EFFECTS OF GREEN RETROFITS: A CASE OF INDUSTRIAL MANUFACTURING BUILDINGS IN SRI LANKA

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The impact of built environment on the global warming, greenhouse gas emissions and natural resources depletion is staggering. Consequently, existing built environment will have very high responsibility in dealing with global issues, unless the rate of green retrofitting is amplified. Existing buildings are accountable for 39% of energy use and 35% carbon dioxide emissions, whereas, green retrofitting can achieve 40%-60% energy saving, which contributes 20%-30% carbon emission reduction. Nevertheless, the building owners are less willing to pay for retrofits due to high initial cost and identifying the most cost-effective retrofits for a particular project is still a major challenge. The current study therefore analyses the costs and saving implications of various green retrofits incorporated into an industrial manufacturing building in Sri Lanka. The study used mixed methods in data collection where professionals involved in green retrofits industrial manufacturing buildings were interviewed to identify the green retrofit technologies implemented and the reasons for selection of those green retrofits and subsequently a detailed costs and saving potential analysis of green retrofits incorporated in the selected green retrofit certified industrial manufacturing building was performed using Net Present Value and Simple Payback Period. The analyses show that the use of retrofits related to energy, indoor environmental quality and water are at a significant level in industrial manufacturing buildings in Sri Lanka. Moreover, the implemented retrofit projects indicate the financial viability of green retrofits with positive net present values and simple payback period of less than 5 years. Considering the lifetime financial returns of those retrofits, each indicates significant benefits compared to initial investment. Therefore, the success of these actual retrofit scenarios would enable to identify the most appropriate retrofits based on the potential expenses and returns involved, and thereby assist building investors to incorporate most feasible retrofits into their existing buildings.

Keywords: cost, green buildings, retrofits, Sri Lanka, sustainability

INTRODUCTION

The majority of existing buildings are designed for long lifespan and expected to be in use for another 50-100 years (Love and Bullen 2009). These existing buildings have already utilised energy when procuring, manufacturing, transporting materials and constructing the building. Thus, replacing an existing building with a new green

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building would take more than 65 years to regain the energy utilised during the whole life-cycle and this is counter-productive to the idea of sustainability (Du Plessis 2007; Township's Boards of Historical and Architecture Review 2008). To this end, Liang, Peng and Shen (2016) and Wilkinson, James and Reed (2009) stressed that the existing buildings should give due consideration to green retrofitting. In fact, green retrofit enables, upgrading existing building towards energy and environmental performance, reduce water use, and improve comfort and quality of space in terms of natural lighting, air quality and noise, in a way that it is financially beneficial to the owner (United States Green Building Council [USGBC] 2003).

However, Davies and Osmani (2011) found that the building owners are unwilling to pay for retrofits due to high initial cost. According to McDonald, Ivery and Gagne (2008), the first costs for green space may be acceptable for new construction but any improvements to existing space require capital expenditure. In fact, Rehm and Ade (2013) found that, green retrofits such as installation of high-performance cladding systems, implementation of rainwater harvesting systems and use of energy-efficient mechanical equipment are very expensive. On the contrary, Zhai, Reed, and Mills (2014) argued that the owners and occupiers are willing to invest on green retrofitting due to reduced construction costs compared to new construction. Notwithstanding, most of the organisations are motivated to invest on energy efficient retrofitting due to lower operation costs and high return on the investment (McGraw-Hill Construction 2009). As per Bond (2010), renewable energy projects provide high return on major investment within a short payback period. However, Kasivisvanathan, Ng, Tay and Ng (2012) stated that the industries are unenthusiastic about green retrofits due to the long payback periods.

In Sri Lanka, Karunaratne and De Silva (2019) revealed that the most commonly used energy retrofit techniques in office buildings were variable frequency devices, LED lighting and low emissivity coatings. Further, Fasna and Gunatilake (2018) identified forty-two (42) barriers affecting successful adoption of energy retrofits in existing hotel buildings, where lack of transparency about energy cost and use and difficulties in properly identifying the energy saving from the retrofitted system are identified as significant barriers. Considering the current green retrofitting situation in Sri Lanka, cost implications and savings throughout the life-cycle should be tracked for green retrofit projects in order to improve the implementation of retrofits. On the other hand, Sri Lankan industrial manufacturers are highly motivated to incorporate green features in the buildings due global clients' pressure on comply with energy and environmental regulations (Weerasinghe and Ramachandra 2018). However, a limited number of buildings have been certified for incorporation of green features. In fact, Weerasinghe and Ramachandra (2018) analysed the profile of the green certified buildings that are registered in USGBC and identified that 47 buildings have been green certified to date, while only 7 industrial manufacturing buildings were implemented green retrofits. Therefore, the current study examines the cost implications and saving potentials of green retrofits in industrial manufacturing buildings in Sri Lanka.

Application of Green Retrofits

Policy makers have acknowledged the retrofitting in the company’s vision and environmental policy as a way of promoting sustainability in the built environment (Wilkinson, James and Reed 2009). Further, Liang, Peng and Shen (2016) explained that the green retrofit for existing buildings should be given due consideration to reduce energy consumption and GHG emission. Accordingly, previous authors studied the application of green retrofits and significant savings achieved. Table 1 presents the various green retrofits adopted in building with respect to sustainable focus areas of: sustainable sites (SS), energy and atmosphere (EA), water efficiency (WE), material and resources (MR), and indoor environmental quality (IEQ) based on LEED rating system.

Table 1: Application of green retrofits

Green Retrofits/Technologies		Sources
EA	Use of energy efficient lighting/plugs, improvement of luminaries and installation of reflectors, use of time-scheduled control	Dascalaki and Santamouris (2002)
	Install heating controls, waste heat recovery, improvement of heating system equipment, preheat upgrade	Fluhrer, Maurer and Deshmukh (2010) Mahlia *et al.,* (2005)
	Implement energy-efficient equipment and appliances; chiller plant retrofit, cooling tower replacement	Chidiac, Catania, Morofsky and Foo (2011)
	Adoption of renewable energy; geothermal, wind, biomass and biogas technologies, solar collectors and PV cells	
	Boiler efficiency economizer and replacement with a condensation gas heater	Fluhrer *et al.,* (2010)
	Insulation of walls, window replacement and upgrading, decrease of window area, cladding replacing and insulations, change of glazing system, low-e double glazing	Dascalaki and Santamouris (2002)
	Install a building management system	
	Use of energy meters on major mechanical systems and sub metering for all systems	Aktas and Ozorhon (2015)
IEQ	Implement demand control/mechanical ventilation, provide natural ventilation, air sealing of ventilation system, air infiltration reduction, install CO2 sensors	Aktas and Ozorhon (2015)
	Install day light sensors, manual or occupant sensing device, motion control systems, Automatic photocell-based controls	Chidiac *et al.,* (2011)
	Use sky lights, task lights	Dascalaki and Santamouris (2002)
	Install insulated reflective barriers, exterior and interior permanent shading devices	Fluhrer *et al.,* (2010)
SS	Construct green/vegetated roof, use high emissivity roof, roof insulation	Aktas and Ozorhon (2015)
	Provide bicycle racks, changing facilities, parking spaces and alternative-fuel refuelling stations	
	Construct open grid paving, use high-albedo materials and light-coloured surface (white asphalt)	
WE	Install low-flow showerheads, install automatic controls dry fixture and fittings	Aktas and Ozorhon (2015)
	Implement grey water and rainwater recycling systems, micro irrigation systems	
	Install a building-level water meter and subsystem-level water meters	
MR	Use environmentally friendly finishes	McGraw Hill Construction (2009)

As shown in Table 1, majority of green retrofits were identified under the EA category which ensure reduce energy consumption and GHG emission. These include lighting, heating, air conditioning, renewal energy, boiler efficiency, building envelop, building management and energy monitoring related retrofits. Amongst, most of the authors focused on using energy efficient lighting and improving heating systems due to the significant savings. For example, Mahlia, Said, Masjuki and Tamjis (2005) highlighted significant energy and cost savings of $37 to $111 million through retrofitting incandescent lamps with compact fluorescent lamps. Further, installing energy efficient air conditioning systems, adoption of renewable energy, improving boiler efficiency, building envelop, installing a building management system and use of energy meters were also highlighted by few authors. For example, Dascalaki and Santamouris (2002) conducted a study on the energy conservation potential of retrofits using computer simulations for five office building and concluded that building interventions on the envelope, HVAC, artificial lighting systems, and passive improvements on heating and cooling reduce total energy use by 48% to 56%. Another study, Chidiac *et al.,* (2011) simulated that retrofits such as heat recovery, daylighting, boiler efficiency economizer, preheat upgrade and lighting load reduction, reduce 20% of electricity consumption in Canadian office building.

In terms of IEQ, improvement in ventilation systems, installing lighting sensors and controllers, use of sky lights, installing insulation and shading devices were highlighted by previous authors. In fact, Fluhrer *et al.,* (2010) revealed that use of these retrofits reduce 105,000 metric tonnes of CO2 emission over the next 15 years. Similarly, considering SS feature, Aktas and Ozorhon (2015) highlighted green retrofits such as upgrade of roofs, provide alternative transportation facilities and improvements for the heat island reductions collectively save energy up to 25%. In terms of WE feature, the highlighted green retrofits were installation of water saving features, implement grey water and rainwater recycling systems and installing water meters. Further, Aktas and Ozorhon (2015) found that use of these retrofits under SS and WE features contribute to significant energy and water savings. However, there seems the integration of retrofits of MR category is comparably less in the buildings.

The above review of literature indicate that green retrofits reduce the operation costs and contribute to savings during the life-cycle, which subsequently reduce whole life cost of the building. Although, these studies have emphasized the effects of green retrofits towards energy efficiency, the actual cost implications are not discussed for each retrofit. Building owners and decision makers are often faced with the challenge of identifying and implementing an optimal set of green retrofits that can maximize the sustainability of their buildings while minimizing the required cost. Therefore, the current study focuses on analysing the cost implications and potential savings of green retrofits implemented in an industrial manufacturing building in Sri Lanka towards recommending the feasible green retrofits.

RESEARCH METHODS

The research was approached using mixed methods where it involved collection of both qualitative and quantitative data related to green retrofits of industrial manufacturing buildings using semi-structured interviews and document analysis.

Initially, the profile of green certified buildings under LEED O+M Existing Building category was studied and found that there were 7 industrial manufacturing buildings certified under different versions of existing buildings, with varying business function, certification level, and green space type, as shown in Table 2. Of those buildings, GB1, GB2, GB3 and GB4 were considered for the study as they were certified under the same rating system and in the same business category. Initially, semi-structured interviews were conducted among professionals such as facilities managers and maintenance managers/engineers who engaged in those industrial manufacturing retrofitting in order to identify the green retrofit technologies implemented and the reasons for selection of those green retrofits. Table 3 presents the profile of the participants which represents work positions, experience and field of expertise of those participants. Subsequently, a detailed analysis into cost implications and potential savings of green retrofits implemented was performed for a selected single case building, GB1 which achieved the highest certification level (Platinum).

Table 2: Profile of green buildings certified under LEED existing buildings category

Building	Rating System (Version)	Certification	Green Space	Business
GB1	LEED O+M: Existing Buildings (v2009)	Platinum	Industrial Manufacturing	Garment
GB2		Gold		Garment
GB3		Gold		Garment
GB4		Silver		Garment
GB5		Gold		Spirits and Wines
GB6	LEED O+M: Existing Buildings (v2.0)	Platinum		Garment
GB7	LEED O+M: Existing Buildings v4.0	Gold	Warehouse	Logistics

The data collected through semi-structured interviews were analysed using manual content analysis. Net Present Value (NPV) and Simple Payback (SPB) were used to determine the life time gain of the project considering the time value of money and time to recover the initial capital cost paid for the project respectively (BSI, 2008). The NPV analysis was carried out for expected life time of retrofits, at the discount rate of 4.26 percent obtained from the Central Bank of Sri Lanka. It was assumed that a similar annual monetary saving would be earned throughout the life time of the project and no scrap value was taken at the end of the project.

Table 3: Profile of Participants

Building	Interviewee	Designation/Position	Work Experience (Years)	Profession/Field of Expertise
G1	I01	Chief Maintenance Engineer	18	Mechanical Engineering
G2	I02	Maintenance Manager	17	Electrical Engineering
G3	I03	Facility Manager	9	Facilities Management
G4	I04	Factory Engineer	16	Mechanical Engineering

DATA ANALYSIS AND FINDINGS

The findings of the semi-structured interviews on the green retrofits implemented in the selected four industrial manufacturing buildings, the reasons for the implementation of green retrofits and analysis of cost implications of green retrofits are presented in the following sections.

Application of Green Retrofits in Industrial Manufacturing Buildings

Sustainable Sites (SS)

Sustainable sites offer several green retrofit technologies that could be incorporated in transforming an existing building to a green. All the interviewees (I01, I02, I03 and I04) agreed that the green features such as bicycle racks, changing facilities, parking spaces to provide alternative commuting transportation, and paving surfaces to reduce heat Island effect were implemented to the respective buildings at the initial stage. Further, the interviewees (I01, I03 and I04) explained that the light-coloured roofing to reduce the heat island effect was implemented in the respective buildings. Additionally, according to the interviewees (I01, I02 and I03), the respective buildings have already implemented low reflectance surfaces to reduce the light pollution. Overall, all the interviewees confirmed that these green features were implemented at the initial stage of the buildings.

Water Efficiency (WE)
Similar to SS, all the interviewees (I01, I02, I03 and I04) confirmed that green technologies such as water meters, automatic controls, dry fixture and fittings and greywater recycling were already implemented in the respective buildings at the initial stage. Therefore, these retrofits were not considered at the sustainability transition of the respective buildings. However, the interviewee (I01) responded that the existing building (GB1) was upgraded using green retrofits such as sub system level water meters and low water flow push taps to further improve the water sustainability of the building. Accordingly, nowadays, most of the building owners invest on sustainable water features at the initial stage of the buildings, rather than waiting to implement these features at the operation and maintenance stage.

Energy and Atmosphere (EA) and Indoor Environmental Quality (IEQ)
Unlike, SS and WE, all the interviewees (I01, I02, I03 and I04) indicated that the focus on energy efficiency was less at the initial construction of those buildings due to cost considerations. Therefore, a considerable number of energy improvements were made when converting those existing buildings into green. According to the interviewees (I01, I02, I03 and I04), the green retrofits such as sky lights, LED lights, steam line insulation and compressed air line modification were used to optimize energy efficiency performance and biomass boiler were implemented in the respective buildings. The interviewees (I01, I02 and I03) mentioned that the system level energy metering has been implemented in the respective buildings. Accordingly, all most all the interviewees agreed that energy retrofits were given the top most priority over other retrofits due to the economic savings.

In terms of IEQ, all the interviewees confirmed (I01, I02, I03 and I04) that installation of sky lights provide the daylight into building, installation of LED bulbs as task lighting for the sewing machines reduce the energy consumption. The interviewees (I01, I02) agreed that the respective buildings have introduced evaporative cooler, energy efficient chiller and VSDs for chiller to ensure the demand control and air infiltration reduction of ventilation system. Overall, all the interviewees confirmed that few of the energy retrofits indicate both energy efficiency and IEQ and those retrofits were used to ensure the ventilation and lighting aspects of the buildings.

Materials and Resources (MR)
In terms of material and resources, all the interviewees agreed that retrofits in this category have given the least priority in the respective buildings, while, the focus has given to sustainable purchasing of consumables and solid waste management. However, the interviewee (I01) explained that existing steel racks used to store the materials were replaced by environmentally friendly plywood racks and environmentally friendly finishes such as zero VOC paints were used for interior wall finishing.

Cost Implications of Green Retrofits in the Selected Industrial Manufacturing Building

The initial costs and annual savings of green retrofits integrated in the GB1 industrial manufacturing building were extracted from relevant documents and subjected to NPV and SPB analyses. In performing NPV and SPB analyses, costs savings achieved due to reduction of energy, water and other resource consumptions through the implemented green retrofits were considered as cash inflows and the initial investment costs were considered as cash outflows of the projects. Table 4 presents the cost implications (NPV and SPB) of green retrofits in the selected building.

As seen from Table 4, twelve (12) energy retrofits and two (02) water retrofits were implemented in the selected building which have positive NPV values and payback period of less than 5 years. Amongst, replacing existing chiller system with evaporative cooler has the highest NPV of LKR 138,947,770 which recovers the initial investment cost with a shot payback time (0.31 years). The retrofit with second highest NPV (LKR 83,381,330) is replacing oil fired steam boiler with biomass boiler with a payback period of 1.52 years. Other retrofits with higher costs savings are low water flow push taps, replacing existing chillers with energy efficient chiller, sub system level water meters, replacing clutch motors with servo motors and replace T8 lamps with LED lights etc. Amongst, the green retrofit: Installation of low water flow push taps has the lowest payback time of 0.004 years with a NPV of LKR 53,428,094. The payback period of most of the green retrofits is less than three years. However, replacing existing chillers with energy efficient chillers (4.28 years) and replacing florescent lamps with sky lights (4.16 years) have payback periods more than three years. Considering the NPV and SPB values obtained, it is viable to invest on all the identified green retrofits, nevertheless, the green retrofits with payback of more than three years would be unattractive to those who expect fast investment returns within first three years of the investment.

CONCLUSIONS

Application of green retrofits in the industrial manufacturing buildings in Sri Lanka was examined through the semi-structured interviews. Overall, the interviews confirmed that the respective buildings have implemented energy, IEQ and water related retrofits, whereas in terms of sustainable sites and materials, green features were implemented at the initial stage of the building and they were not incorporated to the existing building at the sustainability transition stage. Accordingly, the current study highlighted that green retrofits such as sky lights, LED lights, steam line insulation, compressed air line modification, biomass boiler, evaporative cooler, energy efficient chiller and VSDs were implemented in the industrial manufacturing buildings in Sri Lanka in terms of energy and IEQ. Similarly, most of these energies and IEQ retrofits were identified in the previous studies by Aktas and Ozorhon (2015), Chidiac *et al.,* (2011), Dascalaki and Santamouris (2002), Fluhrer *et al.,* (2010) and Mahlia *et al.,* (2005). Additionally, the selected buildings were upgraded using green retrofits such as sub system level water meters and low water flow push taps which were identified in the study of Aktas and Ozorhon (2015).

Moreover, previous studies, Dascalaki and Santamouris (2002) considered building envelope retrofitting as a key to improve energy performance of buildings. However, the respondents of the selected green cases confirmed that the respective buildings haven't done any upgrades to the building envelope other than the existing building conditions. Contradictory views were indicated by previous studies on the initial cost of green retrofits (McDonald *et al.,* 2008; Zhai *et al.,* 2014). The positive NPV values in the current study indicate the significant financial returns over the initial investment. Moreover, the findings on payback period differ to literature findings which indicate that the green retrofits involved long payback periods (Kasivisvanathan *et al.,* 2012). Bond (2010) indicated that the renewable energy projects provide high return on major investment within a short payback period, likewise the payback period equals to 1.4 years and in terms of biomass boilers.

Furthermore, most of the green retrofit projects have recovered the higher initial investment very quickly within less than 3 years, except the energy efficient chillers and sky lights. In terms of costs savings of green retrofits, Mahlia *et al.,* (2005) highlighted significant cost savings of retrofitting incandescent lamps with compact fluorescent lamps.

Table 4: Cost implications of green retrofits

Green Retrofit	Investment (LKR)	Annual Saving	Savings (LKR) Annual	Savings (LKR) Life-cycle	NPV(LKR)	SPB (Years)	Life-cycle (Years)
Replace existing chillers with evaporative cooler	4,098,510	935766 kWh	13,100,735	143,046,280	138,947,770	0.31	15
Replace oil fired steam boiler with biomass boiler	10,745,700	506173 kWh	7,086,423	94,127,030	83,381,330	1.52	20
Install low water flow push taps	50,450	20167680l	12,100,608	53,478,544	53,428,094	0.004	5
Replace existing chillers with energy efficient chillers	20,475,000	341640 kWh	4,782,960	59,289,197	38,814,197	4.28	18
Install sub system level water meters	1,003,507	13312000l	7,987,200	35,299,369	34,295,862	0.13	5
Replace clutch motors with servo motors	1,797,600	225763 kWh	3,160,690	29,220,793	27,423,193	0.57	12
Replace T8 lamps with LED lights	2,241,366	135869 kWh	1,902,169	12,670,435	10,429,069	1.18	8
Insulate steam lines	183,000	178530	2,499,420	9,017,314	8,834,314	0.07	4
Replace florescent lamps with sky lights	4,680,000	80308 kWh	1,124,323	10,394,442	5,714,442	4.16	12
Compressed air line modification	795,450	115227 kWh	1,613,181	3,031,314	2,235,864	0.49	2
Implement a biogas project	1,265,540	36072 kWh	505,015	3,363,928	2,098,388	2.51	8
Install VSD for chiller	475,000	12117 kWh	169,642	1,129,993	654,993	2.8	8
Install VSD for compressor	150,600	3814 kWh	53,400	355,700	205,100	2.82	8
Recovery of flash steam for water heating	80,000	3928 kWh	55,000	198,427	118,427	1.45	4

Per l cost of water = LKR 0.60; Per kWh cost = LKR 14.00

While, the current study revealed that energy retrofits such as use of evaporative cooler, biomass boiler, energy efficient chillers and servo motors provide much economical savings over life-cycle. Accordingly, the study recommends the appropriate green retrofits options such as evaporative cooler, biomass boiler, low water flow push taps, energy efficient chillers, water meters, servo motors, LED lights, steam lines insulation, sky lights, compressed air line modification and biogas project, which provide higher return within a short time.

The lack of knowledge on life-cycle cost and long-term return of green retrofits lead to decisions not to implement green retrofits. Further, the investors who do not have access to enough information will not realize the contribution of green retrofits towards energy, environmental and water performance, comfort and quality of space etc. Lack of knowledge on financial institutions and unawareness of the benefits of green retrofits have primarily affected building owners from implementing green retrofit projects. To this end, the findings of the current study highlight the financial viability of the implemented retrofit projects under water efficiency, energy and IEQ with positive NPV values and less SPB periods. Moreover, considering the life time financial returns of those retrofits, each indicates significant benefits compared to the initial investment. Therefore, the success of these real retrofit scenarios would enable to identify the most appropriate retrofit technologies that can maximize the sustainability of their buildings while minimizing the required cost. Thereby, building investors and owners could apply those retrofits in existing buildings without uncertainty.

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