THE DEVELOPMENT OF ENERGY RISK FRAMEWORK FOR RETROFITTING PROJECT

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This work is dedicated to my family especially my parents for their support, patience, understanding, and prayers throughout this research journey.

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ABSTRACT

Energy demand in existing building growths every year compared with new building. The growth of energy consumption on existing building is significantly soaring throughout every year due to the degradation of energy efficiency and near-end life expectancy of building components. Energy retrofit is proven to improve energy efficiency at the expense of numerous risks as early in pre-construction project. Thus, the influences of risk facing by stakeholders to achieve optimum design strategies granting a huge effect in retrofit project. This research aims to address risks in retrofit project during pre-construction stage by determining the potential risk factors and the relationship with the retrofit elements. This research used convergent-parallel mixed-method within the context of qual-quan research design to administer semi-structured interviews and questionnaires to obtain information from internal stakeholders. With the aid of Computer-Assisted Qualitative Data Analysis Software (CAQDAS), Atlas.Ti version 7, the qualitative data were coded, categorized, and analysed obtained from six respondents. The Statistical Package for Social Science (SPSS) were used for analysing quantitative data collected from 66% of respondents out of 198 samples. The analysis revealed that two critical risk factors was found under planning and design phase. In planning phase, the most critical factor is related with the tenant cooperation in post-planning. The contribution of this risk is influences by the policies, regulation, human factor, and uncertainty factor elements. Likewise, the risk in design phase that require critical concern is related with inaccurate of energy model. It shows that the risk is influences by technologies, uncertainty factor and client expectation elements. The highlighted risks demonstrate the correlation with the retrofit elements to achieve optimum energy efficiency design through developed framework model. The develop framework model was validated across ten respondents and proven to assist construction industry to achieve optimum design strategy by assessing the highlighted risk factors and elements. The validation process in framework is conducted through expert panel in retrofit project and analyse using Krippendorff alpha reliability method.

ABSTRAK

Permintaan tenaga kepada bangunan sedia ada berkembang setiap tahun berbanding dengan bangunan baru. Pertumbuhan penggunaan tenaga di bangunan sedia ada dikaitkan dengan penurunan kecekapan tenaga dan jangka hayat. ‘Retrofit’ di bangunan sedia ada terbukti dapat meningkatkan kecekapan tenaga walaupun berdepan dengan pelbagai risiko seawal projek pembinaan. Pengaruh risiko yang dihadapi oleh pihak berkepentingan untuk mencapai strategi rekabentuk yang optimum memberikan impak pada projek ‘retrofit’. Oleh itu, penyelidikan ini bertujuan untuk menyiasat risiko dalam projek ‘retrofit’ di peringkat pra-pembinaan dengan mengenalpasti faktor risiko dan hubungannya dengan elemen ‘retrofit’. Penyelidikan ini menggunakan kaedah campuran-selari konvergen dalam konteks rekabentuk penyelidikan ‘qual-quan’ bagi menguruskan proses temubual dan soal selidik separa berstruktur daripada responden. Dengan bantuan perisian kualitatif (CAQDAS), Atlas.Ti versi 7, data kualitatif yang diperoleh dari enam responden dikodkan, dikategorikan, dan dianalisis. Pakej Statistik untuk Sains Sosial (SPSS) digunakan untuk menganalisis data kuantitatif yang dikumpulkan dari 66% responden daripada 198 sampel. Analisis menunjukkan bahawa dua faktor risiko kritikal ditemui dalam fasa perancangan dan rekabentuk. Dalam fasa perancangan, faktor yang paling kritikal adalah berkaitan dengan kerjasama penyewa dalam peringkat pengoperasian bangunan. Risiko ini dipengaruhi oleh polisi, peraturan, faktor manusia, dan elemen faktor ketidakpastian. Risiko di dalam fasa rekabentuk adalah berkaitan dengan model tenaga yang tidak tepat. Risiko tersebut dipengaruhi oleh teknologi, faktor ketidakpastian dan elemen jangkaan klien. Model rangka kerja yang dibangunkan telah dikesahan oleh sepuluh responden dan menunjukkan hubungan diantara risiko dan elemen ‘retrofit’ bagi mencapai rekabentuk kecekapan tenaga yang optimum. angka kerja yang dibangunkan terbukti dapat membantu industri pembinaan bagi mencapai strategi rekabentuk yang optimum melalui penilaian risiko dan elemen ‘retrofit’. Proses kesahan model rangka kerja telah dikendalikan oleh panel pakar di dalam projek ‘retrofit’ dan dianalisis menggunakan kaedah ‘Krippendorff alpha reliability’.

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LIST OF ABBREVIATION

BCR	-	Benefit to Cost Ratio
CIDB	-	Construction Development Industrial Board
CITP	-	Construction Industry Transformation Programme
CBD	-	Commercial Building Disclosure
ComBAT	-	Commercial Building Analysis Tool
DPP	-	Discounted Payback Period
EE	-	Energy Efficiency
ECM	-	Energy Conservation Measures
EPC	-	Energy Performance Contract
ESCO	-	Energy Services Company
GBI	-	Green Building Index
GHG	-	Greenhouse Gas
GTFS	-	Greentech Financing Scheme
HVAC	-	Heating Ventilation Air Conditioning
IR	-	Infra-Red
IRR	-	Internal Rate of Return
IEA	-	International Energy Agency
KeTTHA	-	Ministry of Energy, Green Technology and Water
KTOE	-	Kilotons
LEED	-	Leadership in Energy and Environmental Design
MAMPU	-	Malaysian Administrative Modernization and Management Planning Unit
MI	-	Modification Indices
MS	-	Malaysia Standards
M&V	-	Measurement & Validation
MT	-	Million Tonnes
NGTP	-	National Green Technology Policy

NEEAP	-	National Energy Efficiency Action Plan 2016-2025
NPCC	-	National Policy on Climate Change
NREB	-	Non-Residential Existing Building
NZEB	-	Net Zero Energy Building
ORR	-	Overall Rate of Return
QS		Quantity Surveyor
PV	-	Photovoltaic
RE	-	Renewable Energy
RE	-	Retrofit element
RF	-	Risk Factor
ROBEsim	-	Retrofit-Oriented Building Energy Simulator
ROI	-	Return of Investment
SBS	-	Sick Building Syndrome
SEM	-	Structural Equation Modelling
SERDP	-	Strategic Environmental Research and Development Program
SL		Standardized Loading
SPSS	-	Statistical Package for the Social Sciences
SPP	-	Simple Payback Period
T&C	-	Testing and Commissioning
CBECS	-	The Commercial Building Energy Consumption Survey
NABERS	-	The National Australian Built Environment Rating System
USA	-	United States of America
UK	-	United Kingdom
USGBC	-	U.S Green Building Council
USDOE	-	U.S Department of Energy

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Green building has generally been approved as one of the more effective strategies towards sustainable development in many countries, vital to creating a sustainable environment (Yu, Tu, & Luo, 2011). Despite introducing the green concept in construction for many years, there are certain area need to be improved in sustainable concept to further support towards positive impact on the environment, specifically in existing building. Notably, this is largely due to heavily focusing on sustainable development for new construction projects compared to existing buildings (Adeyemi *et al*., 2014). Fundamentally, it is proven that the lifecyle of the existing building performance is degrade over the times and retrofitting is required to sustain and revamp the energy efficiency level (Dong *et al*., 2005). The sustainable development of existing buildings is evolving in recent years through energy retrofit. Retrofits project modifies existing buildings to improve energy and environmental performance, reduce water use, improve thermal comfort, and reduce the noise level by applying new technologies (Hwang *et al*., 2015).

The application of the new technologies in the existing building provides more variation to enhance energy efficiency in the existing building. Therefore, the application of new technologies on the existing building is constantly filled with uncertainty and risk (Lam *et al*., 2010). The process to achieve energy efficiency level in existing building involve a huge of risks due to unforeseen condition occur in the early phase of the project that will affect on post-construction (Xia & Chan, 2012; Deng, Low, & Zhao, 2014; Zhao, Hwang, & Phang, 2014; Zhao *et al*., 2015). The existence of risk in the retrofit project provides challenges to each task as it allows for a different outcome in energy efficiency level by the combination of the planning and design stage (Topouzi *et al*., 2015). Risk can either be prevented or limit the probable effect on the energy retrofit design through addressing the risk (Zou *et al*., 2016). In Malaysia, the retrofit concept is circuitously put into practice in existing buildings, focusing on energy-efficient building design and achieving GBI rating. According to National Energy Efficiency Action Plan 2014, the key initiatives to promote energy efficiency are building design that influences energy-efficient to the existing building (Ministry of Energy Green Technologies and Water (KeTTHA), 2014).

1.2 Background of Study

Buildings are one of the largest consumptions of energy, accounting for up to 32 percent of the overall total global final energy use, and 19 percent of the total is presently related to energy usage (Lucon *et al*., 2014). It is widely recognized that in developing countries, the overall energy consumption of the building sector accounts for approximately 20 to 40 percent of the total energy consumption (Perez-Lombard *et al*., 2008). The energy performance of buildings is calculated based on a methodology that covers the whole annual energy performance of a building, including the requirements in hot and dry conditions, which has greatly impacted energy consumption from the recent years (IE 2010). Central to the debate on the idea of "the important moderation of the environmental impacts resulting from the building sector" is the question of how sustainable development on the building may develop a positive impact on the environment.

However, the introduction of much alternative initiative to reduce greenhouse gas (GHG) does not drastically impact building energy consumption. It can be highlighted that the energy demand and economic growth are robustly interrelated and notably increase every year from new building to the existing building (Nikolaou *et al*., 2011). Surprisingly, the recent study shows that the growth of energy consumption on an existing building is significantly soaring throughout every year due to the degradation of energy efficiency and near-end life expectancy of building components compared with new buildings (Aste & Pero, 2013). In a recent study, Alam *et al*., (2016) described that the energy consumption for an existing commercial building grows every year. In Malaysia, the demand for energy for commercial buildings is up to 38,645 Gigawatts (GWh), while residential buildings consume approximately about 24,709 Gwh (Hassan *et al*., 2014). This, however, has led the construction industry to adopt the concept of green building for existing buildings (Khoukhi, Darsaleh & Ali, 2020).

Despite the fact that the trend of green building is growing every year, the interpretation of the project objectives is still behind the main list. The lack of crystal-clear definition leads to a schizophrenic divide among scholars, which generates potential challenges for deploying and promoting the green building concept per se (Zuo & Zhao, 2014). Green buildings and retrofitting of the existing green buildings is approved as the greatest plan to optimize the energy efficiency into another level. In general, the retrofit is an activity that upgrades the energy efficiency level through the component and feature that did not have when it first construct (Paradis, 2016). Finding an optimal solution to increase the energy efficiency level on an existing building is the main criterion to achieve part of sustainable development (Basarir & Diri, 2012). As a growing set of findings is being provided, the need for advanced project management, energy management, technological capabilities management, and construction management in energy efficiency are valuable to the stakeholder required than ever before (Mohd-Rahim *et al*., 2017). Each of the requirements to fulfil the project objectives is facing various risks to meet the energy efficiency level. The risk associated with a project often reflects an adverse effect on the achievement and encounters unexpected problems despite all the precautions taken accordingly (Urbanski, Haque & Oino, 2019).

Risk in the construction projects is among the critical concerns for each stakeholder due to the potential rebound effect in the full project delivery (Hwang, 2015). Risk is diverse and unique as it presents as an early phase of the project, capable of manipulating the decision-making process (Iqbal *et al*., 2015). Interestingly, the risk is part of the process in a construction project which directly or indirectly consequences the project objectives and cannot be avoided or ignored. Zou *et al*., (2016) described the risk as any exposure to possible loss to the project and failure to meet the project objectives. The identification of uncertainty in the construction project is accomplished by addressing the risks. Risks can be presented in the whole progress of the construction project such as the planning stage, design stage, construction stage, and maintenance stage by granting direct or indirect effect to meet the project objectives (Ma *et al*., 2012). A different combination of risk surrounds each step of the project development, and it is almost certain that the identification of risk in the early stage of the project can break the chain-reaction effect until the end of the project. The impact of the risk in a construction project can provide a negative or positive outcome of the project. It is, however, the implication of the project that will determine the degree of risks (Alam *et al*., 2017). Therefore, addressing risk in a construction project is fundamentally critical to meet the project objectives by controlling cost, time, and quality as early as possible.

The existence of risk in a construction project can be fundamentally described by the surrounding elements contributing to the unpredicted situation, such as policies, legislative practices, information, or tools (Ruparthna *et al*.,2016 & Ma *et al*., 2012). The uncontrollable condition is likely to provide difficulty to the stakeholder to recognize the potential risk that can be a main threat to the project objectives. The identification of risk will expose all possible sources from internal or external influence to the project. However, Barber (2005) highlighted that internal risks are a major challenge for the project team and may require special attention to manage the project effectively. Internal risks are often elusive and difficult to quantify for classifying the risks (Khodeir & Mohamed, 2015). The internal risks may exist broadly, but the clear definition of the continuation is correlated with human behaviour involvement. Tollin (2011) reported that even when the direct source of an internal risk seems to lie in the operation of a process, people are likely to be involved to some extent because it is people who design, own, and operate structures and processes. Performing the risk identification in the pre-construction stage without considering the project's natural elements could result in a huge loss and disadvantage to all stakeholders. The determination of the project characteristic and attributes would reveal the potential risks that can be categorized into threats (Kaur & Singh, 2018).

However, the probability of risk to evolve is significantly high and varies across the construction project, especially in retrofitting an existing building. It is commonly held that existing buildings are not energy efficient and should be dramatically redesigned to boost their efficiency by exploring energy efficiency measures full of risk and multipart (Liang *et al*., 2015). Risk in an existing building is specifically unique and faces large numbers of uncertainties due to the project complexity compared with a new construction project. The risks imposed in an existing building are developed through a series of limitations, constraints, and circumstances that extend the difficulties of recognizing the potential threat (Ma *et al*., 2012). The retrofit project requires a systematic and dynamic approach to adopt the energy-saving objectives starting from the progression of management in the pre-construction stage (Hwang *et al*., 2015). Zou *et al*., (2016) reported that risk in a retrofit project could be addressed in two different phases, such as the planning stage and design stage. In the planning process, the initiation of the project scope and objectives involve the collaboration of stakeholders between each party to achieve project targets (Zhao *et al*., 2015). The important element in project targets, such as project budget, project quality, project scope, and project timeline, are set up during the project planning phase (STBA, 2015). Most significant decisions are made in the project planning phase, and the process is surrounded by risks that exerting a negative influence on project performance (Naeem *et al*., 2018). Identifying and transferring the risk will assist stakeholders in settling on more rational choices on solutions towards achieving energy-efficient goals in the first place. The discussion among stakeholders should also occur when design changes of the previously selected retrofit options are proposed, and when new information becomes accessible during each step of identifying the risk process (Menassa, 2011).

Continuous identification of risk is capable of reducing further the chances of energy performance gap via the design process. Ali (2014) describes that most of the previous study agree on the significant impact of the design process for the success of construction projects. While design costs contribute just about 10 percent to overall project costs, the design phase greatly affects the performance of the retrofit projects. There is also data suggesting that design issues led to almost 80 percent of the quality issue in a project related to the risk. The design process is difficult to control due to the fact that the combination of intensive technological and social tasks is leading to various risks. In addition, due to the extensive use of complex construction technologies and innovative materials to the existing building without knowing the capabilities or limitations, the design process is compounded by numerous risks (Hwang *et al*., 2017).

Such risks in a retrofit project can be minimized and secured through addressing the potential risks that cause an initial negative impact to meet the energy efficiency objectives (Alam *et al*., 2016). Therefore, from the preceding, this research seeks to address risk factors specifically for an existing commercial building in Malaysia that incorporate the retrofit element by developing the proposed framework as a guideline to enhance energy efficiency through retrofitting.

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