AN EXTENDED WHOLE-LIFE APPLICATION FOR THE SELECTION OF HOSPITAL FINISHES

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Motivated by the lack of effective tools that would facilitate the effective choice of hospital finishes; an innovative application for the optimal selection of hospital finishes is proposed. The logic of the application is designed around two generic whole-life costing (WLC) databases. The first is a resource database that houses data for several options for various finishes suitable for various spaces of hospital building. The second database is a project specific database which accommodates WLC data for the selected optimum set of finishes to be used throughout the hospital building life cycle. Their structures have been kept as general as possible. Besides, the use of the concept of the 'building space enables handling a typical building in a practical and convenient manner. Another unique feature is the addition of an easily edited table to store relevant non-financial criteria for each space type with their recommended weights. The paper concludes by introducing further research within the project to extend the proposed application to a useful decision support system.

Keywords: database systems, finishes, hospital design, whole-life costing

INTRODUCTION

In the complex environment of healthcare buildings, the desire to reduce variation for economic reasons has to be balanced against a wide variety of specialist uses and a large number of user groups with widely differing needs. NHS literature, e.g. NHS (2003, 2004), highlight the need for finishes to be above all durable, detailing that cost is secondary to this requirement, and advocate the need for a risk assessment team to have a major influence in the selection of hospital finishes.

Besides, the design or finish selection decisions can often be taken based on factors other than cost criteria, e.g. strength of materials, fire-protection, hygiene, health and environmental protection, safeguarding of use, sound isolation, energy saving and thermal isolation, durability and utilization (Bogenstatter, 2000). As such, a life cycle analysis of hospital finishes requires an alternative value method of analysis.

The practical implementation of whole-life costing as a decision-making tool has faced a number of substantial obstacles that can be classified into two main categories. The first category relates to whole-life data with the difficulty in obtaining appropriate, relevant and reliable historical information and data; adjusting this data to the specific project at hand; and the analysis of various uncertainties in data. In addition, there exists a lack of a standard computerized system for systematic data collection, recoding and analysis.

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This paper is the third in a series reporting on on-going research within an NHS-Estates funded project. This project aims to develop an integrated System for the optimal selection of hospital finishes. Motivated by the lack of effective tools that would facilitate the effective choice of hospital finishes; an innovative application for the optimal selection of hospital finishes is proposed.

In a previous paper (Laing *et al.*, 2006), major non-financial selection criteria for hospital finishes have been identified. Besides, various mathematical models and techniques have been discussed. In a subsequent paper (Kishk *et al.* 2006), an integrated framework for the selection of hospital finishes has been outlined. This framework utilizes desirable features of a number of existing well-developed methods. Besides, it employs a phased approach in the identification of decision criteria and alternatives where each phase results in a more specific list of criteria and alternatives. The main idea is to identify all available alternatives with the smallest set of key criteria. Alternatives that do not meet the statutory requirements and the minimum specification and performance requirements are excluded early in the process. Finally, the ideal alternative is selected based on a rigorous value for money analysis. In this paper, a WLC application based on this framework is developed.

The rest of the paper is organised as follows. In the next section, the structures of the resource and project databases are outlined. Then, the mathematical WLC model is introduced and the application logic is outlined. Next, the development of the application is reported using simple process flow diagrams. Finally, the work is summarised and further future research is introduced.

WLC DATABASES

MS ACCESS 2003® has been chosen to develop two WLC databases because of its flexibility and its user-friendly capabilities for developing, perusing and maintaining databases. Some of the issues considered in the design of the database structure are discussed in this section. First, the concept of a hospital space is introduced. Then, other data requirements are outlined and the relational structures of the project and resource databases are presented. These databases are customised versions of two recently developed WLC databases by Kishk *et al.* (2003).

Space Codes

A hospital building can be conveniently defined as a collection of spaces. Within a healthcare environment, the use of different spaces varies from office and general use to very high wear circulation areas and indoor ‘streets’, to ward areas, to highly specialised theatre areas. Within many of these spaces a range of issues distinguishes healthcare environments from most other building types and needs to be considered in the development of the proposed WLC tool. Perhaps the most important of these issues relates to the control of infection. Hospital environments in particular are subject to spillage of a range of potentially dangerous substances, in areas of general use such as circulation areas, as well as in wards. Here the choice of finishes is not only important in determining cleaning regimes, but may for example incorporate resistance to the spread of infection through the use of antimicrobial agents, fungicides etcetera, as additives to applied finishes (Gelder, 2003). Space has also has an effect on the selection of the finishes in a hospital, especially if rooms are smaller and more cellular (Laing *et al.*, 2006). In other words, selection criteria and their relative weights of importance may be different for various spaces.

Each space is defined by up to three boundaries: its floor, its walls and its ceiling. In this way, three types of finishes are identified for each space: an internal wall finish, a floor finish, and a ceiling finish. Within a typical project, spaces should be clearly defined and coded to facilitate the design and management of the building.

Data Requirements

Data requirements may be grouped into economic, building and space data categories. Economic data including the discount rate and the analysis period (or the life cycle) are required in the WLC modelling process. Data requirements on the building level include the building size, height, location, type and physical data. Space data includes the space elements' type and quality data, the space physical data including area, use and additional non-financial criteria. In addition to these criteria, the building type and quality data are used to identify only relevant options from the resource database for various elements of the space under consideration.

The Resource Database

The relational structure of the database, names of tables and links between tables are outlined in figure 1. As shown, the database design was kept as general as possible. Data are stored in three main tables: (1) the space options table; (2) the option activities table and (3) the activities cost items table. Besides, eleven definition tables are also employed.

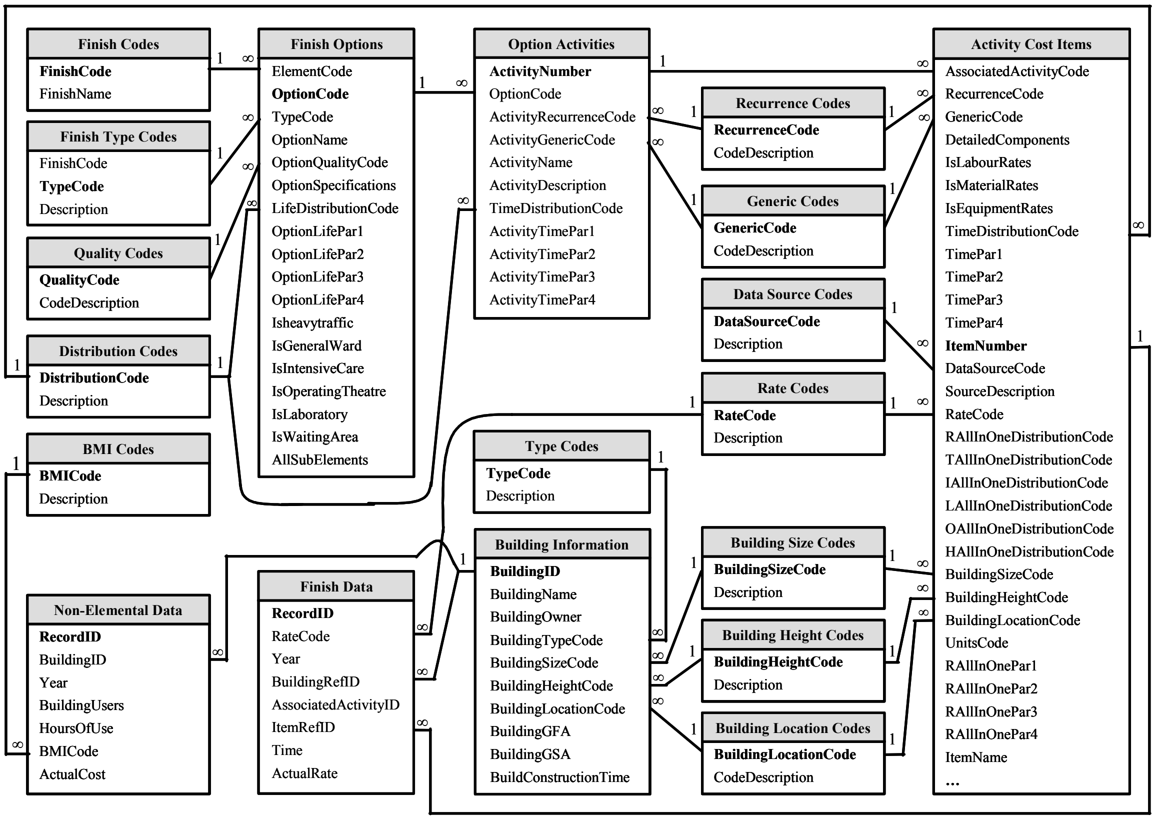

Figure 1: The resource database relational structure.

The unique features of this generic structure include:

- The data structure is kept as flexible and general as possible.
- WLC data can be extracted on four levels: the element, the activity, the cost item, and the cost component levels.

- The number of activities required to construct, maintain/operate and dispose/resale each building element is unlimited.
- The number of cost items required to perform any activity is unlimited.
- Cost items rates can be entered as all-in-one rates or detailed.
- The cost rates are not restricted to the simple £/unit area.
- Various facets of uncertainty can be easily represented.

The Project Database

The relational structure of the project database, names of tables and links between tables are outlined in figure 2. As shown, data are stored in four main tables: (1) the building information; (2) the hospital spaces, (3) the space activities and (4) the space costs. The first table stores the building and economic data while the second table stores the building spaces data. The other two main tables store the activities and cost items of the building spaces. The first two tables are edited by the user while records of the latter two tables are inserted automatically by the application.

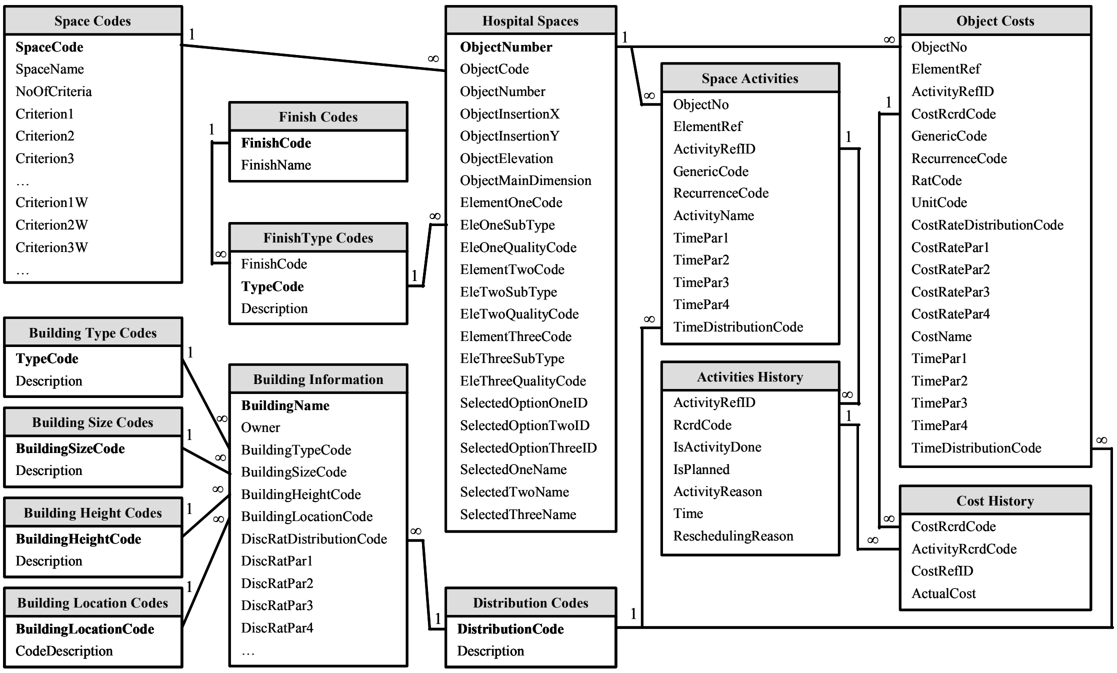

Figure 2: The project database relational structure.

MATHEMATICAL MODELS

The WLC model employed in developing the application is an extension of a previous model developed by Kishk (2001) such that multiple occurrences of cost items can be handled. It calculates the whole life cost of an alternative i, as

$$NPV_i = \sum_{l=1}^{nic_i} IC_{il} + \sum_{m=1}^{nno_i} PWO_{im}F_{im} + PWA\sum_{j=1}^{nar_i} A_{ij} + \sum_{k=1}^{nnr_i} PWN_{ik}C_{ik} - \sum_{v=1}^{nrv_i} PWS\,RV_{iv} \qquad (1)$$

where NPV_i is the net present value of the alternative, $IC_{il}, F_{im}, A_{ij}, C_{ik}$ and RV_{iv} are initial, future one-off, annual-recurring, non-annual recurring costs and resale values of alternative i, and $PWO_{im}, PWA_{ij}, PWN_{ik}$ and PWS are discount factors given by

$$PWO_{im} = (1+r)^{-t_{im}} \tag{2}$$

$$PWA = \frac{1}{r}\left(1-(1+r)^{-T}\right) \tag{3}$$

$$PWS = (1+r)^{-T} \tag{4}$$

$$PWN_{ik} = \frac{1-(1+r)^{-n_{ik}f_{ik}}}{(1+r)^{f_{ik}}-1} \tag{5}$$

$$n_{ik} = \begin{cases} \text{int}(\frac{T}{f_{ik}}), & \text{provided that rem}\left(\frac{T}{f_{ik}}\right) \neq 0 \\ \frac{T}{f_{ik}} - 1, & \text{elsewhere} \end{cases} \tag{6}$$

where r is the discount rate and T is the analysis period.

When non-financial criteria are considered, the ideal alternative is considered based on the total combined score, S_i^C or the benefit to cost ratios, BTC_i given by (Kishk, 2002)

$$S_i^C = \frac{W^{WLC} \cdot s_i^{WLC} + \sum_{j=1}^{m} W_j \cdot s_{ij}}{W^{WLC} + \sum_{j=1}^{m} W_j} \tag{7}$$

$$BTC_i = \frac{S_i}{NPV_i} \tag{8}$$

where W_j are weighing coefficients reflecting the relative importance of cost criteria, and s_{ij} are the corresponding ratings assigned to cost criteria of alternative i, and S_i is the total score for alternative i.

THE APPLICATION LOGIC

According to the implementation framework described in Al-Hajj *et al.* (2001), the choice of the ideal option(s) for various element(s) of each object involve three main tasks: (1) generating a number of competing alternatives, (2) performing WLC calculations and identifying the ideal options and (3) updating the object records in the project database. The WLC application has been developed in four modules: AutoGen, WLCalc, WECalc and Update to undertake these tasks, respectively. These modules are shown in figure 3 and are described in the following subsections.

The AutoGen Module

The AutoGen module generates the data required for the WLCalc module. This is done in the following steps (figure 4):

- A connection to the project database is established and the current object, building and economic data are retrieved.
- A connection to the resource database is established and all options for the space satisfying the screening criteria are identified.
- The options' activities and cost data are retrieved.

- The connection to the resource database is closed.
- For each cost rate, a cost item is generated by interpreting its unit rate with the corresponding building or object physical data item.
- Based on the recurrence and generic codes, cost items and their recurrence times (if applicable) are grouped in a number of two dimensional matrices.
- These matrices as well as economic data (the analysis period and the discount rate) are then carried forwards to the WLCalc module.

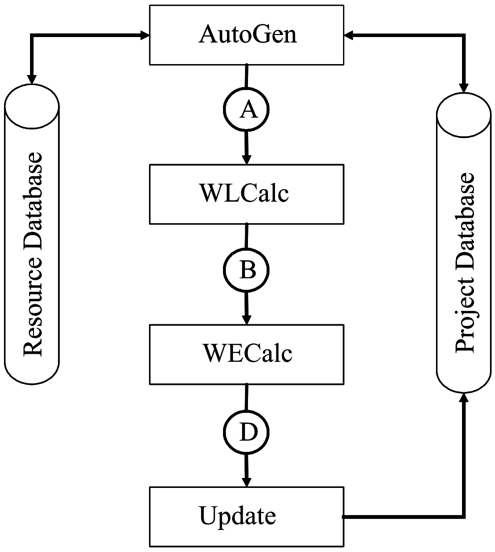

Figure 3: Simplified process flow diagram of the WLC application.

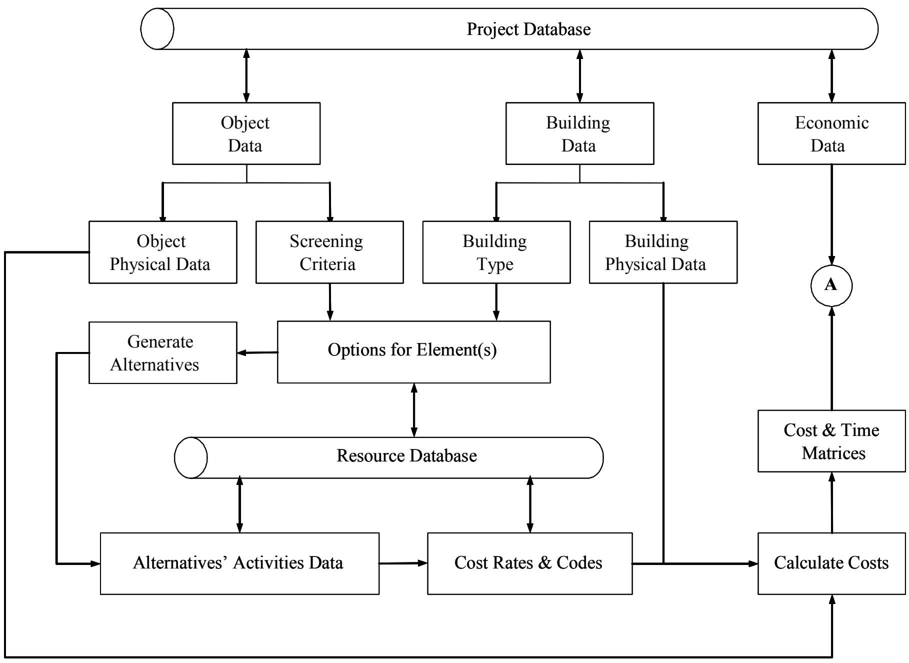

Figure 4: Simplified process flow diagram of the AutoGen module.

The WLCalc Module

The WLCalc module identifies the ideal alternative, i.e. the one with the maximum value for money. This is done in the following steps:

- Each cost item and its recurrence time are transformed to fuzzy numbers using the method described in Kishk (2004).
- The corresponding discount factor (PWO, PWA, PWN, or PWS for future one-off, annual, non-annual recurring or disposal costs, respectively) is calculated.
- The calculated discount factor is used to discount the cost to get its present worth.
- The above three steps are repeated for all cost items of alternative i .
- The above steps are repeated for all alternatives ($i = 1$ to $nalter$).
- The calculated NPVs are carried forwards to the Update module.

A simplified process flow diagram of the WLCalc module is shown in figure 5.

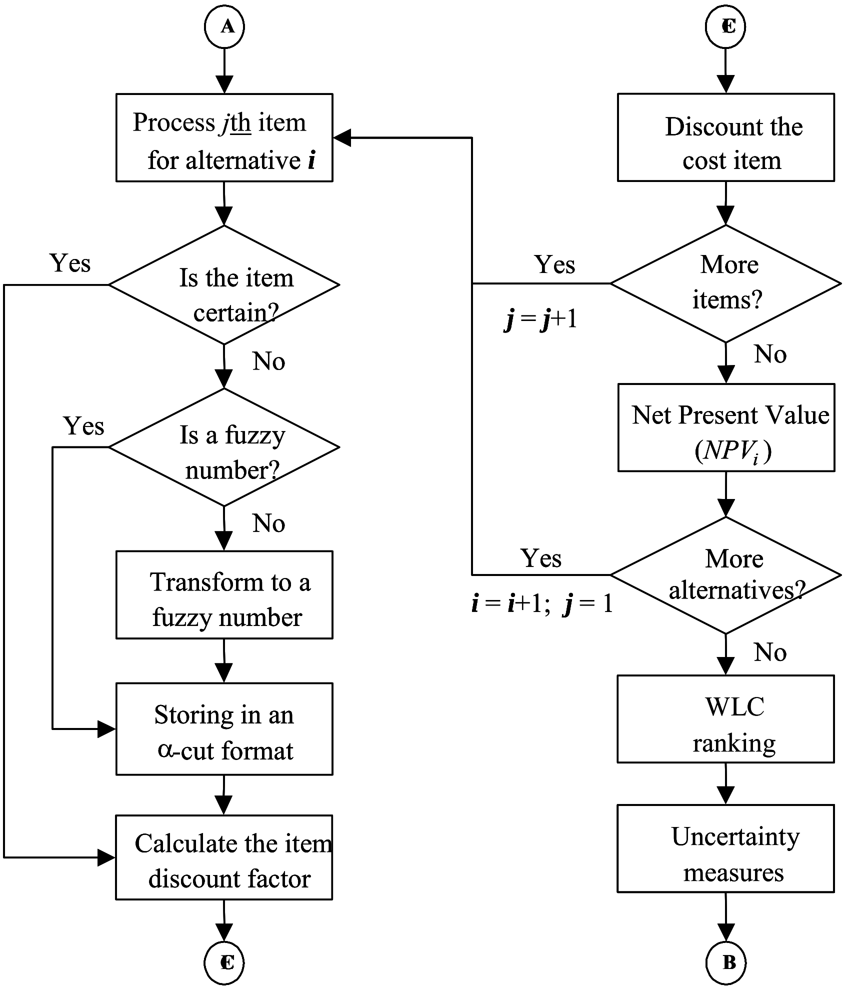

Figure 5: Simplified process flow diagram of the WLCalc module.

The WECalc Module

The WECalc module identifies the ideal alternative, i.e. the one with the maximum value for money. This is done in the following steps:

- Trade-off criteria and their weights for the space under considerations are retrieved.

- Competing alternatives are rated in relation to these criteria as described in Kishk (2002).
- Alternatives are ranked using the procedure described in Kishk (2002) and the confidence measures in this ranking are calculated.
- The ranking order is carried forwards to the Update module.

A simplified process flow diagram of the WECalc module is shown in figure 6.

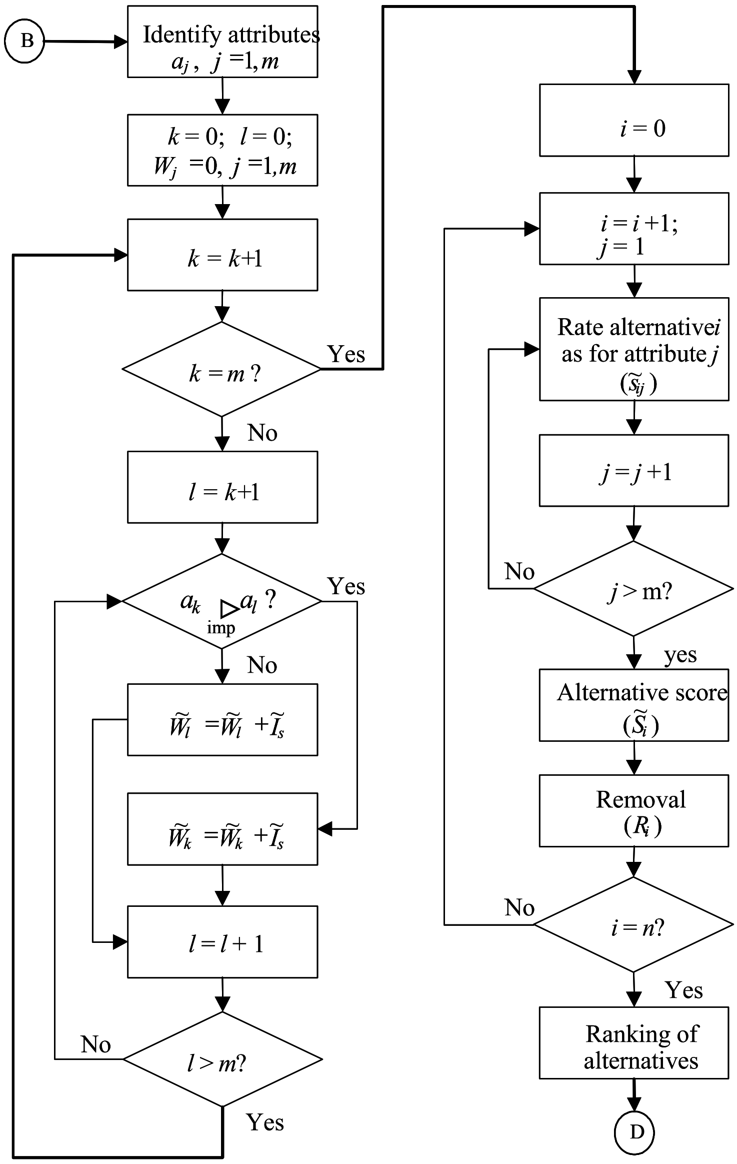

Figure 6: Simplified process flow diagram of the WECalc module.

The Update Module

The Update module updates the current object records in the project database. This is done in the following steps.

- The options of the ideal alternative are identified and assigned to various elements of the current object by updating the last six fields in the building objects table in the project database (Fig. 2).

- Any existing records for the object in the object costs or the object activities tables are deleted. Then, the activities of the ideal alternative are assigned to their corresponding element(s) and stored in the object activities table.
- The costs and their time data of the ideal alternative are assigned to their corresponding element(s) and stored in the object costs table.
- The connection to the project database is closed.

A simplified process flow diagram of the Update module is shown in figure 7.

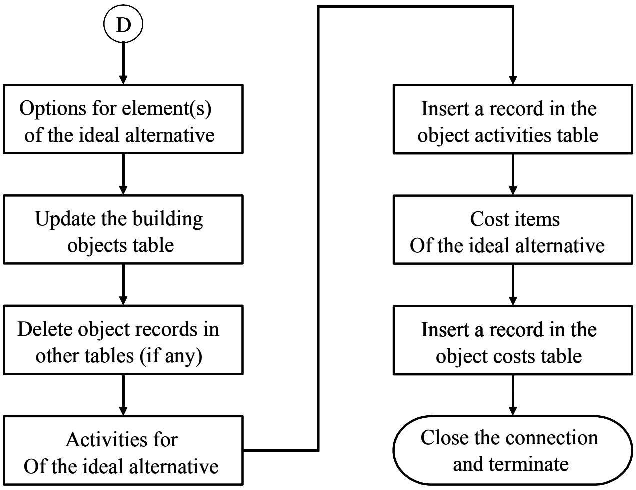

Figure 7: Simplified process flow diagram of the Update module.

The computer implementation of the application and an example application will be reported in a future paper.

SUMMARY AND FUTURE RESEARCH

Two WLC databases have been designed and implemented into MS ACCESS 2003®. Their structures have been kept as general as possible. Besides, the use of the concept of the 'building space enables handling a typical building in a practical and convenient manner. Another unique feature is the addition of an easily edited table to store relevant non-financial criteria for each space type with their recommended weights.

A novel application has been developed to facilitate effective WLC based selection of hospital finishes. The unique feature of the application is the automation of the critical stages of the selection process. In addition, the decision-making process is broken down into simple logical activities that can be easily followed by decision makers.

Future research work within the project include developing an integrated by integrating the proposed application and the two WLC databases through an interactive interface. This system will be tested and validated in four phases. First, the usability of the system's interface will be tested in a laboratory environment. A second phase will be to demonstrate the system both to users and a panel of experts to get feedback on further refinements to the system's capabilities. The third phase will be to use case study healthcare organizations from the Steering Group to demonstrate the validity of the model. The wider market for the system will be tested in a launch event aimed at all major UK healthcare organizations, which will be followed up by training and feedback events by agreement with the client.

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