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SUSTAINABLE CONSTRUCTION THROUGH LIFE CYCLE COSTING

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Abstract

Sustainable construction refers to the integration of environmental, social and economic considerations into construction business strategies and practices. It is the application of the principles of sustainable development to the comprehensive construction cycle from the extraction of raw materials, through the planning, design and construction of buildings and infrastructure, until their final demolition and management of the resultant waste. The implementation of Life Cycle Costing (LCC) in the sustainable construction industry is significantly important to construct the structures and infrastructure projects that will meet all the principles of sustainability. During the process of developing a project, LCC principles and techniques aim to provide best value from a whole life perspective. This paper, in reviewing the application of life cycle costing and sustainable construction, explores the correlation between these two elements and assesses how these can be used to achieve sustainability over the whole life of building projects.

Keywords: life cycle costing; value for money; sustainable construction; pre-construction.

Introduction

Construction industry is one of the most significant industries that contribute toward socio-economic growth especially to developing countries. Since the declaration of independence in 1957, Malaysia has started its development via the initial economic plan (1956-1960) towards achieving a developed nation by 2020. The Government has launched Vision 2020 to envision that Malaysia will be a fully industrialized country by the year 2020. Construction industry contributes significantly to the Gross Domestic Product (GDP) of Malaysia's economy by contributing an average of over 3% to the overall gross domestic product over the last five years from 2008 to 2012 (BNM, 2013). For instance, in 2012, the industry has contributed approximately 3.6% of the country's GDP value for year 2012 (Department of Statistics Malaysia, 2013). The total value of construction projects awarded in Malaysia in 2012 amounted to RM112.5 billion (CIDB Malaysia, 2013) and has created a lot of jobs opportunities to help boost the country's economy.

Given this, under the Tenth Malaysia Plan (2011-2015) and the Economic Transformation Programme (ETP), the government announced several mega development projects hoping that these projects will help to bring about long-term growth to the nation's economy. One such example is the Mass Rapid Transit (MRT) system, which costs over RM40 billion with an estimated demand for up to 130 000 construction workers of various trades. The total value of construction work done in the second quarter 2014 recorded a double digit growth of 10.8% year-on-year to RM25.2 billion (Department of Statistics Malaysia, 2014). These developments has brought significant impacts to the country's economy and also resulted in other implications especially to the environment and social aspect of the country. Generally, construction industry is fragmented and complex where it is on site basis and one-of-a-kind production and resource, and schedule driven nature (Hussin et al., 2013).

The construction industry is one of the biggest contributors to pollution and waste through its life cycle (Horvath, 2004). About 40% of the world's resource and energy use is linked to the construction and maintenance of buildings. These concerns can be addressed by the Sustainable Construction practices, which is more sustainable than current practices. Sustainable construction approaches are environmentally responsible and resource-efficient throughout a building's life-cycle. Sustainable constructions have many benefits, such as better use of construction resources, significant operational savings, and increased workplace productivity. Sustainable construction approaches can be introduced at any stage in construction, from design to demolition. Ideally, the impact of the built environment should be addressed on a life cycle basis, from the origins of the construction material, through the manufacture and installation of the resources, to their eventual deconstruction of the building (Allen and Iano, 2004). Sustainable constructions based on a life-cycle approach can produce significant long-term profit for both building owners and occupants such as helping to reduce environmental impacts; creating healthier, more comfortable and more productive indoor spaces, and reducing building operation and maintenance costs (Hikmat and Saba, 2009).

Life-cycle analysis considers all the inputs and outputs of acquiring, owning, and disposing of a building system. This approach is particularly useful when project alternatives, which fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings (Hikmat and Saba, 2009). There is no doubt that there is a value in sustainable construction, but the way things are today requires us to pay a higher cost to achieve that value. At the 3rd Holcim Forum 2010 held in Mexico City, Alejandro Aravena, an architect based in Chile, had drawn a notable conclusion regarding sustainability and the economy of sustainable construction. He stated that "Sustainable construction has to be cheaper than unsustainable construction. Otherwise, we can make as many projects as we want, but decisions will be made against them." It is common to choose the option that is cheapest at first glance. However, limitations such as budget, time, and material do have a positive aspect as it prevent excesses and foster innovation (Construction, 2013).

In a sustainable construction project, Life Cycle Cost (LCC) practices is particularly suitable in the way that it judges design alternatives which is fundamental, to meet the required performance goals of a building by taking into account initial capital costs, operation and repair costs, as well as the life of the building itself (Sacks et al., 2012). LCC helps in monitoring the cost performance over the economic life span of a building. Therefore, the implementation of LCC in the sustainable construction industry is significantly important to construct the structures and infrastructure projects that will meet all the principal of sustainability (Akasah and Rum, 2011). There could be substantial benefits of using LCC as a road map for promoting and achieving sustainable construction. Additionally, the experience and skills of LCC practitioners could be used to accelerate the understanding and implementing of sustainable construction. During the process of developing a project, LCC principles and techniques aim to provide best value from a whole life perspective. This paper, in reviewing the concept of life cycle costing and sustainable construction, explores the correlation between these two elements and assesses how these can be used to achieve sustainability over the whole life of building projects.

Literature Review

Issues in Construction Industry

Construction industry always faced serious and chronic problems likes time overrun, cost overrun, waste generation, imposing negative impacts to the environment and excessive resource consumption. The construction industries in Malaysia are facing the critical problem of time overrun (Alaghbari, 2007; Sambasivan and Soon, 2007; Ibrahim et al., 2010; Hussin et al., 2013). Achieving completion of construction projects on time is a basic requirement but it seems rarely for projects to be completed on time. Abdullah et al. (2009) reported that more than 90% of large MARA construction projects experienced delay since 1984. Endut et al. (2009) studied on time performance of 359 projects (301 were public projects and 51 private projects) in Malaysia. The study found that only 18.2% of the public sector projects and 29.45% of private sector projects had 0% time deviation (no delays) while the average percentage of time overrun for other projects was 49.71%. Time delay happened due to many reasons including problems of design changes (Mansfield et al., 1994), changes in site conditions (Al-Momani, 2000; Mansfield et al., 1994), financing and payment problems for completed works (Frimpong et al., 2003; Alaghbari, 2007; Sweis, 2008; Fugar and Adwoa, 2010), poor contract management (Ogunlana and Promkuntong, 1997), weather condition (Frimpong et al., 2003), shortage of materials (Ogunlana and Promkuntong, 1997) and others.

Besides time overrun, cost overrun is also a serious problem in the construction industry. This is a major problem both in developed and developing countries. Cost is one of the main considerations throughout the lifecycle of a project. Most of the projects failed to achieve project completion with the estimated cost. Endut et al. (2009) conducted a study on 308 public projects and 51 private projects in Malaysia and discovered only 46.8% and 37.2% of public and private sector projects completed within the budget respectively. A research by Flyvbjerg (2003) regarding cost overruns in the global construction industry, found that 9 out of 10 projects had the overrun and the common overruns are between 50 to 100%. The factors that contribute to cost overrun including lack of contractor's experience (Kaming et al., 1997;Jackson and Steven, 2001; Ameh et al., 2010), inaccurate time and cost estimates (Frimpong et al., 2003; Creedy, 2005; Ali and Kamaruzzaman, 2010), schedule delay (Kaliba et al. 2009; Omoregie and Radford, 2006), frequent design changes (Kumaraswamy et al., 2009; Ameh et al., 2010), fluctuation of prices of materials (Jackson and Steven, 2001; Azhar et al., 2008; Memon et al. 2011), cash flow and financial difficulties faced by contractors (Le-Hoai et al., 2008; Memon et al., 2010).

Construction waste generation is one of the main concerns in Malaysian construction industry. Forsberg and Saukkoriipi (2007) stated that the amount of waste contributed is around 30-35% of a project's production cost. The causes of construction wastes were generated due to many reasons including poor planning and frequent design changes (Zhao and Chua, 2003; Senaratne and Wijesiri, 2008; Yupeng, 2011), low quality materials (Nazech et al., 2008; Lu et al., 2011), material not compliance with specification (Formoso et al. 2002), poor site management (Formoso et al., 2002; Lu et al., 2011) and more others. The increasing production of construction waste has caused problems on illegal dumping. These illegal dumping has caused a risk to human health and environment (Faridah et al. 2004; Rahmat and Ibrahim, 2007). A study conducted in Johor indicated that 42% of 46 illegal dumping sites are of construction waste (Rahmat and Ibrahim, 2007). The increases of illegal dumping problems are due to the cost and location of the construction project. Peoples are not aware about environmental impact of construction industry. Most people assume that a construction project is only temporary activity that lasting for a few years but in reality this industry is one of the major causes of environmental degradation because it consumes large amounts of natural resources and produces a great deal of pollutants.

Sustainable Construction

A construction project is considered to be sustainable only when all the basic principles of sustainability are compatible with each other (Mateus and Bragança, 2011). Kibert (1994) during the First International Conference on Sustainable Construction held in Florida, USA, have defined sustainable construction as "creating a healthy built environment using resource-efficient, ecologically-based principles". Sustainable construction is still too often equated with "green building." However, sustainability principal is based not only on the pillar of environmental but also on economic and social pillars (Table 1). A valuable sustainable construction project requires extra work, extra expense, and extra costs. It requires decision makers to be more flexible and willing to modify their approaches to achieve sustainable construction.

Table 1: Principals of sustainable construction (adopted from Hussin et al. 2013)

Aspects	Descriptions
Economic	• Increasing profitability by making more efficient use of resources, including labour, materials, water and energy • Consider life-cycle costs • Internalize external costs • Consider alternative financing mechanisms • Develop appropriate economic instruments to promote sustainable consumption • Consider the economic impact on local structures
Environmental	• Preventing harmful and potential irreversible effects on the environment by careful use of natural resources, minimizing waste, protecting and where possible enhancing the environment • Increase material efficiency by reducing the material demand of non-renewable goods • Reduce the material intensity via substitution technologies • Enhance material recyclability • Reduce and control the use and dispersion of toxic materials • Reduce the energy required for transforming goods and supplying services • Support the instruments of international conventions and agreements • Maximize the sustainable use of biological and renewable resources • Consider the impact of planned projects on air, soil, water, flora, and fauna.
Social	• Responding to the needs of people at whatever stage of involvement in the construction process (from commissioning to demolition), providing high customer satisfaction and working closely with clients, suppliers, employees and local communities • Enhance a participatory approach by involving stakeholders • Promote public participation • Promote the development of appropriate institutional frameworks • Consider the influence on the existing social framework • Assess the impact on health and the quality of life.

Issues in Sustainable Construction

Many issues of sustainability are interrelated, and the interaction of a construction project with its surroundings has significant impacts for mankind (Hussin et al., 2013). Some of the issues include those of reducing the use of non-renewable materials and water, as well as the production of emissions, waste and pollutants (Table 2). Developing projects under the principals of sustainable construction is complex because the projects are frequently subject to problems that constrain their execution (Wang, 2014). Traditional construction focuses on cost, performance and quality objectives but sustainable construction also includes minimization of resource depletion, reducing of environmental degradation, and developing a healthy built environment to these criteria (Kibert, 1994). Vanegas et al. (1996) stated the shift to sustainability can be seen as a new paradigm where sustainable objectives are within the construction industry. It is considered in decision making at all stages of the life cycle of the project (as cited in Hussin et al., 2013). Figure 1 highlights the evolution and challenges of the sustainable construction concept in a global context.

Table 2: The issues sustainability facing by the construction industry (adapted from Constructing Excellence, 2008)

Issues	Descriptions
Energy, Pollution and Climate Change	• More than half of all resources consumed globally are used in construction, and 45% of energy generated across the world is used to heat, light and ventilate the buildings, with a further 5% arising from constructing those (Edwards, 2001)
Materials and waste	• The amount of construction materials wasted on the site is relatively high and equals 9% by weight of the purchased materials (Bossink and Brouwers, 1996)
Water	• Water supplies are a growing cause for concern for the construction sector, which has particularly high requirements especially in the manufacture of materials such as steel and concrete.
Skills	• Up-skilling employees, the supply chain and the local community can have a positive impact on the sustainability of a business and community, such as greater employment, job satisfaction and business productivity.
Corporate Responsibility	• The construction industry has been slow to respond to the Corporate Responsibility but increasing regulation in areas such as carbon emissions and waste are forcing companies to improve their processes and many clients are beginning to demand responsible approaches to design and construction.
Sustainable Communities	• Social aspects are often missed out of the construction industry's considerations of sustainability despite the important effect that they have on long-term value for money and the well-being of building occupants.
Sustainable Procurement	• The procurement of goods, services and buildings has traditionally been based on two overriding considerations: price and quality. However, the choices people make about what they buy and how they buy it can have a huge impact on all aspects of sustainable development.
Existing Stock	• The methods used in the construction phase of refurbishment, as well as their end-use, have impacts on their sustainability.

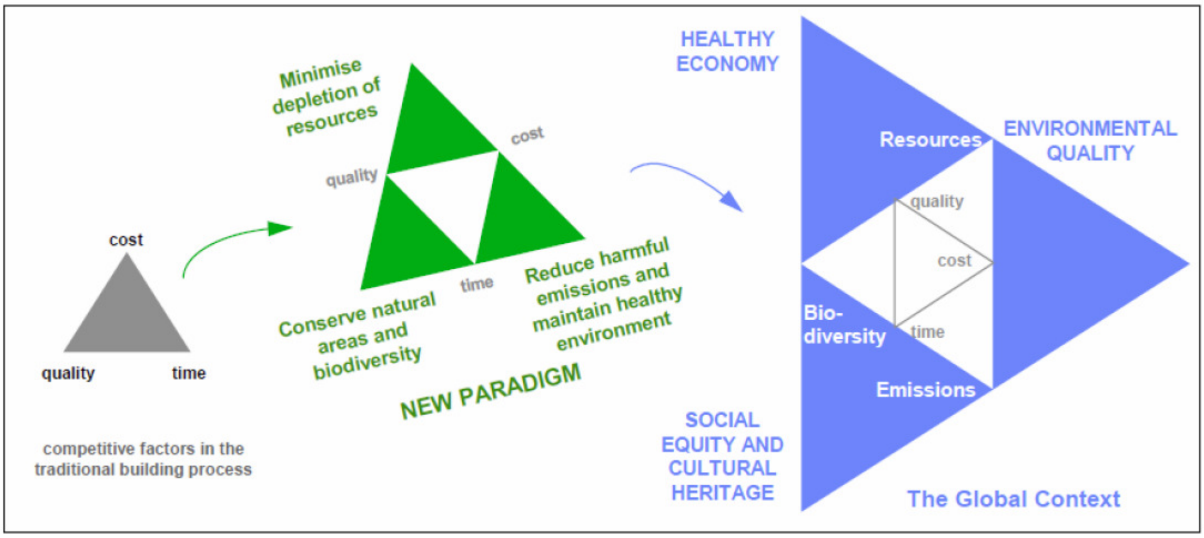

Figure 1: Issues of sustainable construction in a global context (Huovila and Koskela, 1998 as cited in Hussin et al. 2013)

According to the principles of sustainability, in Figure 2, sustainable construction projects maximize positive contributions to the well-being of individuals and simultaneously preserve the sound functioning of ecosystems and social systems. Since characteristics of products, processes, services, buildings or infrastructures are primarily defined through the process of design, it appears necessary to address all relevant sustainability issues right from the start of a project (Gagnon et al. 2012).

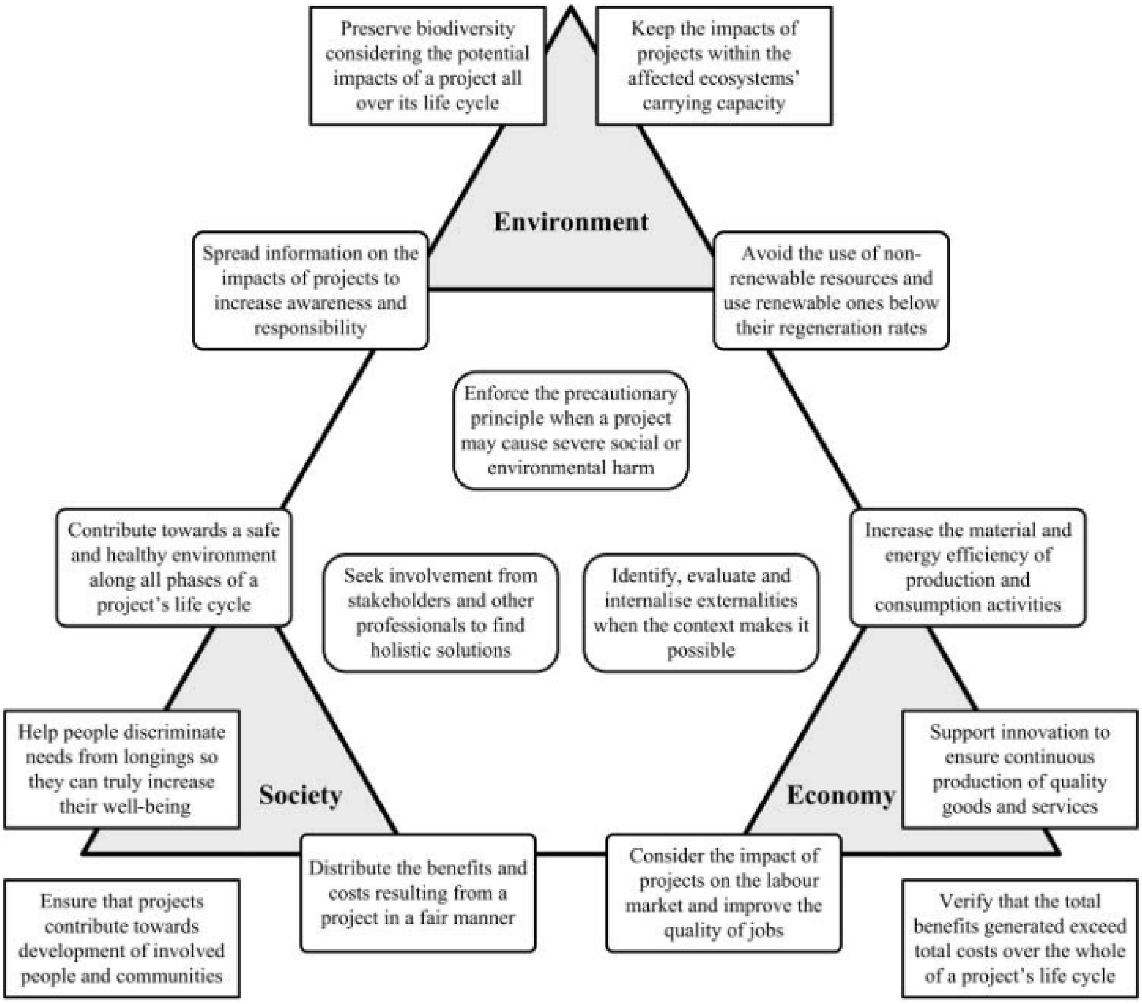

Figure 2: Sustainable construction- principles and issues (adapted from Gagnon et al. 2012).

Understanding Life Cycle Costing

Life Cycle Costing (LCC) technique works as the economic assessment of competing design proposals by including all significant costs of ownership over the life of a building, expressed in equivalent dollars which is specified by an analytical study and experience in estimating the total costs in yearly basis (Langston 2005; Kirkham, 2007). LCC is a tool for assessing the total cost performance of an asset over time including the acquisition, operating, maintenance and disposal cost (Barringer, 2003; Langdon, 2005). It is one of several methodologies that can be used to account and provide cost in a more comprehensive way by involving the systematic consideration of all relevant costs and revenues associated with acquisition and ownership of an asset or a project (Cole and Sterner, 2000).

The main objective in implementing LCC is to figure out and determine the best way to reduce building's ownership costs in order to achieve a financially viable investment (Highton, 2012). Che Mat (2002) describes that LCC approach is effective in the decision making process in four main ways. Firstly, it identifies the total cost undertaken in asset acquisition. Secondly, it facilitates an effective choice between alternative methods by taking into consideration various alternatives which display different capital and running costs. Subsequently, LCC is a management tool that details out all costs associated with capital, running and replacement costs of the building or components within that building. All of these can be summarized as the decision to invest should be made on the total LCC of an asset and not on the basis of initial capital cost alone, because the future is as important as those incurred in the capital acquisition. According Akasah and Rum (2011), life cycle costing adds to all the costs of different options over their life period and enables an evaluation on a common basis for the period of interest, thus enabling decisions to be made in the path full of cost implications.

Life Cycle Costing can be applied at each stage during the life-cycle of the projects (Ofori-Darko, 1997) in which different costs are incurred in between (Cole and Sterner, 2000), but LCC calculations are usually carried out in the design phase of projects where they are more functional since there is a great opportunity to explore and compare different options against each other (Sterner, 2000). Ashworth and Hogg (2000) found the usage of life cycle costing is the most effective during pre-construction phase in terms of overall cost consequences of construction; particularly at conceptual and preliminary design stage whereby changes are able to be made easily and the resistance to making such changes are less likely to occur. This was supported by Che Mat (2002) and Clift (2003), where they suggested the implementation of life cycle costing as early as possible to obtain the maximum effect. Hence, it is very crucial to ensure the decisions made at the design stage are precise because the decisions have deep impacts on the LCC of the building (Flanagan and Jewell, 2005; Ellingham and Fawcett, 2006; Ashworth, 2010; cited in Highton, 2012).

During the initial phase, clients and design team share information seeking to develop the building’s concept. At this stage that procurement method, project and sustainability procedures, building design life time, organizational structure, maintenance, project cost, and timescale are dealt with. Environmental impacts, energy, and life cycle costs related indicators were considered to be those which have a major influence on sustainability and are able to be assessed at conceptual design phase.

Research Methodology

The research method for this paper is mainly based on a literature review of sustainable construction projects and life cycle costing analysis. Although this paper places emphasis upon sustainable construction industry, the literature review, however will not only limited to the industry alone. For the life cycle costing part, the findings from surveys undertaken for academic research at University of Malaya on the construction practitioner’s perspectives about LCC factors that contribute to the overall construction projects’ value, was used as the benchmark in finding the correlation between life cycle costing practices and sustainable constructions. This research, in reviewing life cycle costing and sustainable construction, explores the conceptual linkages between the two topics and assesses how these can be used to achieve best value over the whole life of building projects.

Correlation between Life Cycle Costing and Sustainable Construction

As sustainable construction brings additional value to projects, life cycle costing practices can be used to ensure that these values are maximized. Sustainable construction is concerned with delivering better long-term value for the construction industry’s stakeholders including end users. Sustainable construction means balancing value, risk and waste within project parameters by taking consideration the factors such as land use, materials types, and construction techniques, regeneration and community needs. When considered in terms of sustainable development, construction projects may require a shift aware from tradition standpoints which are from short term to long term; from shareholders to stakeholders; from product to service; from local to global; and from cost to value (Hayles, 2004).

Life cycle costing approaches can be used as a vehicle for achieving sustainable construction but must be applied during the early stages of a project (Table 3). It is a reliable means for creating visions of new direction and obtaining objectives towards a base of desired output including formulating policy. The significance of life cycle analysis can distinguishes needs from wants, thus the fundamental objectives sustainable construction can be collaboratively shaped and achieved successfully. An important principle in accomplishing sustainable construction is the enhancement of living economic standards whilst increasing the overall quality of life for present and future generations.

Life cycle costing is effective in many areas of the construction industry and can be used at different stages in the life of a building project. Applied with flexibility and creativity, life cycle costing is relatively unrestricted in its ability to indicate areas of potential saving that are not readily apparent. Often, life cycle costing can generate significant funds in initial installation and operating costs. It is also one of the best techniques for producing best results in achieving value for money for client (Fong, 1996). Table 3 shows the findings from surveys on the significant of LCC factors on the construction project's value.

Table 3: The significant of LCC factors on construction project's value

LCC Factors	RII	Rank
Application of LCC at **design stage**	0.766	1
Teamwork in LCC preparation at design stage.	0.740	2
Determination of cost implication for design decision when preparing LCC.	0.728	3
Carry out LCC analysis along with the Value Management study.	0.728	3
Indication of design deficiencies while preparing LCC at design stage.	0.687	5
Involvement of stakeholders in preparing LCC at design stage.	0.653	6
Investment of LCC tools.	0.619	7

Note: RII (Relative Importance Index) was done based on the result obtained from Pearson correlations analysis that was done to see the relationship between the LCC factors.

From the Table 3, it can be seen that application of LCC at design stage was chosen as the most significant of LCC factors on construction project's value with the relative importance index of 0.766. This shows that most of the respondents have chosen this factor as the most influential factors towards the construction project value. It was followed by the teamwork factor in preparation of LCC at design stage (RII = 0.740). Teamwork refers to the relationship between each party in the design team and the client. Every member of the design team needs to work together in generating ideas as well as contributing their experience and knowledge in preparing LCC at design stage. Poor human relation, misunderstanding and friction often lead to occurrence of unnecessary cost. Furthermore, Che Mat (2002) stated that it is very important to determine the cost implication for design decision when preparing LCC to ensure that the best alternative is selected for a project.

The literature reviews of sustainable construction (Table 4) has described the common efforts of investors, construction leaders, service representatives, industry suppliers, communities and other stakeholders directed to develop new building considering the environmental, energy, socio-economic and cultural conditions needed to bring integral solutions to society (Shelbourne et al., 2006; Ortiz et al., 2009; Winch, 2010). In practice, it is based on the application of sustainable guidelines for construction processes, with the final goal of improving quality of life and developing the potential of mankind (Ortiz et al., 2009; Winch, 2010). Sustainability is a crucial issue to consider in design stage, not only due to the environmental concerns but also because of economic and social issues, since they promote architectural quality and have economic advantages. If a project is well planned and sustainable criteria are included in its early approach, the possibility to minimize negative impacts is higher and the cost of criteria implementation is significantly reduced, as illustrated in Figure 3.

Improvement of the building's sustainability performance must begin in the design stage, as the potential of optimization in project early phases is higher and the impacts of changes of the building and the construction costs are lower. The integration of life cycle costing might facilitate collaboration between organizations throughout project design and construction, especially life cycle is considered as an influential technique in the construction industry. The sustainable decision is that which uses professional judgment and vision to give the mankind the maximum value for every the resources invested.

Table 4: Factors recognized as critical to sustainable construction projects (adapted from Rafindadi et al., 2014)

Factors and descriptions	Project Phases	References
Team members having previous experience with one other, efficient information exchange, trust and collaboration, team members commitment to sustainability	Planning	FIDIC (2004); Lapinski et al. (2006); Enache-Pommer and Horman (2009); Chinowsky etal.(2008); Swarup et al. (2011);
Owner commitment to sustainability, owners' choice of project delivery systems , project team procurement, contract conditions	All (Esp. in Planning)	Gould (2005); Ling et al. (2004); Korkmaz et al. (2010);
Early involvement of key project participants	Planning	Riley and Horman (2005)
Design collaboration, Integrated design	Design	Riley et al. (2004); Korkmaz et al. (2010); Swarup et al. (2011); Kovacic (2012);
Emphasize on superior planning, design, and construction processes	All	Lapinski et al. (2006)
Hold a design meeting at the beginning of design	Design	Kibert (2004), FIDIC (2004)
Apply life-cycle assessment analysis and energy modeling	Design	NIBS (2006)
Emphasize in bid documents the contractors' roles in sustainable project goals and documentation	Construction Procurement	USGBC Research Committee (2008)
Require sustainability training for on-site workers	Construction	Deane (2005)
Involve building operators in the commissioning process	Construction, Operation	PGGGC (1999)

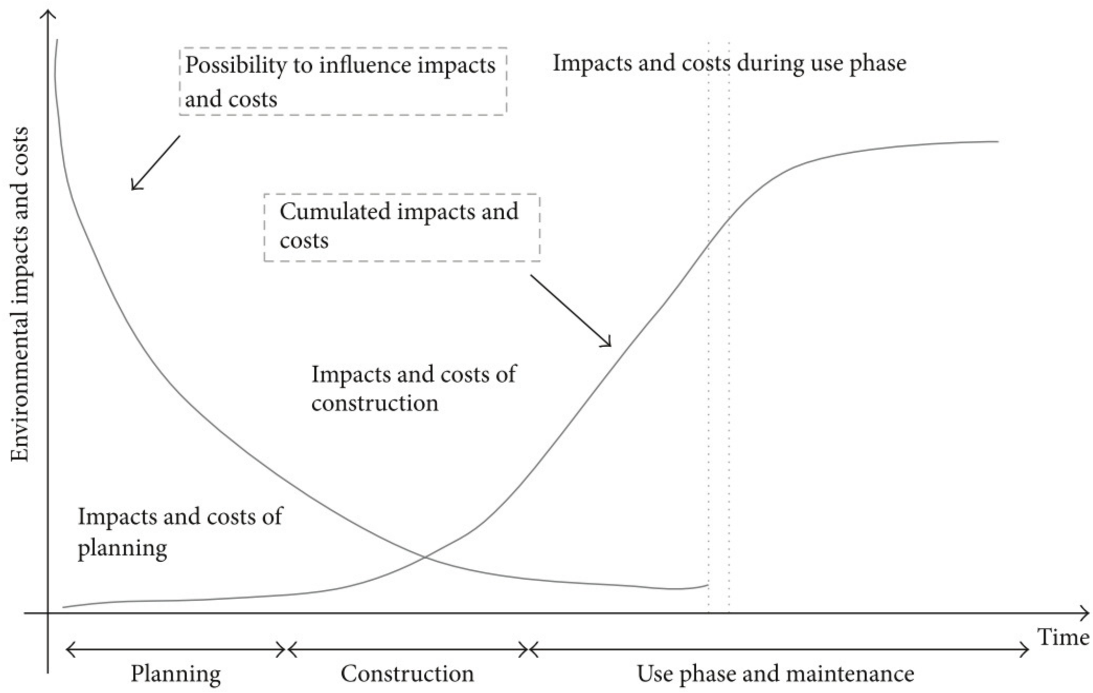

Figure 3: The correlation of sustainability decision with life cycle impact and costing (Gomes and Gomes, 2005).

Conclusion

Life cycle cost (LCC) principles and tools can be used to achieve and improve sustainability development, especially in construction projects. The function analysis phase can be exploited to break down the difficult process into its functional units. There could be significant benefits of using life cycle costing as a vehicle for promoting and achieving sustainable construction. Additionally, the experience and skills of life cycle analysis practitioners could be used to accelerate the understanding and implementing of sustainable construction. During the process of developing a project, life cycle costing principles and techniques aim to provide best value from a whole life perspective. This study, in reviewing life cycle costing and sustainable construction, have explored the conceptual linkages between the two elements and assessed how these can be used to achieve best value over the whole life of building projects. The relationship between the elements can be seen as both emphasize the same factors in order to achieve sustainability, which are the needs of execution during the early stage (pre-construction and design phase) and the importance of involvement and teamwork from relevant personnel's in construction industry. This study opens a way for future studies to explore further on how LCC can statistically assist the sustainable construction, especially to deal with crucial issues of in sustainability. This will be beneficial to support the decision making towards greater environmental, social and economic performance of construction industry.

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