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Risk in Green Retrofits Projects: A Preliminary Study on Energy Efficiency

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Abstract. A green building has generally been adopted as one of the most effective strategies towards sustainable development in many countries which is vital in order to create sustainable environment. Despite the benefits of green retrofit to the sustainable environment, there are still retrofitted building is performed below expectation during planning stage which eventually rising operation cost. Although energy efficiency study is over emphasize in green building field, little attention has been paid off to examine the crucial phases in pre-construction stages for green retrofit and a risk that bring energy deficiency. Therefore, the aim of this research is explore a risk that influencing energy efficiency in each phases of pre-construction stage for green retrofit towards commercial building in Malaysia. The study is further support by interview sessions that has been carried out with five retrofit architects that actively involved in construction of commercial buildings in Malaysia. Based on the interviews, the risk in pre-construction stage is crucial to be assessed to minimizing energy deficiency in retrofit project. The findings of the study may useful for design consultant to deliver retrofitting project towards achieving feasible energy efficiency building.

1. Introduction

Sustainable development practice has widely spread across many countries to reduce carbon emission and greenhouse gas. The approach to reduce environment impact is still debatable which require several sustainable mechanisms not only for new construction project, but to existing building. As a matter of fact, retrofitting is the only way to revamp the building into sustainable building. In general, retrofitting is a term that was originated from the combination of “retroactive” and “fit” [1]. In other word, retrofit can be defined as upgrading building system and technology to gain energy performance [2]. Although there are continuous improvements in energy efficiency policies in Malaysia, the construction key players do not respond well to the energy efficiency program to retrofit the existing building due to various challenges and barriers that impede decision-making process during pre-construction stage [3]. In addition, the challenge in decision-making during planning stage is perceive among stakeholder role which establish performance gap from each retrofit strategy [4]. Therefore, it is crucial for retrofit project to organize every option to obtain feasible energy efficiency objectives as early in pre-construction stage.

2. Background study



In nature of construction project, there is a workflow from the beginning until the project closeout according to the project lifecycle. In new construction project lifecycle, there are eight phase such as pre-feasibility, feasibility, design, contract, implementation commissioning, handover and operation. However, according to Westland, (2006)[5] the project lifecycle can be compressed into four stages consists of initiation, planning, execution and operation.

On the contrary, for green retrofit project lifecycle, there are five major phases consists of project setup and pre-retrofit survey, energy auditing, identification of retrofit option, construction and commissioning, and validation that will lead to the successful of the project [6]. In addition, study showed by Less & Walker (2015)[7], the retrofit process consists of five important phase including pre-planning, planning (pre-construction stage), construction (commissioning), test-out and post-occupancy (post-construction stage). However, both previous studies can be combined since it is similar lifecycle which resulting pre-retrofit survey, energy auditing and identification of retrofit option activities is fall under pre-construction stage. According to Mohareb et al. [4], the significant performance gap is exist between estimate and actual energy model during pre-construction due to various risk and uncertainty. Hence, the process in pre-construction stage is selected and briefed on next section to explore a risk that may influence the energy efficiency.

2.1 First phase: Project setup and pre-retrofit survey

The early stage before retrofitting involves internal stakeholder such as building owner, architect, and consultant in order to determine the scope of work and the project objectives by looking up the budget and the available important resources that influencing the retrofitting. Architect or design consultant such as mechanical and electrical engineering is essential to clarify the building owner about the new green technologies that will be applied. In fact, lack of knowledge in retrofitting during early stage will lead to underperformance energy efficiency thus increasing risk in project financing criteria. Similarly, Jones & Bogus, (2010) [8] highlights that building owner facing difficulties in evaluating and finding feasible retrofit strategy due to limitation of knowledge in engineering and financing. Due to lack of knowledge of amount investment required in retrofitting, the building will eventually turn up to poor performance retrofit building [9]. For instance, Hosseinian et al., (2017) [10] highlights that the building owner is important internal stakeholder for energy efficiency investment as it can influence the overall benefits in financial profit for the future. The decision process to retrofit is influence by roles and responsibility each of the stakeholders as it can lead to key success factor of the project [11].

A pre-retrofit survey may be required in order to achieve better understanding towards building operational problems and tenants of the building. According to Ma et al. [6], the pre-retrofit survey phase may be best carried out by energy professional know as energy services company (ESCO) which has wide range of experience and knowledge in energy retrofit to survey the building at the first place towards developing feasible energy efficiency. Similarly, study by Gram-Hanssen [12], Bu et al. [13] and Gultekin-Bicer, Anumba, & Leicht [14] revealed that the lack of knowledge by internal stakeholder such as architect and consultant in green retrofitting design will eventually affecting energy-saving measures which consequently affecting the decision-making process. Therefore, this phase is considered as the first step to obtain retrofit idea between consultant and building owner to support decision-making process. A summary of risk in the first phase for green retrofit project that was based on previous study is showed in Table 1.

Table 1. Risk in first phase of green retrofit project in pre-construction stage

Risk factor	Authors
Underperformance energy efficiency	De-Selincourt [15]
Poor decision-making process	Gram-Hanssen [12], Bu et al. [13], Gultekin-Bicer, Anumba, & Leicht [14]
Underperformance energy	Basarir, Diri, & Diri [9]

Risk factor	Authors
efficiency	
Unknown retrofit strategy to apply	Jones & Bogus [8]

2.2 Second phase: Energy audit and performance assessment

The second phase comprises of an energy audit and performance assessment where it is used to analyze various energy resources before retrofitting. Performance assessment is employed to benchmark building energy use by using selected performance indicators or by using green building rating systems [16]. For instance, study by Sakina, Fassman, & Wilkinson [17] highlights that the energy retrofit might occurring underperformed due to unsuitable technologies or system applied to the building. In addition, poor usage of energy benchmarking tool in energy audit and performance assessment is part of the reason why the retrofitted building is performing below expectation. According to Al-kodmany [18] stated through usage of DOE-2.2 energy tools for Empire State Building, the planning and design team are able to analyze the energy saving prediction towards various parameters to ensure the project is executed within cost allocated while avoiding error in energy saving. However, Sun et al. [19] argued through case study in LEEDBOM project where the calculation of the energy simulation through selection of retrofit strategies does not meet an actual energy saving. Thus, there are contradictions from previous study regarding energy audit and performance assessment phase which contain risk as show in Table 2.

Table 2. Risk in second phase of green retrofit project in pre-construction stage

Risk factor	Authors
• Improper technology or system	Sakina, Fassman, & Wilkinson [17]
• Miscalculated energy model	Sun et al. [19]
• Energy perform less well than expected	
• Miscalculated energy model	Al-kodmany [18]

2.3 Third phase: Identification of retrofit option

The third phase involves the identification of retrofit options and can be determined by using appropriate energy models, economic analysis tools and risk assessment methods to assess optimum retrofit strategy. The selection of buildings retrofit option is quite difficult to carry out due to variety of complex building systems since it influencing the overall energy performance [20,21,22,23,24]. For this reason, retrofit option can be assisted by several methods to obtain feasible retrofit strategy.

- *Identification of retrofit option through energy model*

Every retrofit option can be assessed quantitatively about the performance in the particular buildings by prioritizing based on the relevant energy and non-energy. According to Ma et al., (2012), each of the retrofit option possess energy models that influencing the budget of the projects by estimating the energy savings that can be achieved with various of retrofitting works. Study by Liu et al., (2018) and Jha & Bhattacharjee, (2018) highlights that the advanced material is interrelationship with the cost as each of the selection in retrofit option resulting different outcome to the energy and cost. Moreover, selecting right technology for the right regional climate will significantly influence the energy efficiency [25].

However, the retrofitting option can be determined through generating the design draft to obtain the energy efficiency results. The decision to selecting retrofitting design is either supported by tools or based on the current state of the building. According to Nielsen et al., (2016) pointed out that the tools to accumulate performance estimation after designing of retrofitting can be assisted by computers software. In fact, the tool is important to simulate energy model since it can avoid performance gap that will affect building occupant [26,27]. This indicates that every retrofit option that has been

identified is essential to simulate the energy model to obtain the specific retrofit strategy that contains performance indicator to the existing building.

- *Identification of retrofit option through economic analysis*

After the detail of energy model is obtained, the next step is to identify the cost impact through economic analysis. According to Ma et al. [16] highlighted that the selection of retrofit measures is a trade-off between capital investment and benefits that can be achieved due to implementation each of the retrofit measures. Similarly, the study by Aste & Del Pero [28] revealed that poor estimation on economic analysis for evaluating the proposed retrofit option can influence the actual payback period of retrofiting. By applying economic analysis which facilitates the comparison among alternative retrofit measures, it can present a sign of whether the retrofit options are cost effective along with energy efficiency [8]. This in line with the findings by Tadeu et al. [29] highlighted that the full-cost investment in any retrofit technologies application does not always reflecting great performance although it is significantly reducing energy usage. Since the retrofit project involve huge investment, the uncertainty in performance is still exist to perceive by internal stakeholder decision during planning stage [30]. Also, the findings by Kontokosta [31] highlighted that the long payback period will increase the difficulty by building owner in decision-making to retrofit.

However, different analytical methods are used to perform the cost-benefit analysis of energy efficiency projects although it depending on theoretical computer simulation which is unknown whether the expected energy savings can be realized. The study by Tan et al. [32] revealed the methodology using mathematical programming to analyzing cost and environmental optimization of energy efficiency between each energy retrofitting measures. In contrast, Sağlam et al. [33] presented a cost optimal approach integrating each retrofit measures related to building envelope, building energy systems and renewable energy to evaluate existing building retrofit. Both recent studies of economic retrofit analysis are lean on computer simulation without knowing actual energy saving in real situation. As a matter of fact, study shown by Liu et al. [34] revealed that the retrofit energy economic analysis based on calculation of cost-benefits over lifecycle building is lower compared to the theoretical calculation made by computer. Therefore, this shows that the economic analysis trough each retrofit option process is vital as it will determine the energy saving through each retrofit design in long period that reflecting with the project cost and investment.

- *Identification of retrofit option through risk assessment*

In risk assessment, it will provide building owner and related stakeholders to create solid decision making by determining the qualitative and quantitative value of risks according to the current condition as well as the threat that they will encounter in retrofitting works begin. This is proven by previous research that highlighted retrofitting is uniquely characterized by the high degree of risk and uncertainty which will influence the management of such a project. In addition, recognizing uncertainty in actual energy savings and the risk of underachieving projected energy savings are the primary factor that prevents investors and building owners from pursuing a retrofit [35]. A study by Tollin [36] revealed that the risk of not achieving considerable savings can lead to owner and tenant dissatisfaction. Therefore, it clearly shows that risk assessment process in indentifying retrofit option is essential to provide decision makers to select and determine the best retrofit solution. A summary of risks in third phase of green retrofit project from literature is indicated in Table 3.

Table 3. Risk in third phase of green retrofit project in pre-construction stage

Risk factor	Author, Year
Project budget	Ma et al. [6]
Cost-benefit Performance gap	Liu et al. [34] , Mohareb, et al. [4], Jones & Bogus [8]
Various result from each retrofit option	Jha & Bhattacharjee [37], Tadeu et al. jha[29]
Poor estimation on payback period	Aste & Del Pero [28]

Risk factor	Author, Year
Difficulties in payback period	Kontokosta [31]
Dissatisfaction among building owner and tenant	Tollin [36]

In overall, the three important phases in pre-construction for green retrofit project is clearly shows that to obtain feasible energy efficiency in existing building required several of strategies and technique to be use by internal stakeholder. Throughout the review from past study, it can be concluded that the green retrofit is still facing uncertainty to achieve optimum energy efficiency and it should be systematically analyzed to avoid unworthy investment for the building owner.

3. Research Methodology

Extensive literatures were conducted in relation to green construction, sustainable development and green retrofits. Additionally, the semi-structured interviews were used to obtain flexible and rich data to support research aim. The respondents were selected based on the experienced practitioner in order to gain significant input from the interview session. The interview is conducted through face-to-face to ensure the findings are strong and provide better understanding. There are five respondents involved in the research and each the interviewees were assigned codes as R1, R2, R3, R4 and R5. Since this research is to gather information based on Malaysia construction industry, all of those respondents are mainly from private firms involved previously in retrofitting project. Data is extract and analyze using content analysis to identify principal themes presented through the data [38]. Table 4 (appendix 1) shows the summary each of respondent background involves in the research.

Table 4. Summary of respondent background

Item	R1	R2	R3	R4	R5
Position	Architect	Architect	Architect	Architect	Architect
Organization	Consultant	Consultant	Consultant	Consultant	Consultant
Location	Kuala Lumpur	Selangor	Ipoh	Kuala Lumpur	Kuala Lumpur
Experience	More than 5 years	More than 5 years	More than 5 years	More than 5 years	More than 5 years
Recent past Project	Office	Hotel	Office	Shopping Complex	Hospital

4. Findings and discussion

4.1 Risk in first phase on pre-construction stage for green retrofit

As discussed in the literature earlier, several studies have found that the early stage of retrofitting process is important as it will determine the early requirement of energy retrofitting by building owner wish for with available resources they had although there are uncertainties in energy savings.

- *Underperform energy retrofit*

“The pre-retrofit survey is important step as to analyze the early feasible retrofit option available as recommended by consultant and guiding the building owner in respect of energy retrofitting to avoid unexpected underperform energy efficiency. Besides that, building owner are not capable in technical terms, they are interested with retrofitting for reducing energy usage for the benefit in long term. We as an architect perhaps assist them in term of limitation and opportunities of retrofitting to their building. This is to ensure the energy efficiency that can be gain after retrofitting can be achievable” (R2)

Respondent have different opinions towards risk in underperform of energy retrofit. R2 and R3 both pointed out that the early plan in retrofit strategy is vital to developed feasible energy efficiency retrofit.

- *Poor decision-making*

“Consultant is hired as to assist and being as decision makers for the building owner before retrofitting. This is to ensure the building owner receive views from consultant regarding each of retrofit strategy option. Since there are few building owner have little knowledge in energy saving technologies, we can suggest them to combine any possible retrofit option to create even more optimum energy saving and avoiding any chance of non-improving strategy. This is to ensure the building owner expectation can be doable” (R4)

“We agreed that the pre-retrofit survey is essential so that the clarification by our team regarding energy retrofit to the building owner will assist them in decision-making to avoid low performance in energy efficiency gain. This is to ensure our team can estimate early retrofit strategy” (R1)

Three out of five respondents agreed that the risk towards poor decision-making will be crucial in first phase for pre-construction stage as to ensure each retrofit strategy is reasonable to be carried out and achieve significant level of energy efficiency. This is main reason on why decision-making is vital to develop early coordination between building owner and design consultant team.

- *Unknown retrofit strategy to apply*

“The pre-retrofit is a stage that project goals and objective is planned between consultant and building owner while it help us to decide the energy saving strategy. The purpose of the survey is to avoid underperform of energy by client requirement. There are limitation and obstacle to retrofit existing building. The expectation from building owner to retrofit should be explained well by consultant on how the energy efficiency can be achieved with each planning in retrofit strategy. Since there is various combination of retrofit option available, the selection of optimum retrofit strategy is very important to obtain desire energy efficiency” (R3)

Respondent have mix opinions toward the effect of unknown retrofit strategy to apply in the first phase of pre-construction stage of green retrofit project. Both respondents agreed that the explanation with the building owner in regards to retrofit strategy will avoid unknown retrofit strategy so that it can be realized within the building capability.

4.1.1 Discussion

This section explains findings of the research by considering previous research. The result shows that the project setup and pre-retrofit survey phase are essential to be carried out as it could avoid poor decision-making process between building owner and design team. This similar with the findings of Gultekin-Bicer, Anumba, & Leicht [14] where they pointed out that the cooperation with building owner will enable the design team to further support in decision-making. The support from the design consultant that have knowledge and experience in retrofit project will help building owner in decision-making process [39]. The results from previous study also found that the expertise in retrofitting is important as to assist in decision-making for building owner before retrofitting process. Hence, it is practical for green retrofit practitioner to considering the project setup and pre-retrofit survey phase as it can further strengthening mutual collaboration between client and design consultant while improving decision-making process.

4.2 Risk in second phase on pre-construction stage for green retrofit

The second phase of retrofit comprises an energy audit and performance assessment that is important to ensure the current energy resources available before retrofitting.

- *Improper technology and system*

Majority of the respondents agreed that the energy audit and performance assessment in green retrofit project will allow them to select the best retrofit strategy and could avoid low cost-benefit of technology or system.

“Normally we often draft retrofit strategies according to our pass experience. Somehow, we are aware with the energy audit as to ensure the strategy that we draft is capable to reduce energy usage and meet client expectation. The purpose of energy audit is to ensure the selection of each retrofit option is suitable with the building state while it perform within our expectation. But it is lengthy procedure to obtain setting up in energy saving since it is influence by many factor, especially in building occupant factor and building condition” (R2,R3,R4 and R5)

- *Miscalculate energy model*

“The energy efficiency can be achieved but depending on several factors such as building condition and the resources. Sometimes, the small scale of retrofit opportunities such as changing the old lighting fixtures into Light Emitting Diode (L.E.D) light will help in achieving energy saving, but such small improvement are not necessary to do an energy audit or performance assessment. This is because the energy saving in lightning fixture is ultimately predetermined and mostly it will reduced energy usage without any major changes to building structure. However, we are aware that if the retrofit project required specific energy target, the energy audit can be vital to avoid energy perform below expectation” (R1).

Only single respondent reviewed differently as compared to other respondents which stated that the implementation of the green technology that contain specific energy efficiency such as lighting fixture will allow them to skip the performance assessment. However, most of the respondent agreed that the energy audit and performance assessment phase in green retrofit project could avoid any potential miscalculate of energy model during design stage.

- *Less energy perform*

“Definitely an energy audit and performance system for any of retrofit strategy that we draft will allow us to predict the energy performance and energy efficiency. This is somewhat compulsory step to achieve optimum retrofit strategy” (R1,R2,R3,R4)

Majority of the respondent mentioned that through energy audit and performance assessment phase, it will minimize any potential underperformed of retrofit strategy especially for deep retrofit project.

4.2.1 Discussion

Data analysis in previous section can be concluded that the risk in second phase of pre-construction stage for green retrofit project revealed that a less energy perform in retrofit design will increase performance gap. Most of the respondent agreed that the energy audit phase is crucial as in can determine the energy saving gain over each retrofit strategy. This is consistent with the findings by Piette et al. [40] proved that energy audit is extremely important to find the low cost technique to increase energy efficiency. Similarly, previous study by Palmer et al., (2013) and Corrado et al., (2017) stated that energy audit can provide various opportunities to improve energy efficiency through propose other option. This means that retrofit practitioners in Malaysia are totally support the energy audit and performance assessment phase and most likely it is crucial process in early stage of green retrofit project. It is impractical to skip energy audit and performance assessment phase as it may perform less energy output over each retrofit design.

4.3 Risk in third phase on pre-construction stage for green retrofit

A considerable amount of literature has been published that showed the identification of retrofit options is crucial for third phase in green retrofit. The interviewees responded well positively in identification of retrofit option as it will influence the whole project goals and objectives.

- *Project budget*

“Identification each of retrofit options will affect the energy regardless it is small scale of retrofit project or deep retrofit project and perhaps it is the most critical part in retrofitting towards pre-construction stage. The retrofit strategy is chosen based on various factors such as project budget, technology, regulation, building occupant and building condition” (R1,R2,R3,R4 and R5).

All respondents mentioned that identification of retrofit option will be beneficial to estimate the project budget and how much energy efficiency that can be saved. Since there are varieties of green technology option available on the market, it will influence the project budget and indirectly changing in energy efficiency objectives.

- *Cost-Benefit*

“We ultimately consider the cost versus benefits during outlining retrofit option to ensure the optimum energy saving can be achieve. Although there are barriers to obtain the design of retrofit option by considering those factors, we prone to decide the optimum retrofit option based on the available budget resources by the building owner as it influencing their payback period” (R1,R2,R3,R4).

All respondents agreed that in the phase of identification of retrofit option, it can determine the cost-benefit that will influence the payback period for a building owner. This is crucial for design consultant to obtain finest strategy between the cost involve over the energy benefits gain for each retrofit option.

- *Energy gap*

“Throughout each of the retrofit identification, it can help us to find optimum solution to achieve energy efficiency” (R1,R2,R3).

Most of the respondent agreed that the energy deficiency can be lowered through identifying each of retrofit option during design stage. In addition, it can avoid energy gap that may develop from the error in design stage.

- *Variable result*

“The target energy saving that we outlined is usually influence by tenant pattern in energy usage. We estimate that there are 10%-20% different between plan and actual energy saving” (R4)

Only single respondent mentioned that through the identification of retrofit option, it can show the variable result since the tenant behavior play a major role in energy saving. Since it is difficult to obtain specific tenant behavior, the energy saving prediction will also affected and the final result of energy efficiency will be variable.

- *Payback period*

“The payback period is essential for building owner as the investment for deep retrofit is large and of course the throughout the identification of retrofit option, we can determine the best strategy with the project budget” (R1,R2,R3,R4)

Majority of the respondents agreed that the identification of retrofit option will allow project budget and the payback period to be determined. It is essential for building owner on how long the payback period over each retrofit option that they decide while it is crucial for design team to ensure the retrofit strategy is capable to achieve significant amount of energy savings.

- *Satisfaction*

“However, the renovation that we plan is also making an allowance for by tenant comfortability. This is because that it will impact their working environment thus it will influence tenant satisfaction over new technology that applied to the building” (R1,R3)

Respondents have mix opinions toward the satisfaction effect through third phase in pre-construction stage for green retrofit project. R1 and R3 pointed out that the identification each of retrofit option will reflect on the tenant satisfaction as it may impact the working environment. However, any retrofit strategy that does not involve any major building structure will not significantly enough to disturb tenant satisfaction.

4.3.1 Discussion

Data analysis in previous section can be concluded that the risks in third phase of pre-construction stage for green retrofit project are project budget, cost-benefit and payback period. The result shows the top three risk is crucial for retrofit practitioners to be concerned as it may influence energy efficiency over each retrofit option. This is in line with the study by Ma et al. [16] that pointed out each of the retrofit option possess energy models that influencing the budget of the projects by estimating the energy savings that can be achieved with various of retrofitting strategy. Although each of the identification of retrofit option may engage variable project budget, it allow design consultant to find out the best cost-benefit of the retrofit strategy. This is consistent with the findings of Liu et al. [34] where the retrofit energy economic analysis based on calculation of cost-benefits over lifecycle building is lower compared to the theoretical calculation made by computer. In addition, it will best for the building owner to acknowledge the payback period in each of the selection of feasible retrofit option because it can influence decision-making and the investment of the project. Similarly, Kontokosta [31] highlighted that the long payback period will increase the difficulty by building owner in decision-making to retrofit. Therefore, this shows that the retrofit practitioners in Malaysia agreed that without the step of identification in retrofit option phase in green retrofit project will forbid them to obtain the project budget, cost-benefit and payback period.

5. Conclusion

This paper presented the three crucial phases for green retrofitting to achieve energy efficiency target in building retrofits that contain effect that may influencing the energy efficiency. From the interview results, it shows that the project setup and pre-retrofit survey, energy auditing and performance assessment, and identification of retrofit options phases are totally contributing to the overall strategy to obtain energy efficiency. In addition, the finding in risk for each phase revealed additional support to shows how significance it will influence the energy efficiency objective. From this study, it may be beneficial for internal stakeholders such as building owner, architect, or design consultant to assess and control the risk in pre-construction stage based on this study. However, the sample size is limited to five respondents to obtain preliminary data which pose limitation of the findings that achieve through semi-structured interview. Nevertheless, the result from the data still provides the understanding of the effect in each risk. Future study on construction and post-construction stage for potential risk will fully expand the understanding in overall retrofit project.

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