A PRACTICAL COST BREAKDOWN STRUCTURE FOR EFFECTIVE WHOLE-LIFE COSTING OF BUILT ASSETS

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ABSTRACT: To undertake a whole-life costing (WLC) exercise, it is necessary to breakdown a built asset into its constituent elements whose costs can be distinctly defined and estimated. Motivated by the lack of a standard WLC data collection and analysis procedure, the framework of a novel cost breakdown structure (CBS) suitable for collection, recording and analysis of whole-life data of built assets is proposed. The development of the framework was designed on the basis of an in-depth analysis of the requirements of various WLC processes during various stages of built assets' life cycle. This has involved three main steps. First, a number of published CBSs are critically reviewed to identify their desirable features and limitations. Secondly, other crucial requirements for effective whole-life costing are identified. Thirdly, the framework is outlined and a practical implementation mechanism is proposed. The development of this framework would encourage systematic data collection and recording and consequently tackling a major barrier to the application of WLC in the industry.

Keywords: cost breakdown structures, cost databases, whole-life costing.

1. INTRODUCTION

There are many difficulties facing designers and managers in adopting a whole-life attitude towards the design and management of built assets. Perhaps one of the major difficulties is the lack of reliable data upon which to base a meaningful whole-life costing (WLC) analysis. WLC data falls into two main categories: discounting-related data and cost-related data. The first category includes the discount rate and the analysis period. The financial status of the client and the particular circumstances of the project under consideration have the major impact data items within this category.

The second category includes cost data and the time in the life cycle when associated activities are to be carried out (i.e. life-cycle phases). To deal with category, is necessary to breakdown the building into its constituent elements whose costs can be distinctly defined and estimated. In a way, this cost breakdown structure (CBS) links objectives and activities with resources and constitutes a logical subdivision of cost by functional activity, area, major element of a system, and/or more discrete classes of common items (Fabrycky and Blanchard, 1991). The CBS may be also seen as another way of classifying costs, with the classification being WLC oriented (Kirk and Dell'Isola, 1995).

The complexity of a CBS for a physical asset and the identification of cost elements and their corresponding scope depend on the scope and objectives of the WLC exercise. However, any CBS should have the following typical characteristics (Fabrycky and Blanchard, 1991; HMSO, 1992)

- All cost categories should be considered and identified in the CBS.
- Each cost element included in the CBS should be clearly defined so that all parties involved have a clear understanding of what is included and what is not.
- Costs must be broken down to the level necessary to provide visibility.
- Cost-significant areas should be easily identifiable.

- Different levels of data could be inserted within various categories. Besides, each cost element should be identifiable with a significant level of activity/work.
- The CBS should allow an analysis of specific areas of interest.
- Costs that are reported through various information systems must be compatible and consistent with those comparable cost factors in the CBS.

The objective of this paper is to develop the framework of a generic WLC cost breakdown structure suitable for data collection and recording. In the following section, a number of CBSs are critically reviewed. Next, additional crucial requirements of an effective CBS for built assets are identified. Then, the framework is outlined and its implementation mechanism is reported. Finally, directions for further research are introduced.

2. EXAMPLE COST BREAKDOWN STRUCTURES

2.1 The RICS Major Project CBS

Figure 1 shows the cost breakdown structure given in the Surveyors' Construction Handbook (RICS, 1999). In this CBS, the cost categories identified are obviously too broad to be useful at all whole-life phases, especially at the detailed design stage. Furthermore, this CBS lacks many of the desirable characteristics mentioned in the previous section.

A. Capital / Initial Costs: • General - Land - Fees on acquisition - Construction cost. - Taxes. • Financing Cost - Finance for land purchase & construction. - Loan charges. **B. Operation Cost:** • Energy. • Cleaning. • Insurance. • Security and Health. • Manpower. - Staff. - Building Management & administration. • Land charges (Rates). • Occupier's Equipment.	**C. Maintenance Costs** • Main structure. • External decorations. • Internal decorations. • Finishes, fixtures and fittings. • Plumbing and sanitary services. • Heat source. • Ventilation & air treatment system • Electrical installations. • Gas installations. • Lift and conveyor system. • External works. **D. Occupancy Cost** • Client occupancy costs. **E. Residual Values** • Resale value • Demolition and site clearance. • Renovation /refurbishment cost.

Fig. 1. Major project breakdown structure (RICS, 1999)

2.2 The BCIS Standard Form

Figure 2 shows the standard form for Property-Occupancy-Cost-Analysis produced by the Building Maintenance Information service (BMI). The aim of this standard format is to allow standardization of data collection and presentation. However, costs collected within this structure are functional costs; i.e. that fulfill specific functions irrespective of the use or form of the building. Besides, cost elements are expressed as a ‘cost per 100 m^2 per annum’ to allow comparisons between the cost of achieving various defined functions, or maintaining defined elements, in one building with those in another. This ignores effects of quality, building type, size and shape as will be discussed in more detail later.

0.0 Improvements and adaptations 1.0 Decoration 1.1 External decoration 1.2 Internal decoration 2.0 Fabric 2.1 External walls 2.2 Roofs 2.3 Other structural items 2.4 fittings and fixtures 2.5 Internal finishes 3.0 Services 3.1 Plumbing and internal drainage 3.2 heating and ventilation 3.3 lifts and escalators 3.4 electrical power and lighting 3.5 other M & E services 4.0 Cleaning 4.1 windows 4.2 external surfaces 4.3 internal	5.0 Utilities 5.1 gas 5.2 electricity 5.3 fuel oil 5.4 solid fuel 5.5 water rates 5.6 effluent and drainage costs 6.0 Administrative costs 6.1 services attendants 6.2 laundry 6.3 portage 6.4 security 6.5 rubbish disposal 6.6 property management 7.0 Overheads 7.1 property insurance 7.2 rates 8.0 External works 8.1 repairs & decoration 8.2 external services 8.3 cleaning 8.4 gardening

Fig. 2. BMI Property-Occupancy-Cost-Analysis Form (BMI, 2004)

2.3 The Cost Element Concept

Fabrycky and Blanchard (1991) criticized top-down CBSs in that they do not ensure accountability and control. Furthermore, the cost analyst cannot readily determine what is and what is not included, nor can he or she validate that the proper relationships or parameters have been utilized in determining that are inputted into such a structure. Another useful CBS is based on the cost element concept outlined in the BS 5760 (BSI, 1997). This concept can be illustrated by a three-dimensional matrix as shown in figure 3. This matrix involves identification of the following aspects: of a product/work:

- Breakdown of the product to lower indenture levels.
- The time in the life cycle when the work/activity is to be carried out.
- The cost categories of applicable resources, e.g. labour, materials, equipment.

This approach has the advantages of being systematic and orderly, thus giving a high level of confidence that all essential costs have been included.

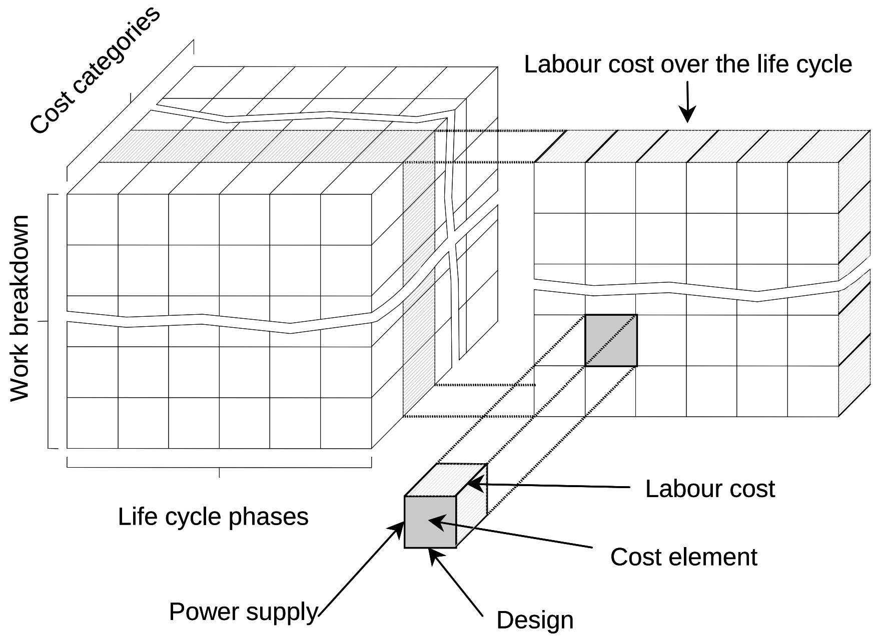

Fig. 3. The cost element concept (adapted from BS 5760, 1997)

2.4 El-Haram Generic CBS

El-Haram et al. (2002) developed a top-down WLC breakdown data structure for buildings. Their CBS is divided into five levels: project, phase, category, element and task. In the development of the CBS, they employed the BCIS and BMI codifications, where appropriate to record costs at various stages and levels. This would allow existing data sources to be easily utilized. Besides, this CBS has another obvious advantage of being applicable at various stages of a building life. Furthermore, it has many of the desirable advantages discussed earlier in sections 1 and 2.3.

However, this CBS has the main disadvantages of all top-down CBS. Besides, there exist some inconsistencies in its design. For example, an external finish cost element is used in contradiction with the standard BCIS codification where an external wall cost element includes the external finish as standard. In addition, it did not provide a means for recording the context information of cost data, e.g. the occupancy profile, type, size, location of the building. Furthermore, no practical implementation mechanism has been proposed.

3. ADDITIONAL CRUCIAL REQUIREMENTS

3.1 The CBS Format AND CAD

An object oriented CAD application, e.g. AutoCAD®, is used at the design stage to allow the design team to create, manage and manipulate various components of the building under consideration. In a typical CAD application, a facility is defined as a collection of objects. These objects are usually the components, elements, systems or subsystems of the facility. In other words, these objects represent a work breakdown structure (WBS) of the facility. This suggests that an elemental format is crucial for the implementation in the integrated environment. Furthermore, an elemental format relates well with the kind of decisions made at various design stages as noted by Kirk and Dell'Isola (1995).

3.2 Category Cost Classification

By definition, cost data required for WLC purposes include initial costs and future follow-on costs that may include maintenance and repair costs, operating costs, replacement costs, disposal costs and resale values. The grouping of cost items into these generic categories allows producing various planning schedules and profiles and cash flow diagrams during various stages of the project. Thus, it is crucial to include the generic category of each cost item in the CBS.

3.3 Time Horizons

The times in the life cycle of the project when the cost-associated activities are to be carried out should also be recorded. These time horizons are crucial in the calculation of whole life costs. They are also necessary to develop various profiles and diagrams mentioned in the previous subsection. It is also crucial to include a recurrence code to make a distinction between one-off, annual recurring, and non-annual recurring activities. In this way, the contribution of each cost item to whole life costs can be effectively calculated without the need to express the item by a number of cash flows over the analysis period (Kishk, 2001).

3.4 Other Crucial Data Requirements

Al-Hajj (1991) has shown that building-size and number-of-storeys as well as design-purpose influence the running costs of buildings. Even, different buildings used for the same purpose but with different physical aspects will incur different costs. Thus, the range of applicability of each cost for various building types, sizes, heights and location should be recorded as well. In this way, cost data can be interpreted with physical data and the type of building that incurred them.

3.5 The Context of Cost data

Hobbs (1977) and Flanagan et al. (1989) stressed the importance of the hours of use and occupancy profile as other key factors especially for public buildings such as hospitals and schools. This view was supported by Martin (1992) who showed that users and not floor-area had the greatest correlation with costs-in-use of hospitals. In addition, WLC data is expected to be gathered from different sources and with different uncertainty types and levels. The CBS should be designed to accommodate the variability of data collection method(s), parameter definitions, statistics indicating variability in parameter values, references, reliability, geographical relevance, etc. In other words, the context of the data should be recorded (Kishk et al., 2003a).

Therefore, other data normalisation methods, or rate codes, should be also employed depending on the basic nature of the cost under consideration. Another justification of this requirement is that no single source would provide the data for the database (Al-Hajj et al., 2001). Examples of the required rate codes include cost per element area, per element length, per element volume, per gross floor area, per gross surface area and per building use.

3.6 Standardisation and Elemental Interaction

Because the CBS should be coded to allow an analysis of specific areas of interest and to facilitate the flow of information around various life cycle phases, a selection of a standard codification of the CBS seems inevitable. The BMI codifications appear to offer a logical choice as the core structure of a whole-life CBS in the sense that BMI publications are the only regular sources of occupancy and maintenance data in the UK. However, it seems more reasonable to choose the well-known BCIS standard form of cost analysis because it is more element-oriented.

The use of a standard CBS is crucial but is not enough. Besides, the collection, recording and feedback of information through the CBS should also reflect interaction between various elements in the CBS. This is crucial especially when dealing with cost items that cannot be linked to a specific element/object of the built asset such as energy costs.

3.7 Computerized Implementation

According to Ahmed (1995), making decisions based on data requires that management have confidence in the data collected and therefore data must be accurate, timely, and reliable. The time needed for data collection and the analysis process may leave inadequate time for the essential dialogue with the decision-maker and the re-run of alternative options. This is one of the reasons why computerized models are valuable (Griffin, 1993).

A computerized system is also crucial to handle uncertainties in whole-life data. The inclusion of the effect of the building use, size, type and location as discussed in section 3.5 and the utilization of different rate codes for various cost elements would eliminate some of the uncertainty in cost and time data. However, there is still a need to consider the variability of data. This variability can be represented in the database of a computerized system by a distribution rather than by a single value. According to the type of uncertainty in the data item, either a probability distribution function (PDF) or fuzzy number (FN) can be used (Kishk, 2001).

4. A NOVEL WHOLE-LIFE CBS

Based on the above arguments, a whole-life CBS can be proposed (figure 4). A shown, data can be handled on 5 levels: the building; objects; elements; activities; cost items; and resources. As discussed earlier, a building is defined as a collection of objects. This necessitates that a set of objects should be clearly defined and coded within the project database. To be compatible with the resource database elemental codes (Kishk et al., 2002), each of these objects should include one or more of the building cost information (BCIS) elements used in the resource database. Figure 5 shows schematically how BCIS cost elements have been grouped into 9 building objects. As shown in the figure, each object consists of one to three BCIS elements.

Figure 6 shows a simplified diagram of an implementation mechanism for the developed CBS. It allows feedback of actual performance and cost data of occupied buildings to a resource database that can be used in future similar the design of future useful projects. The mechanism has been recently employed within a whole-life management application (Kishk et al., 2003b). Figures 7 and 8 show the relational structure of two extended versions of the two project (Kishk et al., 2002b) and resource (Kishk et al., 2002a) databases employed by this structure.

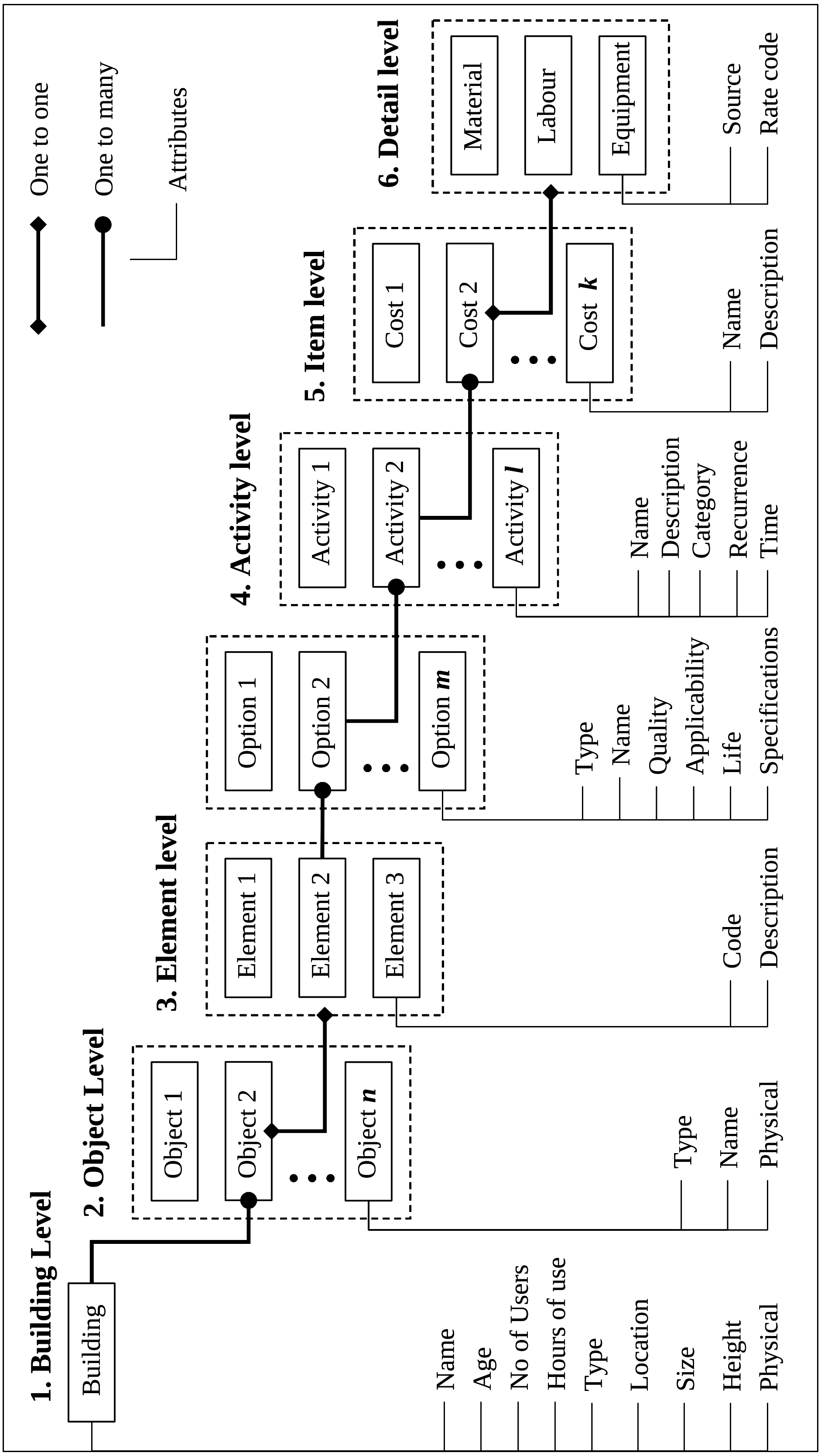

Fig. 4. Schematic representation of the proposed CBS

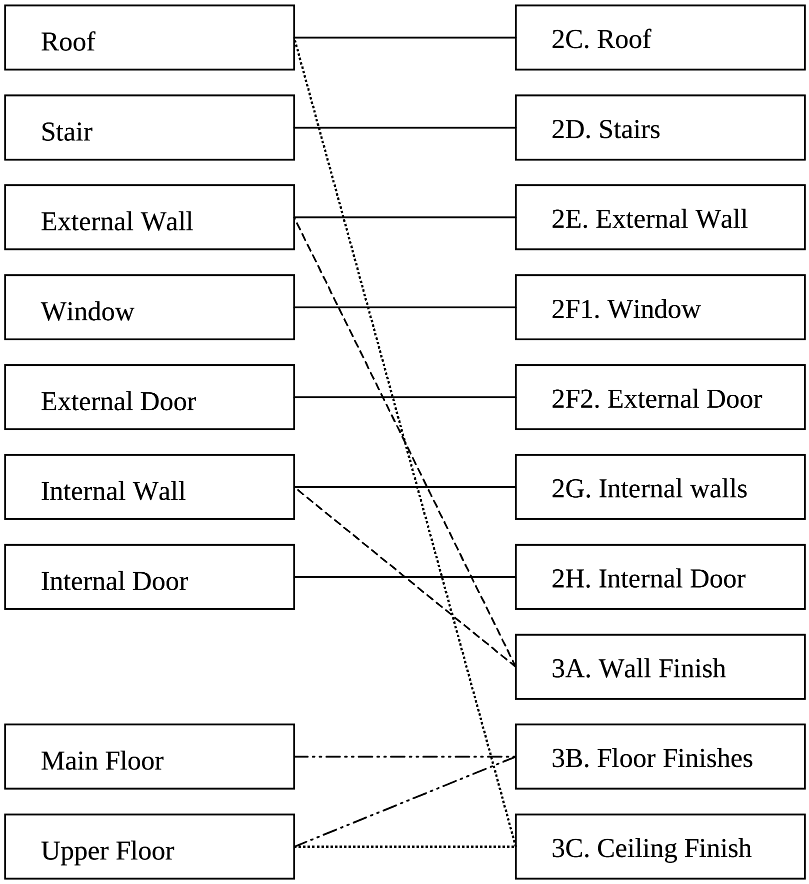

Fig. 5. Grouping of BCIS elements into building objects

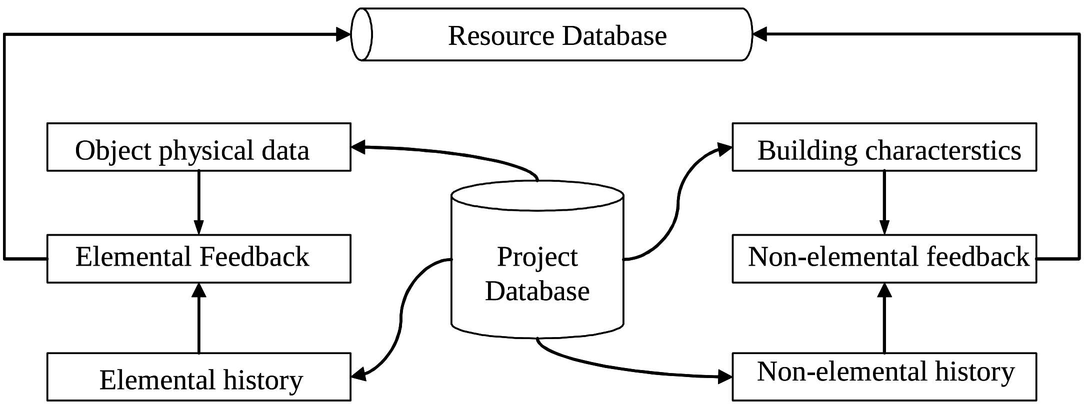

Fig. 6. The implementation mechanism.

The feedback process is done in the following steps:

- The building physical and general data are retrieved from the project database.
- A connection to the resource database is established.
- The resource database is checked for an existing record for the building. Otherwise, a new record is inserted.
- The records of elemental costs for the current year are retrieved from the project database. Each cost item is transformed to a cost rate through interpretation with the corresponding object/building physical data. Then, a record is inserted in the corresponding table in the resource database.

- The records of the building non-elemental data for the current year are retrieved from the project database. Then, a record is inserted in the corresponding table in the resource database.
- The connection to the project database is closed.
- The connection to the resource database is closed.

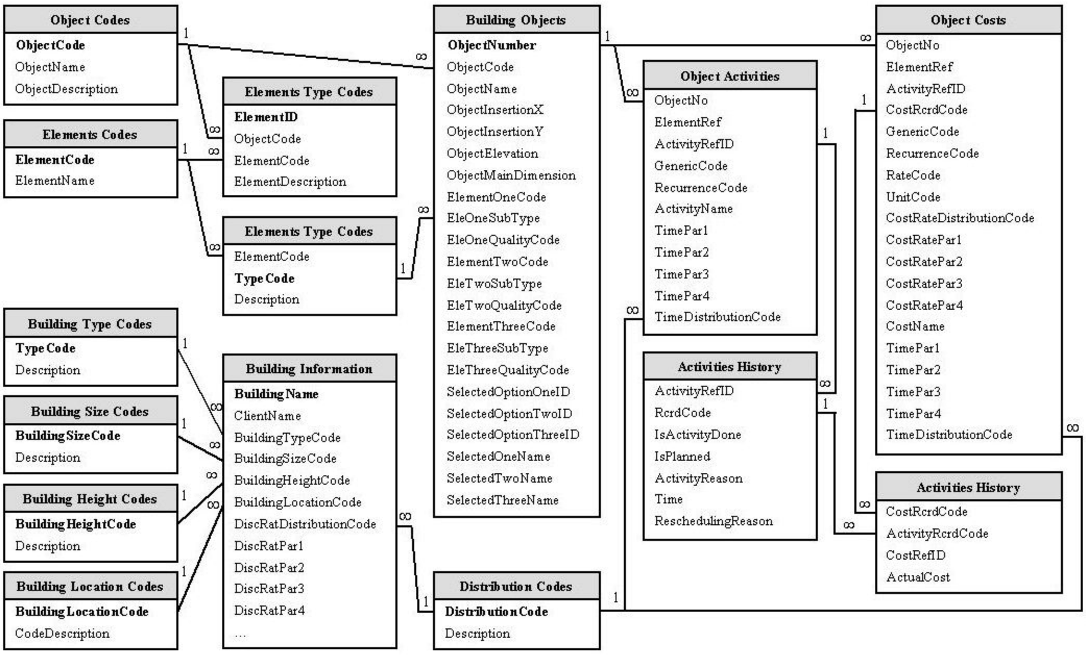

Fig. 7. The structure of the extended project database

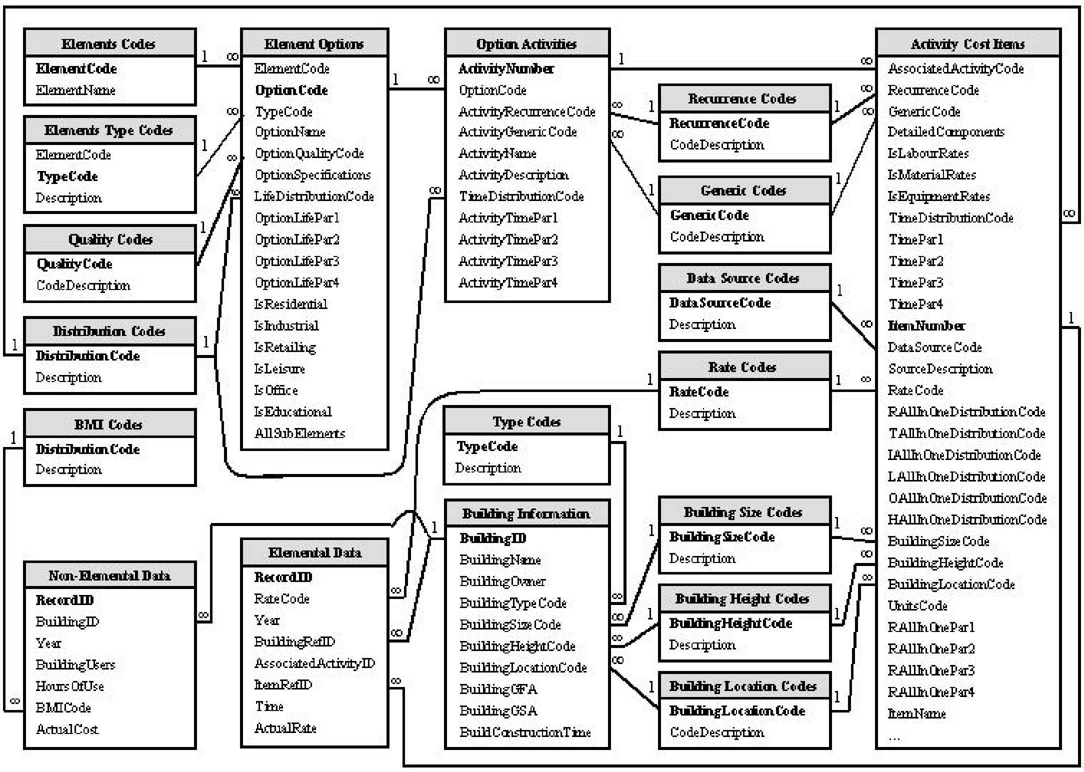

Fig. 8. The structure of the extended resource database

The feedback process aims to provide the link between occupied buildings and similar subsequent buildings whereby performance and cost data collected during the occupancy stage can be fed back to the design stage. In this way, the design of new buildings will be based on real information leading to informed WLC-based decision making during the design process. Without this feedback loop, however, this process will remain entirely based on arbitrary assumptions or expectations. More details of the feedback algorithm and implementation of the CBS are given in Kishk et al. (2002a, 2002b, 2003b).

5. CONCLUSIONS AND THE WAY FORWARD

Almost all cost breakdown structures currently in use for built assets are limited in scope. Besides, they are too broad to be useful at the design stage where the use of the technique is beneficial. Furthermore, they do not provide a means for recording the context information of cost data, e.g. the occupancy profile, type, size, location of the building. Without being supplemented by this information, any collected data is of an uncertain value.

Based on an in-depth analysis of the requirements of effective WLC, a novel CBS has been developed. This CBS has five unique merits. First, it puts forward a systematic framework for data collection and recording keeping its context information. Secondly, it is flexible and handles data on 6 useful levels: the whole building, building objects, building elements, activities, cost items, and resources. Thirdly, the employment of the concept of the 'building object' enables manipulating various areas and components of the building in a practical and convenient manner. Fourthly, there is no limit on the number of activities, cost items or resources that can be attributed to these options. Finally, and more importantly, it has been integrated into a practical feedback mechanism that can link occupied buildings to the design process.

The CBS and its implementation mechanism, however, handle elemental and non-elemental costs independently. It should be developed further to cover the interaction of various building elements and operating costs of the building. Besides, the transformation of actual costs to cost rates is done through a predefined code that identifies which object/building physical quantity to use. In the future, a procedure should be included to identify which physical quantities have the greatest correlation with actual costs.

6. ACKNOWLEDGEMENTS

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