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Post-construction stages cost management: Sustainable design approach



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Abstract This paper addresses solving sustainable construction economic benefits enigma as ‘high capital costs’ and ‘low market value’, comparing with conventional building, creates a dilemma for developers and stakeholders. Many developers and stakeholders do not give much attention to Post Construction stages. The lack of accurate information related to ‘Sustainable construction industry cost’ and ‘value’ means that clients and developers are unable to take the right decisions concerning sustainability. It should be taken in consideration that meeting ‘Sustainability goals’ does not end after the building design is completed.

The paper aim is proving that profitable residential buildings are approached by applying project management concepts on sustainable construction projects using ‘Life Cycle Method Approach’ in the ‘Post Construction’ stages, The paper aim would be accomplished through some objectives as: Motivating decision makers to use ‘Sustainable Approach’ in residential buildings industry and Convincing developers and stakeholders to start using a ‘Sustainable Construction’ method. The research concluded that applying project management concepts on sustainable construction projects, specially housing sector, and capital could be the same as, or lower than, that of a traditional building, in addition to that it could be profitable on the long run by considering ‘Life Cycle Method’.

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1. Introduction

‘Sustainable Construction Industry’ economic benefits is considered an enigma, the high ‘capital costs’ and low ‘market value’, compared to conventional building, forms a mystery for developers and stakeholders. Developers and stakeholders

also do not give much attention to Post Construction stages; they do not pay attention to their effect on the project total cost on life-time.

The paper aim is to prove that profitable residential buildings could be approached by applying the concepts of project management on sustainable construction industry projects using ‘Life Cycle Method Approach’. Paper aim accomplished through some objectives such as: Motivating and Convincing decision makers and stakeholders using ‘Sustainable Approach’ in residential buildings. This research is an ‘analytical research’ work, in addition to employing ‘qualitative’ and

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'quantitative' research methods. Post-construction stages in the paper are subdivided to 'Occupation' phase and 'Maintenance' phase. In each phase three dimensions are covered ('Life Cycle Method Approach', 'Sustainable Design Approach' and 'Cost Management').

2. Post-construction stages: occupation/maintenance phases

Post Construction stages is the time to collect all as built drawings from vendors and consultants and approved by architect, collect warranty manuals, maintenance manuals, Certify all vendor bills after collecting all documents and attending snags, Prepare detailed statement of all vendor details with contacts of key persons for approaching client for any kind defects created, Prepare of Completion certificate based on all documents & Drawings, Assist in finding suitable facility Manager, Hand over all documents and giving basic guidelines about the project to facility manager. After all this steps it's the time to start 'Occupation' phase and 'Maintenance' phase [1,2].

2.1. Occupation phase

Occupation is the period stipulated in construction contract, follows construction phase. Also, in other words it could be called guaranty phase/warranty phase. Moving the venture from the administration of a building site to an involved working facility while causing negligible disturbance and taken a toll to extend could be come to through client arrangements for occupation. It is critical to arrange for occupation as early as conceivable, so that any issue considered amid the plan and development stages. Occupation phase considered one of the most critical stages as most of natural impacts happens other than being the longest stage, in respect to time [3].

An investigate was done proposes a show to conduct the life cycle appraisal of a private building home in Pittsburgh, PA, from a construction materials and vitality utilization angle, along three lifecycle phases: construction, occupation, and disposal. The demonstrate takes into thought life cycle costs and normal impacts considering facilitate and circuitous associations among economy components considering lifetime 50 a long years [4]. The Comes about appeared in Table 1.

The comes about appear how occupation 'post-construction' considered an vital portion in construction industry life cycle, and how compelling it could be coming to any alter in the impacts of this phase. Long term plans using sustainable approach valuable when stakeholders and developers put in their mind its weight in future.

2.1.1. Evaluation

Assessment must be performed as 'Post-occupancy' assessment is a fundamental instrument to be able to illustrate either the

venture goals have been accomplished or not [5]. The taking after Fig. 1 appears occupation stage assessment sorts:

- Operational Review: 3–6 Months after handover

Evaluation centers on guaranteeing that extend conveys the yields and esteem for cash distinguished in extend, and covers the time of the commissioning, fitting out. The Client ought to distinguish the lessons learned, especially in respect to the obtainment prepare, so up and coming ventures can be conveyed with made strides productivity [6].

- Functional performance: 12–18 months after handover

The Client must carry out advance survey at slightest 12 months after occupation to make beyond any doubt the reasonableness of venture is fulfilling needs and entirety life plan. The fundamental center is on the execution, capacities of particular regions and the specialized and utilitarian execution. The performance review will highlight where alterations and rectifications were required to the building and its frameworks in expansion to distinguishing cost in utilize. The results will assist is refining good practice and may affect strategic plans for the future [5,6].

- Strategic: 3–5 years after handover

The fundamental center of the strategic review is looking at organizational alter and the buildings reaction, to see how the buildings might respond to modify in the future, and how amplify has responded to term needs and changes. Feedback can be utilized to influence Key choice making in the future [6].

2.1.2. Water consumption

In occupation stage daily usages reducing any amount in consumption is a great point to reach. On the off chance that we confronted the truth that 1 child kicks the bucket each single diminutive since of infection caused by contaminated water



Fig. 1 Occupation phase evaluation types [Researchers, 2018].

Table 1 Economic and environmental impact analysis for Pittsburgh case study [4].

'Concept'	'Unit'	'Construction'	'Occupation'	'Disposal'	Life time	%Occupation
'External Costs'	\$	2000	18,000	90	20,000	90%
'Electricity Used'	kW h	32,000	390,000	800	430,000	90.6%
'Energy Used'	MJ	590,000	13,000,000	18,000	14,000,000	92.8%
'Fuels'	MJ	550,000	13,000,000	17,000	14,000,000	92.8%
'Global warming potential'	Equivalent kg of Co ₂	43,000	581,000	1000	620,000	93.7%

[7]. We will think twice some time recently devouring each drop of water. Rate of day by day water utilization for each individual in Egypt is 450 L. We should also take in consideration that Egypt is battling to manage with water deficiencies. Egypt has as it were 20 cubic meters/individual of inner renewable freshwater assets, and as a result the country considers the Nile for its main source of water [8]. Many studies focusing on Renaissance Dam effects already held by the Egyptian National Panel of Experts mentions that the construction of the Dam will have catastrophic effects on Egypt. Egypt's share of water supply could diminish from anyplace 9–12 billion cubic meters per year [9]. All the past reasons make feasible approach a must to decrease water utilization as much as we can. The country can no longer delay action and must act by and by. Residents also are facing a water bill every month which eats a part of their monthly income. As occupation stage is the stage where the sustainable approach gains are clear, reducing the bill is one of the gains in addition to the environmental gain [10]. The taking after Fig. 2 appears that most of residential water utilization is streak water which for illustration can be diminished utilizing sustainable strategies.

2.1.3. Energy consumption

Numerous building plan approaches and advances offer assistance viably in minimizing energy costs. The integration between architectural and mechanical features makes a difference in minimizing energy utilize and diminishes cost while keeping up consolation. The integration is best done amid the exceptionally early stages, when the most cost-effective all-encompassing framework can be planned. Lower lifecycle costs resulting annual cost savings approached [12].

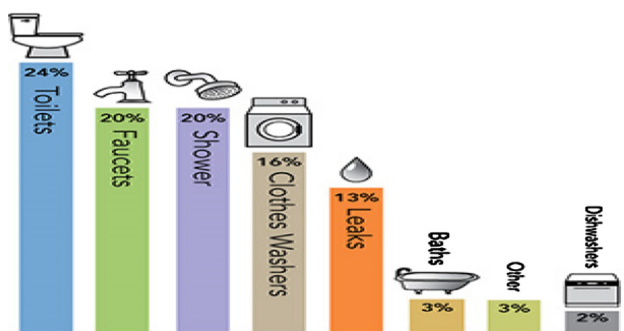


Fig. 2 Average residential water usage [10].

Egypt is Africa biggest non-‘OPEC’ oil maker, second biggest dry natural gas maker on the landmass and acts as a fundamental travel route for oil dispatched from ‘Persian Gulf’ to ‘Europe’ and ‘United States’. One of Egypt’s fundamental challenges is fulfilling residential oil request expanding. Add up to oil utilization developed 3% yearly over the past 10 a long time; averaging almost 770,000 bbl/d in 2013. Egypt is Africa’s biggest oil and natural gas customer, accounting for more than 20% of add up to oil utilization and more than 40% of add up to dry natural gas utilization in Africa in 2013 [13]. Petroleum production/consumption per individual appeared in Fig. 3.

Electricity which considered secondary energy source average rate of electricity consumption in Egypt in kilowatt hours per person (kW h/person) [13] shown in graph Fig. 4.

Electricity costs reflect the fetched to construct, fund, keep up, and work power plants and the electricity lattice. A few for-profit utilities too incorporate a money related return for proprietors and shareholders in their power costs.

2.2. Maintenance phase

Contractors let stakeholders know any required maintenance related to products or materials. A few little acts as utilizing durable sustainable materials, designing buildings with areas for efficient and convenient collection of recyclable materials such as: paper, plastic, and glass, moreover utilizing fluorescent lights, which last around 10,000 h as restricted to 1000 h for incandescent lights, can diminish yearly squander transfer costs and repair costs [15].

3. Sustainable design approach

Sustainable Design Approach aim is to enhance the quality and sustainability of buildings by implementing a new national building quality standard [14]. Sustainability is moreover characterized as economic development which meets the current era needs without compromising the opportunity and the potential for the coming era needs [16]. Meeting sustainability goals does not end after the building design is completed. Traditional buildings have also similar needs. Contractors are planned to come in occasionally and check building’s framework. Sustainable design includes preventative maintenance to include auditing, performance measuring, analysis, and optimization. All the past steps can diminish costs by catching

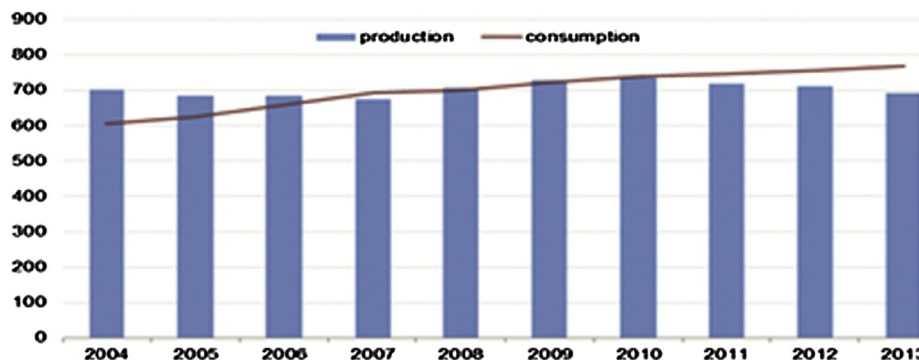


Fig. 3 Petroleum production/consumption per person [13].

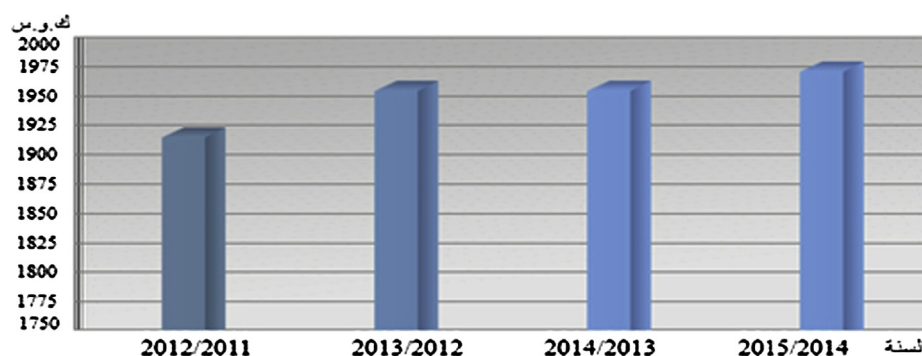


Fig. 4 Average electricity rates in Egypt [14].

issues well some time recently a framework breaks. A system that is running 20% too much or is not performing to its design may lead to the equipment failing before its expected lifetime or the system consuming more energy than is needed. Operation and maintenance is a nonstop handle takes after arrange distinguishing and adjusting building framework issues to preserve crest building execution over time. This process is a nonstop cycle of arranging, reviewing, measuring, analyzing, and rectifying [17].

3.1. Example: Masdar City

Masdar City is located in Abu Dhabi, United Arab Emirates with an approximately 6,000,000 SQM total site area and approximately 4,000,000 SQ M total gross floor area. The city is outlined by British engineering firm 'Foster and partners'. The city provides a mix between green print for cities of the future and traditional Arabic architecture blending together to form a state of art, in expansion to advanced innovation to maximize effectiveness of energy. Masdar City is outlined to have up to 40,000 inhabitants and 50,000 commuters after being completed [18]. Fig. 5 appears an outside shot for the city.

This mixed-use development point is to supply a curiously, sustainable environment, with arranges residential and commercial zones, along with broad entertainment facilities. Masdar is authentically the Middle East's greatest exporter of renewable energy. Masdar City has the base camp of 'International Renewable Vitality Agency' (IRENA) [17]. Masdar City got to be a domestic to around 300 full-time understudies of Masdar Institute of Science and Technology. Around 2000 lofts are beneath development or in plan [19].



Fig. 5 Masdar city [18].

3.2. Masdar city awards

Since it broke ground in 2008, Masdar City has been considered as one of the world's most sustainable, low-carbon urban developments, as one of the most advanced, sustainable communities and an rising innovation cluster [18]. It was permitted a wide number of prizes appeared up in Table 2.

High-performance buildings reduce Masdar city's water and energy consumption by over 40% and diverting 15,000 tons of Carbon emissions per year in addition to 10 MW solar PV plant enough to power more than 1000 homes [18].

3.2.1. Masdar City Eco-Villa

On the smaller scale the Masdar City Eco-Villa continues Abu Dhabi's tradition of innovation by following a new concept for the design, construction and operation of sustainable family homes. Eco-Villa is a great example on how life cycle method is successful, and how much the return is great. Life method approach return appears in post construction stages. The difference in return between constructions either they are sustainable or non-sustainable is clear after occupation phase starts [11,18]. Fig. 6 shows Masdar villa interior and exterior shots.

Masdar city's Eco-Villa, a pilot extends consolidating water and energy saving advances. The 405 m² Eco-Villa is the first estate to accomplish a 4 Pearl rating agreeing to the Abu Dhabi Urban Planning Council's 'Estidama Pearl Building Rating System'. It will utilize around 72% less vitality and 35% less water than a commonplace comparably measured estate in Abu Dhabi, anticipated to expend as it were 97 kW h/m² and uprooting around 63 tons of carbon dioxide yearly. The housetop can hold 87 solar panels which are able of providing as much as 40,000 kW h of power to the national framework [19]. There are two sorts of Eco-Villa: Standard and Net-Zero Vitality, the distinction between them is appeared in Table 3.

Table 2 Masdar city prizes [Researchers, 2018].

Year	Prize
2011	'International Award (RIBA)'
2013	Outstanding 'International Architecture Project (British Expertise International Awards)' 'First Prize for Sustainability Award' (Cityscape)
2014	'Green Project of the Year' (Big Project ME Awards)

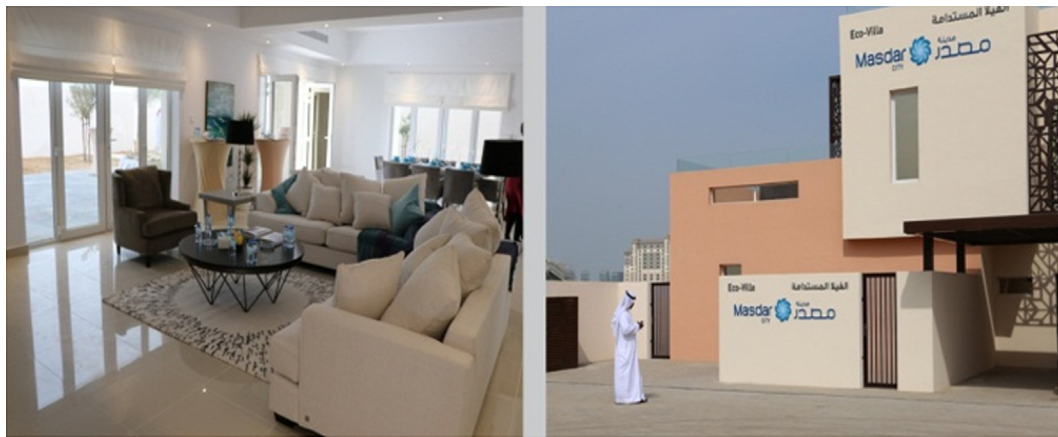


Fig. 6 Masdar Villa interior/exterior shots [18].

Table 3 Masdar Eco-Villas types [Researchers, 2018].

Type	Characteristics
Standard Eco-Villa	Achieves nearly 1/4 of the energy consumption of standard older villas
Net-Zero Energy Eco-Villa	Advances sustainability and deploys PV panels to generate renewable energy

4. Life Cycle Method approach

From BREEAM point of view the fundamental point of utilizing 'Life Cycle Strategy Approach' and utilizing life cycle costing is to provide the entirety life. 'Life Cycle Costing' is the most fabulous instrument in terms of viability. As well as considering the influence on the building design in terms of sustainability evaluation, the client should to assess the arrange not as it were in terms of construction cost, but besides in terms of running costs over the life of the building. The greatest cost to a building owner is the people in the building. The intent of IEQ is to provide systems that will insure the quality of the indoor environment [20,21].

A comparison was done between two buildings, **Building A** is a Green Mark Platinum construction and **Building B** is random chosen, both have approximately same area, design and scope over 30 years period divided into 3 terms: (1–3 years), (4–10 years) and (11–30 years) to compare the cyclical replacement cost [20]. The followings results shown in Fig. 7 are found.

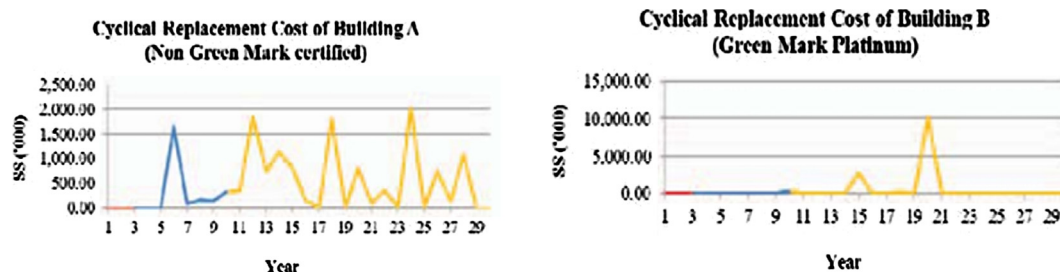


Fig. 7 Cyclical replacement cost [22].

The previous graph shows how Sustainable construction industry is more economical taking in consideration life time cycle. In general the payback period for Green Sustainable building is 2.5–6.5 years as shown in the following Table 4.

5. 'Project Cost Management'

'Project Cost Management' put stakeholder necessities in thought in arrange to oversee costs. Assorted stakeholders degree venture costs in distinctive ways and times. 'Project Cost Management' is essentially concerned with required assets taken a toll to total extend activities, moreover consider venture choices impact on the consequent repeating cost of utilizing, keeping up, and supporting the venture. 'Project Cost Management' may address shapes and different budgetary management techniques as return on venture, stamped down cash stream, and theory payback examination [20,23]. No one runs a business to lose cash, or else the commerce cannot survive, and everybody will be out of a work [24,25].

5.1. 'Sustainability' in 'Project Management'

'Sustainability' in 'Project Management' implies considering full life-cycle (from conception to disposal) expand given the future presentation of the concept of sustainability. 'Project management' address numerous questions as: How do the standards and viewpoints of sustainability impact the societal and organizational setting of the venture? What is the influence on the venture? [26,27].

Table 4 Comparison between replacement cost for buildings A & B [Researchers, 2018].

Time Period	Building A (Traditional)	Building B (Sustainable)
1–3 years	No replacements needed	No replacements needed
4–10 years	Replacements start to be inquired	Approximately no replacements needed still
11–30 years	Needs more frequent replacements	First major replacement cost after 15 years

5.2. Study case: Masdar City Eco-Villa

By applying our typical prices in Egypt: **72%** less energy and **35%** less water than a typical comparably sized villa, on a typical unit in Egypt, using average energy rates in Egypt [28], we could reach lower rates estimated as shown in Table 5.

While water consumption in Egypt daily is around **450 L/person** which are an extreme rate compared to Europe consumption rate which is around **150 L/person** and Saudi Arabia **264 L/person** in 2015, which means that we are in a great need to reduce our consumption by any mean. Reducing consumption by **35%** as shown in Masdar city Eco-villa could be one of the solutions we need to follow.

$$450 \text{ L/person} * 0.65 = 292.5 \text{ L/person}$$

Reaching average 292.5 L/person of water daily is not yet the best rate to achieve, we need more efficient solutions and ideas to follow, but it could be a good step to start with. To start late is much better than never starting. And for the residents it's a great profit to save 35% of water bill monthly. It's one of the sustainable approach positive points saving much more money in occupation stage. Saving about 72% energy and 35% water will return with profit on both government and residents. Residents will get significantly diminished water bills and power bills. This could be used in manufacturing, opening more projects and saving water and electricity to the national grid. In addition to reducing the amount of carbon dioxide produced annually which is a great environmental and financial target regarding governmental side and society.

6. Results and discussion

Hence any improvement in construction industry affects directly occupants and government, applying sustainable

construction principles affects directly the occupation phase. It was found that residents will get significantly diminished water bills and power bills, while government will save energy and water needed to be supplied. Moreover since Post-construction stages shape the longest organize in life cycle of the building; it is the most successful stage where the effect of 'Sustainability' on client appear.

Masdar city provides a mix between 'green print' for 'cities of the future' and 'traditional Arabic' architecture blending together to form a 'state of art' in addition to 'modern technology' to maximize 'energy efficiency'. Masdar is considered a 'utility-scale', 'grid-tied' project providing energy communities away from 'electricity grid'; and 'carbon abatement' projects. People expect a sustainable design approach to be more expensive, but Masdar Eco-Villa concept challenges this misconception by reducing energy and water consumption and bills paid by government and stakeholders. Reaching savings about **72%** energy and **35%** water is a great profit compared to Abu Dhabi intends for **7%** of its energy to come from sustainable sources. Working on an Egyptian model could reach different results as environmental, economical, and social aspects differ, but putting Masdar city as a model to simulate with some minor changes could be a good start.

Masdar city is evidence that applying sustainable approach is profitable, as the payback appears clearly while considering post-construction stages. Using Life-cycle method in arbitrating Masdar city (or any sustainable project) is the most appropriate way, as the payback appears while considering the post-construction stages. Cities had to be as sustainable as possible, but also had to become commercially viable. The risk in building a sustainable city hoping people and businesses would come, most that it would likely result in having an empty city. Indeed you cannot call a place a 'city', if no one lives there. Masdar City is proof that a sustainable city is no longer a utopian vision but a genuine urban model that substantially reduces greenhouse-gas emissions and saves energy.

7. Conclusion

It is concluded that applying 'Project Management' concepts on 'Sustainable construction' industry ventures, specially housing division, is productive on the long run by considering Life Cycle Strategy as the payback period frequently short and the 'lifecyle cost' is lower than the cost of 'traditional' buildings. 'Sustainable construction' has lower yearly costs for energy, water and maintenance. 'Sustainability' gives roundabout financial benefits to building proprietors and society, not only just direct cost savings. 'Sustainable construction' advance way better wellbeing, consolation, well-being, 'greenhouse' gas outflows related with climate alter, water contamination, and resources consumption. Some aspects of sustainability are found in the standards of project management, it has to be concluded that sustainability impact is not

Table 5 Electricity rates [Researchers, 2018].

Year	Consumption rates, kW h/person	Estimated rates, kW h/person
2015/2014	1966	550.5
2014/2013	1950	546
2013/2012	1950	546
2012/2011	1910	534.8
2011/2010	1850	518
2010/2009	1782	499
2009/2008	1720	481.6
2008/2007	1680	470.4
2007/2006	1575	441
2006/2005	1450	406
2005/2004	1450	406
2004/2003	1350	378
2003/2002	1350	378
2002/2001	1350	378

fully recognized yet. When constructing 'cost-effective' buildings, it is common to forget that either success or failure of any construction project depends on its IEQ. Sadly, this simple truth is often lost, as it is easier to focus on the first cost of a project than it is to determine the value of increased user productivity and health.

In order to implement sustainable building approach successfully, all stakeholders would benefit from a 'comprehensive' model that incorporates sustainable building 'strategies' and 'technologies' in every stage of a building's life cycle. 'Cost' overrun is a common problem worldwide, but it is a 'significant' challenge in developing countries. Sustainable construction industry provides indirect economic benefits to both building owner and society, in addition to direct cost savings, as it promotes better health, comfort, well-being, and reduces air pollution emissions, greenhouse gas emissions, solid waste generation, water pollution, and natural resource depletion.

Entire decision makers of construction industry, developers and stakeholders cannot benefit from sustainable construction approach advantages until the already existing obstacles in establishing sustainable construction in Egypt are identified. Government should start setting long-term commitments for improving environmental performance of all buildings, across their life cycle and beyond zero carbon, promoting publicizing sustainable materials as it is an essential factor results in more sustainable selections by stakeholders and decision makers, promoting green construction culture, and enforcing Green regulations to drive sustainability in the Egyptian construction industry. Also Stakeholders should start designing buildings with efficiency in mind to meet high efficiency performance benchmarks, using integrated design process to make new buildings and developments more efficient and enhancing knowledge which is the major challenge in adapting sustainability in the construction industry is the stakeholders.

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