An integrated life cycle costing database: System proposal and methodology

Aouad, G, Bakis, N, Amaratunga, RDG and Sun, M

Title	An integrated life cycle costing database: System proposal and methodology
Authors	Aouad, G, Bakis, N, Amaratunga, RDG and Sun, M
Type	Conference or Workshop Item
URL	This version is available at: http://usir.salford.ac.uk/9901/
Published Date	2002

An Integrated Life Cycle Costing Database: System Proposal and Methodology

G. Aouad[1], D. Amaratunga[1], N. Bakis[1], M. Sun,[1], M. Kishk[2], A. Al-Hajj[2] and R. Pollock[2]

[1]Research Centre for the Built and Human Environment, School of Construction and Property Management, University of Salford, UK.

[2]School of Construction, Property and Surveying, The Robert Gordon University, UK.

Abstract
Life Cycle Costing (LCC) techniques are being used across a wide range of projects across different industries and have attracted considerable attention. However, LCC techniques are not widely used within the construction industry because of problems associated with LCC related processes such as data capture, reliability and certainty. Recent technological developments will undoubtedly help in resolving some of the above problems associated with LCC techniques. Salford University together With Robert Gordon University have commenced a research project, which looks into the development of innovative systems that facilitates the implementation of LCC in various design and occupancy stages. To this effect, this paper outlines the research methodology associated with the development process of an integrated LCC database, data capturing mechanisms and associated limitations with the development process.

The proposed system on which this papeis based, attempts to overcome some of the limitations associated with the use of LCC and tries to develop mechanisms which will allow the user within a VR environment to navigate inside a building retrieving all information about the building components. By creating such systems, it tries to provide opportunities to take maximum advantage of using LCC techniques and related information through out the building life cycle. This proposed system will allow LCC data to be updated continuously and thus can be used as and "asset register".

Life Cycle Costing? What does it mean?

With occupancy costs representing up to 70% of the total cost of a building over its life time (Flanagan, 1989), Life Cycle Costing (LCC) has become a valuable concept as the pre-occupation with capital expenditure has led to designs which do not offer the client best value for money in the long term.
There are a number of definitions for LCC. CRISP Performance Theme Group adopts the definition which implies LCC as: " the systematic consideration of all relevant costs and revenues associated with the acquisition and ownership of an asset" (Clift & Bourke, 1998). For construction, this is expected to take into account capital or procurement costs such as initial construction or major refurbishment purchase or leasing, interest and feed and other associated recurring or occupancy costs.

LCC is further defined by British Standards (1997) as: " the process of economic analysis to assess the total cost of acquisition and ownership of a product". Kirk and Dell'Isola (1995) describe LCC as a "methodology to identify the significant costs associated with alternatives, add groups of cost by year, discount them back to a common base and finally to select the optimum cost alternative; tempering final selection with non-economic considerations".

Background to the study

The technique of LCC is not new and methods which facilitate LCC forecasting had been available since 1970s. However, the barriers to adopting these methods were great and they included (Osbaldiston and Aouad,2001):

- The information necessary for such analyses was simply not available, or was inaccurate;
- The resources required to obtain this information, far outstripped any perceived financial gain;
- The uncertainty inherent in forecasting future financial trends, especially over a long period (up to 60 years) was deemed unacceptable;
- Capital costs and operating expenditure were met from different budgets often by different parties, offering no incentive on behalf of those responsible for construction to reduce subsequent costs-in-use. (Ferry and Flanagan, 1991);
- The exercise itself is expensive. Estimates of between 0.2% -0.5% of the project initial cost has been tendered for a professional analysis;
- The necessity to keep construction costs within prescribed budgetary constraints; and
- The failure of designers to visualise whole life issues and to understand the impact of their designs on operating and maintenance costs.

Consequently, predictions made using LCC methods were unreliable, leading to a general distrust in the technique (Bull, 1993). Over the years, research in this field (Garnett and Owen, 1995; Al-Hajj and Horner, 1998; CPN, 1998; Aouad et al, 1998) have attempted to address these and other related issues with a view to making LCC more acceptable to practitioners.

In this context, it is critical that designers are fully aware of the impact of their design decisions on the subsequent costs-in-use of a facility. This can be difficult since the information required to make these judgements such as maintenance and operating costs may be inaccurate or may not exist in a form, which the designer can easily interpret.

Enabling Visualisation of Life Cycle Costing using OSCON

In attempting to address some of the drawbacks of applying the LCC concept as identified above, possibility of using the technology, particularly Integrated Databases and Virtual Reality, has been explored (Greening and Edards, 1995; Sun, 1998; Aouad et al, 1994; Rezgui et al, 1996). This was partially achieved using the OSCON (Open Systems for Construction) database. OSCON (Aouad et al, 1997) is a set of integrated software, which includes CAD application, and will extend the Virtual Reality Interface to allow the visualisation of life cycle costs. This system was developed with the aim to ease and actively share construction information via a central project oriented project database.

The OSCON application currently supports the functions of design, estimating and planning by allowing these phases to effectively share information dynamically and intelligently. The linage of LCC analysis tool to OSCON will increase the functionality of the system, particularly the design element and will effectively extend the scope of the OSCON suite to the occupancy stage (Osbaldiston and Aouad, 2001).

System Proposal

As apposed to the uses, benefits and limitations of LCC applications identified above, this paper introduces development phases and data capturing methodologies of a system which is aiming at developing applications of whole LCC to facilitate flexible methods of predicting total LCC of construction assets and their components. Particular emphasis is given to discuss the issues associated with the development of the framework for data collection and recording appropriate for LCC analysis.

LCC and Integrated Environments

One of the main objectives of the proposed system is to minimise the effort required to perform the LCC analyses. It combines the integrated environment together with the LCC database. LCC database provides the LCC data where as the integrated environment provides other relevant information about the proposed building. An integrated LCC environment not only simplifies the LCC analysis process, but also provides the flexibility for better consideration of the factors that have an influence on the LCC of buildings. As integrated environment has knowledge on the building model, it provides more opportunities to link to LCC component into the integrated environment. The integrated LCC environment further assists on complication and storage of LCC data for different uses. Integrated environment with LCC database, act together in prviding the opportunity for automating the LCC calculations.

Outline of the System

It is well known that the benefits to be gained from a LCC analysis are maximised by applying the concepts as early as possible during the design phase of a construction project (Kirk and Dell'Isola, 1995). It is therefore critical that designers are fully aware of the impact of their design decisions on the subsequent costs-in-use of a facility. This can be difficult since the information required to make these judgements such as maintenance and operating costs may be inaccurate or may not exist in a form, which the designer can easily interpret. The problem designers have in visualising expenditure beyond the construction phase is also a critical one. It is well known that the benefits to be gained from a LCC analysis diminish significantly if it is applied only after the design has been agreed (Kirk and Dell'Isola, 1995, Al-Hajj and Aouad, 1999). Since LCC is essentially used to facilitate a choice between possible alternatives based on economic factors, it is important that this is seen as an integral part of the design phase, not simply an ad-hoc tool that can be used to justify any chosen design (Osbaldiston and Aouad, 2001).

This research, as indicated above, aims to provide designers and clients with a tool which will enable them to visualise the implications of their design decisions on the associated Life Cycle Costs. This tool will be based on the OSCON Integrated Database and will extend the Virtual Reality Interface to allow the visualisation of life cycle costs. Figure 1 shows the architecture of the existing suite and the proposed extensions:

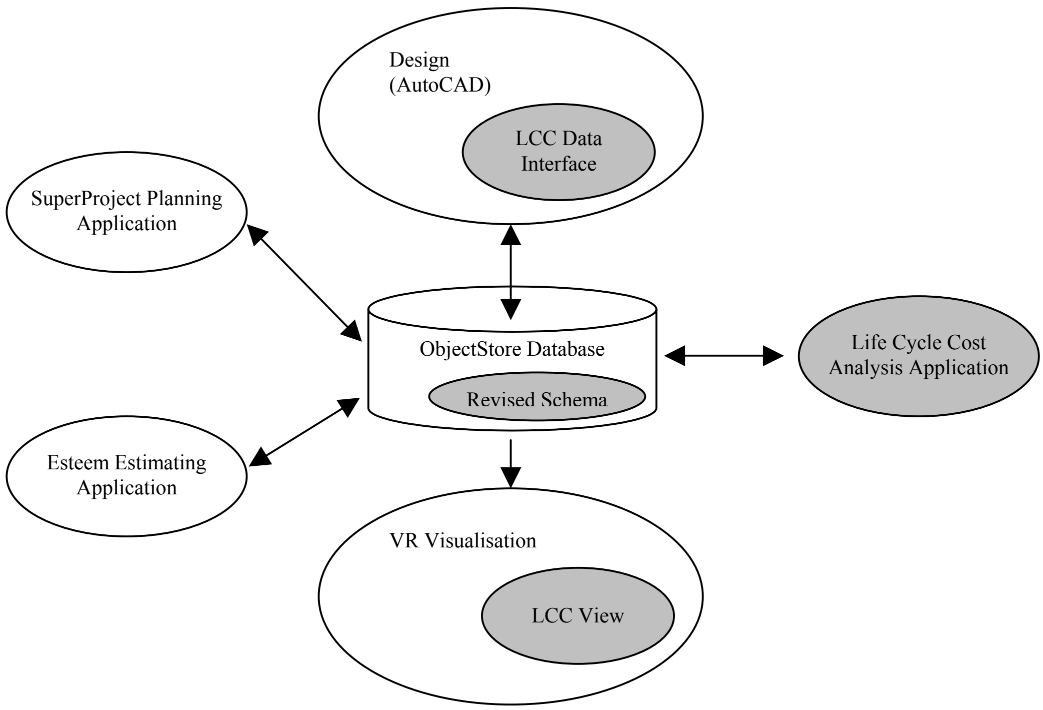


Figure 1 – OSCON Architecture and proposed extensions to accommodate LCC element (Osbaldiston and Aouad, 2001)

Development of the LCC database

A comprehensive literature review was undertaken in the areas of LCC, Integrated Construction Environments and VR visualisation. This has led to the identification of the most appropriate methodologies and technologies for use during the project. The review of the literature included an in-depth examination of the material relating to current LCC applications in general, issues relating to database development and in its IT related applications in particular. The literature review revealed the established and generally accepted facts and has enabled to identify and understand the theories or models, which have been used by previous researchers in the field. The main purpose and outcome of this was to identify important components to be addressed in the database development. Although the area of LCC is not new, the constructs are neither well established nor standardised across and even within the construction profession. There are, therefore, an abundance of areas that required further investigation.

Development of LCC has attracted little attention in the field and only a limited number of small scale databases have been developed so far (Al-Hajj & Aouad, 1999).

Following sections summarises several issues underlying the LCC databases development.

Level of granularity of LCC data

LCC data is derived at various levels of granularity with each one of them reflecting a different level in a building decomposition hierarchy. At the lowest level of granularity, that is, at the highest level of the building decomposition hierarchy, the LCC data are quite generic and are concerned with the building as a whole. At this level, most of LCC data are expressed in generic terms such as costs per building floor area per year. At the highest level of granularity and lowest level in the building decomposition hierarchy, the LCC data becomes explicit and are concerned with specific properties of building components, such as life expectancy, energy efficiency etc. Therefore, in the integrated LCC database development process, it is required to decide on which level or levels of data should be stored in the database. Should it be data only at the building and component level or should it be at each level in the building decomposition hierarchy, and which levels of building's composition hierarchy to be taken into consideration are some of the issues that needs to be decided upon.

In an integrated environment, the building decomposition hierarchy is defined by the common building model. But in a specific integrated environment which consists of specific CAD tools, levels of data required by each tool needs to be identified and needs to supports only the selection. However, attention is required in identifying a specific integrated environment if an open integrated environment and a database that can be shared across applications over the Internet needs to be achieved. A LCC database, as has been envisaged, needs to provide data at any possible level within the building decomposition hierarchy. Compilation of data for each level of building's decomposition hierarchy is a complicated process and when such data is not readily available, the database should be capable of generating such data dynamically on the basis of available data relating to lower levels of the building decomposition together with information conveyed by the building model. Of course, this type of data estimates and conversions might be fairly complex to define, might not be always feasible and might not be always accurate. However, the requirement to provide LCC data at any level in the building decomposition hierarchy remains a priority in the research and these issues were carefully analysed in developing the system, briefly described in the data capturing methodology section.

Type of database management system to be used

There are three main options available in deciding on which database management system be used: a Relational Database Management system (RDBMS), an Object Oriented Database Management System (OODBMS) or an Object Relational Database Management System (OORDMS). The choice of the system will depend on the complexity of data and the complexity of queries that the system will receive. RDBMSs are more appropriate for raw data within which many joint operations are not required. OODBMSs are more appropriate for complex data and for simple queries. The approach identified in this research for the automatic estimation of LCC data requires maintenance of interconnections between LCC data at different levels of the building decomposition hierarchy and frequent navigation between the interconnected data. If such an approach is to be followed, OODBMS will be more appropriate to play the role of LCC database. However, how the interrelationships between components are described, stored in the database and used by the system to make predictions remains as open issues to consider in the research.

Organisation of LCC data

The main purpose of the LCC database is not to provide efficient access to LCC data, but to facilitate what-if analysis to different design options in order to identify the best possible design solutions. This issue becomes even more important especially in an integrated environment where what-of analysis could be automated. As an enabler to this process, the designer or the integrated design tool needs to query the LCC database for costs of alternative components. But how can the alternative components be identified in the database? Classification of components on the basis of their functionality is one of the options available.

Storage of LCC related information

In developing a LCC database, attention is required to identify the way in which factors that influence LCC data are stored in the database and used in LCC analyses. This represents one of the major problems of using LCC data, as they are dependent upon many different factors, which are more complex and very difficult to quantify in most circumstances. Development of different sets of data and databases for different types if buildings, is a way of avoiding many problems related to the complexity and diversity of LCC data and the factors that influence them.

Handling of complexity of operations

Handling of LCC related data is fairly a complex process when different levels of decomposition within a building is considered. But, the development of a LCC database can be substantially simplified without a significant loss in the accuracy of predictions by identifying ad using only the most important components and most important factors that have an influence on these components. Figure 3 highlights components which has been identified to handle the complexity of LCC data. Al-Hajj and Horner (1998) justify this decision as they have shown that only 16% of costs collected are adequate to predict the total running costs of a building to an accuracy between 2.5% - 5% and the annual costs to an accuracy of 7%.

LCC data are very sparse – how to deal with this complexity?

If different databases for different types of buildings are used, then there should be schemes devised for sharing data, which are common to all types of buildings. Developing a shared LCC model is once again a complex task and requires considerable effort. However, it is envisaged that such a shared model will provide solutions to some of the conflicting problems of non-availability of extensive data and satisfying the requirement of reasonable accuracy of available data. The wide acceptance of the Internet and the World Wide Web provides the opportunity for developing databases that are shard by a community of users. Therefore, development of shared LCC databases could be identified as the only practical solution to the problem of providing access to a large amount of LCC data. But there will be limitations associated with such developments as certain participants within the building life cycle such as consultants, will not be willing to share their LCC data as they present them a strategic advantage. Therefore, such limitations need to be overcome by creating an awareness of the importance of sharing LCC information across the building supply chain. Further, development of such a shared database requires development of standard LCC data recording formats, which will simplify and will enable the complication of recorded data.

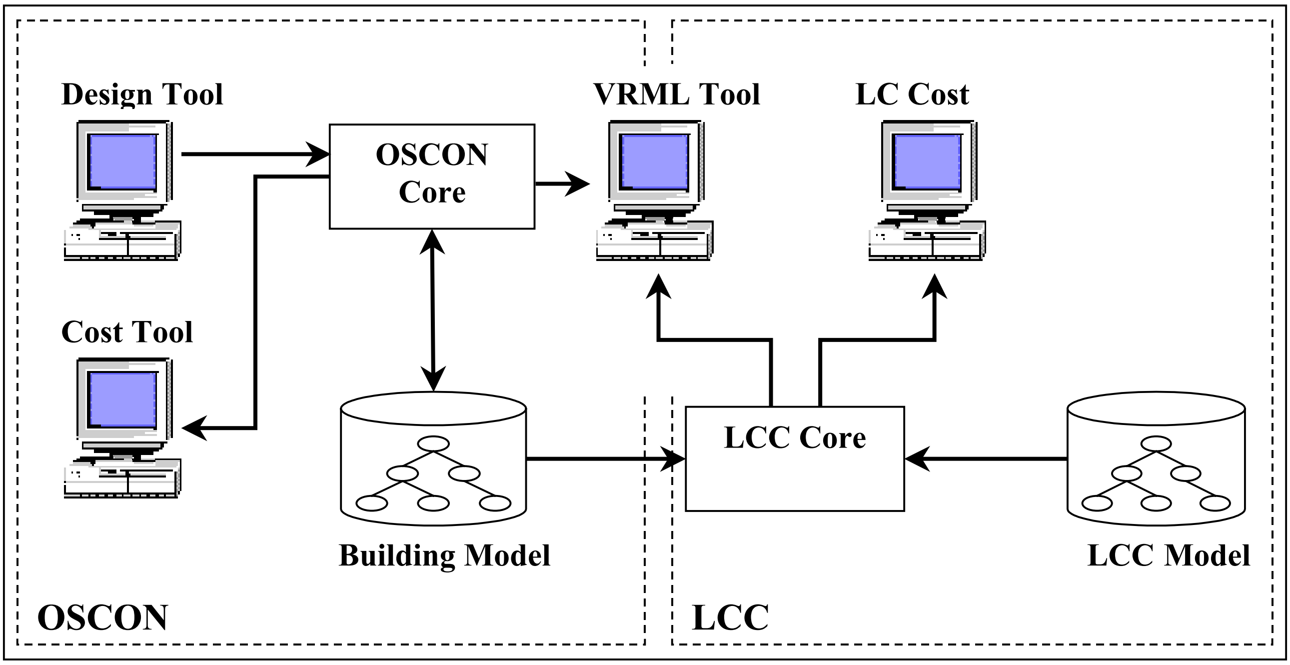


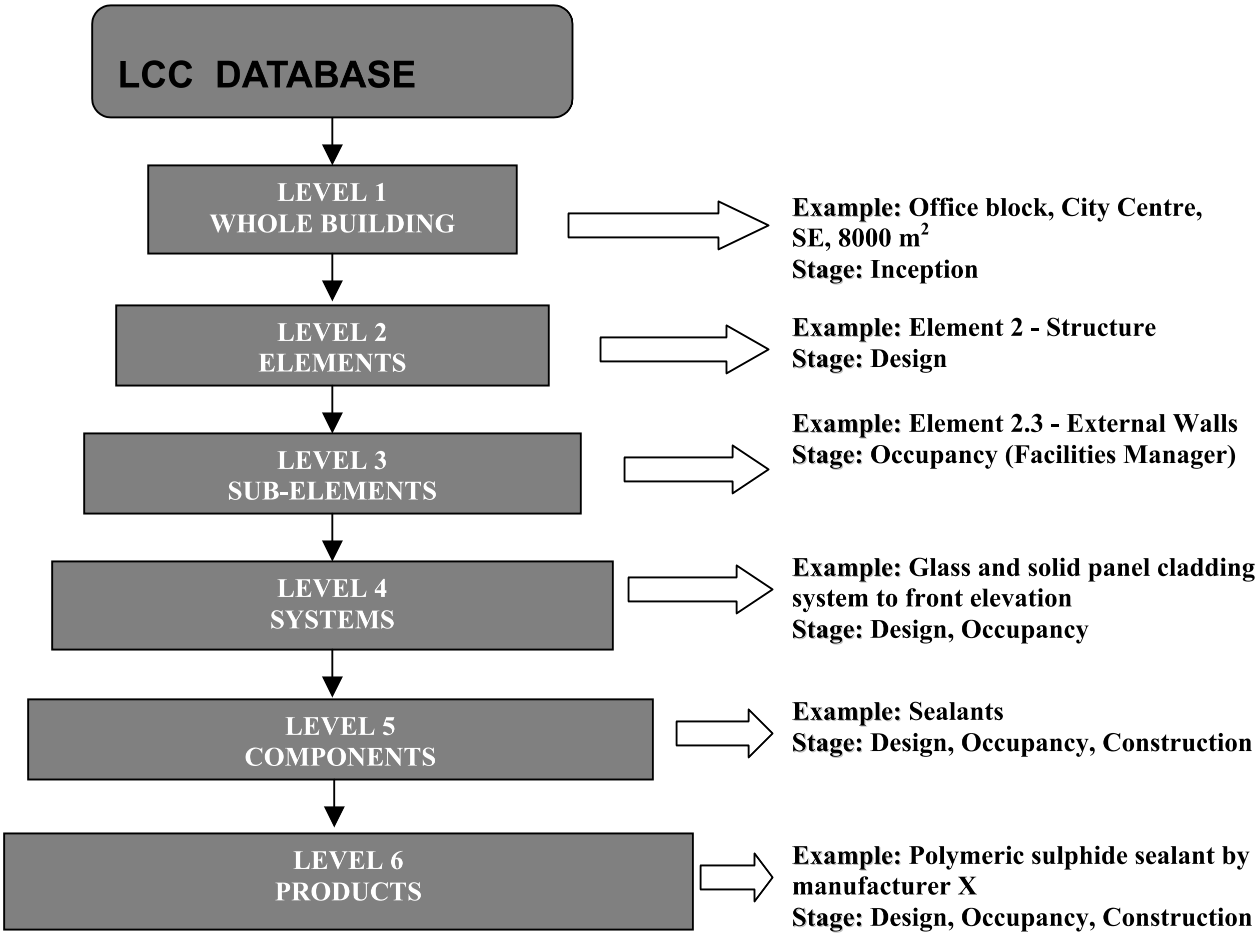
***Figure 2**: The LCC system proposal*

On the basis of the issues identified through the above discussion, a framework has been proposed, as illustrated in Figure 2, for the development of the LCC database.

Data Capturing Methodology

By taking into consideration, factors discussed above, the LCC analysis will be conducted on two levels as proposed by Whyte (1999). First level of analysis is at the building, or overall asset level, and will give an indication of building performance, including such issues as energy consumption, management, cleaning, rates and insurance. Secondly, individual elements will be considered, taking into account all planned costs over the life cycle of that particular component. These costs will include acquisition, maintenance, operating, disposal and any others considered to be significant for that element. (Figure 3). Such a system will help to overcome the problems associated with lack of universal methods and standard formats for the calculation of whole life costs and the difficulty in integrating operating maintenance strategies at the design phase, as indicated by CRISP and the Technology Foresight Panel (cited in Clift and Bourke, 1998).

The models developed to facilitate this multi level LCC analysis will link to other components of the integrated environment (Figure 2). This will safeguard the integrity of the model and ensure compatibility with existing OSCON functionality. Once the functionality commences, the database will form an object oriented asset register, which will be of use not only to designers but also to Facilities Managers and others throughout the life cycle of the building.



Levels 1,2 7 3 are Building dependent and Levels 4,5 & 6 are Building independent
Figure 3 *: LCC Database – Overview*

Any LCC analysis is only as good as the input data allows, and future cost predictions, but their very nature have some uncertainty associated with them. It is therefore important that a risk analysis is performed on all input data and that the results are fed back to the user giving an indication as to the reliability of the forecast. It is anticipated that the proposed VR interface, in addition to displaying the costs will also provide a method by which the level of reliability may be visualised. Virtual Reality is considered a more natural means for interfacing with complex information (Aouad et al 1998). Using this system, anyone with an interest in the building design will have at their disposal within a single visually appealing environment, all the data necessary to make informed decisions based on Life cycle cost as well as aesthetic criteria.

In order to test the application, sufficient data will be required to enable realistic cost comparisons to be made between a number of alternative designs and between the use of different building elements. Case studies which have been used to verify previous LCC research will also be employed, in addition to a fresh case study currently being undertaken. In the first instance, tests will be restricted to certain well-defined areas of application such as internal decoration and roof design in order to validate the technique and to establish interest before extending the application industry wide.

Initially, data will be entered via forms designed specifically for the purpose, which will be accessible from within the CAD package. This will allow designers to enter data in a familiar environment, whilst being encouraged to consider the life cycle implications of their proposals at every stage (Whyte, 1999). The feasibility of retrieving data directly from existing electronic sources will be considered for future investigation.

Associated Limitations

The degree of automation of LCC data with the use of integrated environments will be largely dependent upon the degree of availability of LCC data to reflect different circumstances, as it was argued that LCC data will depend on may complex and diverse factors. Those factors, for e.g. the life expectancy of a building must be taken into account if reasonably accurate estimations are to be made. However, may of LCC associated factors are difficult to quantify in a form that can be interpreted by computer systems. Thus, experts in LCC often use their expertise and human judgement to adjust the data to use particular situations and circumstances. However, use of computer systems provides two options in dealing with LCC data: either to identify the factors that influence the data to quantify them or create a semiautomatic and interactive environment where the judgement of the LCC expertise is invited to update information. A balance between the two is often suggested, the exhaustive intervention of the LCC expertise and the automatic but less accurate operative systems must be achieved. How this is to be achieved has been an open question and attempts have taken to find answers to such questions in the research.

Conclusion

Whole life costing is a technique which could be used to facilitate effective choice between alternatives in the search of value for money. However, a lack of accurate data and a difficulty amongst design teams to visualise the impact of their decisions on occupancy costs have reduced the effectiveness of this technique.

This paper has given an overview of a project currently in progress to embed a LCC analysis tool within the design phase of an Integrated Construction Environment. Particular emphasis was given to discuss LCC database development and its associated limitations and constrains and to outlines suggestions to overcome those barriers.

References

Al-Hajj, A., and Horner, M. (1998). Modelling the running costs of buildings, *Construction Management and Economic*s. Vol. 16. E & FN Spon, pp459-470.

Al-Hajj, A. and Aouad, G. (1999). The development of an integrated life cycle costing model using object oriented and VR technologies, *Proc. 8th International conference on durability of building materials and components*, Vancouver, Canada.

Aouad, G., Betts, M., Brandon, P., Brown, F., Child, T., Cooper, G., Ford, S., Kirkham, J., Oxman, R., Sarshar, M., and Young, B. (1994). *ICON (Integration of Construction Information): Integrated databases for the design, procurement and management of construction*, Final Report, Dept of Surveying and Information Technology Institute, University of Salford, July.

Aouad, G., Child, T., Marir, F. and Brandon, P. (1997). *OSCON final report*. University of Salford, July.

Aouad, G., Child, T., Brandon, P., and Sarshar, M. (1998). Linking construction information through VR using an object oriented environment, *Proc. ARCOM 14th annual conference*, University of Reading, September.

Aouad, G., Child, T., Brandon, P., and Sarshar, M.(1998). Linking construction information through VR using an object oriented environment, *Proc. ARCOM 14th annual conference*, University of Reading, September 1998.

Augenbroe, G. (1995). An overview of the COMBINE project, *Proc. ECPPM '94: Product and process modelling in the building industry*, Scherer (ed.) Balkema, pp547-554.

Björk, B.C. (1994). The RATAS project - an example of co-operation between industry and research toward computer integrated construction, *Journal of Computing in civil engineering*, ASCE. Vol.8. No.4. pp401-419.

British Standards Institute (BSI), 1997, *Guide to Life Cycle Costing*, BS 5760: part 23: 1997.

Bull, J.W. (1993). *Life cycle costing for construction*, Chapman and Hall, London

Clift, M. & Bourke, K. (1998). *Study on whole life costing*. Building research establishment Ltd. Watford

Construction Productivity Network (CPN). (1998). Questionnaire and Workshop Report CPN801L, Whole life Costing: the new BS handbook, CIRIA publication, London.

Faraj, I., and Alshawi, M. (1999). A modularised integrated computer environment for the construction industry: SPACE, *Electronic Journal of Information Technology in Construction*, Vol. 4. at http://www.itcon.org/1999/3.

Fisher, N., Barlow, R., Garnett, N., Finch, E. and Newcombe, R.(1997). *Project Modelling in Construction….seeing is believing*, Thomas Telford, London.

Flanagan, R., Norman, G., Meadows, J. and Robinson, G. (1989). *Life cycle costing: Theory and practice*, BSP Professional Books, Oxford, UK.

Garnett, N., and Owen, K. (1995). Life cycle costing techniques: how the construction industry could learn from other industries, *Proc. RICS COBRA conference*, Heriot Watt University, September, pp89-94.

Greening, R., and Edwards, M. (1995). ATLAS Implementation scenario, *Proc. ECPPM '94: Product and process modelling in the building industry*, Scherer (ed.) Balkema, pp467-472.

ISO/TC184/SC4 (1994). *Part 1: Overview and fundamental principles*, International Standard, ISO, Geneva. Vol. 4.

Kirk, S.J., and Dell'Isola, A.J. (1995). *Life cycle costing for design professionals*, second edition, McGraw-Hill Inc., New York.

Osbaldiston, S.J. and Aouad, G. (2001), Modelling and Visualising Life Cycle Cost Data in an integrated environment, *Proceedings of the first international postgraduate conference*, The University of Salford, UK.

Rezgui, Y., Brown, A., Cooper, G., Aouad, G., Kirkham, J. and Brandon, P.(1996). An Integrated Framework for Evolving Construction Models, *The International Journal of Construction Information Technology*. Vol.4. No.1., pp47-60.

Tah, J.H.M., Howes, R. and Iosifidis, P. (1999). Integration of design and construction through shared objects in the CO-CIS project, *International Journal of Computer Integrated Design and Construction*,. Vol.1. No.1. May.

Whyte, A. (1999). *The state of life-cycle costing in construction*, Draft Internal Research Paper, The Robert Gordon University, Aberdeen, September 1999.

Acknowledgement

The LCC integrated system described in this paper is being developed as part of an EPSRC-funded research project, undertaken through a joint collaboration between the Robert Gordon University and the University of Salford.