Emerald Facilities

IDENTIFYING METHODOLOGY TO INVESTIGATE COST DATA INPUT IN LIFE CYCLE COST ANALYSIS OF A BUILDING

Journal:	*Facilities*
Manuscript ID:	f-09-2014-0073
Manuscript Type:	Original Article
Keywords:	Building, Building life cycle, Building management, Data Collection, Life cycle costing, Method study

Table 1: Cost components and types of cost data of LCC of a building

Cost component (Cost unit)	Cost data
Initial capital costs	Land acquisition cost, construction work costs (i.e. substructure, superstructure, finishes, fittings, services installation, external works, preliminaries, contingency including risk allowances, and contractor's design fees,), other construction related costs (i.e. professional services fees, marketing costs, decanting, infrastructure charges, infrastructure adoption and maintenance cost, highway cost, utility charges, licenses and permits, planning application and building regulation fees, party wall cost, rights to light cost, client's design development, financing cost, insurance, contingency including risk allowances), and client definable costs (e.g. cost incur to make value added on the building), landscaping cost
Operation costs	Utilities costs, insurance, service costs, administration costs, security costs, cleaning costs, local and statutory charges in connection with the building operation
Maintenance and replacement costs	The costs of regular custodial care and repair, annual maintenance contracts, maintenance management, adaptation or refurbishment, redecoration, and salaries of facility staff performing maintenance tasks, repairs and replacement of minor components
Financial costs	Discount rates, inflation rates, interest rates and taxes
Salvage costs	The cost, or gain, of getting the rid of assets after use at the end of study life (residual value, demolition cost, transferring cost, disposal inspection cost).

(Kirk and Dell'Isola, 1995; BS ISO 15686-5, 2008; BSI, 2008; Fuller, 2009; Kelly and Hunter, 2009; Langdon, 2010)

Table 2 Qualitative, quantitative and mixed method researches

Research strategy	Functions	Nature of research
Qualitative strategy	It explores and evaluates attitudes, behaviour, experiences and definitions based on opinions, views or perceptions from the respondents on a particular subject (Creswell and Clark, 2007; Royse 2008).	The nature of research is subjective and data is rich (Creswell and Clark, 2007; Royse 2008).
Quantitative strategy	It evaluates numerical data using statistical analyses (Naoum, 2007; Fellows and Liu, 2008).	The nature of research is objective and data is hard, tangible and reliable (Naoum, 2007; Fellows and Liu, 2008).
Mixed methods research strategy	It combines the quantitative and qualitative researches that can counterbalance the differences of the other, eradicate weaknesses of the strategies and provide more opportunities for the researcher to	The nature of research and data is combined characteristics of qualitative and quantitative researches (Creswell and Clark, 2007; Fellows and Liu, 2008).

	explore in deep the problems and subject of the research from the perspective of qualitative and quantitative researches (Creswell and Clark, 2007; Fellows and Liu, 2008).	

METHODOLOGY TO INVESTIGATE COST DATA INPUT IN LCC

Abstract

Purpose –Life Cycle Cost (LCC) estimation process can be divided into three main phases: data inputs, conversion and outputs. The objective of this paper is to identify the most appropriate methodology to investigate the quality of data used as inputs in LCC estimation for building works in the Malaysian construction industry. The focus of quality data here is cost data inputs of building LCC. This paper reports part of a three-year research programme to enhance quality of LCC outputs through the enhancement of quality data input requirements.

Design/ Methodology/ approach – A comprehensive literature review was carried out to critically review all the methodologies used to study LCC data inputs in other countries. The goal is to identify the most appropriate methodology to investigate the quality of cost data inputs in LCC analysis of building with regard to the context of Malaysian construction industry

Findings – The outcomes of the study proposed that a qualitative research strategy comprises of two approaches, i.e. a literature review and modified Delphi as the most appropriate methodology to critically review and examine behaviours of cost data inputs in LCC analysis of the building based on the opinions from a collective intelligence panellists.

Research limitations - The considerable limitation of modified Delphi is to find the appropriate level of panellists that possess skills, knowledge and expertise in the field of LCC. In addition, the Delphi process is normally long and time-consuming because it involves multi-round of questionnaires.

Keywords Life cycle cost, building, cost data input, methodology, Malaysian construction industry

Paper type Research paper

1. Introduction

Life Cycle Cost (LCC) is an economic assessment technique that uses mathematical method to produce outputs, which will give useful cost information to the clients, cost estimators and researchers in facilitating them to make better decision in the process of determining the most optimum total ownership cost of an asset over an anticipated life or in comparing the most cost-effective of mutually exclusive alternatives. The LCC analysis calculates the total ownership costs of the building which include the initial capital cost, operation costs, replacement costs, financial costs, and salvage costs over an anticipated life (BSI, 2008; Langdon, 2010).

The LCC analysis process can be categorized into three main phases, i.e. data inputs, conversion and outputs (BS ISO 15686-5, 2008; Rist, 2011). Past studies have confirmed that the reliability of cost data used as inputs as well as the method used for the LCC analysis are of paramount importance to produce reliable LCC outputs (Langdon, 2010; Rist, 2011; Author1 and Author2, 2011a, 2011b, 2011c, 2012). The underlying idea is that the inputs in terms of cost data that are quality for LCC analysis would produce reliable LCC outputs, on the assumption that the conversion process is also reliable and appropriate.

2. Literature review

LCC is concerned with time value of money which indicates the value of money today is worth more than the value in future as the money could be earned in the interim. The time value of money is a concept of discounting the future values to present values, using a specified discounting rate over a particular period of time (BS ISO 15686-5, 2008; BSI, 2008; Fuller, 2009; Kelly and Hunter, 2009). There are many kinds of data required as inputs for producing a comprehensive LCC analysis. Table 1 provides in summary the types of cost data for each category of cost components of LCC of a building.

"Table 1: Cost components and types of cost data of LCC of a building"

The literature review on the history of LCC in the Malaysian construction industry has not identified any information when the LCC technique was actually started but the technique was first academically applied in 2007 using the LCC software (i.e. LCCsoft) by Mohd Mazlan through his research to compare the most cost-effective of amongst mutually exclusive components of roof finishes (i.e. concrete roof tile, clay roof tile, metal roof decking) for Educational, Cultural and Scientific Building (B11) at Faculty of Built Environment in Universti Teknologi Malaysia, Johor Bahru, Johor (Mohd Mazlan, 2007). LCC has been taught as one of the topics in the economic subject of Bachelor degree in the tertiary institutions of Malaysian education system. The LCC analysis has become one of the research topics in the higher research programmes, i.e. Master and Doctorate in several major local universities. The Construction Industry Development Board (CIDB) together with the Building Industry President Council (BIPC) have made recommendations to the clients' organization and building owners on the importance of adopting LCC in the investment decision making process in an effort to achieve the best value for money in the Construction Industry Master Plan (CIMP 2006-2015) (CIDB, 2007; Mohd Mazlan, 2010). The LCC technique has been quoted in several national standard guidelines as an economic assessment tool for large construction projects in Malaysia. Such standard guidelines are the Public Private Partnership (PPP) Standard Guideline, 2009 (3PU, 2009a: 6; 3PU, 2009b: 5; 3PU 2010a, 2010b), and *"Panduan perlaksanaan pengurusan nilai dalam program/projek kerajaan"* [Value management implementation guideline for Government project/programme] (EPU, 2011).

Several local researchers and commentators like Abdul Rashid (2009, 2010), Che Mat (2002, 2010), Khairuddin (2010), Majid (2010), Ismail (2010), Ali et al. (2010), Gheisari (2009), Tapsir (2007), Mohd Kamar et al. (2011), and Mohd Mazlan (2007, 2010) have suggested that LCC analysis is suitable to be employed as a tactical tool in assessing alternatives considered in the line of the Government objectives, to advise and facilitate the Government in planning and managing the newer approaches and techniques of project delivery system, which include the Public Private Partnership (PPP), Value Management (VM), facilities management (FM), sustainable building and Industrialized Building Systems (IBS), and the Red Book procurement system of the Government-Linked Companies (GLCs).

Nevertheless, many researchers and commentators consistently pointed out that one of the major hurdles of implementing the LCC practice to estimate life cycle cost of a building is somewhat homogeneous: lack of reliable, accurate, and current cost data inputs (Levander et al., 2009; He and Yin, 2010a, 2010b; Rist, 2011; Author1 and Author2, 2011a, 2011b, 2011c, 2012). It was observed from the literature review that most published cost data in the Malaysian construction industry present fragmented costs as there is a lack of orientation on the thinking of building life cost data inputs (Gheisari, 2009; Author1 and Author2, 2011a, 2011b, 2011c, 2012). It was found from the review on the current practice of LCC in the Malaysian construction industry, the main interest of the local data producers in producing cost data is for traditional building cost estimating, which solely focuses on initial capital costs rather than putting orientation on the total ownership cost of building (Ismail, 2005; Mohd Mazlan, 2010; Author1 and Author2, 2011a, 2011b, 2011c, 2012). In addition, the main focus of the practitioners and scholars on LCC is on LCC conversion, which includes the methodology and models of computing LCC, however very little emphasis is given on the quality of data as inputs into the process of producing reliable LCC outputs in present time (Mohamed, 2007; Mohd Mazlan, 2010; Author1 and Author2, 2011a, 2011b, 2011c, 2012). All of these aforementioned factors are identified as the key setbacks that have hindered the implementation of LCC practice in the Malaysian construction industry.

3. Objective and motive of the paper

The objective of this paper is to present the identification of the most appropriate methodology to investigate the quality of data used as inputs in LCC estimation for building works in the Malaysian construction industry. The focus of quality data here is cost data inputs of building LCC. The study being reported in this paper is drawn from a three-year programme of research carried out by the first author to enhance the quality of LCC outputs through the enhancement of quality data input requirements. This paper follows the other six papers that have been presented elsewhere (Author1 and Author2, 2011a[1], 2011b[2], 2011c[3], 2012[4], 2013a[5], 2013b[6]).

4. Review of research strategy

Research is an activity that requires a comprehensive investigation of a certain topic using an appropriate methodology to attain specified aims and objectives (Fellows and Liu, 2008; Royse, 2008). Experts suggested an appraisal on research strategies should be carried out to identify the differences and to ascertain the most

appropriate strategy for the research (Naoum, 2007; Fellows and Liu, 2008). The factors that may influence the determination of the research strategy are the aims and objectives of the research, the ability to obtain the current and reliable data, the way the data should be collected and recorded, impact on the data, the style of data reporting, and the constraints of the strategy (Naoum, 2007).

The literature review has identified three types of research strategies, namely qualitative, quantitative and mixed methods research (Creswell and Clark, 2007; Fellows and Liu, 2008). The key differences of these three research strategies are shown in Table 2.

"Table 2 Qualitative, quantitative and mixed method researches"

The literature study has identified the following as the key reasons of why the qualitative research is the most appropriate strategy to investigate the quality of data inputs of LCC for the study rather than the quantitative and mixed methods research:

i. The nature of research in LCC data inputs is subjective and the data is often rich. Hence, the research requires the researchers to examine the data inputs and data behaviours based on the opinions, ideas, views and perceptions from the panellists that have knowledge, skills and expertise in LCC (Author1 and Author2, 2011a, 2011b, 2011c, 2012).
ii. LCC deals with long term financial costs and there are key parameters of LCC about which uncertainties exists (Levander et al., 2009). The recent study carried out by Langdon (2010) on the current practice of managing data uncertainty and risks of LCC analysis in 15 construction projects across 11 countries in Europe has identified that many LCC estimators preferred to use non-risk management techniques, i.e. conducting interviews with different property owners, experts, suppliers and specialists in the construction industry to overcome the problem of data uncertainty in LCC analysis rather than risk management techniques (i.e. sensitivity analysis, Monte Carlo simulation, and fuzzy approach) (NATO Research and Technology Organisation, 2007; Langdon, 2010; Goh et al., 2010).
iii. The qualitative research is more appropriate to establish the background, evolution and the present practice of LCC with specific reference to its practice in the construction industry. The qualitative research also is more suitable to critically review the previous published and unpublished information with regard to the scope of costs of the LCC analysis, data input requirements, methodology, its setbacks and the present practice of LCC analysis in the Malaysian construction industry.
iv. The qualitative research is more appropriate to generate a consensus of expert opinions regarding the state and degree of data availability, accessibility, and reliability in the Malaysian construction industry as inputs for producing LCC analysis as the data for LCC analysis is affluent and profound. The qualitative research strategy can generate data from the analysis of opinions, views and judgments from a group of panellists that have knowledge, skills and expertise in LCC.

In addition, the literature study has identified several past researches that have chosen qualitative research as the strategy to study the concepts, practice, data inputs and methodology of LCC analysis based on the valuable opinions, experiences and perceptions from a group of respondents, i.e. Joyce et al. (1992), and Iyer (1999), Ismail (2005), King (2007), Gheisari (2009), Mohd Mazlan (2010). Three of the researchers, namely Mohd Mazlan (2010), Gheisari (2009) and Ismail (2005) used qualitative research to investigate the concepts and practice of LCC analysis and its data inputs in the context of the Malaysian construction industry.

5. Literature review

The literature review was carried out at the initial stage of the study to critically review what other people have studied, thought and discussed on the subject of the research (Naoum, 2007; Fellows and Liu, 2008; Wiersma and Jurs, 2009). The literature review is essential for the researchers as it provides a platform for seeking answers to the objectives of the research (Hesse-Biber and Leavy, 2006; Royse, 2008). The literature study has identified the following kinds of secondary data sources related to the subject of the research, i.e. academic

journals (refereed), refereed conferences, dissertation/thesis, reports/occasional papers, government documents/publications, market research reports, technical reports, working papers, etc.

6. Fieldwork approach

The fieldwork approach is categorized as a primary data source (Creswell and Clark, 2007; Fellows and Liu, 2008; Knight and Ruddock, 2008). The literature review was carried out to identify the differences of the fieldwork approaches and to choose the most suitable approach for the qualitative research. The literature study has identified the following as the key reasons of why a modified Delphi is the most appropriate fieldwork approach rather than other typical approaches (e.g. surveys, case studies, action research) to acquire primary data in the qualitative research of the present study:

i. The modified Delphi is more appropriate than other typical research approaches in a situation where the nature of the research lacks current and reliable data, insufficient theory, and limited number of respondents to provide a sufficient response rate (Wiersma and Jurs, 2009; Hauck et al., 2007 as cited in Giannarakis et al., 2011; Goh et al., 2010). For example, a. survey approach was rejected because of limited number of respondents that have knowledge, skills and experience in LCC to produce an appropriate response rates for the study.

ii. The complexity of the research domain has made the other typical research approaches (e.g. surveys, case studies, action research) relatively difficult and expensive to be conducted to provide explicit, precise and reliable data for LCC studies (NATO Research and Technology Organisation, 2007; Wiersma and Jurs, 2009; Hauck et al., 2007 as cited in Giannarakis et al., 2011). In addition, this approach was also acclaimed as "the best known qualitative, structured and indirect interaction futures method" to acquire primary data for particular studies that complex in nature (Woudenberg, 1991 as cited in King, 2007: 68).

iii. Several scholars claimed the modified Delphi technique is the most appropriate approach to procure data that is affluent and profound as the data is generated from the analyses of opinions, views, and judgments of the collective intelligence of the panellists, i.e. the experts, practitioners, knowledgeable persons and learned spectators in the LCC environment (NATO Research and Technology Organisation, 2007; Korpi and Al-Risku, 2008; Wiersma and Jurs, 2009).

iv. Several scholars asserted that the modified Delphi approach can be initiated through non face-to-face interactions (i.e. mail, e-mail, phone calls) if the respondents resided far from the research location and were unable to meet the researcher (King, 2007; Wiersma and Jurs, 2009). This approach is considered very time efficient and cost effective as all the panellists do not have to agree to meet at a specified time and place for the face-to-face discussion (Romano, 2010).

v. In comparison with the traditional way of collecting opinions from the panellists as practiced in the focus group discussion, the panellists in the modified Delphi approach are working individually, anonymously, free of influences from others to provide independent judgments, and have no constraints if wishing to provide extreme opinions in answering the Delphi questions (Parsons et al., 2008; Wiersma and Jurs, 2009). The anonymity of the Delphi panellists is maintained throughout the process to avoid open debate and dishonest opinions because the value of the output is specified based on the quality of the opinions rather than who proposed the idea. In addition, the non-face-to-face interaction between the researcher and panellists can maximise the amount of unbiased responses because there is no manipulation that can be forced in the communication process (Wiersma and Jurs, 2009.).

vi. There are many high impact publications that have indicated the Delphi technique as a reliable and valid research approach to collect primary data for the research. It was reported by Gordon (n.d.) based on the Scopus database assessment which was carried out in September 2008, that there are more than 15,000 peer-reviewed professional journals from 4,000 various publishers used Delphi technique as a fieldwork approach to develop, identify, forecast and evaluate primary data. Besides, Skulmoski et al., (2007) reported that there are more than 280 dissertations and theses used Delphi technique as one of the primary approaches to collect primary data for the research

The modified Delphi approach is classified as a structured group communication process that involves the process of acquiring responses and exchanging ideas from a group of experts through a number of sequential

questionnaires, followed by a synthesis and analysis of opinions and ideas to generate reliable data for the research (King, 2007; Sandrey and Bulger, 2008; Giannarakis et al., 2011). This technique was developed by Norman Dalkey of the RAND Corporation in the 1950's to generate data from a consensus of expert opinion for a U.S. Air Force sponsored military project. The Delphi technique has been used widely in many areas of decision making process particularly to solve complicated problems (e.g. lack of current and reliable data, insufficient theory, data is affluent and profound), and generate forecasts about the future (King, 2007). The Delphi approach has also been characterized as a family of methods with many variations and modifications as the process involves four essential elements, i.e. (i) sequential questionnaires, (ii) reiteration and controlled feedback, (iii) anonymous responses and (iv) statistical group response (King, 2007; Sandrey and Bulger, 2008; Landeta and Barrutia, 2011; Giannarakis et al., 2011).

The process of the Delphi approach was initially conducted using traditional mail in 1960s but now the process has been improved using electronic devices in order to accelerate data flow and reduce time delay between the rounds of questionnaires (DeReus, 2004). The modified Delphi approach is more robust than the basic Delphi approach because the initial round of the questionnaire can be conducted through a face-to-face interview that can improve the response rate and provide a solid grounding in previously developed work (King, 2007). Although the modified Delphi approach is comparable to the basic Delphi approach in terms of the process to attain consensus of expert opinion, however the significant difference is that the modified Delphi approach initiates the process with a set of carefully selected items derived from various sources including related competency profiles of panellists, synthesized reviews of literature, and interviews with the selected panellists (Franklin and Hart, 2006; King, 2007).

6.1 The advantages of the modified Delphi approach

The literature review has identified the following as the key advantages of the modified Delphi approach:

i. The panellists enjoy the flexibility of time to express valuable opinions and creative ideas before an agreed deadline (Sandrey and Bulger, 2008; Wiersma and Jurs, 2009; Romano, 2010; Giannarakis et al., 2011). Several scholars preferred to use this approach in their research works because it can avoid the problems of communication delay (Ciptono, 2007; Wiersma and Jurs, 2009). This approach is also practical if the panellists could not make to agree to meet either because they are located or reside far away from the research location, or no available time can be set for the discussion (Wiersma and Jurs, 2009; Romano, 2010)

ii. In-depth interviews can be carried out to explore detailed information regarding the future trends, events and occurrence of future developments (Wiersma and Jurs, 2009). This approach can be used to provide a complete documentation of responses on a large scale of respondents (Skulmoski et al., 2007; Giannarakis et al., 2011). Indeed, this approach can facilitate the researcher to procure a maximum amount of unbiased responses and information from the panellists that work on the same issue because no manipulation can be forced in the Delphi communication process (Wiersma and Jurs, 2009). In most cases, this approach was used to recommend oriented solutions to the problems that arose in the research (Wiersma and Jurs, 2009). In addition, Gordon (n.d.) asserted there is no method that was found to have had more competitive advantage than the modified Delphi approach to procure and synthesize the most reliable opinions and creative ideas in line with the forecasting analysis of future market trends and events.

iii. Several scholars asserted this approach is flexible as it can be used in many varieties of structure processes ranging from the qualitative to quantitative, and to mixed-methods research (Skulmoski et al., 2007; Gordon, n.d.). It can be used in the quantitative simulation models, where a detailed scientific analysis can be carried out to determine significant differences about the value of independent variables based on the factoring outputs produced from the factor analysis (Skulmoski et al., 2007; Hon et al., 2011). Besides, other researchers like Hon et al. (2011) used Delphi in quantitative research by using mathematical formulas (i.e. Kendall's coefficient of concordance, Spearman's rho correlation, Kruskal-Walls test, Mann-Whitney U test) to evaluate responses and test hypotheses to determine whether every individual panellist provided a similar response using the same method and style on 5-point Likert-type scale (Hon et al., 2011).

6.2 Reliability and validity of the modified Delphi approach

Reliability in the research can be defined as the dependability or consistency of data, which implies how comparable the data to the actual value arrived from similar and repetitive methods under the same research condition (Ashworth, 2004; Creswell and Clark, 2007). Whilst, validity can be defined as the truthfulness of the data. The results can only be considered valid if the analysis is accurate, dependence, significant and justifiable (Creswell and Clark, 2007).

Several experts asserted that the modified Delphi approach can produce more reliable and valid outputs associated within the particular issues of research topic rather than procuring judgment based on the capability of a single individual expert (Linstone and Turoff, 1975, as cited in King, 2007; Gordon, n.d.). Besides, several experts claimed that the modified Delphi approach is "the best known qualitative, structured and indirect interaction futures method" to obtain explicit, precise and reliable data for the particular studies that complex in nature (Woudenberg, 1991 as cited in King, 2007: 68).

A recent study carried out by Langdon (2010) on the practice of LCC in 15 construction projects across 11 countries in Europe has identified that many LCC estimators preferred to use alternative methods that are not part of risk management techniques to overcome the problems with regard to the absence of current and reliable data in LCC, i.e. conducting interview with different property owners, suppliers and observing opinions and judgements from the LCC experts, suppliers and specialists in the construction industry (Langdon, 2010: 68). The main reason why the risk management techniques (e.g. sensitivity analysis, Monte Carlo simulation) were rarely applied by the LCC estimators in the construction projects in Europe is the absence of data required as inputs for risk management analysis (Langdon, 2010; Goh et al., 2010; NATO Research and Technology Organisation, 2007). Hence, it is not incorrect to state that the interviews with different panellists that have knowledge, skills and experience in LCC using the modified Delphi is the most appropriate and applicable fieldwork approach to investigate the quality of data inputs in LCC estimation for building works in the Malaysian construction industry.

6.3 The limitations of the modified Delphi approach

The literature study has identified several considerable limitations that can hinder the implementation of modified Delphi approach in the study. One of the limitations is to identify the appropriate level of panellists that possess the required skills, knowledge and expertise in the field of LCC. The competency and experience of the panellists and quality responses are some of the crucial factors in the implementation of Delphi practice. However these two aforementioned factors are beyond the control of the researcher (Sandrey and Bulger, 2008).

The Delphi process is normally long and time-consuming as it involves multiple rounds of questionnaire to move the panellists toward of the consensus of opinion (Ratnasabapathy and Rameezdeen, 2006). Hence, the long Delphi process may affect the commitment of the panellists to complete all the rounds of Delphi process. The time constraint to complete the long Delphi process may persuade the panellists to response quickly and agree with the majority, which can become cause of poor quality answers to the questions (Sandrey and Bulger, 2008).

7. Conclusion and recommendation

This paper presents the outcomes of the study on the identification of the most appropriate methodology to investigate the quality of cost data used as inputs in LCC estimation for building works in the Malaysian construction industry. The findings have suggested that the qualitative research, including two approaches, i.e. literature review and modified Delphi as the most appropriate methodology for the said study. The modified Delphi approach was identified as the most reliable and valid fieldwork approach to identify and generate consensus of expert opinions on the state of quality of data of LCC based on the evaluation of opinions and judgments from a collective intelligent panellists that possess skills, experience and knowledge in field of LCC. However, the modified Delphi approach is limited by constrains in finding the appropriate level of panellists that have accessibility skills, experience and knowledge in the field of LCC. The Delphi process is also long and time-consuming. Further research is encouraged to find appropriate strategies to mitigate the aforementioned limitations of modified Delphi, which can be proposed as second part of the study

Notes

1. Author1 and Author2. (2011a, June), "A literature review on the state and practice of LCC in Malaysia", in the *Proceedings of the International Building and Infrastructure Technology Conference 2011 (BITECH 2011),* Universiti Sains Malaysia, Malaysia.
2. Author1 and Author2. (2011b, July), "Proposing a methodology to investigate the reliability and validity of data inputs for building LCC", in the *Proceedings of the 10th Management in Construction Researchers Association (MiCRA) Conference 2011*, International Islamic University Malaysia, Malaysia.
3. Author1 and Author2. (2011c, September), "Investigating the reliability and validity of data inputs for building Life Cycle Cost (LCC)", in the *Proceedings of the Seventh International Conference on Multi-National Joint Venture for Construction Works: Joint Venture for Infrastructure Development in the context of Decentralization and Globalization*, Institute Technology of Bandung, Indonesia, Kyoto University, Japan, International Islamic University Malaysia, Malaysia.
4. Author1 and Author2. (2012, December), "Issues on data availability, accessibility, currency and its reliability as inputs in the LCC studies in Malaysia", in the *Proceedings of the Management in Construction Research Association (MiCRA) Postgraduate Conference*, Universiti Teknologi Malaysia, Malaysia.
5. Author1 and Author2. (2013a, November), "Strategies to enhance quality data input requirements of life cycle cost (LCC)", in the *Proceedings of the International Conference of Architecture and Built Environment 2013 (ICABE2013) Redefining the concept of 'Islamic Architecture' and 'Islamic Built Environment*, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia.
6. Author1 and Author2. (2013b, December), "Constraint of the results of modified delphi study on enhancing the quality data input requirements of life cycle cost (LCC)", in the *Proceedings of the 12th Management in Construction Researchers' Association (MiCRA) Conference and Annual General Meeting 2013*, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia.

Acknowledgement

The first author is an Academic Trainee that received research funding from the Ministry of Education Malaysia and the International Islamic University Malaysia (IIUM) to carry out a three-year programme of research on the "Development of Life Cycle Cost Strategy and Protocol on Cost Data Input in Malaysia" under the supervision of the second author (Ref: KPT (BS) 790816016443; IIUM/202/C/1/1/AT113). Since January 2014, the first author has been appointed as an Assistant Professor at IIUM (Ref: IIUM/202/C/1/1/0006985).

REFERENCES

Abdul Rashid, K. (2009), *Understanding Private Finance Initiative (PFI)*, Scholarmind Publishing, Selangor, Malaysia.

Abdul Rashid, K. (2010a, August), "PPP within the context of the procurement paradigm", paper presented at the Malaysia's Public-Private Partneship Seminar (2010) organised by the Procurement & Project Delivery, System Research Unit, Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia in collaboration with Public-Private Partnership Unit, Prime Minister Department, Petaling Jaya, Selangor.

Ashworth, A. (2004), *Cost studies of buildings* (4th edn.), Pearson Education Limited Harlow, England.

Ali, A. S., Kamaruzzaman, S. N., Sulaiman, R., & Peng, Y. C. (2010), "Factors affecting housing maintenance cost in Malaysia", *Journal of Facilities Management*, 8(4), 285-298. Retrieved December 18, 2010, from Emerald database.

BS ISO 15686-5. (2008), *International Standard: Buildings and constructed assets-Service Life Planning. Part 5: Life Cycle Costing* (pp 1-40). Standards Policy and Strategy Committee. Retrieved Jun 9, 2010, from University of Bradford database.

BSI. (2008), *Standardized method of life cycle costing for construction procurement: A suppliment to BS ISO 15686-5 Buildings and constructed assets-Service Life Planning. Part 5: Life Cycle Costing* (pp 1-87).

London: British Standards Institutions. Retrieved August 4, 2011, from Universiti Tun Hussein Onn Malaysia database.

Che Mat, M. M. (2006, June), "Value management as an effective tool for organizations in making strategic decisions", paper presented at the International Conference on Construction Industry 2006: Toward Innovative Approach in Construction and Property Development. Retrived January 5, 2011. http://www.fab.utm.my/download/ConferenceSemiar/ICCI2006S1PP19.pdf.

Che Mat, M. M. (2010, April), "Application of Value Management: Value Management-the way forward", paper presented at the Seminar Achieving Better Value in Construction Industry Through Value Management & Life Cycle Costing organized by CIDB, Putrajaya.

Ciptono, W.S. (2007, August), "Application of analytic hierarchy process in prioritization of critical success factors of TQM", paper presented at the 9th International Symposium on the Analytic Hierarchy Process for Multi-Criteria Decision Making, Chile. Retrieved April 24, 2011. http://www.isahp.org/2007Proceedings/Papers/Working%20Sessions/Project %20Evaluation/Critical%20Success%20Factors%20of%20TQM.pdf.

Creswell, J. W. & Clark, V. L. P. (2007), *Designing and conducting mixed methods research*. Sage Publications, Inc., London, UK.

DeReus, D. L. (2004), "Comparative analysis on the cost of oversight for the new national security space acquisition policy—a Delphi method approach", Unpublished master dissertation, Graduate School of Engineering and Management, Air Force Institute of Technology, Air University, Air Education and Training Command, United States of America. Retrived October 8, 2011. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc. pdf&AD=ADA422619

Fellows, R. & Liu, A. (2008), *Research Methods for Construction*. Wiley-Blackwell, Oxford, UK.

Franklin, K. K. & Hart, J. K. (2006), "Influence of web-based distance education on the academic department on the academic department chair role", *Journal of Educational Technology & Society*, 9(1), 213-228. Retrieved Jun 13, 2011. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.103.7378.

Fuller, S. (2009), "Life Cycle Cost Analysis (LCCA)", *National Institute of Standards and Technology (NIST)*. Retrieved May 15, 2010. http://www.wbdg.org/resources/lcca.php?r=hospital.

Gheisari, M. (2009), "A web based environment for buildings' Life Cycle Cost Analysis", unpublished master dissertation, Universiti Teknologi Malaysia, Johor, Malaysia. Retrieved July 27, 2010. http://www.efka.utm.my/thesis /IMAGES/4MASTER/2009/JSB-P/MasoudGheisarifullthesis.pdf.

Giannarakis, G., Litinas, N. & Theotokas, I. (2011), "A Delphi study to identify Corporate Social Responsibility indicators: the case of Greek telecommunication sector", *Journal of Sustainable Development*, 4(2), 16-32. Retrieved April 24, 2011. http://ccsenet.org/journal/index.php/jsd/article/view/10171/7269.

Goh, Y.M., Newnes, L.B., Mileham, A.R., McMahon, C.A. & Saravi, M.E. (2010), "Uncertainty in through Life Costing-review and perspectives", *IEEE Transactions on Engineering Management*, 57, 4. Retrieved November 1, 2011 from IEEE database, International Islamic University Malaysia

Gordon, T. J. (n.d), *The Delphi method. The Millennium Project*. Retrieved March 3, 2011.http://www.gerenciamento.ufba.br/Downloads/delphi%20%281%29.pdf.

He, W. & Yin, Y. (2010a), "A design-oriented LCC database freamework according to partnership theory", *IEEE*. Retrieved December 5, 2011. http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5535846.

He, W. & Yin, Y. (2010b), "OLII: An owner-oriented LCC Information Integrated Approach paper title", *IEEE*. Rerieved December 5, 2011. http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5563748.

Hon, C.K.H., Chan, A. P. C. & Chan, D. W. M. (2011), "Strategies for improving safety performance of repair, maintenance, minor alteration and addition (RMAA) works", *Facilities*, 29(13/14), 591-610. Retrieved April 6, 2012, Emerald database.

Ismail, A. N. (2005), "The extent of implementation of Life-Cycle Costing in Government project with specific reference to Jabatan Kerja Raya Malaysia", unpublished bachelor dissertation, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Kuala Lumpur, Malaysia.

Ismail, M. (2010, April), "Implementation of value management in the public sector", paper presented at the Seminar Achieving Better Value in Construction Industry Through Value Management & Life Cycle Costing organized by CIDB, Putrajaya.

Iyer, P. (1999), "The effect of maintenance policy system maintenance and system life cycle cost", unpublished master dissertation, Vrigina Polytechnic Institute and State University, U.S. Retrieved October 1, 2011. http://scholar.lib.vt.edu/theses/available/etd-042199-212844/unrestricted/etd.pdf.

Joyce, B.D., Poppert, D.E. (1992), "Life cycle cost of alternative ICBM second stage designs", unpublished master dissertation, Faculty of the School of Systems and Logistics of the Air Force Institute of Technology Air University, U.S. Retrieved October 1, 2011. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA258264.

Kelly, J. R. & Hunter, K. (2009), *Life Cycle Costing of sustainable design*. London: RICS. Retrieved Jun 14, 2010. http://www.rics.org/site/scripts/download _info.aspx?downloadID=4529 - 24k.

Khairuddin, A. Z. (2010, August), "PPP guidelines: a conceptual framework", paper presented at Malaysia's Public-Private Partnership Seminar organised by Procurement & Project Delivery, System Research Unit, Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia in collaboration with Public-Private Partnership Unit, Prime Minister Department, Selangor.

King, R. J. (2007), "A decision-making framework for total ownership cost management of complex systems: A Delphi study", unpublished doctoral dissertation, University of Pheonix, US. Retrieved May 25, 2011. http://gradworks.umi.com/3302636.pdf.

Kirk, S. & Dell'Isola, A. (1995), *Life cycle costing for the design professional*, McGraw-Hill, New York, USA.

Knight, A. & Ruddock, L. (2008), *Advanced Research Methods in the Built Environment*, Wiley-Blackwell, United Kingdom.

Korpi, E. & Al-Risku, T. (2008), "Life cycle costing: a review of published case studies", *Journal of Managerial Auditing* 23(3), 240-261. Retrieved January 10, 2011, from Emerald database.

Langdon, D. (2010), *Development of a promotional campaign for Life Cycle Costing in construction*, United Kingdom: Langdon. Retrieved November 20, 2011. ec.europa.eu/index_en.htm

Levander, E., Schade, J. & Stehn, L. (2009), *Life cycle costing for buildings: Theory and suitability for addressing uncertainties about Timber Housing*. Retrieved November 30, 2010. http://www.inpro-project-eu/media/LCC_for_buildings_Levander_Schade_Stehn-pdf.

Majid, N. N. (2010, August), "An Overview of PPP and the Malaysian Experience", paper presented at the Malaysia's Public-Private Partneship Seminar (2010) organised by Procurement & Project Delivery, System Research Unit, Kulliyah of Arcitecture and Environmental Design, International Islamic University Malaysia in collaboration with Public-Private Partnership Unit, Prime Minister Department, Petaling Jaya, Selangor.

MCM Value Sdn. Bhd. (2010), *User manual: LCCsoft (version 4.0)*, Author, Malaysia.

Mohamed, O., Abdul Karim, S.B., Kho, M.Y. & Mohd Nor, F. (2007, August), "The practice of life cycle costing (LCC) in the Malaysian construction industry-Application during design stages", in the *Proceedings of the Management in Construction Researchers Association 5th Annual Conference and Meeting (MiCRA 2007)*, Univeristi Teknologi Mara, Shah Alam, Selangor.

Mohd Kamar, K. A., Abd Hamid, Z., Azman, M. N. A., Ahamad, M. S. S. (2011), "Industrialized Building System (IBS): reverting issues of definition and classification", *Int. J. Emerg, Sci.*, 1(2), 120-132, June 2011. Retrieved July 15, 2011. http://ijes.info

Mohd Mazlan, M. Z. (2007), "Kos kitaran hayat bagi kemasan bumbung [Life cycle cost for roof finishing]", unpublished degree dissertation, Faculty of Built Environment, Universiti Teknologi Malaysia, Malaysia.

Mohd Mazlan, M. Z. (2010), "Application of Life Cycle Costing for construction projects in Malaysian Government-Linked Companies", unpublished master dissertation, Faculty of Architecture, Planning and Surveying, Universiti Teknologi Mara, Malaysia.

Naoum, S. G. (2007), *Dissertation Research and Writing for Construction Students* (2nd edn.), Elsevier Butterworth-Heinemann, Oxford, UK.

NATO Research and Technology Organisation. (2007), "Methods and models for Life Cycle Costing", *RTO-TR-SAS-054 Technical Report*. Retrieved February 22, 2011. http://www.dtic.mil/cgibin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA515584.

Parsons, A. M., Almasude, A., Dunn, S. & Green, K. (2008), "A Delphi study of best practices of online instructional", unpublished doctoral dissertation, Capella University, United States. Retrieved December 31, 2011, from ProQuest LLC database, International Islamic University Malaysia.

Ratnasabapathy, S. & Rameezdeen, R. (2006, September), "A muntiple decisive model for construction procurement system selection", in the *Proceedings of the Annual Research Conference of the Royal Institution of Chartered Surveyors, COBRA 2006*, University College London. Retrieved April 25, 2011. http://www.rics.org/site/download_feed.aspx?fileID=3267&fileExtension=PDF.

Rist, T. (2011), "A path to BIM-based LCA for whole buildings", unpublished master dissertation, Faculty of Engineering Science and Technology, Department of Civil and Transport Engineering, Norwegian University of Science and Technology. Retrieved January 10, 2012. http://www.ntnu.edu/c/document_ library/get_file?uuid=de2c6e9e-853c-4870-897d-1c8d48e42286&groupId=163835.

Romano, A. R. (2010), "Malleable Delphi: Delphi research technique, its evolution, and business applications", *International Review of Business Research Papers*, 6(5), 235-243. Retrived October 21, 2011. http://www.bizresearchpapers. com/18.Anthony-FINAL.pdf.

Royse, D. (2008), *Research methods in social work* (5th edn.), Thomson Learning Academic Resource Centre, United States of America.

Sandrey, M. A. & Bulger, S. M. (2008), "The Delphi method: an approach for facilitating evidence based practice in athletic training", *Athletic Training Education Journal*: 2008, 3(4), 135-142. Retrieved October 1, 2011. www.nataej.irg.

Skulmoski, G.J, Hartman, F.T. & Krahn, J. (2007), The Delphi method for graduate research", *Journal of Information Technology Education*, 6. Retrieved April 18, 2011. http://informingscience.org/ jite/documents/Vol6/JITEv6poo1-0215kulmoski212.pdf.

Tapsir, S. S. (2007, April), "Life cycle cost approach in design of affordable housing in Malaysia, in the Workshop on Building Maintenance, Commissioner of Building (COB). In MBAM (ed.), *Master Builders 2nd Quarter 2007 Bulletin*, pg.22. Kuala Lumpur: MBAM.

Wiersma, W. & Jurs, S.G. (2009), *Research methods in education: An introduction* (9th edn.), Pearson., Boston, USA.

3PU. (2009a), *Public Private Partnership (PPP) guideline*, Putrajaya, Malaysia: Public-Private Partnership Unit, Prime Minister Department. Retrieved August 15, 2010. http://www.3pu.gov.my/html/themes/miu/ content/ppp_bi_131109.pdf.

3PU. (2009b), *Garis Panduan Kerjasama Awam-Swasta* [Public Private Partnership-PPP], Putrajaya, Malaysia: Unit Kerjasama Awam-Swasta, Jabatan Perdana Menteri. Retrieved August 15, 2010. http://www.3pu.gov.my/html/themes/miu/content/GP_PPP_agensi_web.pdf.

3PU. (2010a, August), "Public Private Partnership Unit Prime Minister's Department: Background", paper presented at Malaysia's Public-Private Partnership Seminar (2010), Procurement & Project Delivery, System Research Unit, Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia in collaboration with Public-Private Partnership Unit, Prime Minister Department, Selangor.

3PU. (2010b, June), "Public Private Partnership (PPP) in Malaysia", paper presented at the 56th MBAM Annual General Meeting, Master Builders Association of Malaysia (MBAM) organized by MBAM, Kuala Lumpur.