building need to match the provision of reliable information about alternatives, including technical specifications with indications of service life and performance over time (Trinius & Sjöström, 2005). It can be concluded that the attained weightings for technical performance are supported by academic theories and the literature on the importance of technical performance in buildings.

The empirical findings of this study indicate that, based on the judgment by the panel of experts, the PRIs have significant differences. The results suggest that the relevant stakeholders in the facility or maintenance management of higher educational buildings should pay greater attention to the priority of indicators that have a significant risk impact, ideally the top priority indicators. This suggestion is also made by Olanrewaju et al., (2010a) and Olanrewaju (2010a, 2010b), who asserted that the maintenance organisation in university buildings must look far beyond the immediate objectives of the products or services to the users. In his study, Olanrewaju (2010b) found that the maintainers' involvement is critical. Since the performance evaluation in university buildings is under the responsibility of the facility or maintenance unit, information on building performance should be well documented in a safe register. The risk and uncertainty involved with maintenance services is undoubtedly unsuitable for maintenance works.

5.6 Summary

The results in the main survey have produced valuable data for the development of a building performance-risk rating tool, which is the main aim of this study. By integrating criteria from different assessment schemes, academic theories and previous research, this study builds on the strengths of each and provides a more holistic assessment approach, paying careful attention to the Malaysian context. It can be summarised that the results and presentation of analysis for main survey have achieved the third research objective of this study.

The next step in the development of the tool is the stage involved in defining the evaluation criteria and performance assessment for measuring the degree or level at which the performance indicators are met. Performance assessments were established to measure the degree, and the evaluation criteria were defined by relating the characteristics of the performance indicators within the degrees in the performance grade. These are explained in detail in the next chapter.

CHAPTER 6

DEVELOPMENT OF THE BUILDING PERFORMANCE-RISK RATING TOOL

6.1 Introduction

As described earlier, this study aims to develop a building performance-risk rating tool, for risk mitigation concerning the health and safety aspects of the building occupants in higher educational buildings (HEBs). The study suggests an improved performance assessment of HEBs by allocating weightages to the performance-risk indicators (PRI) as a means to improve performance assessment. At the same time, it is able to reduce risk hazards to the building's users in terms of health and safety risks. This chapter describes the developmental steps towards the establishment of the building performance-risk rating tool (BPRRT). The steps incorporate several considerations and address the evaluation of a building's performance, as the main task to generate a rating classification for academic buildings in HEBs. The development of the tool is based on the results of the preliminary survey and the main survey, which were presented and discussed in the earlier chapters of the thesis.

6.2 The Weightings of the Assessment Criteria

Ideally, there are several matters to consider before building performance rating tools could be developed. According to Ali and Al (2008), the developed tool should define building performance from different aspects such as environmental, social, and economic aspects, and it should respect different climatic, cultural and economic conditions. For this study, previously established rating tools were reviewed in the literature chapter as a guide to constructing an initial list of performance-risk indicators (PRI). Ali and Al (2008) also emphasized that the aspects, categories, and indicators of the developed tool should acknowledge the local context within which the tool is developed. This is also carried out for this study where the suitability of the indicators for the Malaysian context was validated through a preliminary survey using semi-structured interviews with the building operators of Malaysia's higher educational buildings.

The weighting process for the PRI should be comprehensive, and hence the AHP method is used. The AHP method was included in the questionnaire of the main survey, and the results from the main survey (presented in Chapter 5) have produced the relative weightings assigned for each PRI. In AHP, comparative judgments are required for pairwise comparison of ranking of PRIs to derive the criteria weights and relative priorities of PRIs (Ali & Al, 2008; Fu & Lin, 1988; Ishizaka & Labib, 2009; Saaty, 2008). The result of weightings has successfully helped to further develop the building performance-risk rating tool for this study.

6.2.1 Developing the Summary of Assessment for Performance-Risk Indicators

The performance of academic buildings is determined by means of building performance assessment. Therefore, before the building defines its performance grades and impact of risk towards the users' health and safety, a condition survey must be carried out to indicate the performance and risk ratings of the building. According to Che-Ani et al. (2010), without a proper assessment of the building performance, it is difficult to determine a built asset's current condition; so failure to inspect can contribute to the asset's future failure. Ho et al. (2008) insist that site visits and building inspections are a necessity for verifying the actual health and safety conditions of a building, because the information from other sources often does not reflect the real situation of a building.

The steps amd process for the proposed rating tool was adapted from the previous building performance and green rating tools, such as Malaysia's Green Building Index (GBI), BARIS and SABA Green Building Rating System, developed by Ali and Al (2008). To develop the rating tool in a more thorough and systemic process, three steps must be carried out and included in the building assessment. The first step is to evaluate the performance and risk of the indicators and the second step comprises calculating the overall score for the PRIs. The third step is the application of the tool in an assessment where the assessed building is classified using the rating classification developed. The key activities and procedures in these three steps are described in the following sub-sections.

6.2.1.1 Step 1: Evaluation for performance and risk of each indicator

In this step, the evaluation of performance and risk indicators shall be carried out so as to capture the performance grading on the building. Hence, the assessment outcome, which is known as the performance-risk assessment score (*PR score*), suggests five scales that range from 0.2 to 1.0. A smaller scale value indicates a poor performance for the indicator, which represents greater risk impact on the users. If the score achieves 1.0, it generally means that the item measured by the indicator is performing excellently and presents an insignificant risk impact on the users. Table 6.1 shows the scores and descriptions for the scales used. The description of scale for the performance-risk assessment was adopted and modified from the risk precedence of order and risk assessment in BARIS (Integrated Asset Planning Branch (CPAB), 2015; Public Works Department, 2013) and also earlier studies relating to risk in building assessment (Massingham, 2010; Whitfield, 2003; Zou et al., 2008). However, it has been adjusted in accordance with the building performance terms that must indicate the condition of performance for the assessed building.

Table 6.1: Scale and Description for Performance-Risk Assessment Score (*PR Score*) for each indicator

SCALE	DESCRIPTION OF SCALE
0.2	• Poor performance with catastrophic building defects • Catastrophic: Presents risk that results in multiple fatalities; may result in human death or serious injury/illness
0.4	• Low performance with major building defects • Significant risk: Presents risk of serious or fatal injury to occupants or major injury/illness
0.6	• Medium performance with moderate building defects • High risk: Presents risk of significant impact with minor injury or minor occupational illness
0.8	• Good performance with minor building defects • Medium risk: Presents risk of minor physical discomfort to occupants or minor occupational illness
1.0	• Excellent performance with few building defects • Low risk: Presents risk with insignificant impact, minimal impact, or no apparent impact at all

(Adapted and modified from: BARIS by PWD, Massingham,2010; Whitfield, 2003; Zou et al.,2008)

Table 6.1 shows that the level of risk impact differs according to the condition of building performance in higher education buildings. The description makes clear that a larger risk is imparted to users' health and safety when there is occurrence of poor building performance. The relation between performance and risk impact has successfully been derived from the findings of the preliminary survey, using semi-structured interviews with Malaysian building operators. The link between performance and risk has also been highlighted in previous studies (Almeida et al., 2010; Dewlaney & Hallowell, 2012; Lützkendorf & Lorenz, 2007, 2006; Meacham, 2010; Meacham et al., 2005; Wolski et al., 2000), which show that effective performance of buildings reduces the risk and the perception of risk for the buildings' users.

As previously described and discussed in the analysis chapter, the listed performance-risk indicators (PRI) are assigned a weightage score. The score was derived from the results of the Analytical Hierarchy Process (AHP) that was included as part of the main survey for this study. The weightage defines the importance of the ranking of the indicators: a higher score indicates a greater impact on the outcome of the assessment. As mentioned in step 1, the performance of each indicator is evaluated using a performance-risk assessment score (*PR Score*) that ranges from 0.2 to 1.0. The score obtained is then multiplied by the weight assigned to each indicator. Equation 2 simplifies the computation to compute the score of each indicator based on the *PR score* and the *weightage (W)*:

$$\textit{PRI Score} = \sum \mathrm{PRI}^{n}{}_{W \times \textit{PR Score}} \qquad \text{(Equation 2)}$$

Where;

PRI score : the score of each performance-risk indicator

W : weighted score for each PRI

PR score : performance-risk assessment score

PRI^{n} : total number of indicators

The above equation shall be applied to each PRI, where the total of overall *PRI score* generates the score of performance elements (functional performance, technical performance and indoor environmental performance). The *PRI score* is obtained from the multiplication of weight (*W*) and the *PR score* at the end of the row for each indicator. The weight for each PRI is derived from the result of the AHP survey, which has been described in the previous chapter. Since the weight (*W*) is static and unchanged, the *PRI score* generally depends on the scale of performance (*PR score*) during the assessment of building performance.

Each indicator needs to be assessed in accordance to the condition or performance during the time of the observation survey. Hence, the assessor shall acknowledge the aspect or criteria of assessment for each indicator. This is important since the aspect of assessment is related to the impact of risk to the users, in terms of health and safety. Since it is related to the users' health and safety risk, the assessment must address the condition or performance of the indicators on the current population of building users. As included in the assessment form, Table 6.2 shows the aspect of assessment for each indicator. This is also to help the assessor while he or she is carrying out the assessment or condition survey.

Table 6.2: Aspects to be addressed for Performance and Risk Assessment

ITEM	INDICATOR	THE ASPECT FOR ASSESSMENT
FP1	Spaces	The aspect was concerned with the size or the measured area able to cater to the users' population
FP2	Orientation	Refers to the good orientation or positioning of windows, rooflines and other features to the sun's path
FP3	Infrastructure	Size, location and shape of vehicle parking, landscape, walkway and pedestrians (any narrow bays or poor location)
FP4	Access/entrance	Proper allocation of access/entrance and surveillance enhanced - designed to be easily accessible by occupants and visitors
FP5	Circulation area	Proper spaces of corridors and lobby area that able to cater to the users' population – no vertical segregation or obstruction
FP6	Ergonomic building facilities	Ergonomic furniture or facilities that do not pose any risk of injury or danger to users
FP7	Adequacy of building signage	Proper allocation of signage in a building and provision of clear interior signage/directories with colour codings
FP8	Emergency exits	Visibility of emergency exits or escape routes with supplemental emergency lighting and indicates signs for proper evacuation in the event of fire
FP9	Building-related illnesses/sick building syndrome	Attributed directly to the airborne building contaminants or an area that may affect safety, health or skin irritations when the users stay in that area

Table 6.2 continued

FP10	Amenities	Good ambience, open space and access of basic amenities for the population of users in HEBs - free from crime and vandalism (toilets, cafeteria, pantry, prayer's room)
TP1	Design of building fittings/fixtures	Any damages of design, materials and poor allocation of the openings - door, window, ironmongery, door fittings, window glass (all opening accessories)
TP2	Structural stability	Stability of structural items; column, beam, floor slabs, concrete walls, roof slabs (any major cracks, hollow or damages prone to safety and health hazards)
TP3	Information technology systems operations	Well functioning and proper installation of an automation system in a building (access card, public address system, building automation system, surveillance system)
TP4	Electrical services	Well functioning of electrical systems and devices
TP5	Plumbing services	Well functioning of pipes, fixtures, fittings, valves, and traps (any corrosion, leaking or aged plumbing)
TP6	Fire prevention services	Well functioning of all fire fighting systems and devices
TP7	Materials and internal finishes	Type and workmanship quality of interior materials that exposed surfaces of a building (floor finishes, wall finishes, ceiling finishes)
TP8	Roof	Well functioning of roofing system including water proofing systems (any possibility of structural degradation and deterioration)
TP9	Lift	Well functioning of the system and easily maintained, with minimal problems and low frequency of breakdowns
IE1	Cooling (thermal comfort)	Well functioning of the cooling devices and acceptable level of air cooling (performance of thermal comfort)
IE2	Artificial lighting	Adequacy, control and level of brightness of artificial lightings (no poor glare or discomfort)
IE3	Natural lighting	Adequate penetration of natural daylight into the building, that may be enhanced though atriums, curtain glass walls, bigger window openings
IE4	Waste disposal	Proper management of waste within buildings – separations of recyclable materials, organic and inorganic waste
IE5	Building ventilation	Adequate ventilation and circulation of air throughout a building (removes air either naturally (windows) or mechanically)
IE6	Acoustic comfort	Proper management of noise in a space (free from excessive noise or lower levels of noise)
IE7	Level of cleanliness	A scale of cleanliness level that ensures the building is free from dirt (proper management of hygiene and disease prevention)

6.2.1.2 Step 2: Overall Score for Performance-Risk Indicators

For the next step, the overall score of PRI can be calculated by summing up the individual PRI scores after the performance assessment for all indicators is completed. This will generate the overall score of performance elements, according to the category of functional performance, technical performance and indoor environmental performance. The overall performance elements score (*PE score*) can be computed using the following calculation, as shown in Equation 3:

$$\sum \text{PE score} = \overset{FP}{[\sum \text{PRI}^{n}{}_{W} \times {}_{PR\ Score}]} + \overset{TP}{[\sum \text{PRI}^{n}{}_{W} \times {}_{PR\ Score}]} + \overset{IEP}{[\sum \text{PRI}^{n}{}_{W} \times {}_{PR\ Score}]} \quad \text{(Equation 3)}$$

Where;

PE score	:	overall score of performance elements
FP	:	Sum-up score for functional performance
TP	:	Sum-up score for technical performance
IEP	:	Sum-up score for indoor environmental performance

A summary of scores for each performance elements is then calculated and tabulated as shown in Table 6.3. Since each of the performance elements are assigned with the maximum weightage that is derived from the result of AHP, the score that shall be obtained from the performance assessment cannot be more than the maximum weightage. The maximum score for *PR score* is 1.00 (Table 6.3), where if all the indicators achieve excellent performance with *PR score* equal to 1.00, the overall score for performance elements will receive a similar score as per maximum weightage (i.e. functional performance 36.7%, technical performance 49.9%, indoor environmental performance 13.4%).

Table 6.3: Summary of scores for each performance elements

NO.	PERFORMANCE ELEMENTS	MAXIMUM WEIGHT (%)	SCORE (%) (based on the assessment)
1	Functional Performance (FP)	36.7	
2	Technical Performance (TP)	49.9	
3	Indoor Environmental Performance (IEP)	13.4	
Total Performance Elements Score *(PE SCORE)*		100	

6.2.1.3 Step 3: The Performance-Risk Rating Classification

The final step in the performance assessment using the building performance-risk rating tool (BPRRT) is to determine the rating classification for the assessed building. The rating classification generates the performance grade and the level of risk. There are five ratings that determine the final performance measurement of the assessed building; i.e. “Excellent”, “Good”, “Medium” “Low” and “Poor”. The determinants of the rating classification depend on the final score (*PE score*) attained from the performance assessment of all indicators.

Table 6.4: Performance-Risk Rating Classification

TOTAL PERFORMANCE ELEMENTS SCORE *(PE SCORE)*	RATING	DESCRIPTION
80 - 100	Excellent	Excellent building performance with low impact to the users' risk on health and safety
60 - 79	Good	Good building performance with medium impact to the users' risk on health and safety
41 - 59	Medium	Medium building performance with high impact to the users' risk on health and safety
31 - 40	Low	Low building performance with significant impact to the users' risk on health and safety
20 - 30	Poor	Poor performance building with catastrophic impact to the users' risk on health and safety

(Adapted and modified from: BARIS by PWD, Massingham,2010; Whitfield, 2003; Zou et al.,2008)

As shown in Table 6.4, the description of each rating is adapted from BARIS (Integrated Asset Planning Branch (CPAB), 2015; Public Works Department, 2013) Massingham (2010); Whitfield (2003); Zou et al. (2008) and modified from the combination of scale descriptions for *PR score*. The proposed rating is concerned with both areas of assessment: building performance and risk to users' health and safety aspects. For the rating, the assessed building will achieve an "Excellent" rating if the PE score is from 80 – 100. The range of score for each rating was determined in accordance with the calculation of the Performance-Risk Assessment Score (*PR Score*) for all indicators. A detailed justification for the range of scores for each grade is described below:

- Poor (Score 20 – 30): If all of the indicators obtain the lowest *PR score* of 0.2, the overall final *PE score* will be 20. This is the minimum rating score to be achieved and the performance grading will be allocated as the lowest rating; **poor** performance.
- Low (Score 31 – 40): If all of the indicators obtain a *PR score* of 0.4, the final PE score will be 39.5 ~ 40. Hence, the benchmark of scores for a rating of **low** performance must achieve 40, as the maximum score.
- Medium (Score 41 – 59): The score starts from 41, since the previous rating ended at 40 (as the maximum score). If all of the indicators obtain a *PR score* of 0.6, the final *PE score* shall be 59. Hence, the benchmark score for a rating of **medium** performance must achieve 59, as the maximum score.
- Good (Score 60 – 79): The score starts from 60, since the previous rating ended at 59 (as the maximum score). If all the indicators obtain a *PR score* of 0.8, the final *PE score* will be 79. This is the maximum final score for a grading of **good** performance.

- Excellent (Score 80 to 100): The score starts from 80 since the previous grading ended at 79 (as the maximum score). If all the indicators obtain a *PR score* of 1.0, the final PE score will be 100. This is the maximum final score that receives the grading of **excellent** performance.

The final risk rating classification will act as a benchmark for the performance assessment of Malaysia's higher educational buildings, in the context of building performance and the risk to users' health and safety. Although there are similarities in the indicators as compared to previously established rating tools, there are differences in the weightings and the descriptions for the rating classification. The proposed building performance-risk rating tool (BPRRT) has merged the concepts of building performance and risk into a comprehensive and strategic model. This differentiates the main concerns of this tool from those of the previous rating tools (such as BREEAM, LEED, GBI, Green Star, CASBEE) that are more focused on green building issues and energy efficiency. The main steps involved in using the proposed rating tool are summarised in Figure 6.1.

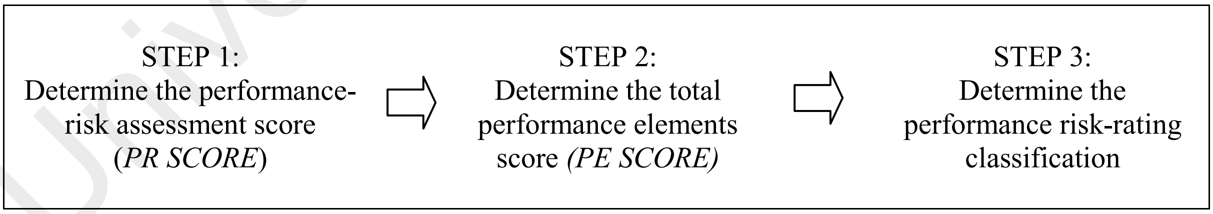


Figure 6.1: Summary of steps for the proposed building performance-risk rating tool

The proposed BPRRT developed in this study will enable local operators of higher education buildings (HEBs) to assess the condition of academic building from the dual perspectives of both performance and users' risk. According to Che-Ani et al. (2010), surveys that employ ratings instead of descriptions are gaining wide acceptance in the industry because they cater to the need for numerical analysis output. The current situation of performance evaluation or maintenance management in Malaysia's HEB is based on a cyclic process of maintenance programmes, which is corrective, scheduled and condition-based maintenance programmes. This conventional maintenance management depicts the process of planning, organizing, directing and controlling a client's resources for a short time in HEBs (Olanrewaju, 2010a). Hence, through the application of the building performance-risk rating tool (BPRRT) as proposed in this study, an improved proactive procedure for performance assessment and maintenance in HEBs can be initiated. The sample performance assessment for the proposed BPRRT is attached in Appendix C.

6.3 Potential Application for the Building Performance-Risk Rating Tool

Since the main type of building focused on by this study is higher education buildings (HEBs), the proposed building performance-risk rating tool (BPRRT) can potentially be applied by building operators in the facility management organisation in Malaysian HEBs. The application provides operators with holistic information concerning exposure towards performance deterioration damage and the impact of performance on users' health and safety risk. This will benefit HEB owners and stakeholders who need to specify an acceptable level of risk and performance. Through the information on building performance and risk impact, insurance provider companies can support more competently their initial lending decisions or calculate insurance premiums based on adequate risk-related information. This will support the management and operation of the HEB throughout its lifespan, and hence achieve sustainability.

The proposed BPRRT also provides important information on the level of risk to the users of HEBs. Students, academicians, administrative staff and other supporting personnel in HEBs are the entity or group of individuals who are users of HEBs. The building users can be presented with a warranty that the building fulfils the performance optimization with a precise risk level in terms of health and safety aspects. These two aspects of risk are the most crucial information that needs to be conveyed to the users; however, without a proper assessment, users are deemed to accept the risk in HEBs without knowing the impacts that may jeopardise their health and safety.

In summary, then, the proposed BRPT not only benefits the owners, but at the same time it benefits the operators, the designers, and also the building users.

6.4 Validity And Reliability Of The Proposed Rating Tool

The validation process in this research is depicted as the final stage in confirming the reliability of the framework's development. In order to strengthen the reliability and applicability of the proposed rating tool, the validity process was carried out via two methods; i) a face validation interview with the industry experts, and ii) testing of the tool for building assessment.

6.5 Validation Interview

To ensure that the proposed rating tool is appropriate and applicable for use within the industry's context, the views and feedback from the identified panel of experts were solicited in this final stage. Panel experts are defined as experienced practitioners or researchers in the specific area of judgment (Beecham et al., 2005; Creswell, 2012;

Leifker et al., 2011). Previous studies on building performances (such as those of Ali & Al, 2008; Almeida et al., 2010; de Santoli & Felici, 2005; Erhorn et al., 2008; Ho et al., 2008; Kim et al., 2005; Poveda & Lipsett, 2011) also used experts to validate the proposed rating tools and framework of their study. Therefore, the sample of experts was drawn based on purposive sampling from registered industry practitioners. Following Beecham et al. (2005), the qualifying criteria of the experts were predetermined and listed. The classification of experts from the group of practitioners is based upon three criteria:

i. Holds a principal or director level position in a facility management (FM) organization or FM unit
ii. Is responsible for building performance assessment or building audit
iii. Possesses knowledge and has more than 15 years experience relating to the building users' health and safety aspects.

The interview was carried out to elicit the experts' views on the appropriateness and applicability of the proposed rating tool for the Malaysian context. Hence, the experts were chosen from those who had experience with both government and private organisations. Semi-structured interviews were used as the instrument in this validation process. The interview questions consisted of 4 open-ended type questions. The interview process began by briefing the interviewee on the purpose of the interview and giving a detailed explanation of the development of the proposed rating tool. Each interview session took around 30 to 45 minutes per participant. The sample of the interview questions is provided in Appendix D.

The validation interview process with the experts was conducted in three separate sessions. The first session was conducted during the Facility Management Asia

Conference 2015 (FAMC). The FMAC conference was organised by the Malaysia Association of Facility Management (MAFM) on the 3rd November 2015, at Putrajaya, Malaysia. The seminar gathered FM experts and practitioners from the leading FM organisations in Malaysia and Singapore as speakers and delegates. Thus, it provided a good platform and facilitated the process of selecting the experts for the validation process.

The second and the third interview sessions were conducted at the experts' own organisation. Arrangements on the date and time for the interview session were first set with the experts before proceeding with the interview session.

6.5.1 Analysis of the Validation Interview (face validity)

A total of four experts agreed to participate in the validation interviews, and they represent both government and private organisations. All of the experts are acknowledged and well known in the Malaysia's FM sector. Participant 1 (P1) is experienced in the FM assessment exercise and is a leading FM consultant, with a few large corporate organisations in Malaysia as his clients. He often shares his knowledge and experience through in-house training, seminars and conferences. Participant 2 (P2) is experienced in information technology in the sector of FM. He has won several awards through the creation of Intuitive Business Transformation (IBT) and Total Infrastructure Facilities Management (TIFM) driven revolutions in Malaysia and the South East Asian region. Participant 3 (P3) is acknowledged as the team leader of building condition assessment for government and public buildings in Malaysia. He is also one of those responsible for introducing the BARIS scheme in the division of facility maintenance and management of the Public Works Department (PWD) in

Malaysia. Lastly, participant 4 (P4) is well known as a leader in the Malaysian construction industry and has widely executed and promoted the FM industry through research designs and innovations. He is also one of the advisors for FM academic courses offered by Malaysia's institutions of higher learning. Table 6.5 shows the background of the experts who participated in this validation interview:

Table 6.5: Background of the Validation Experts

REF	TYPE OF ORGANISATION	DESIGNATION LEVEL	BUSINESS CORE	ACADEMIC BACKGROUND	YEARS OF EXPERIENCE
P1	Private	Director / Vice President	FM and building performance assessment exercise	Mechanical Engineering	More than 15 years
P2	Private	President	Information Technology in the facilities management (FM) sector	Land Surveying	More than 15 years
P3	Government	Senior Principal Assistant Director	Building condition assessment for government and public buildings	Civil Engineering	More than 15 years
P4	Government	Chief Executive Officer	Construction industry and FM innovations	Civil Engineering	More than 15 years

Based on the above details, it can be seen that all of the participants hold top positions in their organisation, and have more than 15 years' working experience. This confirms that they all fulfil the predetermined criteria to qualify as participants in this validation interview. Their core business and expertise is in the field of facility management and building performance assessment. Hence, the responses and feedback from the experts are reliable to validate the proposed rating tool. The findings from the interview session were analysed using *Atlas.ti* qualitative software and are presented in both figures and tables.

6.5.1.1 The Appropriateness of the Rating Tool

The first question asked to the interview participants (the experts) was regarding the appropriateness of the content in the proposed rating tool. The network of responses on the appropriateness is shown in Figure 6.2.

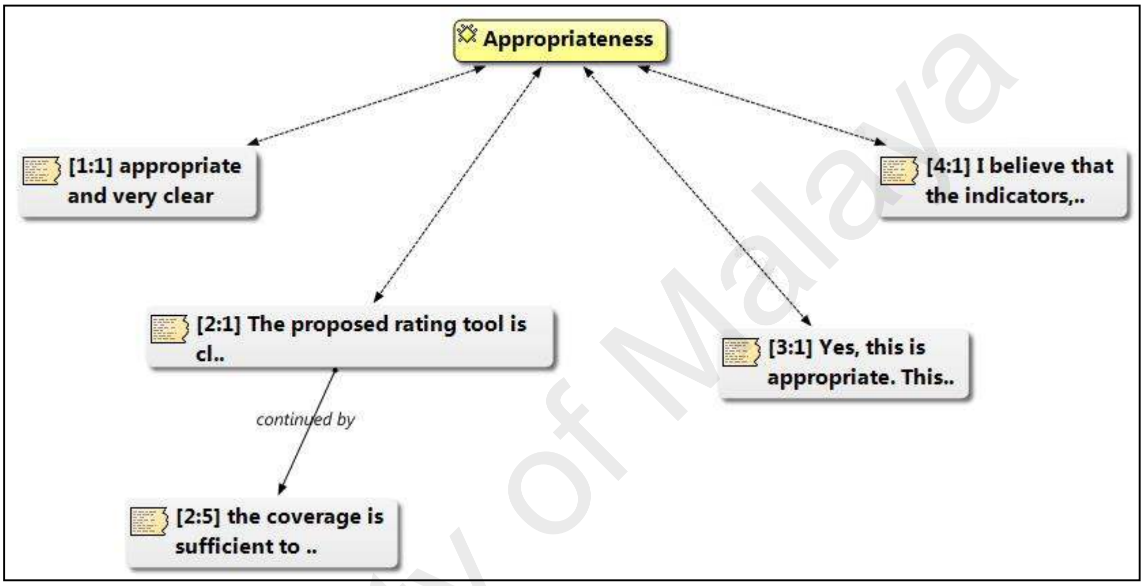


Figure 6.2: Network of responses in terms of appropriateness of the rating tool

All of the experts agreed with the appropriateness and clarity of the proposed rating tool, as evidenced by participant 1, quotation 1 (P1:q1) and the rest of the participants (P2:q1q5, P3:q1 and P4:q1). The overall responses concerning the appropriateness are from the fact that there is no current rating tool for building performance assessment that specifically focuses on the aspect of users' health and safety risk. The experts also felt that the incorporation of risk elements into a comprehensive list of building performance is an excellent approach. Thus, the development of the building performance rating tool that relates to users' health and risk aspects is significant as an aid for the improvement of building performance. Table 6.6 presents the views and justification of the experts concerning the appropriateness of the tool.

Table 6.6: Justifications for the Appropriateness of the Proposed Rating Tool

PARTICIPANT	RESPONSE / FEEDBACK
Participant 1	*Yes, it is appropriate and very clear. This is an excellent approach.*
Participant 2	*The proposed rating tool is clear and the content is appropriate. I believe it can be used as our reference to improve the process of building assessment.*
Participant 3	*Yes, this is appropriate. This is in line with the government's Circular and Act on the enhancement of performance assessment for public buildings.*
Participant 4	*I believe that the indicators, the weightage and the steps in this tool are appropriate. The aspect of users' risk in the assessment is clearly shown.*

6.5.1.2 Applicability to the Industry Context

All the participants agreed with the applicability of the proposed rating tool to the industry context, as supported by the quotations shown in Figure 6.3 (P1:q2, P2:q2, P3:q2, P4:q2). Participant 4 in quotation 3 (P4:q3) pointed out that the indicators are widely established and provided in various types of building, even though the rating tool was developed in the context of performance and maintenance management of higher education buildings (HEBs). It was also found that the participant's agreement based on several quotations (P2:q6, P2:q7, P3:q4, P4:q3) were provided with further justifications. A more complete response from the experts concerning the applicability of the rating tool is presented in Table 6.7.

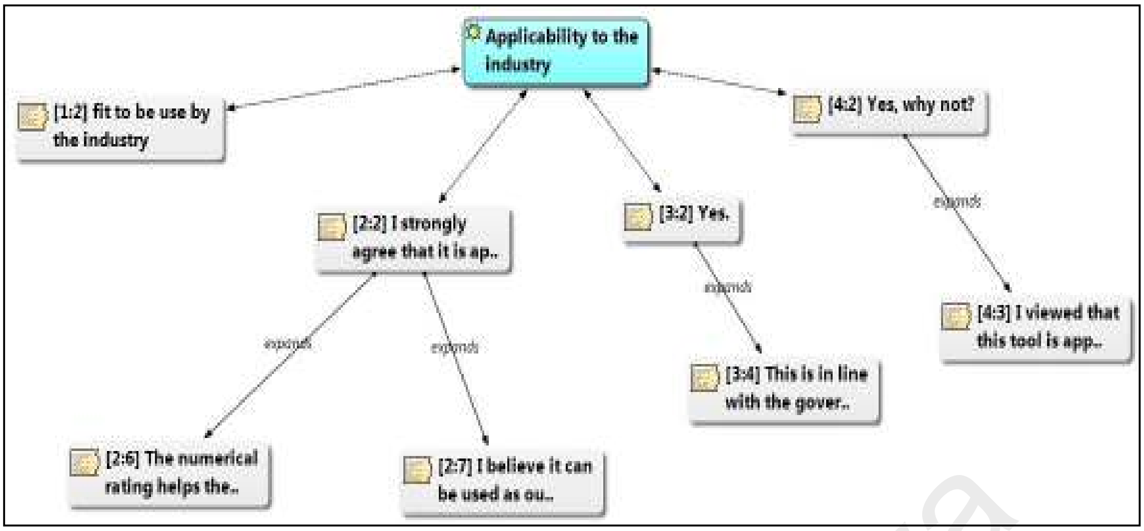


Figure 6.3: Network on the Applicability of the rating tool to the industry

Table 6.7: Responses on the Applicability of the Proposed Rating Tool

PARTICIPANT	RESPONSE / FEEDBACK
Participant 1	*Yes, the rating tool is fit to be used by the industry. But ideally, the building that needs to be assessed must include all the listed indicators.*
Participant 2	*Yes, I strongly agree that it is applicable to the industry. As I said earlier, the coverage is sufficient to be referred to improve the process of building assessment.*
Participant 3	*Yes. Although we have an existing rating currently, but several criteria are not similar. I viewed that all indicators are assigned with weightage; this is good.*
Participant 4	*Yes, why not? Even though that your study concentrates on HEBs, I view that this tool is applicable to be used for other types of buildings too.*

6.5.1.3 Recommendation on Usage

The experts were asked whether the rating tool could be recommended as an improved measure for performance optimization and risk mitigation for the building users. All the participants agreed that the proposed rating tool should be recommended in the industry, as shown clearly by their quotations in Figure 6.4 (P1:q3, P1:q3, P3:q3, P4:q4).

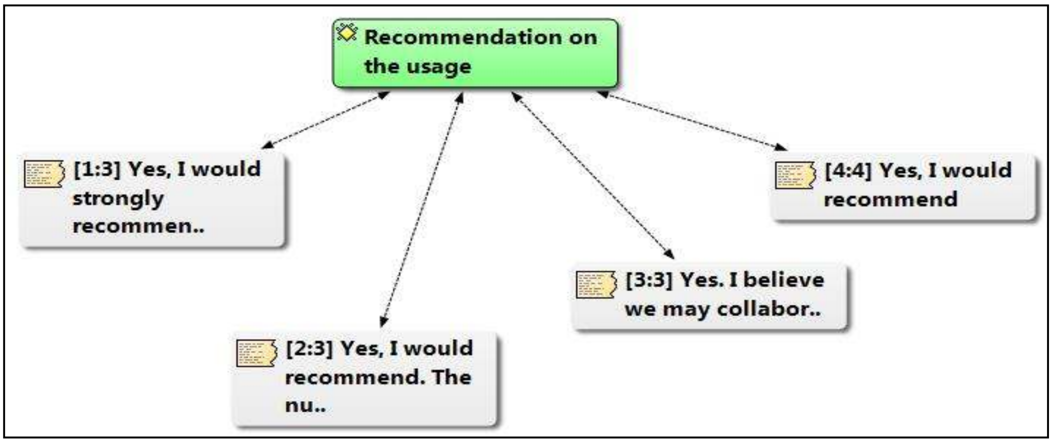


Figure 6.4: Network of recommendations for the usage of the rating tool

A full response on recommendations for usage of the rating tool is also presented in Table 6.8. Participant 1 would recommend the tool if the assessed building has all the listed indicators. Participant 2 believed that the numerical rating helps the process of monitoring in building assessment. Thus, the implementation of maintaining and monitoring of building performance is able to be carried out every day. Participant 3 recommended that usage may be further enhanced through collaboration between industry practitioners and academia. There are also several suggestions pointed out by participant 4 that emphasize the recommendation of the rating tool as a lesson learned for performance improvement.

Table 6.8: Feedback for Recommendations on the Usage of the Framework

PARTICIPANT	RESPONSE/FEEDBACK
Participant 1	*Yes, I would strongly recommend. However, before the assessment is carried out using this tool, the assessed building is mandatory to have all the indicators. For example, lift is included as one of the indicators in the proposed rating tool. A building without lift is therefore not suitable to be assessed using this rating tool.*
Participant 2	*Yes, I would recommend. The numerical rating helps the process of monitoring in building assessment. You may see that the weightage can be imported into our system of assessment and it is clear enough to analyse the condition of performance. There will be no more maintaining and monitoring the building performance once in every 3 or 6 months, but we shall implement it every day.*
Participant 3	*Yes. I believe we may collaborate together on detailing the items of this proposed rating tool with the current existing rating that we used. As a government organization, we always welcome academia to contribute their expertise and their research outcome into the industry context, so improvement could be made towards our building condition assessment (BCA) system from time to time.*
Participant 4	*Yes, I would recommend. However, it is subject to few suggestions. I hope that the result from the assessment can be fed forward as a lesson learned for future construction. Just like the concept of post occupancy evaluation (POE), where the users' feedback is taken into consideration for the next development. In terms of value chain, the evaluation of criteria can be incorporated into the design phase.*

6.5.1.4 Additional Comments and Suggestions

In the final question, all the participants provided additional comments by giving suggestions for further improvements on the applicability of the rating tool. Figure 6.5 shows the network of responses on the suggestions.

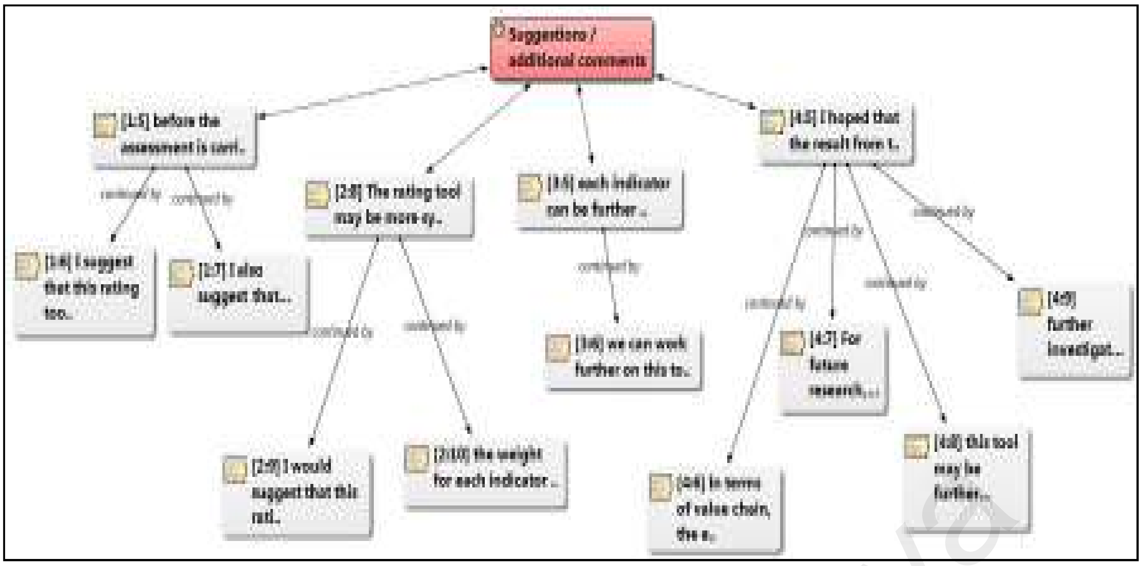


Figure 6.5: Network on the additional comments and suggestions on the rating tool

As seen in Figure 6.5, all of the participants made a variety of suggestions (P1:q5q6q7, P2:q8q9q10, P3:q5q6, P4:q5q6q7q8q9). Participant 1 recommended that the sequence of items should be arranged to suit the physical structure of the building, so as to ease the process of assessment (P1:q5). Participant 2 advised that the rating tool should be used by a competent assessor. Participant 2 and Participant 4 both suggested that the rating tool be further enhanced into information technology system or building information modelling (BIM) system (P2:p9, P4:q8). In addition, Participant 2 and Participant 3 suggested that each indicator in the rating tool could be expanded into further elements, each with smaller weightage (P2:q10, P3:q5).Full responses on the suggestions and additional comments on the proposed rating tool are presented in Table 6.9.

Table 6.9: Further suggestions for future improvement of the Tool

PARTICIPANT	RESPONSE/FEEDBACK
Participant 1	*As I have mentioned before, I suggest that this rating tool should be used for buildings that have all of the listed indicators. It is not fair to assess a building without lift, for example, as the performance assessment score for the indicator cannot be 1.0 (since the building has no lift). I also suggest that the assessor must be very competent and knowledgeable in all aspects.*
Participant 2	*Yes, there are a few suggestions based on my experience. The rating tool may be more systematic if the list of indicators is organised in accordance to the sequence of building arrangement. So that the assessment process able to carried out in a proper direction. Second, I would suggest that this rating tool is developed into an automated system instead of manual form. Using a numerical score as performance approach is very clear, you can submit the analysis of assessment to the client even before you step out from the building. Third, the weight for each indicator may be further sub-divided into smaller scale or weight. For example, under the indicator "Infrastructure" with weight 2.1, it can be divided into sub-indicators such as parking, landscape and also assigned with individual weight.*
Participant 3	*I hope that each indicator can be further expanded in detail, or maybe combine with the current rating system that we used. Perhaps we can work further on this together to bridge the academia and the industry practitioners into one team. I am so happy and overwhelmed with this knowledge sharing session.*
Participant 4	*For future research, I would love to suggest that the indicators of assessment may look into the items for disabled people, so that we can incorporate design criteria for people with special needs since planning phase. Other than that, I believe this tool may be further enhanced into the technology of BIM, which can incorporate the visual drawings and the criteria into one modelling system. I would also suggest that further investigation for correlational study of the risk impact of the performance elements able to carry out. This is due that you have already provided mean distribution analysis on the impact of risk to the health and safety separately.*

The findings from this validation interview have successfully supported the appropriateness and applicability of the proposed building performance risk rating tool (BPRRT) in the context of higher education buildings (HEB). The findings have also strengthened the reliability of the proposed BPRRT for use in Malaysia. It is also found that the range of expertise among the experts provided diversity in the suggestions for improvement to the proposed BPRRT. The suggestions and recommendations from the experts are also forwarded as opportunities for future research. As part of the reliability process for the proposed BPRRT, the next section explains how the assessment under the BPRRT is applied in a real-life situation.

6.6 Testing The Tool For Building Assessment

Due to time constraints for this study, testing of the tool was carried out on only one academic building, since it was impractical to assess a large sample of academic buildings in all public universities in Malaysia. The chosen academic building is located at the Faculty of Architecture, Planning and Surveying (FSPU), Universiti Teknologi MARA (UiTM), Seri Iskandar, Perak. This building is the largest academic building in UiTM Perak. Since the building is accessible to the researcher and has all the elements to fulfil the required indicators listed in the BPRRT form, it was chosen as the sample building on which to test the tool. Since the assessment involves technical terms and aspects of the building, therefore, the building assessment was carried out with the help of the building assessor and technical staffs from the university's facility management unit. The tool has to be used by the professional assessors, hence, the determinants of elements needs to be affirmed with the experts; as well as the final rating tool. Participation from the building users may be considered if the assessment requires current information on satisfaction or comfort on the existing situation of the building. The assessors were acquainted with building diagnosis and legislation in university buildings, and this facilitated the process of assessment in the selected building.

The period of assessment was conducted in one (1) day, started at 8.30am and completed at 5.30pm. Before the building assessments began, briefing sessions were arranged to explain the assessment schemes of the proposed BPRRT to the technical staff who were acting as assessors. This briefing was essential because it enhances the degree of objectivity and consistency in the assessments. To make sure the assessors understood the purpose of the assessment, the aspect of assessment for each indicator in the proposed BPRRT was explained at the very beginning of the building inspection (as seen in Figure 6.6). It is essential that the assessors are familiar with the aspects of assessment since the performance is related to building users in terms of health and safety risk.

Each of the steps and numerical weights in the proposed BPRRT were also explained in detail, including the impact of performance assessment on the final rating classification. Following that, each of the measurements or inspection items was described in detail with the aid of site photos and building floor plans. Apart from unit assessment, feedback and responses from the building users were also taken into considerations during the survey. Hence, the users' responses were incorporated as remarks and helped the assessors to decide upon the performance assessment score.

Figure 6.6: Briefing session with the building assessors and the technical staff

To further reduce the chances of bias and error, the on-site surveys for each unit and area were photographed, and notes and remarks were taken during the survey. In this way, mistakes attributable to misinterpretation or carelessness were minimized. The assessments by the assessors were also monitored by cross checking with the building floor plans and site photos.

6.6.1 Sample building

The chosen building for the tool testing of the proposed BPRRT is Quantity Surveying Complex (KUB) of the Faculty of Architecture, Planning and Surveying (FSPU), as shown in Figure 6.7.

Front

Rear

Figure 6.7: Quantity Surveying Complex, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA Perak

The 4-storey building was constructed in April 2010 and fully occupied in May 2011. The gross floor area of the building is approximately 15,875m2. The building was originally built for the Faculty of Business and Office Management, but currently it is occupied by the Quantity Surveying program. The current population of building users numbers approximately 1,240 people, consisting of students, academic staff and supporting staffs. Details of elements or units of the building are presented in Table 6.10.

Table 6.10: Units in the Sample Building

UNIT	NUMBER OF UNITS
Lecture Halls	3
Lecture Rooms	18
Studios	5
Computer labs	8
Seminar rooms	4
Cafeteria	1
Surau	2
Lecturer's rooms	72
Amphitheatre (external)	1
Pantries	3
Toilets	14

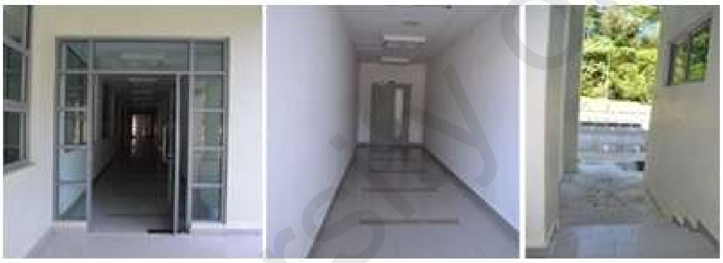
6.6.2 The result of the building assessment

According to the assessment procedures of the building performance risk rating tool (BPRRT), the first step is to obtain the score for each performance risk indicator (PRI) based on its actual condition. Hence, each indicator is assessed in accordance with the scale of performance and risk level (PR score). In terms of indicators of functional performance, the spaces, circulation area, vehicle parking and pedestrians are adequate to cater for the current population of users. The building orientation is inclined towards green features, with large window openings and glass panel installation. The site photos taken during the assessment of indicators under the functional performance category are shown in Figure 6.8.

Access and orientation – adopts green features but no proper surveillance at the main entrance

Circulation area – spacious and fit for users

Parking, lecture rooms and lecture halls - adequate space to cater the current population



Alternative access - quite hidden and dark; may present risk of crime or nuisance

Emergency exits – only installed at exits but no signs for proper evacuation in the event of fire or disaster

Ergonomic facilities – several studio chairs were broken and not fit to be used

Building related illness - dampness of suspended ceilings in several lecturers' rooms create unhealthy environment in those affected units

Figure 6.8: Site Photos on the Indicators of Functional Performance

However, several aspects need to be improved in mitigating the risk of health and safety aspects to the users:

- Access or entrance - Main access is clearly visible; however there is no proper surveillance (for instance: CCTV) at the main entrance. Other access (left and right wings) is quite hidden and it may present risk of crime or nuisance.
- Building signage - Building signage is installed for room indication but there is no proper sign for directions to the rooms, which would be normally placed at the entrance hall or near the lift.
- Ergonomic building facilities - The majority were in good condition, but several studio chairs were broken and not suitable to be used by the users.
- Emergency exit - exit signs were found at all exits. However, there were no proper evacuation signs in the event of fire or disaster. There were no signs to inform users where they should assemble in the event of fire (assembly area for evacuation)
- Building related illness – Even though there had been no reported cases, there were some minor defects in several rooms. Complaints from the users were made due to dampness of suspended ceilings in several lecturers' rooms, which created an unhealthy environment in those affected units (eye irritations and respiratory disorder)
- Amenities - The basic amenities are well provided; however the allocation of space and quantity of amenities may not be adequate to cater to the current population of building users.

The assessment scores for the PRI under the functional performance category are shown in Table 6.11.

Table 6.11: Result of Assessment for Functional Performance

PERFORMANCE-RISK INDICATOR		WEIGHT *(W)*	ASSESSMENT SCORE *(PR Score)*	TOTAL SCORE *(W x PR Score)*
FP1	Spaces	1.3	0.8	1.04
FP2	Orientation	1.4	0.8	1.12
FP3	Infrastructure	2.1	0.8	1.68
FP4	Access/entrance	2.7	0.6	1.62
FP5	Circulation area	2.2	0.8	1.76
FP6	Ergonomic building facilities	4.5	0.6	2.70
FP7	Adequacy of building signage	3.7	0.4	1.48
FP8	Emergency exits	6.8	0.4	2.72
FP9	Building-related illnesses/ sick building syndrome	7.4	0.8	5.92
FP10	Amenities	4.6	0.6	2.76
Total score for functional performance				**22.80**

The next assessment is for the indicators under the category of technical performance. Generally the structural elements and the fittings elements were in good condition, with only few items presenting some minor defects. There were also indicators that were in good condition during the assessment survey but had previously been found to have performance failure, such as lift and electrical fittings. Based on users' complaint, the lift had failed to function in multiple times and several users had been trapped inside the lift. The site photos during the assessment of indicators under the functional performance category are shown in Figure 6.9.

Only one CCTV is installed at staff punch card area (weak surveillance).

Lift was functioning during the survey. However, the lift had previously broken down and a few users had been trapped in the lift

Electrical services - Improper installation of electrical wiring were found in the toilet (ground floor level)

Plumbing services – leakage of fittings, the cover of floor traps were not properly closed

Fire prevention services - fire fighting system is functioning but some of the fire extinguishers were not found during the survey

Roof and ceiling finishes - leakage at the ceiling of several lecture halls, classrooms and lecturers' room due to poor waterproofing of roof

Figure 6.9: Site Photos on the Indicators of Technical Performance

Based on the assessment, it was found that several aspects needed to be improved and the analyses of the assessment are as follows:

- Information technology systems operations - Access card is installed for access to the management office but only one CCTV is installed at staff punch card area (weak surveillance).
- Electrical services - Improper installation of electrical wiring was found in the toilet (ground floor level) and it presents a health and safety risk to the users. Some of the fittings are not properly functioning, but no failures are present in major areas.
- Plumbing services - The cover of floor traps are not properly closed and may jeopardise the safety of users. Some of the fittings are not properly functioning, but the failures do not represent major areas
- Fire prevention services – The fire fighting system is functioning but some of the fire extinguishers are not found during the survey. Assessors explained that the fittings are placed in the facility unit to avoid theft.
- Materials and internal finishes - All finishes are in good condition except failure of workmanship for ceiling finishes to some areas. However the failure is due to improper installation of waterproofing from the upper floor level.
- Roof - Leakage at ceiling in several lecture halls, classrooms and lecturers' room due to poor waterproofing of the roof. However it does not represent major areas.

Therefore, the score of assessment for the PRI under the technical performance is shown in Table 6.12.

Table 6.12: Result of Assessment for Technical Performance

PERFORMANCE-RISK INDICATOR		**WEIGHT** *(W)*	**ASSESSMENT SCORE** *(PR Score)*	**TOTAL SCORE** *(W x PR Score)*
TP1	Design of building fittings/fixtures	2.7	0.8	2.16
TP2	Structural stability	14.9	0.8	11.92
TP3	Information technology systems operations	1.7	0.4	0.68
TP4	Electrical services	6.3	0.6	3.78
TP5	Plumbing services	3.3	0.6	1.98
TP6	Fire prevention services	9.1	0.6	5.46
TP7	Materials and internal finishes	2.7	0.8	2.16
TP8	Roof	4.1	0.6	2.46
TP9	Lift	5.1	0.6	3.06
			Total score for technical performance	**33.66**

The last assessment is for the indicators under the category of indoor environmental performance. For this category, all of the indicators are non-visible items, hence the assessment is based on the building's general area and also feedback from the users' experience. In terms of cooling, the air-conditioned area is comfortable, the distribution suits the area, and all devices were in good functioning order. The features of natural daylighting perform well as most of the openings are large and installed with glass panels. The penetration of natural lighting is adequate, including in the lecture rooms and lobby area. The areas are clean, thus showing that the waste management system is performing well. Since the building is spacious, the air circulation provides good ventilation due to large lobby areas, openings and connecting corridors. The site photos during the assessment of indicators under the indoor environmental performance are shown in Figure 6.10.

Majority air-conditioning devices were installed in lecture rooms and studios

Adequate penetration of daylighting

Good natural daylighting due to the design of large openings and glass panels, including in the lecture rooms, cafeteria and lobby area

Good level of cleanliness and waste management. However, there is no separated recycle bins being provided

Figure 6.10: Site Photos on the Indicators of Indoor Environmental Performance

Based on the assessment, several aspects need to be improved and the analyses of assessment are as follows:

- Artificial lighting – it is found that the lightings at the lobby areas were switched on all day. This may not be necessary since the area is clearly bright with natural daylight. Energy consumption can be saved by switching off the lightings to unnecessary areas.
- Acoustic comfort - Due to the position of rooms and halls, noise is controllable. However, unoccupied rooms were found to have noise due to the vibration of mechanical devices (air conditioners and fans).
- Level of cleanliness - All areas are clean. However, there is no isolated recycle bins provided in the building area. Hence, it is assumed that waste recycling practices in this building is poor. The management needs to take extra measures to ensure that wastage and trash in waste bins is not exposed to trespassing animals. This is due to the location of the building that is near to some areas of secondary growth. Trash will attract animals such as monkeys and pigs, as well as feral cats and dogs to rummage through the rubbish, thus creating an unhealthy environment.

The score of the assessment for the PRI under the indoor environmental performance is shown in Table 6.13.

Table 6.13: Result of Assessment for Indoor Environmental Performance

PERFORMANCE-RISK INDICATOR		**WEIGHT** *(W)*	**ASSESSMENT SCORE** *(PR Score)*	**TOTAL SCORE** *(W x PR Score)*
IEP1	Cooling (thermal comfort)	2.0	0.8	1.60
IEP2	Artificial lighting	1.1	0.6	0.66
IEP3	Natural lighting	0.9	0.8	0.72
IEP4	Waste disposal	1.6	0.6	0.96
IEP5	Building ventilation	4.1	0.8	3.28
IEP6	Acoustic comfort	1.4	0.8	1.12
IEP7	Level of cleanliness	2.3	0.8	1.84
Total score for indoor environmental performance				**10.18**

After all the indicators were completely examined and assigned with the assessment score, the overall score of assessment can be calculated. The total score of all indicators in accordance to the category of performance elements is summarised in Table 6.14:

Table 6.14: Result of Performance Element Score and Final Rating Classification for Sample Building

PERFORMANCE ELEMENTS	ELEMENT SCORE *(PE SCORE)*
1. Functional Performance (FP)	22.80
2. Technical Performance (TP)	33.66
3. Indoor Environmental Performance (IEP)	10.18
Total Performance Element Score	**66.64**
Final Rating Classification	**GOOD (60 – 79)**

In accordance with the description of the performance-risk rating classification, the performance condition of the KUB building is rated as "Good" (see Table 6.4). Based on the description of ratings listed on Table 6.4, the performance level of the building is good, but with some minor defects. Even though that the rating is "Good", the level of risk to the user's health and safety is in the category of *medium risk*. In accordance with the description of *medium risk*, the building presents risk of minor physical discomfort to occupants or minor occupational illness. It was also found that the obtained score for FP was 22.8, or 62.1% of its maximum achievable weightage (maximum weight 36.7). While the corresponding percentage of total achievable score for TP and IEP were 67.5% and 76% of its maximum achievable weightage, respectively. This indicates that the current condition of the PRI under the performance elements of FP and TP may jeopardise users' health and safety, if there is no remedial action or improvement to their condition or performance.

Based on the results of performance and the impact of risk, it is highly recommended to carry out the risk response for the next risk transfer process and mitigate the risk by introducing several actions or responses. A probe feedback from the users in regards to the risk level should be further investigated.

6.7 Summary

By integrating the performance-risk indicators from the perspectives of functional, technical and indoor environmental performance, this research strengthens the assessment of the current state of building performance with risk concerns for users' health and safety. The proposed BPRRT provides a more holistic assessment approach that takes the Malaysian context into consideration. Since the weightings are rated in accordance to its importance for Malaysian context, the weightings may need to restructure if the tool is adopted by other countries outside of Malaysia. This is crucially dissimilar by looking into different risk attitudes and risk cultures.

It is recommended that the proposed BPRRT should be used by the relevant organisations as it has been developed and established through multiple strategies, with the participation of FM experts who contributed their knowledge and experience in the collaborative process. The proposed BPRRT suits the local context of Malaysia's HEBs as it is validated in regard to various instruments such as review of literature, academic theories, semi-structured interviews, questionnaire survey and also the Analytical Hierarchy Process (AHP) method. The proposed BPRRT consists of three performance elements and 26 performance-risk indicators that are the sub-items of the performance elements. The significant finding for the proposed BPRRT is the value of the weighting system (AHP system) included to assess the indicators and performance elements.

Significantly, there are differences in the weighting of each indicator, although there are similarities regarding the category level between the proposed BPRRT and previous performance rating tools. The approach adopted in this study was able to produce significant benefit that was not likely to result from standard practices, as well as its ability to ensure maximum beneficial social and economic impacts. Its contribution is thus far greater than what would have been achieved by merely concentrating on the conventional approach of building condition improvement and minimizing risk towards the users. It can be concluded that the fourth objective of this study has successfully been achieved through the development of this proposed Building Performance-Risk Rating Tool.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter concludes by describing how all the findings and results in this study achieved the research objectives and answered the research questions. This research has successfully achieved its main aim of developing the building performance-risk rating tool (BRPT), paying attention to risk mitigation concerning users' health and safety. The conclusions are desired to explain explicitly all the steps used in the research. Therefore, this chapter sets out the summary of conclusion and recommendations of the research. The limitations of the research are also explicated in this chapter. Finally, areas for future research are suggested based on the limitations.

7.2 Establishment of Research Objectives

The clear establishment of all research objectives has led to the achievement of the main aim of this study. Hence, the conclusions for establishment of the research objectives are described according to the sequence of study objectives. The proposed building performance-risk rating tool (BPRRT) developed in this study provides a standardised tool for assessing the performance or condition of higher educational buildings (HEBs) in Malaysia. At the same time, the performances are also related to the context of the building users' health and safety risk, which was previously lacking in performance assessments currently used in HEBs. With this tool, the actual performance and the risk impact of complex buildings in HEBs can be evaluated within a short period of time. With the assessment results using numerical weightage and a rating description in BPRRT, explanatory studies of building performance and users' risk can be conducted empirically with more reliable data.

7.2.1 Identification of the concept of building performance assessment used for higher educational buildings (HEB)

In accordance with the study area of this research, the literature review covered the main focus of the study pertaining to building performance, users' risk and also the background of higher educational buildings (HEB) in terms of performance assessment or maintenance. The study began with the exploration of the background of HEBs that described the problems and issues pertaining to their performance. It was identified that potential risks may arise from the building's performance; thus, HEBs potentially have opportunities for enrolled adaptation and solutions for the rest of society in campus operations. However, the current system of management for performance assessment and maintenance of HEBs remains cyclic and reactive; being based on a routine scheduled maintenance and also based on users' complaints or reports.

It is concluded that the first objective for this research; identification of the current concept of building performance assessment in HEB is partly achieved through the exploration and analytical review of the literature. Full achievement of the first objective was validated from the analysis of the preliminary survey. The preliminary survey used semi-structured interviews of 18 building managers and operators of 20 Malaysian public university buildings. From the comprehensive description of the results from the preliminary survey, it was concluded that indicating the users' risk would optimise the building performance in higher educational buildings (HEB). The interview findings achieved the first research objective by concluding that the current instrument or current assessment system does not incorporate an established rating tool. It also concluded that there is no incorporation of risk aspects for users in terms of health and safety in the current performance assessment, or in the list of assessed building items in local university buildings. Hence, there is a need for proactive approach and standardization of assessment tools and methods due to inconsistent use of assessment and the reactive measures for performance assessment currently practiced in local HEBs.

7.2.2 Identification of the indicators that contribute to the performance requirements and the users' health and safety risk

As previously described in the discussion of the first objective of the study, the main focus of the study was focused on the area of building performance, users' risk and also the background of higher educational buildings (HEBs) in terms of performance assessment or maintenance. The literature review explored the concept of Building Performance Evaluation (BPE) with reference to the findings from studies regarding the issues and problems raised from the poor performance of building. It is agreed that a building should minimize the potential risk and losses arising from the identification of hazards in the living built environment. The literature review then proceeded to a review of the previous established BPE tools and schemes. A total of 13 performance schemes were reviewed; BREEAM, LEED, BQA, TBP, CASBEE, GreenStarNZ, PROBE, GBCA, BHHI & BSCI, HK-BEAM, CEPAS, GBI and BARIS. It was found that majority of the performance aspects of these tools were mainly concerned with energy issues, green aspects and environmental building conditions. However, in meeting the current changing needs in a building, performance is not restricted only to energy. It was found that an integrated risk-performance rating tool is needed to overcome the lack of concern for social aspects of BPE for HEBs, which are able to provide opportunities for improvement of building performance and the relationships with users' risk in the social context.

The literature review identified a wide variety of risk factors with the potential to affect the different dimensions of building performance. It was revealed that the identification of risk in the risk management process can help to optimize building performance, which has a direct impact on building users' comfort and satisfaction. Chapter 2 of this study has explored the requirements and indicators relating to building performance, risk and the users of HEBs as the society perceiving the risk impact from the failure of building performance. The literature led to the initial constructs of the PRIs.

It is therefore concluded that the second objective, the identification of the indicators that contribute to the performance requirement and to users' health and safety risk, was also partly achieved through the literature review. The full achievement of the second objective was carried out by means of a preliminary survey using semi-structured interviews which validated the findings from the literature review. The semi structured interviews were used to obtain the views and opinions from 18 experienced building managers and operators in Malaysian public HEBs. The findings established that it is appropriate to categorise performance into three broad categories: functional performance, technical performance and indoor environmental performance. The categories of performance elements were further divided into 26 indicators, as a result of the semi-structured interviews with the local building operators. Each of the indicators represents a specific characteristic of each sector they described; they are concerned with the goals and objectives of mitigating user's risk in terms of health and safety. Hence, it is concluded that the interview findings also contributed to achieving the second objective of this study by identifying the performance-risk indicators that constitute health and safety risk to HEB users.

7.2.3 Determinants of the relative importance score as weightage/ratings in the performance-risk indicator constructs

The third objective of this study, which was resolved in the questionnaire survey that formed the main survey stage of this study, was to determine the relative importance score or weightage of each performance-risk indicator (PRI). As described previously, the objective of the main survey was to determine the weightage or rating for each indicator. The Analytical Hierarchy Process (AHP) method was adopted in the main survey stage to determine more valid and dependable ratings. The main survey process involved 12 facilities management (FM) professionals and experts as the respondents for the questionnaire survey. The weightings from the result of the AHP procedures represented the relative importance assigned to each PRI by the experts in respect of users' health and safety risk in higher educational buildings.

As a result of the AHP survey, each of the 26 PRIs under the functional performance, technical performance and indoor environmental categories was assigned a relative weight. The weighted scores were then calculated in a summation score to establish the total scores for each of the performance categories. The result of the AHP found five indicators that were ranked as the most important factors; structural stability (14.9%), fire prevention services (9.1%), building-related illnesses (7.4%), emergency exits (6.8%) and electrical services (6.3%). These results have usefully supported the importance of the indicator of structural stability on the impact upon users' health and safety risk.

The summation scores from the indicators in accordance with the three categories of performance elements show that the top ranking is achieved by technical performance (49.9%), followed by functional performance (36.7%) and indoor environmental performance (13.4%). Technical performance was revealed to be the most critical performance element that had the greatest impact in the context of building performance and users' risk. Thus, the result and presentation of analysis for the main survey achieved the third research objective of this study, i.e. determining the relative importance scores as weightages of the performance-risk indicators. The weight obtained as the outcome result of this AHP survey facilitated the development of the building performance-risk rating tool (BPRRT).

7.2.4 Development of a Building Performance Rating Tool incorporating both building performance level and users' risk level

The fourth objective of this study was successfully achieved in the final phase of this study. The development of a building performance-risk rating tool (BPRRT) was established based on the analyses and results of the preliminary survey (semi-structured interviews) and the main survey (questionnaire survey and AHP method) in this research. The results from the interviews successfully constructed the final list of 26 performance-risk indicators (PRI) into the initial construct of the BPRRT. The 26 indicators were categorised under the performance elements of functional, technical and indoor environmental performance. The result of weightings from the questionnaire survey using the AHP method further developed the building performance-risk rating tool. A weightage was generated for each of the PRIs based on pairwise comparisons of the importance assigned to the indicators by the experts. The resulting weightages were calculated and analysed using the computer package the *Expert Choice* 11 version 3.10. Hence, the BPRRT was introduced as an improvement to the current performance assessment of HEBs by addressing the risk hazards to users in terms of health and safety risk.

The proposed BPRRT was developed as a performance assessment scheme for Malaysia's HEBs. It involves three steps of assessment. The first step is to evaluate the performance and risk of the indicators, using the weightage derived from the AHP method; the second step is to calculate the overall score of PRIs for each performance category; and in the third step of the BPRRT, the three scores obtained in step two are summed as the final process of assessment, thereby providing an overall score for the building, from which it is assigned a rating classification: "Excellent", "Good", "Medium", "Low" or "Poor". The indication of the risk rating classification suggests further actions that should be taken to in improve the performance of the building and mitigate the users' health and safety risk. This can be carried out by the assessors of HEBs by referring to the descriptions that accompany the grading. The findings from the validation interview (face validity) carried out with the industry experts strengthened the expected reliability of the proposed rating tool for the local industry. The expert panel provided positive feedback in terms of the appropriateness and the applicability of the proposed rating tool. Finally, the tool was tested in a real-life situation, by applying it to the assessment of a sample university building. Therefore, it is concluded that the fourth objective of the study in developing the BPRRT was successfully achieved in this research.

It is also summarised that the attainment of all objectives had helped to achieve the main aim of research; to develop a building performance risk rating tool, as performance assessment measure concerning the users' health and safety risk in higher education buildings (HEB).

7.3 Limitations of the Research

As in most other studies, this study has its own limitations. There are a few limitations of this research that may derive from various challenges and obstructions in terms of time, resources, and financial and external forces. The first limitation concerns the establishment of the list of performance-risk indicators (PRI) for academic buildings in Malaysian universities. Since universities have a range of building types and building units, this research was limited to the academic buildings that are involved in activities that support the learning and teaching process. The areas included for academic buildings consist of lecture halls, classrooms, studios, workshops and computer labs. The establishment of the indicators was not concerned with other areas or units in public HEBs; for example, students' housing, administrative offices, library, language centres, laboratories, facility and development offices, mosque and religious facilities, sport centres and guest houses.

Another limitation is that the research was limited to three categories of performance: functional performance, technical performance and indoor environmental performance. The performance mandates or elements were generated based on their applicability in the context of building requirements in HEBs. The research also limited the social behaviour factor for users' risk in terms of health and safety risks.

7.4 Recommendation For Future Research

Future research on topics similar to that covered in this research is highly encouraged. The recommendations are based on the limitations described in this study. In reference to the topic of this research, it is strongly recommended that the following topics should be considered for future research:

i. It is suggested that this tool be further enhanced through integration into the technology of Information Technology (IT) and Building Information Modelling (BIM) that may link visual drawings and criteria for assessment into a single database. This will help assessors to verify the usability of the building areas in accordance to the as-built plans and point out actions that need to be taken in the affected area.

ii. The indicators may be further expanded with sub division of items into smaller scale or weight. For example, under the indicator "Infrastructure" with weight 2.1, it can be divided into sub-indicators such as parking, landscape and also assigned with individual weight. Basically, the scales and factors may have similarities or differs in accordance to the requirements in the specific areas of building, hence, future research is recommended to explore on other factors for the said areas.

iii. Other social aspects could also be considered, such as financial risk and reputational risk of the assessed buildings. These two risk frames may be more attractive to building owners, as the financial consequences of dealing with building risk and users' risk reflects the building operations for long term benefits.

iv. It is recommended that experimental research using different techniques of statistical analysis be applied to test the variables or criteria used, which will depend on the objective of the research. The relationship of performance (as dependent variable/s) and indicators (as independent variables) can be further tested through a correlational study or regression analysis. Experimental research may also be applied to establish the relationships among the variables and other factors.

7.5 Conclusion

It can be concluded that this research has successfully achieved its main aim of developing the building performance-risk rating tool (BRPT), that address to risk mitigation concerning users' health and safety. It is also concluded that the presentation in this section swathe up the establishment of the research objectives and provide evidence in answering the research questions.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

A. PUBLICATIONS

1. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum (2016). Ranking The Indicators of Building Performance and The Users' Risk via Analytical Hierarchy Process (AHP): Case of Malaysia. *Ecological Indicators*. Vol. 71, pp.567-576 ***(ISI/ Web of Science)***

2. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum (2016). The Performance-Risk Indicators (PRI) in Building Performance Rating Tool for Higher Education Buildings. *Journal of Facilities Management*. Vol. 14 (1), pp. 36-49 ***(ERA 2012 Journal List)***

3. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum (2015). A Survey On The Performance-Risk Rating Index For Building Performance Assessment In Higher Education Buildings. *Jurnal Teknologi*. Vol. 75 (9), pp. 57–63 ***(Scopus indexed)***

4. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum, Husrul Nizam Husin (*2015*). Benchmarking Users' Feedback as Risk Mitigation in Building Performance for Higher Education Buildings (HEB). *Procedia Social and Behavioral Sciences*. 168 (2015) pp. 171 – 180 (***CPCI/Thomson Reuters) (SCOPUS indexed)***

5. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum, (2015). The Conceptual Framework of Building Performance-Risk Indicators (PRI) For Buildings Users in Higher Education Institutions. *Applied Mechanics and Materials.* Vol 747*,* pp 363-366 ***(SCOPUS indexed)***

6. Natasha Khalil, Syahrul Nizam Kamaruzzaman, Mohamad Rizal Baharum, (2014). Significance of Attaining Users' Feedback in Building Performance Assessment. *MATEC Web of Conferences,* Vol. 15 (01004) pp.2 -7 *(2014) (ISSN: 2261-236X)*

7. Natasha Khalil, Syahrul Nizam Kamaruzzaman & Husrul Nizam Husin (2014). Literature Review on the Concept of Building Performance and Incorporation of Users' Feedback. *Proceedings of The 3rd International Building Control Conference 2013*, Kuala Lumpur, Malaysia. pp. 238-244 (ISBN: 978-967-5878-90-9)

8. Natasha Khalil, Syahrul Nizam Kamaruzzaman (2013). Integrating Risk in Building Performance for Higher Educational Buildings: A Proposal and Conceptual. *International Journal of Advances in Management, Technology & Engineering Services*, Vol. 2, Issue 6 (II) (March 2013), pp. 46-49 (ISSN: 2249-7455)

B. PAPERS PRESENTED

1. Paper title "Analytical Hierarchy Process For Developing A Building Performance-Risk Rating Tool". Presented in the 4th International Building Control Conference (IBCC2016) at Pullman Hotel, Bangsar, Kuala Lumpur, Malaysia on 7th March 2016

2. Paper title "Development Of Building Performance-Risk Rating Tool (BPRT) For Higher Educational Buildings". Presented in the Penang Invention, Innovation & Design 2013 (PIID2015) at UiTM Pulau Pinang, Malaysia on 25th – 26th October 2015.
   Award: Silver Medal

3. Paper title "Performance-Risk Rating Index For Higher Educational Buildings" presented in the Three Minute Thesis Competition 2015 (university level) at IPPP Auditorium Hall, Universiti Malaya, Kuala Lumpur, Malaysia on 12th June 2015.
   Award: 1st Place (Faculty level)

4. Paper title "The Conceptual Framework of Building Performance-risk Indicators (PRI) for Buildings Users in Higher Education Institutions". Presented in the International Conference on Science, Engineering and Built Environments (ICSEBS 2014) at Sanur Paradise Hotel, Bali, Indonesia on 24th – 27th November 2014

5. Paper title "Benchmarking Users' Feedback as Risk Mitigation in Building Performance for Higher Education Buildings (HEB)". Presented in the Asia Pacific International Conference on Environment-Behaviour Studies (AcE-Bs) at Sirius Business Park, Berlin,Germany on 24th -26th February 2014

6. Paper title "Conceptual Framework of Performance-Risk Indicators (PRI) associated to Building Users in Higher Institution". Presented in the International Research, Invention, Innovation & Design 2013 (RIID2013) at UiTM Melaka, Malaysia on 16th -17th December 2013.
   Award: Silver Medal

7. Paper title "Literature Review on the Concept of Building Performance and Incorporation of Users' Feedback". Presented in the The 3rd International Building Control Conference (IBCC2013) at Royale Chulan Hotel, Kuala Lumpur, Malaysia on 21st November 2013

8. Paper title "Integrating Risk in Building Performance for Higher Educational Buildings: A Proposal and Conceptual". Presented in the International Conference on Safety, Hazardous and Disaster Management at First Hotel, Bangkok, Thailand on 5th -6th March 2013