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An Expert System That Estimates Budgets For Residential Construction Projects

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Abstract

This paper describes the development of a knowledge based system (KBS) that produces strategic cost estimates for residential construction projects. This system is building on the results of an Alvey Community Club project that produced the commercially successful ELSIE system that budgets commercial developments. While there are similarities to ELSIE, the new system has to deal with multiple properties on a single site. The paper describes the implementation and object oriented architecture of the expert system. It also describes the advantages that AI technology brings to this problem; namely, reducing the quantity of data input, since a KBS can infer data. This enables the system to provide strategic estimates before plans have been draw up. Moreover, the system can use its knowledge to explain its conclusions. This gives greater confidence in the system's results.

This paper describes the background to this specific KBS, briefly outlining how its development has been managed. It describes its implementation, some specific features, and the benefits of the system. The paper concludes with the potential for further development.

1. Introduction

The LC-Budget system is one knowledge based system (KBS) of a pair developed at the University of Salford. LC-Budget was developed as part of a DTI/SERC funded project known as EDESIRL (the **E**volutionary **D**evelopment of **E**xpert **S**ystems in **R**eal **L**ife). The other system of the pair is LC-Maintenance Plan, a strategic housing maintenance planner [Watson et al., 91 & 92a]. The pair of KBS have been developed as part of a project researching a client centred approach to KBS development aimed at small and medium sized enterprises (SME's) [Basden et al., 91; Watson et al., 92b&c].

LC-Budget is intended for use at the feasibility stage of a residential accommodation construction project. Its purpose is to enable the reliable and accurate estimation of budget costs and the speedy evaluation of alternative solutions before detailed plans have been produced.

An Alvey Community Club project at the University of Salford developed a similar integrated KBS package called ELSIE that is now commercially available and is used widely within the UK construction industry [Brandon, 88; Ashworth, 88]. LC-Budget represents a development of the ELSIE system, progressing the knowledge into new domain (ELSIE has two variants dealing with commercial and light industrial projects). LC-Budget also moves ELSIE's rule-based structure into an object-oriented architecture.

2. Development of the System

LC-Budget has been developed using a "Client Centred Approach." Basden [89] believes that a problem common to most current KBS development methods is that they are technology centred. They place too much emphasis on the activities used to develop the systems, such as "elicitation," "implementation" and "verification", and not enough emphasis on what the clients can see and understand. It has been argued that by putting people at the centre of the development process [Diaper, 87 & 89] there is a greater chance of the resulting system being useful.

The Client Centred Approach (CCA) is a staged method covering the development life cycle of a KBS. It provides milestones to guide the project. These milestones refer to what the clients can see being demonstrated and not to the conventional tasks of elicitation, acquisition, and so forth. This accepts that the clients may not understand the jargon or the distinction between the tasks involved in development but will be able to perceive changes in the

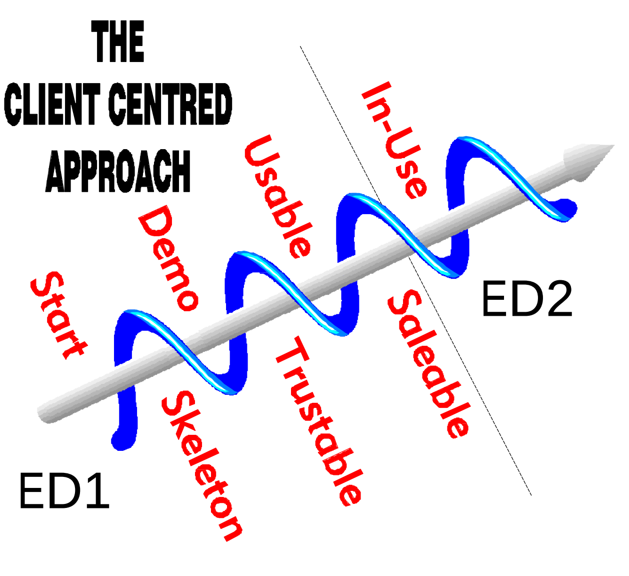

Figure 1 Seven Stages of the CCA

evolution of the system.

LC-Budget has been developed in close collaboration with the Royal Institute of Chartered Surveyors and twenty or so of their professional members. It is these surveying practices who have been the research team's "clients." The background and details of the CCA are given in full detail in [Basden et al., 91; Watson et al., 92b&c].

3. System Overview

3.1. Architecture and scope

LC-Budget was implemented in the object-oriented development environment Kappa-PC™ produced by Intellicorp™. LC-Budget is intended to be operated by building professionals such as quantity surveyors, general practice surveyors, project managers and architects working for, or on behalf of, housing associations, local authorities, private developers and construction companies. This target user group are not assumed to be computer experts.

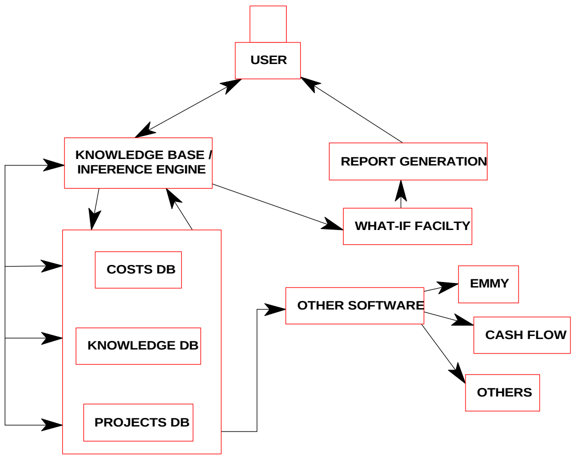

Figure 2 System Architecture

The system is designed to provide the user with maximum flexibility and the system developer with simplified maintenance. A basic schematic diagram of the system architecture can be seen in **Error! Reference source not found.**.

The bulk of the knowledge representation is maintained within a main knowledge base where it is most easily integrated with the inference mechanisms. Knowledge that changes with time such as costs (rates, quality and complexity plussages etc.) and constants (some building dimensional and geometric criteria) are stored in separate databases as dBase III files. This enables users to receive periodic updates to this information. It also allows them to change the data themselves if required.

User flexibility is provided by the reporting and what-if facilities. These provide complete details of the project, as interpreted by the system, and enable any answers previously given by the user, or assumptions made by the system, to be changed. The consequences are then be propagated throughout the knowledge base.

Hooks for communication with other software are also provided. These are intended to talk other members of the LC family and to other third party software (e.g., word-processors, DTP's, spreadsheets and software designed for use further along the building design path).

LC-Budget has been developed with knowledge pertaining specifically to traditional single family housing types. However, future development is planned to encompass dwellings of multiple occupation such as blocks of flats, communal accommodation, nursing and student residencies, sheltered accommodation, etc.

3.2. Operation

The system has three distinct operational phases:

1. Entry of dwelling details.
2. Entry of external works details.
3. Reporting and what-iffing.

In the first phase users are asked to enter details of each dwelling (or group of like dwellings) on the projects. Typical details would include the building type and items falling into the following basic categories:

1. site
2. funding
3. timing
4. specification
5. planning
6. client body

The result will be a Budget Cost for all the dwellings on the project.

The second phase asks for the entry of details applicable to site works such as roads, car parking, street lighting, landscaping, security, etc. The result, when combined with phase one, is a Budget Cost for the project as a whole.

The third phase informs the user of the results and allows for their interrogation. The project can be saved to a project's database at this point and it would also be the entry point for projects retrieved from the database.

The cost forecasting is based on standard Building Cost Information Service elements. The rates are adjusted to reflect the timing and location of the project as input by the user.

LC-Budget’s knowledge about house design enables it to construct detailed models of dwellings from general rules. LC-Budget contains design knowledge relating to detached houses and bungalows, semi-detached houses and bungalows and terraced houses.

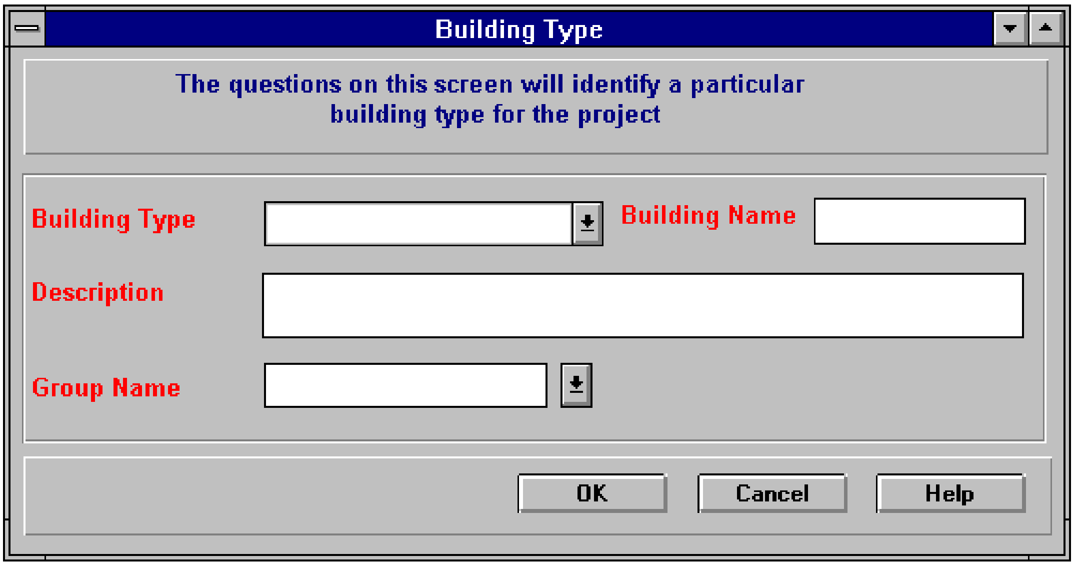

Figure 3 Building Type Screen

To initiate a consultation the user simply selects the house type(s) to be considered from a pull down list (see Figure 3). The system then accesses the knowledge database and retrieves any applicable groups of knowledge.

The user is then prompted for more information about the buildings (see Figure 4). Questions marked with “**” are optional, LC-Budget will use defaults if the user does not answer. Details are passed into the main knowledge base and integrated by the inference engine. As many different house types as required can be entered.

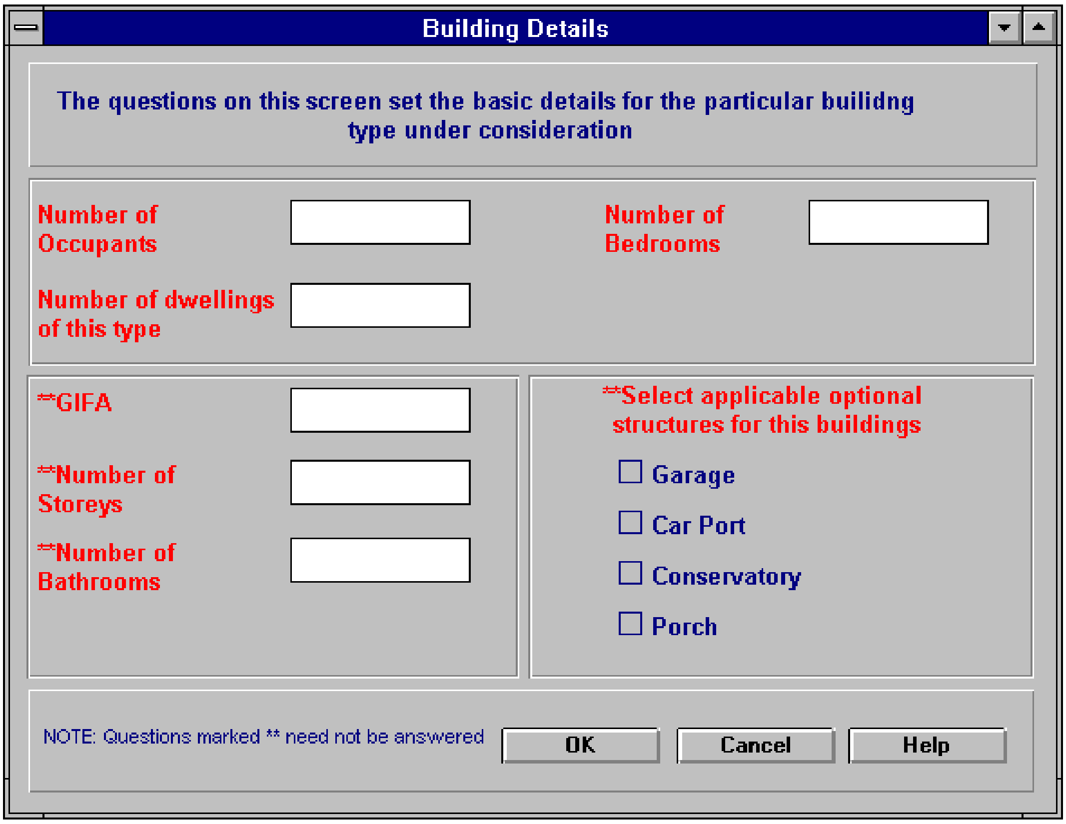

Figure 4 Building Details Screen

3.3. Reporting

Professional users of KBS usually require printed output, either to pass around a board room or meeting or to send to their clients. However, we found that the new generation of KBS development tools place most of their emphasis on the graphical user interface. Indeed many of the Windows based tools the project reviewed before choosing Kappa-PC had worse text reporting mechanisms than their DOS counterparts. A GUI may be suitable for many application areas but for the reasons above LC-Budget had to provide printed reports.

Generating ASCII text files was not too difficulty, but we found that we needed formatting to make the results legible. Considerable effort was put into generating formatted reports in Rich Text Format (RTF) that could then be imported into any standard word processor. Before RTF files are generated the user can view the results in three ways:

1. A project wide report that summarises the whole of the scheme. It comprises of a summary report plus supplementary reports designed to convey a picture of the scheme as a whole as in Figure 5.

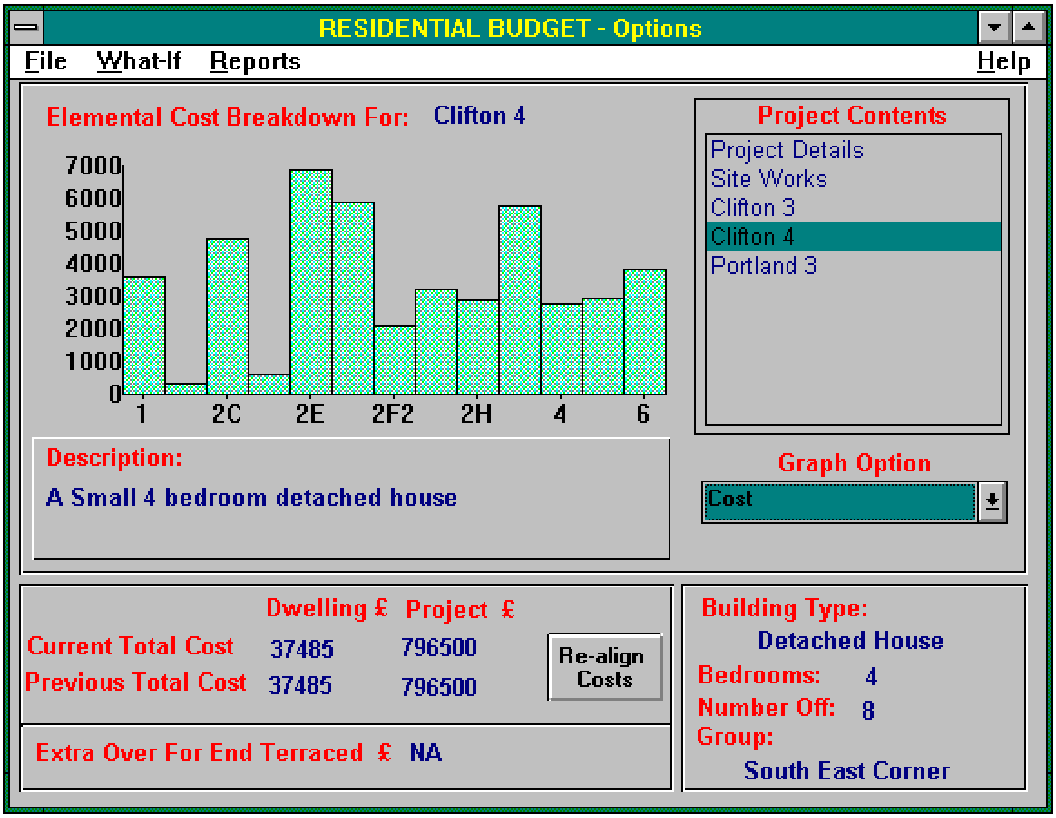

Figure 5 Project Summary Screen

2. A house type report that summarises the results for each house or group of like houses. shows the elemental breakdown report for an individual house as in Figure 6.

3. An assumptions report which itemises, in detail, the line of reasoning and all factors considered in producing the result.

Elemental breakdown

Total GIFA – 73.3992

IdNo	Element	Cost	Cost/ sqm GIFA	EUQ	EUR
1	Substructure	3563	48.55	44.54	80.00
4	Fittings&Furnishings	1016	13.84	1.00	1016.00
2B	UpperFloors	1412	19.25	36.70	38.50
2C	Roof	2895	39.44	44.54	65.00
2D	Stairs	641	8.73	1.00	641.00
2E	ExternalWalls	4824	65.72	109.64	44.00
2F	Windows&ExternalDoors	5991	81.63	25.97	230.74
2H	InternalDoors	196	2.67	1.00	196.00
2G1	Partitions	35	0.48	1.00	35.00
2G2	PartyWalls	30	0.41	1.00	30.00
3A	WallFinishes	25	0.35	1.00	25.50
3B	FloorFinishes	32	0.44	1.00	32.00
3C	CeilingFinishes	28	0.38	1.00	28.00
5A	Sanitary&DisposalInstallations	1516	20.65	1.00	1516.00
5D	WaterInstallations	32	0.44	1.00	32.00
5H	ElectricalInstallations	1266	17.25	1.00	1266.00
5I	GasInstallations	116	1.58	1.00	116.00
5K	ProtectiveInstallations	46	0.63	1.00	46.00
5L	ComunicationInstallations	41	0.56	1.00	41.00
5M	SpecialInstallations	91	1.24	1.00	91.00
5N	BuildersWork	266	3.62	1.00	266.00
5G	VentalatingSystems	216	2.94	1.00	216.00
5F	SpaceHeating&AirTreatment	2016	27.47	1.00	2016.00
6B	Drainage	22	0.30	1.00	22.00
6A1	SitePreparation	26	0.35	1.00	26.00
6A2	SurfaceTreatment	28	0.38	1.00	28.00
6A3	SiteEnclosure&Division	16	0.22	1.00	16.00
6A4	Fittings&Furniture	16	0.22	1.00	16.00

Print report | View house report | Exit

Figure 6 The Elemental Breakdown of a Single House

3.4. What-iffing

What-iffing provides the user with the opportunity to interrogate the project results. Through a series of screens access is provided to all variables, either those inputted by the user or those assumed by the system. By intelligent use of this facility the user can quickly assess the effect of changes in project parameters.

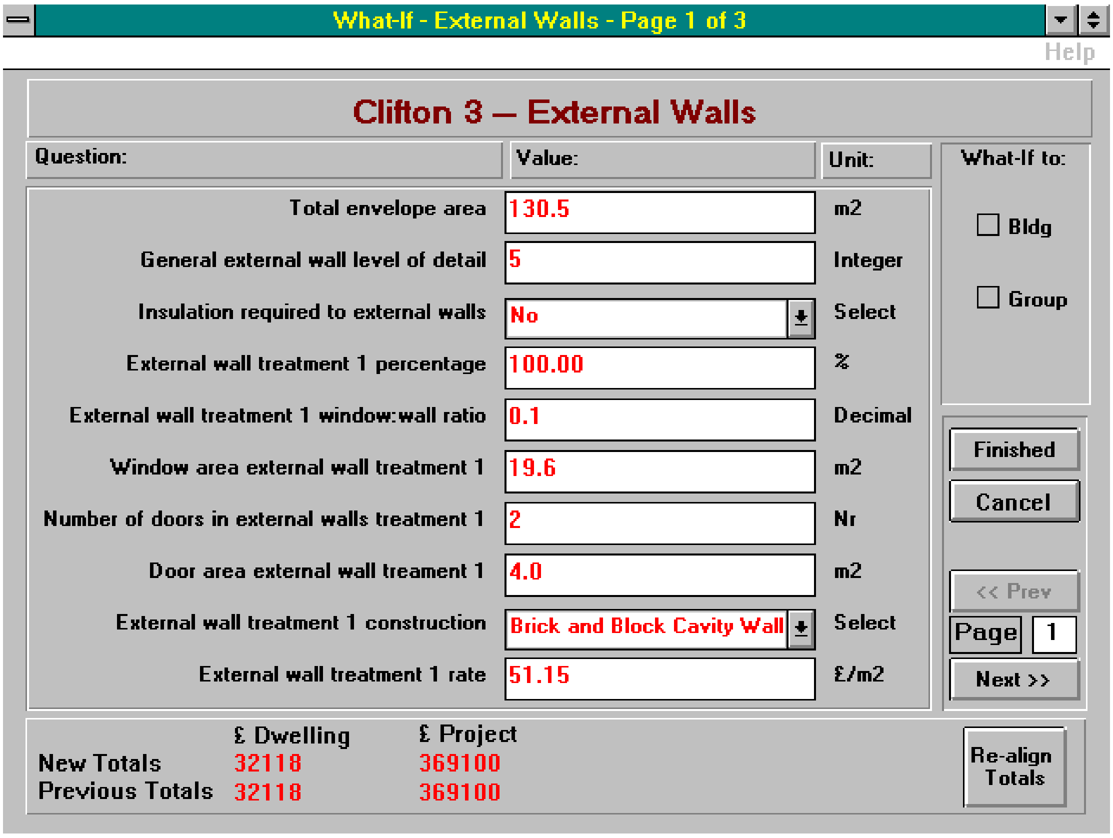

Figure 7 Page 1 of the External Walls What-If Screen

The what-iffing facility operates by a data driven propagation through an inference net. Thus if the user changes the default Facings this cause the Base Rate to be recalculated. This in turn causes the Front External Wall Rate to be recalculated which then results in the Front External Wall Cost being recalculated. Finally, The Cost of the external wall is recalculated. This inference net is shown in Figure 8.

4. Differences from Conventional Software

One of the fundamental strengths of a KBS is its ability to reason with uncertainty or incomplete knowledge [Alty & Coombs, 84]. Where specific information is unavailable, LC-Budget makes reasoned assumptions.

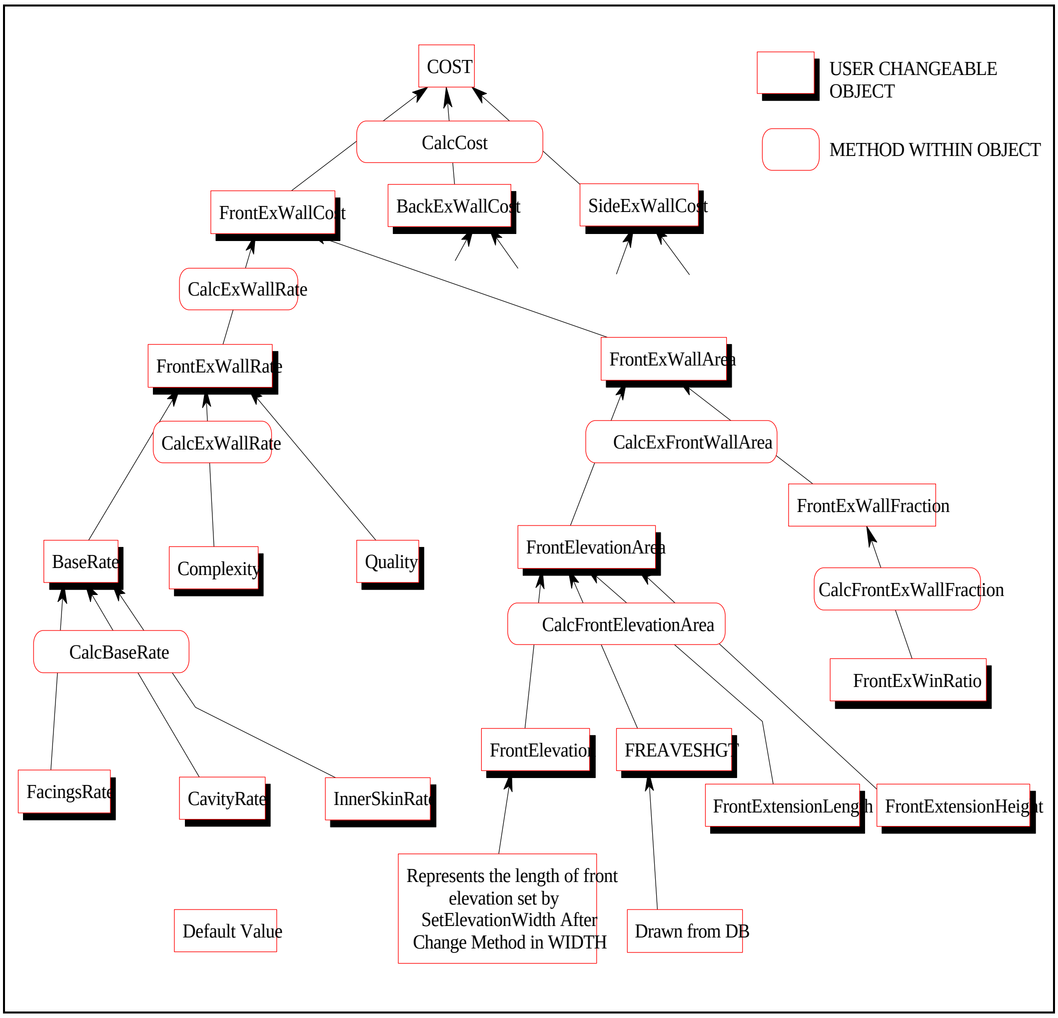

Figure 8 The Inference Net for External Wall Cost

Although there are many computer systems that provide budget estimates, they all share three problems:

- they require a lot of data input,
- they cannot explain how they obtain their results,
- and they tend to be inflexible.

However KBS can directly address all three of these problems [Cryos, 89; Schoenemann et al., 90; Warszawski, 85; Stretton & Stephens, 90]:

- LC-Budget can reason with uncertain data,
- it can explain its result, and
- it allows the user to alter all the system's basic assumptions to explore different alternatives.

This “what-if” facility is central to the use of KBSs as decision support tools [Brandon, 90]. It enables the user to evaluate different options based on varying criteria. In this way the user can explore a full range of possibilities and how they affect the result as well as how the results were obtained. Since its functions are no longer obscure, user confidence in the system's results is improved.

5. Benefits

The setting of a realistic budget for any construction project is of great importance. The use of a KBS such as LC-Budget to assist in this area allows the user to evaluate many alternative solutions relatively speedily and with reliable accuracy. The following benefits accrue:

- The system can infer data where it is missing or unavailable, thereby reducing data input.
- The consistency of approach and the output format provided by a KBS helps to prevent omissions.
- All relevant details, along with lines of reasoning, are available thus supporting the advice given to the client.
- The user need not be a “computer expert” since the system is designed for intuitive use by building professionals.
- The information can be easily tailored to specific project details and local conditions.
- The methods by which the results will be obtained will be accessible to the user, thereby increasing confidence in the results.
- The user can ask "what-if" so that alternative scenarios can be considered.

Since the users are not simply provided with the results, but are encouraged to explore various possibilities, they must take responsibility for the decisions. Hence, LC-Budget supports decision making. It does not take decisions.

6. Conclusions

The EDESIRL project ended in March 1994. LC-Budget and LC-Maintenance Plan are now being marketed by EMIIS Ltd after being in beta-test with several surveying firms for six months. In the long term it is planned to extend the knowledge domain of the system to cover other types of residential accommodation, as described above, in addition to general family housing.

The integrated package of LC-Budget and LC-Maintenance Plan provides a powerful set of tools that enables strategic decisions concerning many aspects of housing to be explored. The systems are of particular benefit to housing associations and to the smaller developer who may lack specific professional expertise. It is hoped the systems will ensure a more rapid spread of good practice throughout the sector.

The development method that has been used to develop LC-Budget is still undergoing refinement [Basden et al., 91; Watson et al., 92b&c]. The method addresses some of the problems usually associated with rapid prototyping [Berry & Broadbent, 86], in particular, auditing the development process, and project management. We believe that involving construction industry professionals in the development of their own KBS is essential for the technology’s acceptance [Brandon & Watson, 94].

Acknowledgements

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