THE CHALLENGES OF LIFE CYCLE COSTING APPLICATION OF INTELLIGENT BUILDING IN MALAYSIA CONSTRUCTION INDUSTRY

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ABSTRACT

The economic growth in Malaysia is contributed mainly by the construction industry. The advance of the Information and Communication Technology developed the growth of the intelligent building and sustainable development. However, many construction projects are not seriously care about the cost and values of the building but only the appearance and smart looking buildings. It is important to show the building owner to minimize the production cost and increase the profit while at the same time provides the comfort, safer and effective buildings. For this purpose, this paper describes the life cycle cost as the main economic method used in the construction industry because it can identify and evaluate the cost saving for the building. The aim of this paper is to determine the challenges of the life cycle costing in the construction industry. This paper also identifies the criteria of the intelligent building and the integration of the life cycle cost in the intelligent building. The main sources used in the literature research are taken from the books, journals, articles, and internet based. The results of this research will give the useful reference materials to the researcher and also for the construction industry in Malaysia.

Keywords: *construction industry, intelligent building, life cycle costing*

INTRODUCTION

Construction industry is becoming crucial and acts as the stimulus to the development of other industries in Malaysia. This is to achieve the aims of the government effort and vision for the sustainable development by the year 2020 (Noor Azizah & Zainal Abidin, 2012). In the past two decades, various advanced building technologies have been developed and improved to achieve the building performance that suits with the human needs, environmental and economic values (Chen, Clements-Croome, Hong, Li, & Xu, 2006; J. Wong, Li, & Lai, 2008). The development of buildings that provides safer, comfort and energy efficient environment at a minimal operating and occupancy costs has been the expectations of building owners and occupiers (Cho & Fellows, 2000; J. Wong et al., 2008).

Most researchers agreed that intelligent building is not intelligence by them but they can equip the occupants with more intelligence and enable them to work more efficiently. Usually, intelligent building is known as the systems that assist developers/owners and occupants in minimizing the operating and occupancy costs with more safer, flexible and comfortable environments (Albert T.P., Alvin C.W., & K.C., 1999; Cho & Fellows, 2000; J. Wong & Li, 2008). Being intelligent, building monitoring systems are able to control various systems such as lighting system, air temperature, security, fire detection and others to manage them in the most energy efficient way (Nikolaou, Kolokotsa, & Stavrakakis, 2004; Preiser & Schramm, 2002). Thus, it provides good opportunity in evaluating the building performance to stay advanced in building industry.

However, the developers/owners need to overcome the challenges of the intelligent building because they failed in the building design stage due to a lack of a systems approach in the design process (Derek & Clements-Croome, 1997). The intelligent building projects will affect the construction processes and financial consequences need to be correctly evaluated such as tax effects and time value of money (CABA, 2002). The integration of life cycle costing analysis gives the additional aspect and credibility of the system and technologies in the whole process of the identification, selection, estimation and response for the implementation in the intelligent building (CABA, 2004; Keel, 2003; Yang & Peng, 2001a).

Levander et al (2007) and Mohamed et al (2007) studied that life cycle cost is the main tool for the design and construction teams in the decision making at the early stage design. However, Buys et al (2011) argued they are not often implementing the life cycle cost in the construction projects due to “not worth the effort”. For that case, the life cycle cost needs time and effort to create the clear output motive to use the techniques for it to be a worthwhile effort for the owners (Kishk et al., 2003; Noor Azizah & Zainal Abidin, 2012). Rum and Akasah (2012) proposed that the running cost is expected to be 40% of the capital cost or more than that. Researchers suggested only 10% of the total cost is actually required to complete the project while the rest 90% is associated with the maintenance and running cost.

Life cycle cost method include the purchase, installation cost, capital investment cost, future cost (operating cost, maintenance cost, energy cost, replacement cost, resale, financing cost, salvage or disposal cost) over the life time of the product or project (Fuller, 2005). The initial construction cost will create a big impact to the maintenance and operating cost. So, the greater construction cost might bring the future maintenance and operation cost to reduce and as a result the life cycle cost of the buildings will reduce (Buys, Bendewald, & Tupper, 2011; Kishk et al., 2003; Levander, Schade, & Stehn, 2007).

There are many problems and barriers in the implementation of life cycle cost. Life cycle cost is not broad enough in the construction industry (Flanagan & Jewell, 2005). Any method that attempts to account for future conditions is essentially risky, as the future is unknown. The concept and theory of life cycle cost models are available and well developed for calculations; however the practice in the construction industry is still inadequate (Raymond J. Cole & Sterner, 2000). Main reason leads to the problems in implementing life cycle cost is lack of awareness and understanding among the practitioner in construction industry. In addition, the government is unaware to the application of life cycle costing in the non government construction project. They should play an important active role in developing the construction in more precise and accurate design cost, decision making and planning procedures.

LIFE CYCLE COSTING

Life Cycle Cost Definitions

The economic evaluation which is known as life cycle cost has become the framework for measurement by the researchers in the past two decades (Flanagan & Jewell, 2005; John

R Kelly, 2009; Kishk et al., 2003). Owner, occupants and organization have common interest in improving the lifetime quality and cost effectiveness of buildings. There are several terms used such as "cost in use", "life cycle cost", "whole life costing" and "whole life appraisal". According to Flanagan and Jewell (2005), the terminology has changed over the years from "cost in use" to "life cycle costing" and further to "whole life appraisal". ISO Standard 15686 (2005) makes a difference between the "whole life costing" and "life cycle cost" which is the whole life costing covering wide range of analysis that include external cost and future cost of a building (Korytarova & Hromadka, 2010). Although the terms used are interchangeably, the life cycle cost is used equivalent to whole life costing/appraisal and the term life cycle cost is better known term used in the practice today (Levander et al., 2007; Mohd Fairullazi & Khairuddin Abdul, 2011).

Flanagan & Jewell (2005) and Ayob & Rashid (2011) stated that the older resources might refer the term as cost in use, changing over the year to the life cycle cost and further to whole life costing / appraisal for better represent concept. Different terms are actually interchangeably among them. Table 1 shows the definitions of life cycle cost by the organizations and researchers.

Table 1: The definitions of the life cycle cost according to the organization and researchers

Organizations / Researchers	Definitions of Life Cycle Cost (LCC)
Section 707 of Executive Order 13123	Life cycle cost is the total of present values of capital costs, investment costs, energy costs, installation costs, operation cost, maintenance costs, and disposal costs over the life time of product or project.
Australian government document (Treasury, 2000)	Life cycle cost is the sum of cost during its life time with design, planning, support and acquisition costs and any other costs directly to having the project.
Royal Institution of Chartered Surveyors (2001)	Life cycle cost of an asset over its operating life which is the initial capital cost, occupation costs, operating costs, maintenance costs and the benefit of the refurbishment or disposal of the asset at the end of its life.
(El-Haram, Marenjak, & Horner, 2002)	Life cycle cost is a technique for identifying and evaluating all the costs in money terms direct and indirect including designing, building and facility management of a building throughout its service life with the disposal or refurbishment cost.
(Sirin, 2007)	Life cycle cost is the method of identifying and documenting the initial cost and external future cost of the development project during the lifetime of the building.

Most of the researchers have the same meaning and terms in expressing the definition of the life cycle cost. According to the Australian government document, the terms of "cost in use", "life cycle cost", "whole life costing" and "whole life appraisal" is the terms that used interchangeably which brings the same meaning but in different period of time. It is the economic evaluation in the construction project from the beginning to the end stages using the construction cost, operating, maintenance cost, wasting cost and other cost to achieve the aims of minimization life cycle cost. The best investment program will be chosen to improve the quality of the project and gain minimum cost target and to reach the most social and most economic in the construction project (Li, Zhu, & Zhu, 2012).

Economic Evaluation Method

Life cycle cost is an economic method to evaluate the life cycle cost effectiveness in which all costs form arising, operating, maintaining and disposing of a project in order to determine the best decision. There are many types of method that used in the calculations of life cycle cost depend on the data available. Some of the economic evaluation methods are shown in Table 2. Most of the researchers are agreed that the net present value (NPV) method is the mostly common method used in the analysis of life cycle cost.

Table 1 : The economic evaluation methods

Economic Evaluation Methods	Descriptions	Advantages	Disadvantages
Simple Payback	• The number of years required to return the initial investment cost (1,2,3) • The shortest pay-back time is the most profitable investment (1) • Used in rough estimation or only as the screening tools (1,2)	• Quick and easy calculation • Easy to interpret	• Does not use discounted cash flows thus, ignores the time value of money (2) • Does not take into inflation or interest (1)
Net Present Value (NPV)	• Traditional method specific to the net present value of the investment from the present value of the benefit project (9) • Present value of cash flows minus the present value of cost (3) • If the result of NPV is positive, so it is useful to invest (4,5,6) • Most commonly techniques used in the construction industry (1,7,8,9)	• Use the time value of money into account (1) • Uses all available data (1,7)	• Not suitable if comparing the alternatives which have different life lengths (1) • Difficult to interpret (1,7)
Internal Rate of Return (IRR)	• Discount rate that makes the estimated NPV of an investment equal to zero • Compare the profitability of investment (4) • To determine the average rate return to the condition that the	• Results are presented in percent form which is easy to interpret (1)	• Need trial and error procedure (1)

	values equal to zero at the initial point of time (5,10) • Highest IRR is the best option (5,10)		

Legends:

1. (Flanagan & Jewell, 2005)
2. (Fuller, 2005)
3. (Davis Langdon, 2005)
4. (Buys et al., 2011)
5. (Levander et al., 2007)
6. (Noor & Eves, 2010)
7. (Kishk et al., 2003)
8. (Noor Azizah & Zainal Abidin, 2012)
9. (J. K. W. Wong, Li, & Wang, 2005)
10. (ISO/DIS, 2004)

Life Cycle Cost Equations

The American Society for Testing Materials create the formula to differentiate between the energy and other running cost which is functional in take on different discount rates for different cost items. Researchers revealed that most of the mathematical life cycle cost models use the same basic equation in the calculations (See Figure 1). The sum of present values of each type of cost and minus the present values of any positive cash flows such as resale value will result to the total of life cycle (Fuller, 2005).

NPV = C + R – S + A + M + E

C : Investment / Capital cost

R : Replacement costs

S : The resale value at the end of study period

A : Annually recurring operating, maintenance and repair costs (except energy cost)

M : Non-annually recurring operating, maintenance and repair costs (except energy cost)

Figure 1: Mathematical equation for net present value (NPV) method (Kishk et al., 2003; Levander et al., 2007; Noor Azizah & Zainal Abidin, 2012)

Cost Variables

Life cycle cost usually needs many cost inputs for calculating the cost for different stages of a project life cycle. The cost variables are divided into groups (Davis Langdon, 2005; ISO/DIS, 2004).

I. Acquisition Cost - Site cost, design cost, temporary cost, planning cost, construction, earthworks, commissioning cost,In-house administration

II. Maintenance, Operation, and Management Cost

- Rates, insurance, energy cost, cleaning, water and sewage costs, facilities management, security, replacement, refurbishment, revenue from ownership, annual regulatory costs, regulatory maintenance, cost of disposal, demolition

III. Other cost variables - discount rate, inflation, taxes, subsidies, utility costs including energy cost.

Application of Life Cycle Cost in Construction Industry

Life cycle cost is able to assist in the effective management completed buildings and projects also being able to select the choice between alternatives. Rum and Akasah (2012) propose the integrated life cycle design as the method that integrates the design, construction, maintenance, management, and operation of buildings into the comprehensive life time engineering. The life cycle cost can be implementing in various areas such as in the intelligent building, sustainable building, facility management, value management and others.

A. Life Cycle Cost in the Sustainable Building

Sustainable building is known as a building that is planned, constructed and effectively managed by the occupants where the service life of building preserves the environment, ecological performance requirement, able to meet the capabilities and needs of future generation (Siti Hamisah, Fathoni, & Jamaludin, 2005). The advantages of a sustainable building are (Mohd Fairullazi & Khairuddin Abdul, 2011):

- Increase energy saving
- Usage of recycled materials
- Reduces the emission of toxic substances

Even though the progress of the sustainable building is widely explored and it's essential to balance total economic cost, ecological performance and social life in Malaysia, there is no standard technique has been formulated to calculate the life cycle cost of a sustainable building.

B. Life Cycle Cost in the Value Management

Value Management analysis used the life cycle cost as the common technique to the lowest cost among the options for the purpose of eliminating the unnecessary cost. The other performance criteria to meet the client's requirements also are evaluated through value management process such as:

- Increasing the cost savings
- Quality
- Reliability
- Safety
- Fitness for purpose
- Sustainability
- Technology

- Maintainability
- Aesthetics

C. Life Cycle Cost in the Facility Management

The application of life cycle cost in the facility management is still new in Malaysia. According to the Tenth Malaysia Plan (2011-2015), the government encourages life cycle cost technique to become as a part of development culture in maintaining and preserving the asset in holistic manner and efficient (Mohd Fairullazi & Khairuddin Abdul, 2011).

D. Life Cycle Cost in the Public Private Partnership program

Public Private Partnership (PPP) is a new procurement approach in Malaysia that refers to a working relationship between government and private organization. The aim of this program is to achieve the common goal in the public infrastructure and services (Mohd Fairullazi & Khairuddin Abdul, 2011). PPP program concentrates on the life cycle cost, private sector innovation, service approach, and management skills for the long-term relationship between public and private division to gain value of money. However, this program is still new in Malaysia and the implementation of life cycle cost is still limited.

INTELLIGENT BUILDING

History of Intelligent Building

In the early 1980s, the term intelligent building was originated in the United States to describe the buildings (Cho & Fellows, 2000; Derek & Clements-Croome, 1997; J. K. W. Wong et al., 2005). The development of information technology creates the concept of intelligent building which becomes the sophisticated demand for comfortable environment and occupants able to comfort their own environment. According to Wong, Li & Wang (2005), early phase development of intelligent building did not suggest user interaction among the occupants but only focused on the technology aspect. Figure 2 shows the three stages in the growth of intelligent building (DEGW, 1992).

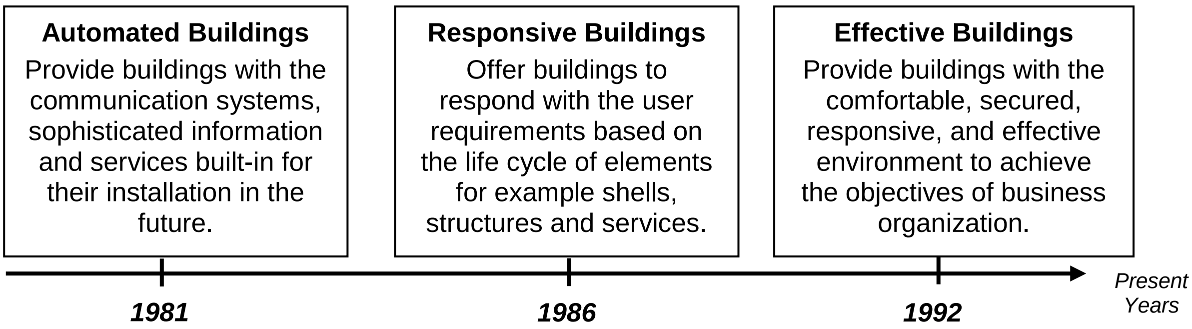

Figure 2: The stages growth of the Intelligent Buildings (DEGW, 1992)

Intelligent Building Definitions

Every country around the world has their perceptions and concept of intelligent building. However, their concepts of intelligent buildings are mainly on ensuring the building is suits with the occupants to work and life in securely, healthy, comfortably, and efficiently environment (CABA, 2002; Ionnidis, 2011).

Table 3: The definitions of Intelligent Building based on the organizations/country

Country / Organizations	Definitions	References / Sources
Intelligent Building Institute (IBI) Washington	An intelligent building is an integrated various system including structures, services, and management and interrelationship between the system to create a productive and cost-effective environment.	(Derek & Clements-Croome, 1997) (CABA, 2002)
European Intelligent Building Group	Intelligent building gives the opportunity to meet the organizations objective business and maximizes the productivity of its occupants whilst get lower life cycle cost.	(Arkin & Paciuk, 1997) (Smith, 1998)
Continental Automated Buildings Association (CABA) Canada	Integrated technological building systems controls and communication to develop building that fulfills flexible, comfort, productive and safe environment for the owners and occupiers.	(CABA, 2002) (Ionnidis, 2011)
Japan	Intelligent building monitors the effective working environment, advanced technologies for future changes in the need of the working environment to improve the building's capability organizational.	Cited in Fujie and Mikami, (1991)
Public Works Department of Singapore	Intelligent building must achieve three requirements of building condition which are the building should have automatic control systems to monitor all the facilities, good networking services to enable data flow between floors and buildings give efficient communication facilities.	(Albert T.P. et al., 1999)
Shanghai, China	Intelligent building is known as "3A" or "5A" which means the building provided three automatic functions such as office automation, building management automation and communication automation. The others "A" are fire automation system and maintenance automation system.	(Albert T.P. et al., 1999)

Table 3 above shows the different concepts and definitions of intelligent buildings based on the organizations from United States (US), United Kingdom (UK), Canada, Japan, China and Singapore. As can be seen, European more focused on the user's requirements compare to the technologies of the intelligent building. In the UK and Canada, they have similar definitions of Intelligent Building which are focus strongly on the technologies and systems for the user's efficient and comfort environment. Most researchers stated that Asian emphasis for the Intelligent Building to have the automation or advanced technologies for the facilities in the building. Ionnidis (2011) proposed that intelligent building system does not just offers the security, comfort and effective but also cost saving benefits.

Intelligent Building Systems

Many researchers proposed the major and minor systems that should have in the intelligent building which be used for improving and optimizing the environment of building. From the Table 4, researchers stated that heating, ventilation and air conditioning system, lighting system, communication system, security, life safety / fire safety, vertical transportation and building automation system are the most important systems in the intelligent building. The others systems are the minor or the supporting elements for the main system in the building.

Table 4: Researchers proposed the systems in the intelligent building

Researchers & Intelligent Building Systems	**(Arkin & Paciuk , 1997)**	**(Cho & Fellows , 2000)**	**(CABA , 2002)**	**(Nikolaou et al., 2004)**	**(J. K. W. Wong et al., 2005)**	**(J. Wong et al., 2008)**	**(Ionnidis , 2011)**
Heating, Ventilation & Air Conditioning (HVAC) system	√	√	√	√	√	√	√
- Thermal zoning & control		√					
- Fresh air intake		√					
- Back up air conditioning		√					
Lighting system	√	√	√	√	√	√	√
Voice and Data Communication system		√	√		√	√	
Telecommunication	√			√			
Security	√	√	√	√	√		√
Life Safety System			√	√			
Fire detection / Fire alarms	√	√			√	√	√
Elevators / Escalators / Vertical transportation system	√	√	√	√	√	√	
Energy Efficiency			√	√	√		
- Energy management system		√				√	

- Energy conservation measures		√					
Building Condition Monitoring		√	√			√	
Building Automation System (BAS)		√		√	√		
Integrated building management system		√				√	
Space management system		√					
Computerized maintenance management system		√				√	
Internal Layout System		√				√	
Access Control		√				√	√
- User's access to environmental control		√					
Sanitary / Plumbing	√						
Data processing	√						
Power	√						
- Small power		√					
- Backup power		√					
Occupancy	√						
Public health, hygiene & cleaning		√					
Refuse disposal		√					
Combinations of various systems			√				√

Lifespan of Intelligent Building

Chen et al (2006) said that the lifespan of buildings is the series of interlocking methods, begins with the initial architectural and structural design, then to the construction and afterward the control, monitor and maintenance of the buildings. Table 5 shows the comparison of the proposed lifespan of the buildings according to the researchers. CABA (2002) suggested that buildings usually have a lifespan about 25 years or two/three technology cycles however, Yang & Peng (2001) divided the lifespan of building into categories/systems with more detailed.

Table 5: The lifespan of the buildings

Categories	**(Yang & Peng, 2001b) Years**	**(CABA, 2002) Years**
Structure	100	25-100
Skin (exterior)	50	
Mechanical System	25	
Electrical system	10	
Interior partition	5	
Information Technology	1-3	

Life Cycle Costing In Intelligent Building

Life cycle costs and benefits rely on the design of the building. Different designs will imply different values of building. If we compare a conventional building to an intelligent building, construct on the same site, we should assume different income streams, as well as expenditures. The intelligent building is said financially feasible if it gives greater net present value than the conventional building (CABA, 2004; Ionnidis, 2011). It gives benefits to the intelligent building which will receive higher rent. The construction may be higher in cost but the recurrent costs may be lowered and intelligent building can have long term usage. Cost data, capital and recurrent for both conventional and intelligent buildings can be improved from the data bases information of different countries but the method is universal (Albert T.P. et al., 1999; CABA, 2004).

Intelligent building offers an immediate return on investment (ROI) to the projects that are owner occupied such as the corporate, government, and organizations in terms of bigger employee productivity and lower operating expenses. According to Menelaos (2012), the implementation of advanced energy efficient facilities and services is only the basic for obtain the excellent high performance operation.

The life cycle cost is important for the evaluation of intelligent building technologies investment. Usually, the life cycle cost divide into two key functions. First, it is used in evaluation of options in various aspects. It applies in examining the building performance with various initial investment cost, different operating and maintenance and repair costs. Second, it can be used as an asset management system in product life cycle. This method is widely implemented in many aspects of construction and building project (J. K. W. Wong et al., 2005). The other researchers such as, Yang and Peng (2001) used the life cycle cost to evaluate many design alternatives. Their approach starts with the selection of design alternatives and then identifies the capital cost and cost budget for each alternative.

In addition, Keel (2003) practically used the life cycle cost analysis to compare and evaluate the total investment life cycle costs of intelligent building at different stage of integration. The NPV method was used to measure the life cycle cost for each models. Results suggested that the whole integrated intelligent building had the lowest life cycle cost compared with non-integrated and partially integrated intelligent buildings (Keel, 2003).

RESEARCH AIM

The aim of this paper is to understand the challenges of Life Cycle Cost (LCC) application for the intelligent building in construction industry in Malaysia. From this research, the performance indicators of the intelligent building will also be identified. The importance of the economic values in the intelligent building is also highlighted.

SCOPE OF STUDY

The research is focus in determining the life cycle cost of the intelligent building. The scope of this study is specifically to the office building in the area of Kuala Lumpur, Malaysia. The results will be compared between two case studies which are the conventional and intelligent building. Office buildings are suitable for the intelligent systems in order to produce excellent LCC.

RESEARCH METHODOLOGY

Figure 3 shows the flowchart of the research methodology. The method that be used for this research was the qualitative method. There are surveys and interviews with the persons who are expert and related to develop the life cycle costing for the intelligent building projects. The interviews were carried out together with the site visit to obtain data information related to challenges of life cycle cost implementation in the intelligent building.

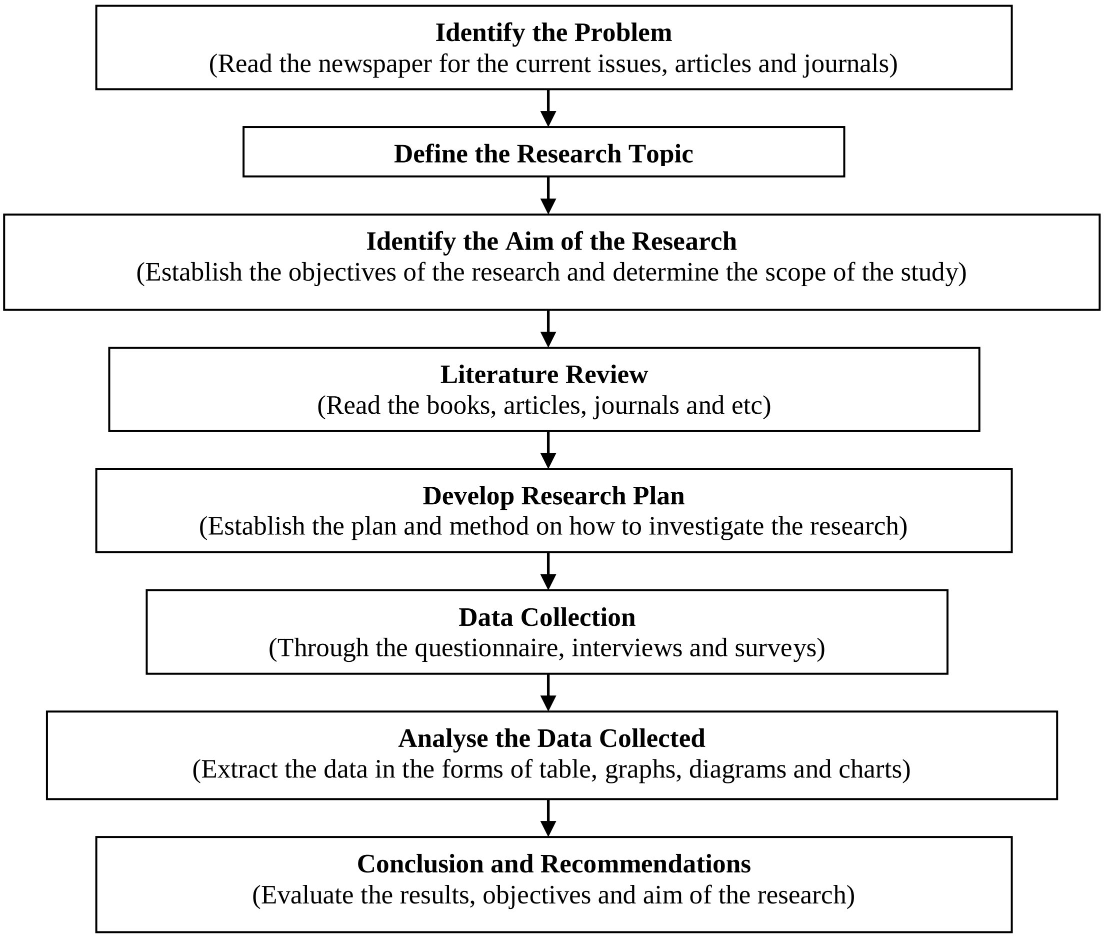

Figure 3: Research Methodology Flow chart

RESULTS / OUTCOMES

According to the study, it was found that most of the building owners and design team, lack of awareness in implementing the life cycle cost in the construction project. This is due to some problems which are lack of guidelines in understanding how the life cycle cost operate and lack of incentives from the government and institution.

The intelligent building will be resulted in lower life cycle cost compared to the conventional building. An effective energy management system provides lowest cost energy and helps user productivity and comfort levels (CABA, 2002). Arja et-al (2009) proposed that the analysis in the life cycle cost should be widen and implemented in various type of building to gain more reliable outcomes and different LCC evaluation method to contribute to other building facilities such as building design, commissioning, costing, decision making, planning and management process.

DISCUSSION

From the literature review, although the life cycle cost have been explained in detailed and widely known in the construction industry, there is still problems and challenges in application for construction projects. Table 8.0 shows the differences and similarity of the challenges in the application of life cycle costing in other countries and Malaysia.

Table 6: The challenges of the application of life cycle costing in Malaysia and other countries

<table>
<tr><th colspan="2">The Challenges of Life Cycle Costing</th></tr>
<tr><th>Other countries</th><th>Malaysia</th></tr>
<tr><td colspan="2">Lack of awareness of the application life cycle cost among the building owners and design teams in construction industry. (1,2,3)</td></tr>
<tr><td colspan="2">Lack of understanding of life cycle cost concepts and principles among the quantity surveyors and clients. (4,6,7)</td></tr>
<tr><td colspan="2">Lack of incentives from government in their management policy or strategy related to the life cycle cost. (1,3)</td></tr>
<tr><td colspan="2">Poor demand from the construction clients in the construction project. (4,6)</td></tr>
<tr><td>Lack of framework for collecting and storing data. (5)</td><td>Reluctance to commit to a change in their management policy or strategy related to the life cycle cost. (3,7)</td></tr>
<tr><td>Difficult to determine, examine and respond to the changing cost during the whole process of construction project including the maintenance and till the end process. (8)</td><td>Focus on the theory only but lack of involvement to the cost data inputs and outputs in the life cycle cost. (6)</td></tr>
</table>

Legends:

1. (Flanagan & Jewell, 2005)
2. (Raymond J. Cole & Sterner, 2000)
3. (Noor Azizah & Zainal Abidin, 2012)
4. (Chiurugwi, Udeaja, Hogg, & Nel, 2010)
5. (Kishk et al., 2003)
6. (Mohd Fairullazi & Khairuddin Abdul, 2011)
7. (Mohamed, Karim, Nor, & Kho, 2007)
8. (Munro, 2008)

Most of the building owners and consultants in the Malaysian construction industry are unaware on the life cycle cost concept and practice. According to Noor and Eves (2010), the advance of life cycle cost in Malaysia development is still at the beginning phase compared to the developed countries for example Australia, Singapore and United Kingdom.

In general, lack of understanding of LCC among the practitioner in construction industry lead to the poor perception of LCC benefits. According to the Chiurugwi et al (2010), lack of the usage of LCC reflects to poor demand from the construction clients because no one promotes the LCC to them.

There is no fixed or standard framework and guideline used to collect and compile all the important cost data for example initial capital cost, maintenance cost, operation cost, disposal cost and wastage cost. The changing cost in the operation and maintenance during the process of construction are not easy to identify and evaluate. This gives the challenges and problems for the design teams in implementing the life cycle cost in their projects.

In Malaysia, there is no specific research has been carried out to identify the flowchart of costing in the life cycle cost (Mohd Fairullazi & Khairuddin Abdul, 2011). The life cycle cost mostly attracts the academicians to study the theory and concept but not so much attract by the design teams to apply it in the construction projects. Government and related institution not give full support and encouragement to the designers and building owners in construction industry to apply the life cycle cost in their construction project. They should take into consideration the importance and benefits from the usage of life cycle cost in the projects.

According to the Table 7, many researchers agreed that the economic indicators become one of the most important indicators to evaluate the intelligent building. It is important to determine the cost and budgets, whole life value, and investment for the building project. The others important indicators stated among the researchers are the environmental indicators, responsiveness and suitability.

Table 7: The proposed building performance indicators and main issues by the researchers

Building Performance Indicators & Key Issues	**(Cho & Fellows, 2000)**	**(Yang & Peng, 2001b)**	**(Liao & Sutherland, 2004)**	**(Alwaer & Clements-Croome, 2010)**
Environmental Indicators	√	√	√	√
- Indoor air quality	√	√	√	
- Thermal comfort / Hygiene	√	√	√	√
- Lighting	√	√		
- Acoustics	√			
- Materials used, durability, waste		√		√
- Productivity			√	
- Energy and natural resources			√	√
- Transport and accessibility			√	√
- Land use and site selection			√	√
Economic Indicators	√	√	√	√
- Investment		√	√	
- Resources		√	√	√
- Cost and budgets		√	√	√
- Building manageability		√		√
- Whole life value	√	√		√
- Flexibility and adaptability				√
- Marketability	√			
- Energy consumption	√		√	
- Energy conservation measures	√		√	
Technological Indicators		√		√
- Intelligence		√		√
- Controllability		√		√

- Communications and mobility		√		√
Socio-cultural Indicators			√	√
- Functionality				√
- Architectural considerations				√
- Indoor environmental quality				√
- Innovation and design process				√
- Building management system			√	
- Maintenance			√	
- Facility management			√	
- Reporting system			√	
Business Performance	√			
- Productivity	√			
- Chum rate	√			
- Application of IT	√			
Suitability	√	√	√	
- Readiness for change	√	√		
- Special use			√	
- Flexibility	√	√	√	
- Internal flow & operational planning		√	√	
- Redundancy	√			
- IT infrastructure	√		√	
Responsiveness	√	√	√	
- Response of building operators	√	√	√	
- Building automation	√	√	√	
- Safety and security	√	√	√	
- Awareness			√	
- Decision making			√	
- Flexible usage		√	√	

CONCLUSION

As a conclusion, the intelligent buildings apply integrated system technologies to improve the working environment, productivity and comprehensive access for occupants while controlling the costs. An effective energy management system offers highest cost saving and assists user in safer environment, effectively and comfort levels (CABA, 2002).

This research also will give benefits and advantages not only to the building owner or developer but also to the government bodies involved in the construction sector. This will also give the chances for the existing building owner in Malaysia to upgrade their system to the intelligent or sustainable building and create an effective and safe environment for the users. As a result, they can increase the productivity of the building and reduce the maintenance costs.

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