INTEGRATION OF COST PLANNING IN ARCHITECTURAL DESIGN OF HOUSING - "CP/CAD MODEL"

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ABSTRACT

Cost estimation in the initial phases of a project is of great interest to the construction industry. This paper proposes a new way of the integration of an architectural project and its cost estimate so as to optimise the design solutions, according to technical and economic criteria. This work explores the capacity of an elemental cost estimation method for residential buildings, when integrated with Computer Aided Design systems, to increase cost estimate precision during the early stages of design.

A Cost Planning and CAD model (CP/CAD) is developed by the integration of a database and a CAD system which provides for the automatic exchange of information relative to the geometric layout of the building, the construction element build-up and the construction costs of the same.

Finally the CP/CAD model is tested through the estimation of costs for some theoretical cases and also for a group of one-family houses with similar architectural characteristics. The results show the increased precision and the advantages of the model for cost estimation in the early design stages.

1. INTRODUCTION

This article aims to contribute to the optimisation of the process of designing and construction cost estimating of residential buildings during the initial phases of the project. The nature of the problem is to investigate how calculations could be simplified and simultaneously precision of estimates be increased [7].

In terms of Computer Cost Modelling, "Computer Aided Design" systems can contribute to the realisation of construction project management through their ability to store object attributes and properties. However to be able to use these abilities in supporting the economic management of projects it is necessary to conceive the integration of the

graphical and non graphical information of the CAD system with data bases which support the information necessary to the calculation of the cost and quantity forecasts[6].

2. INTEGRATED SYSTEMS FOR BUILDING PROJECTS

New computer technology has allowed the development of support systems to many areas in civil construction. Today there is not one area or phase in which the computer cannot intervene. Nonetheless the problem now is to investigate how computer systems can help designers to carry out alterations in the initial phase of the project in a way which will optimise the interests of the groups involved in the construction process.

Next some examples are given of what has already been produced in research about integrated systems that technically and economically support the conception of buildings.

i) The GOAL education system, was developed by the research group ABACUS (Architectural and Building Aids Computer Unit, of Strathclyde). This system helps the designer to analyse the impact of the layout of the building, its exposure to the sun and the type of alternative materials. Such impact is measured notably against the construction costs and energy consumption [11].

ii) The system developed by Curran and Christie [4], is a system developed with AutoCAD^{TM} software which measures quantities of elements. Through the application of conversion factors adapted to the phases of the project, these data are used for project and construction management, notably as refers to planning and control of costs.

iii) The system proposed by Retik and Warszawski [13, 14], within the scope of CIC (Computer Integrated Construction), is an integrated expert system in support of the design and pre-fabrication of precast structural elements of buildings (beams, slabs, columns). On basis of the client's brief, the system helps the designer by proposing structural solutions and then preparing the detail design drawings necessary to the production of the prefabricated parts.

iv) Another expert system, 'ELSIE', developed at Salford University [6], is the first commercial software to offer consultancy involving economic evaluation and cost estimation in the initial phases of the building project.

3. COST ESTIMATION FOR RESIDENCIAL BUILDINGS

In general, the construction cost of a building plays a major contribution to its total cost. So the need to estimate the construction cost with due reliability in the early design stages is important [9].

In the cost model used for this work, buildings are divided into their main constituent parts and an estimate is developed for each one of these. These estimates are then added up to give a total cost. An example of this type of cost model is the ARC Method [2, 3], which provides a basis for the model herein presented. This method was conceived for the analysis, planning and control of residential building construction costs during the different design phases.

The ARC method divides the residential building into two main types of spaces:

1. dwellings or residential units;
2. communal or private areas outside the dwellings, communal equipment and communal parts (roofs and foundations).

Finally the cost of the dwelling spaces or annexes is obtained through the sum of the costs for three groups of elements: vertical elements, horizontal elements and indoor equipment (services).

4. INTEGRATED COST PLANNING MODEL

This section shows how a model was developed to support the architect in construction cost estimating for residential buildings. Using the ARC cost estimating method as a base, the model aims to increase the efficiency and precision of the method in addition to simplifying and developing the exchange of information between the architectural project and the cost estimate study [8].

The CP/CAD model was conceived and developed using a relational database interconnected with a set of special modules and an operator interface allowing the user to control the system (Figure 1). Each module can be developed using specific programming languages. Although each module corresponding to a given specialty represents a specific function in the project they work in conjunction linked through the database system.

At the moment the software PRO-IV database by Mcdonnell Douglas supports the exchange of information between the following modules:

- The Drawing Module
- The Geometric Analyser

- The Constructive Solutions Module
- The Cost Estimate Module

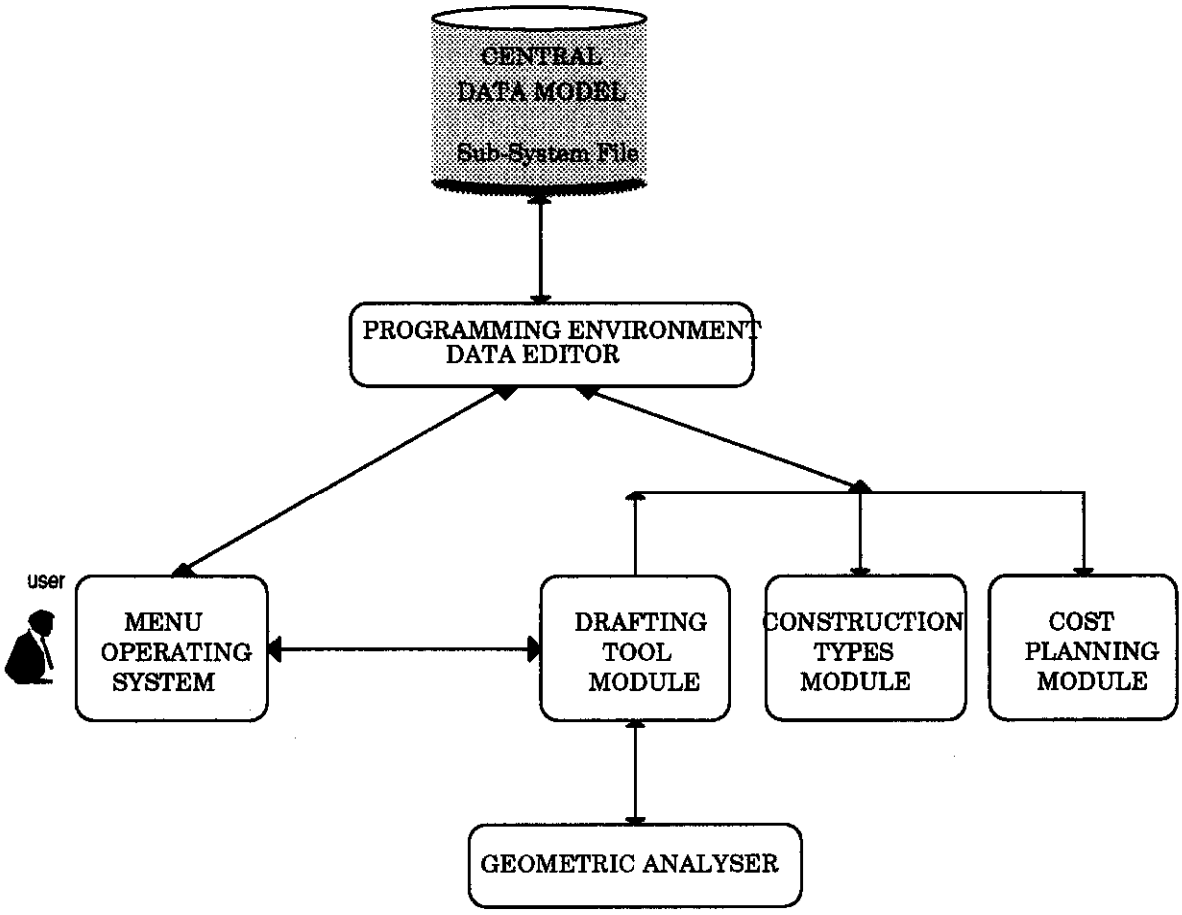

Fig. 1 - Structure of the CP/CAD Model

The first two modules were developed using the software AutoCAD by Autodesk, Inc., while the other two were developed in the PRO-IV environment.

The Drawing Module has its own operative menu system which allows the carrying out of the drawings of the buildings under study, along with changes to them and access to the graphical information contained in the drawings. This graphical information contained in the drawing files produced by AutoCAD is necessary to produce the cost estimates.

The Geometric Analyser Module was developed with the AutoLISP language. Through the attribution of different colours to different types of wall it allows the designer to

automatically define the types of walls along with the measurement of all the perimeters and areas of the building under study.

The Constructive Solutions Module consists of a set of tables referring to the constituent elements of the building. For each table of elements a set of materials is proposed, which in turn are classified by their unit costs and quality level.

These three modules allow results to be obtained which are in themselves useful to the designer. However they also have the function of generating data for the Cost Estimate Module.

The Cost Estimate Module allows the estimation of the construction cost of the constituent elements of the building for the preliminary and sketch design stages of the project.

To manage these modules an operative menu system was developed also within the PRO-IV environment, which through the Main Menu allows the user to do Cost Estimates and also access all of the project information that is contained in the database or in the CAD system.

5. DYNAMIC INTEGRATION OF ARCHITECTURE WITH COST PLANNING

This section aims to explain the validation of the computer cost estimating model which allows the designer to obtain an initial estimate of the construction cost with due precision and check whether this estimation is maintained during the project design using a structure of costs by elements.

First the validity of the principles behind the cost estimating model was tested as refers to the building shape/cost relations on which the integrated system is based [8]. Next one of the one-family houses [15], is used to exemplify how the model easily integrates the architecture and cost analysis in a way to help the designer to compare the solutions and economically optimise the design.

The first study shows that the model is able to represent the changes in the construction costs due to variations in the configuration of the building. The second study shows the potential of the model for dynamic interaction when an layout is considered and its cost estimate calculated. This characteristic is important as usually the designer is prepared to

develop the architecture though it is difficult for him to obtain estimates of alternative solutions with the costs distributed over the main construction elements.

To demonstrate the interactive capacity, the model was used for two houses with the same gross construction area. The differences mostly concerned the exterior envelope and the distribution of the interior walls, with similar types of materials.

- Alternative Solution 1 - Gross Area: 97.1m2

This is the first solution carried out with the Drawing Module from which the designer can obtain a detailed estimate of the construction costs after choosing the materials and the corresponding unit costs from the data base. It is on this plan that the alterations will be made (Figure 2).

In this type of buildings the contribution of the walls including coverings and apertures to the total cost of construction is known to amount to about 48%.

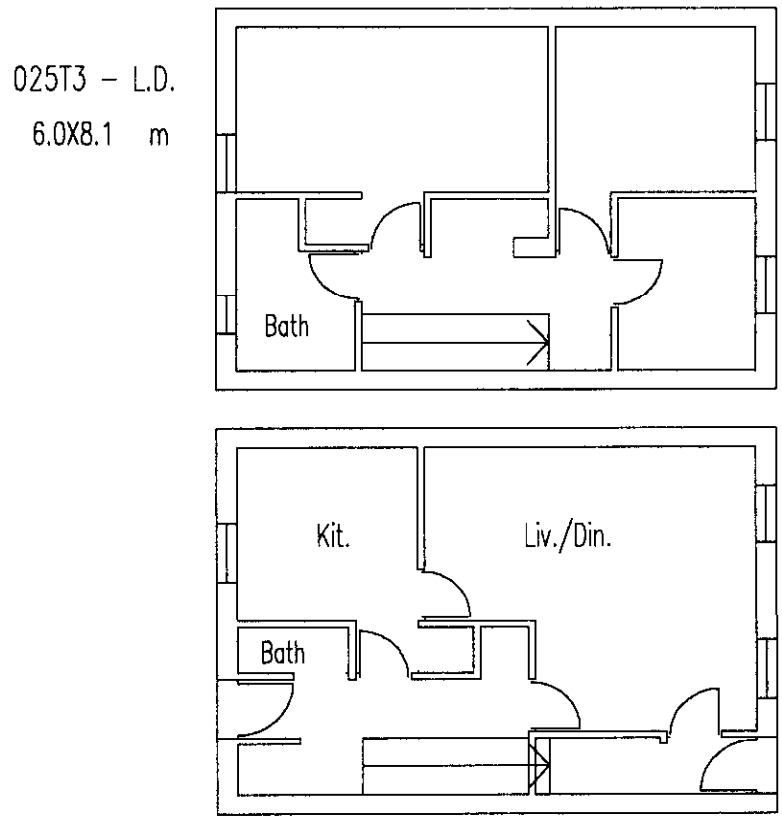

Fig. 3 - Terraced House with 3 Bedrooms

Thus, taking into account such a large contribution, the desiger knows that when changing the distribution of the walls to improve the housing quality in functional terms he simultaneously changes the initial estimate. Nevertheless so that these cost differences

can be noticeable to the designer, he must have easy access to a cost estimating model that quantifies any changes introduced.

Table 1 presents a cost estimate for solution 1; costs are divided into the ten most important groups of elements that characterize the house in the preliminary phase.

Table 1

NFA: 74.8m2	GFA: 97.1m2		
H = 2.5 m	QUA. = 2		
1.	- Residential unit	205.17	£/m2
1.A	- Horizontal Elements	46.03	£/m2
1.A.1	- Upper floors	13.95	£/m2
1.A.2	- Floor finishes of wet rooms	4.54	£/m2
1.A.3	- Floor finishes of dry rooms	27.54	£/m2
1.B	- Vertical Elements	99.22	£/m2
1.B.1	- External wall of facades	19.94	£/m2
1.B.2	- External wall of gables	15.50	£/m2
1.B.3	- Internal wall and partitions	21.64	£/m2
1.B.4	- Internal wall finishes	42.14	£/m2
1.C	- Internal Fittings and Services	59.91	£/m2
2.	- Circulation, External Equipment and Roof	108.09	£/m2
3.	- Frame	30.73	£/m2
	- Building Cost-NFA	343.98	£/m2
	- Total Cost Residential unit	25729.96	£
	- Building Cost-GFA	264.98	£/m2

- Alternative Solution 2 - Gross Area: 96.8m2

Using the computer model some changes were carried out on the envelope and interior distribution, thus obtaining the alternative solution 2, (Figure 3).

Through the analysis of the quantities supplied by the model one finds that a decrease in the facade area occurred although the total exterior area has increased. Also the areas of the so-called wet zones (kitchen and bathroom) did increase.

This new solution is fairly different from the earlier one in functional terms and in the setting-out, though flooring areas and the type of materials have remained unchanged. This means that the estimate obtained through the Construction Area Method, widely used in Anglo-Saxon countries, would be the same for the two alternative solutions. However the estimate calculated with the model and represented in Table 2 show a decrease in the overall cost.

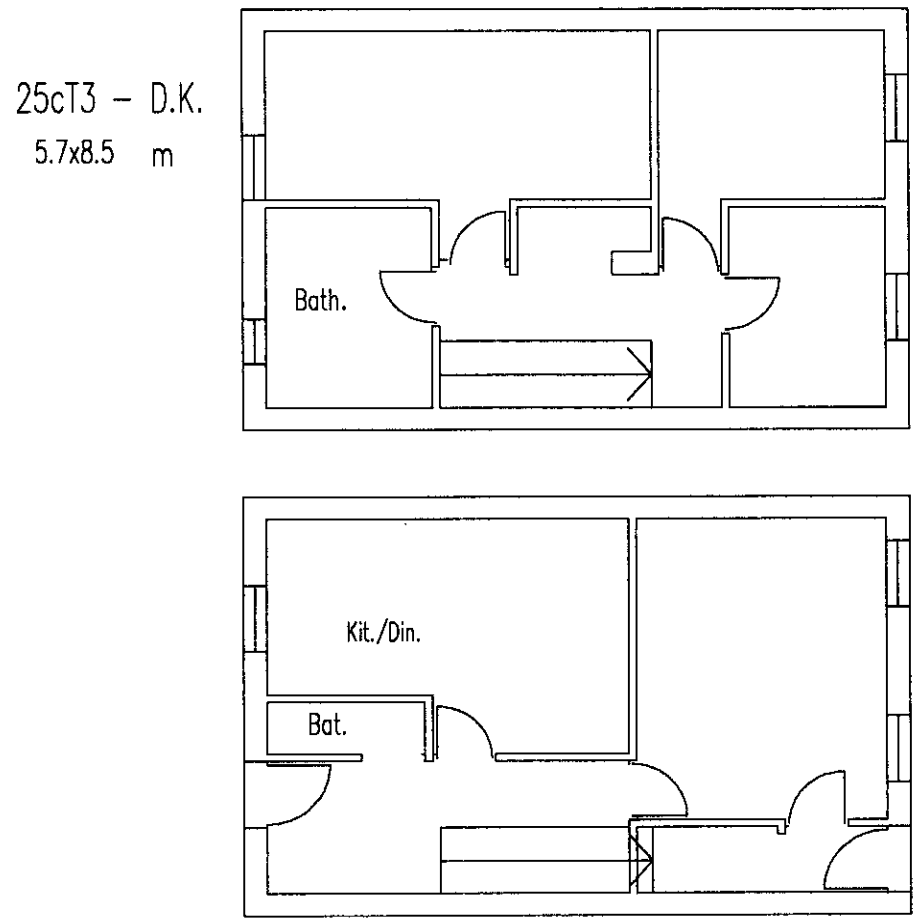

Fig. 3 - Terraced House with 3 Bedrooms

Table 2

NFA: 74.6m2	GFA: 96.8m2		
H = 2.5 m	QUA. = 2		
1.	- Residential unit	199.91	£/m2
1.A	- Horizontal Elements	45.31	£/m2
1.A.1	- Upper floors	13.95	£/m2
1.A.2	- Floor finishes of wet rooms	6.88	£/m2
1.A.3	- Floor finishes of dry rooms	24.47	£/m2
1.B	- Vertical Elements	96.23	£/m2
1.B.1	- External wall of facades	18.62	£/m2
1.B.2	- External wall of gables	16.06	£/m2
1.B.3	- Internal wall and partitions	20.49	£/m2
1.B.4	- Internal wall finishes	41.06	£/m2
1.C	- Internal Fittings and Services	58.37	£/m2
2.	- Circulation, External Equipment and Roof	105.32	£/m2
3.	- Frame	30.71	£/m2
	- Building Cost-NFA	335.94	£/m2
	- Total Cost Residential unit	25061.43	£
	- Building Cost-GFA	258.90	£/m2

It is worth mentioning too that this model helps the designer only through the results of the estimation; in fact, it is up to the designer to analyse the project in what concerns its quality in terms of functionality and serviceability.

6. CONCLUSIONS

The model presented is an application which aims to help the designer in attempting to balance the best architectural layout with the lower maintenance and construction cost.

The direct support to the designer through the interactive calculation of construction cost estimates or through carrying out cost analyses from the information held in the model's database is the primary function of the model. Moreover due to its high precision in elemental cost estimate calculation the model is sensitive to small alterations in the architecture and consequently can be useful in surveying and defining general cost pointers in relation to the global costs such that they too can be helpful to the designer in making his decisions at the early stages of a design.

Finally the model was tested using almost a hundred real projects sample. The results were analysed and the main benefits are as follows:

i) the model reflects the influence of the building configuration on the construction costs by considering some parameters such as perimeter/floor area ratio, building compactness and distribution of internal and external walls;

ii) the model helps the designer to define indicators for the construction costs percentages between the main elements into which the building is broken down;

iii) the model provides the capacity for dynamic integration of the architectural project and cost planning in the initial design phases.

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