The application, benefits and challenges of retrofitting the existing buildings

IOP Conf. Series: Materials Science and Engineering **271** (2017) 012030 doi:10.1088/1757-899X/271/1/012030

The application, benefits and challenges of retrofitting the existing buildings

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Abstract. Sustainable development has been the main topic of debate for years in some countries such as United Kingdom, United State of America and Malaysia. Depletion of natural resources, global warming, economics uncertainty and health issues are some of the reasons behind sustainable development movements, it is not just a political debate in the parliament but more towards collective works among sectors in order to minimizing the negative impact of development to the environment and other living organism. Retrofit an existing building is one of the solutions to reduce the dependency on constructing new buildings. There are huge numbers of existing building stocks that suitable to be retrofitted such as historical buildings, offices, residential, warehouse, factories, vacant buildings and other historical buildings. Therefore, the aim of this research is to provide information on the application, benefits and challenges of retrofitting an existing building. Two buildings were chosen as case studies following by site visits and observation to the buildings. The data were then compared in a table form. Primary and secondary sources were also used for this research. The application of retrofit should be promoted across the construction and conservation industries since it has significant tangible and intangible benefits. It is one of the most environmentally friendly and efficient solutions to optimize the energy performance and could also helps to extend the life of the existing building or historical buildings while ensuring optimum thermal comfort for the occupants which leads to higher productivity.

1. Introduction

The depletion of natural resources, global warming, economic uncertainty and health issues leads to sustainable development movements across the world [1]. There's a need for mechanisms or approach that can reduce the negative effects of development, construction and urbanisation to the environment. Retrofitting an existing building is one of the most environmentally friendly, sustainable and efficient solutions to optimize the energy performance of building [2-4]. As a matter of fact, when compared to new buildings construction, this kind of intervention reduces the consumption of land energy and could be applied to a large building stock [5].An in-depth interviews with 37 key players, Dixon et al., [2] found that many instances a distinction was indeed made between retrofit, where a building(s) could be refitted with relatively "light touch" energy efficiency measures, for example, whilst a tenant was still in occupation, as opposed to the case of "refurbishment" which entails a much "deeper" level of refit with changes to the internal and external fabric of the building, with the latter frequently occurring at lease renewal. However, in other cases refurbishment was used rather than retrofit [2].

National Refurbishment Centre (NRC) United Kingdom referred green refurbishments as the use of multiple sustainable fabric measures applications which are then applied to a specific space, room or even to the whole existing building, such as insulation mechanism or micro-generation solutions. Retrofit in the other hand, refers specifically to the installation of micro-generation solutions to buildings or a single measure, such as fitting insulation to an external wall, while 'renovate' is more commonly used in Europe including in the UK to specifically describe the improvement activities or repair works on dilapidated heritage buildings, which may also include the installation of new energy-efficient system or to a whole house [6].

2. Methods

Two buildings were chosen as case studies, which is Kuala Lumpur performing art centre (KLPac) and Shah Alam Royal Theater. Site visit and observation to the two buildings were carried out. The data were then compared in a table form followed by a discussion. Primary and secondary sources were also used for this research.

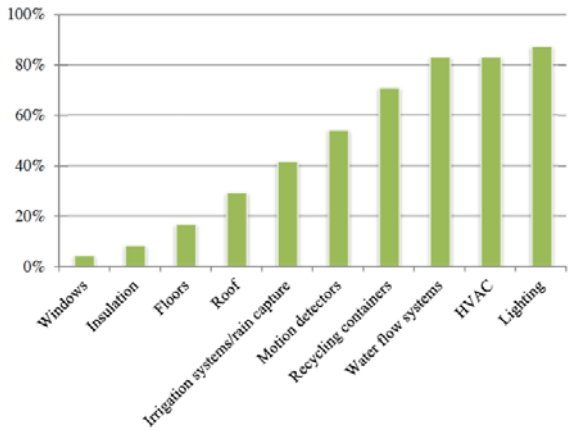
3. Retrofitting Mechanism and Application

Dixon *et al*., [2] stated that retrofit measures not only focusing on energy, but also look into the usage of water and the production of waste as well. As an example, up to 30% - 40%energy cost per annum could be reduced by light-touch retrofit, such as installation of energy-efficient lighting and controls, building services and management systems and controls. In addition to that, recycling water and waste (e.g. in shopping centre, office, school and public buildings) could also bring significant and positive sustainability and cost impacts. Furthermore, research from UK by Dixon *et al*., [2] and from USA Institute for Building Efficiency [7] also suggests the following retrofit measures are the most common in the commercial property sector:

- energy-efficient lighting and controls;
- management systems and controls; and
- building services.

However, the research studies done by Nils Kok *et al*., [4] found out that there are other more expensive improvements and retrofitting measures such as replacing roofs, installing PV solar cells, changing floors, insulation, and operable windows or better glazing system that could be done to an existing buildings as shown in Table 1. This associate to thermal comfort of the buildings as well as making the space more usable and to improved productivity of the space.

Table 1. Major improvement during Retrofitting [4].



From the Table 1, window is one of the elements that were improvised during retrofitting. Estimated USD 20 billion was spent in 1990 to offset heat losses through windows in the commercial and residential buildings in United State [8]. United State Energy Information Administration, United State Department of Energy [9] estimated, 33% of the average heat losses arise through window and doors, which caused by poorly fitted and air leak. Resulting the heating system to work more in order to maintain the desire temperature in the winter, thus increasing the power consumption of the heater. Caulking and weather stripping are the easiest way to overcome air leak in windows and doors, while draperies works as thermal barrier and could help to reduce heat loss by 25%. Installing insulated window panels, windows films panels or Low-Emissivity (Low-E) windows may also help to reduce infrared (IR) heat transfer into the buildings, thus ensuring the thermal comfort level is achievable without causing extra power consumption from the heater or air-condition [9]. Windows can help minimize the cost of cooling, heating and lighting if it is selected properly based on the building typology.

In order for the carbon targets to be successfully achieved, an estimated 28 million building which includes 25 million homes from almost 30 millions buildings (domestic and non-domestic) in the UK are required to be retrofitted by 2050 [10-11]. According to UK Green Building Council, the existing buildings may requires retrofit measures to enable the occupants to live and work more sustainably. The council furthermore noted that refurbishing the existing buildings will be one of the major solutions to reduce carbon emissions [12]. The UK government has proposed an incentive for businesses (non-domestic) owners and households (domestic) owners to take up the energy efficiency measures, and offers variable stamp duty, variable council tax and an energy efficiency feed-in-tariff to create an attractive market opportunity for the industry [12].

4. Retrofitting Matrix

NRC also produced Retrofitting Matrix. The matrix was first developed by the East Midlands Development Agency. It is a self assessment tool that was created to help any individual or organisation to develop their own retrofit strategy or integrated and holistic approach on energy efficient projects that meet the local demands or requirement and achieving the goals of the projects. It also aimed to help the users to assess their current situation or activities and what is needed to solve problems or enhance their retrofit strategy. It highlights eight critical themes and each one of it sets out a series of suggestion for the users. The eight critical themes in the retrofit strategic matrix tools are; partnership, governance and leadership; evidence and monitoring base; finance and investment; planning, development and regulatory control; skills and knowledge; industry and business development; procument; cultural and social factors which then cross-check with five maturity level [6]. In order to develop a strategy based on the prompts, the user need to use one of the theme as a Chapter heading and the prompts in the matrix itself to both assess the current scenario of authority or partners, which then brings to critically plan what is needed to enhance and improve the current scenario for each themes.

5. The Benefits & Challenges of Retrofitting

The contribution of existing buildings in regards to sustainability should not be underestimate. Through retrofitting, existing buildings can be benefited for sustainability purposes hence lessening the wastage [13]. The time has come to begin concentrating on retrofitting the existing buildings [14]. Tangible and intangible benefits from greening the existing buildings could be achieved through retrofitting. The tangible benefits are any benefits or advantages that can be measured in financial terms such as cost of construction and intangible benefits are any benefits or advantages that cannot be measured by financial term but it still has significant impact to business or project such as comfort level and satisfactory level [15].

According to Abdul Qayyum *et al*., [13] one of the advantages of executing retrofit to an existing building compared to constructing new green buildings is that, the production of associated wastes could be prevented while conserving the embodied energy. It is also a cost-effective way to greening

the existing buildings by cutting down the energy consumption, cost of operation and the lifecycle cost thus creates higher investment returns to the client. As a result, retrofitting the existing buildings is a highly significant approach in achieving the aim of sustainability [13].

Another outcome of retrofit is related to productivity of building occupants. The productivity of the employee plays an important role in any organization and each company would want their employees to be productive. Surprisingly over 50% occupants who work in environmentally certified buildings found their employees to be more productive [16-17]. A survey done by Corenet Global [18] members in 2012 suggested that the tenants wanted more natural light, better ventilation and better temperature control in their buildings. These features are consistent with more sustainable and greener space [4]. Furthermore, greening the existing building through retrofitting could provide better indoor environment quality for the end users and the construction period could be completed in a shorter time compared to building up a new green buildings which takes longer time to be completed [13]. In term of equipment, retrofitting existing equipment can be a cost effective, timesaving and technically sound solution, as opposed to purchasing new equipment. In addition to that, by reusing back the existing equipment to the maximum limit, may results in lower financial expenditure compared to the installation of new equipment [19].

Energy efficiency in buildings is often reported as one of the direct economic benefits for real estate investment companies when considering energy efficiency and sustainability in their portfolios [4]. Jones Lang LaSalle [20] reports stated that, 115 office properties in its portfolio managed to improve the building energy efficiency in 2006, which leads to an average savings of USD 2.24 Mil in 2007 and USD 3.0 Mil in 2008.

CIOB through its Carbon Action 2050 [21] has listed down the benefits and the challenges of retrofitting as follows:

The benefit:

- Retrofitted buildings are more adaptable and suitable to existing activities or future activities if required, more comfort;
- Retrofitted buildings are more energy efficient, lower carbon emissions from the building operations;
- Greater sustainable use of embodied-carbon investment (capital carbon).

The challenges of retrofitting:

- Expensive and inconvenient;
- Internal spaces may reduce upon installation of internal wall-insulation;
- Might cause negative impact to heritage and archaeological assets caused by usage of unproven methods, technologies or instruments;
- Further research is needed especially on insulation mechanism on walls and the effect on retrofit on buildings fabrics;
- More education, training and activities on maintaining and preserving the buildings need to be taught to address issues and to create awareness;
- The risk of retrofitting needs to be highlighted, not just focusing on the benefits of retrofitting and discussion between retrofit and refurbishment.

Other benefits of retrofit existing buildings includes; cost saving in long run by reducing the usage of energy and water by incorporating new technology, services or equipment; increasing the comfort level in a building by redesign the façade and interior to improve end users productivity and satisfaction through improving interior thermal comfort; lowering the greenhouse emission and optimizing the water usage in building; future-proof buildings which means the building will be use and last for many years when it is equipped with current technology based; and preserving cultural and heritage significance of an existing buildings by enhancing the building exterior and interiors to meet current standards and design based on the needs of end users [22].

Although CIOB highlighted cost of retrofit as one of the challenges, it is still open for more research to be done on this. Retrofit could be a cheaper solution to some existing building; if it is compare between constructing new buildings that has same function and capacity (e.g floor area or number seats) with retrofitting the existing building. Two buildings were compared in this research, between Kuala Lumpur Performance Art Centre (KLPac) and Shah Alam Royal Theater, followed by site visit and observation. The two buildings were selected due to the same typology, total number of seats, its usage and the location which both are situated in Klang Valley. Data collected were compared as shown in the Table 2 below, noted that the research was unable to get detail data on the cost and pricing of construction phases such as earthwork, machineries and fittings due to private and confidential information by the developer.

Table 2. Comparison between KLPac and Shah Alam Royal Theater.

Building	KLPac	Shah Alam Royal Theater
Construction Type	Retrofit existing railway warehouse	New
Typology	Theater	Theater
Seats	794 [23]	800 [25][26]
Construction Cost (MYR)	30 Mil [23]	44 Mil [25][26]
Construction Period	15 months [23]	44 months [25][26]
Spaces  KLPAc  Shah Alam Royal Theater	*Pentas 1* [24]*:* A 504-seat proscenium theatre (fixed seating) *Pentas 2:* A 190-seat experimental black box theatre (modular seating) *Indicine:* A 100-seat flexible space *The Actors Studio Academy @ klpac:* 9 studios for rehearsals & training *Supporting facilitie:* Holding Room, Resource Centre, Box Office, Pentas 1 Foyer Bar, Pentas 2 Foyer Art Gallery, Surau, Merchandise Counters, Workshop, Green Room for Artistes, Wardrobe & Laundry Room, Costume & Props Store, Technical, Training Studio, Security Office, Conference Room, Administration Office & Production Offices	Main stage with 800 seats, easy-to-move stage, conference rooms, multipurpose hall, cafeteria, exhibition hall, management office and surau [26]

There is a significant cost saving of MYR 14 Million on retrofitting the existing building based on the 2 buildings above. KLPac project also managed to significantly saves construction time by 29 months earlier as compared to construct a new building, which has identical same numbers of seating; KLPac with 794 seats and 800 seats for Shah Alam Royal theater.
The reason behind the time and cost saving factor was because, KLPac reused back some of its original structure sand fittings from the existing railway warehouse which includes the original brick walls and large doors that can still be seen clearly until today. The original structures were carefully chosen based on its rigidity, strength and suitability to be integrated with the new design and additional spaces. The new 'add-on' spaces were carefully design by the in-house architect from YTL Sdn Bhd in order to intergrade with the existing buildings while maintaining the architectural balance

of design which includes material selections and the proportionate scale between the original structures and additional structures. New column were added to support the additional new floors, new roof, new electrical-mechanical equipment, fittings and finishes. Natural lighting and natural ventilation were used as the main source of lighting and ventilation in KLPac but the Pentas area, toilet, surau remain using the electrical-power lighting and only the Pentas were equipped with centralised air-condition which the unit located at the back of KLPac while the other active spaces like the office and studios was equipped with the split unit air-condition which can be control accordingly. The optimisation of natural lights and natural ventilation in KLPac was possible due to the unique design features from the architect and the usage of large uv-coated swing windows that can be open from inside, thus permits natural air to enter the buildings. This will helps to minimize the operational cost of KLPac in long run. Interestingly, railway woodblock and bricks from the original railway warehouse were also being reused for KLPac landscape, thus creates unity between the buildings and the surrounding landscape.

Different scenario with Shah Alam Royal Theater where it was built from ground up from its first project inception resulting higher embodied energy through out the construction period of 44 months. The whole building was equipped with centralized air-condition unit and electrical lighting units while only the lobby area used large uv-coated window that permit natural lighting. With this it may result in a higher operational cost of the buildings in term of electrical power usage since the building depending on the air-condition unit to ensure the thermal comfort for the occupants.

The cost-effective approach to turn existing buildings into green buildings requires consideration of various factors and aspect of complexities such as technology, funding, law and knowledge [13, 27, 28, 39]. Although there are available support from the government such as Green Building Index certification for existing building, National Policy on Climate Change, Green Technology Financing Scheme for retrofitting, and MS1525:2007; a Malaysian code of practice on energy efficiency (EE) and renewal energy (RE) [30] to encourage retrofitting the existing buildings in Malaysia, but still not many clients had taken an extra mile to grab the opportunity and experience the benefits of retrofitting to their buildings. This unfortunate event caused by the lack of awareness among professionals and developers in the construction industries, thus resulting in the slow progress and reluctance of retrofitting [31].

Dixon et al., [2] has found that the inflexible regulations, complicated validating and approval process for new technologies, selective authorized lists of technologies are all seen as aspects that can reduce the entry of new retrofit products into the market. Furthermore the insignificant payback periods in funding, contracting arrangements, difficulties with the process of validating and approving technologies were also identified as problem that hinder retrofitting technology [2]. Therefore, the vast stock of existing buildings in Malaysia need to be retrofitted if the Malaysia building sector wanted to achieved sustainability by sustaining the building energy consumption and finding ways to generate and sustain more energy from renewable energy sources that later could use for the buildings [13].

Even though retrofit bring benefits to the buildings, environment and end user of the buildings, the planning of making good the existing buildings such as the historical buildings need to be done with manner and respect to its authentic building elements and the surrounding community. Fail to do so may result on negative impacts such as damaging the most authentic building elements of the buildings or creating nuisance to the community. Nuisance to the local community may occur if the newly retrofitted buildings crossed the line of private privacy. As an example, the residents of residential building, Neo Bankside which situated besides Tate Modern Museum London, launched a legal bid in London High Court to force the Tate Modern shut its newly open Switch House viewing platform due to constant surveillance from the visitors and which some then post photographs film of their homes on social media which breaching the European Convention of Human right, respect for private and family lives and their homes [32].

Thus it is very important for the architects, planner and conservator to work closely with each other and understand the needs of local community and gets feedback from them before construction started. Any information will then help the designer to design a building that has consideration and respect to

the surround community especially on humans privacy, avoiding any negative impact socially and economically in future to both sides.

6. Suggestion

Retrofitting the existing buildings is one of the most environmentally friendly, economical competent and proven as an efficient solutions to optimize the energy performance and could also helps to prolong the life of the existing building especially to the historical buildings. Thus, the application of retrofit should be promoted across the construction and conservation industries. More research need to be done in order to have complete sets of detail data on the direct and indirect impacts of retrofit to the environment, cost differences between retrofit with the normal construction of a building, cost of maintenances as well as, the impacts to the end users and to the surround area of retrofitted buildings.

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Acknowledgement
Acknowledgment goes to Ministry of Education Malaysia through Fundamental Research Grant Scheme (FRGS) and Universiti Teknologi MARA for their financial supports.