A COST-BASED INTERIOR DESIGN DECISION SUPPORT SYSTEM FOR LARGE-SCALE HOUSING PROJECTS

SUBMITTED: August 2007
REVISED: December 2007
PUBLISHED: February 2008
EDITOR: B-C. Björk

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SUMMARY*: In the early stages of a large-scale housing project, many interior design alternatives remain to be confirmed after a rough review of the costs. The project participants move on to the later stages of budgeting and construction without the exact information on the interior costs, and several occasions may arise when costs increase or time delays occur, driven by interior design specification changes resulting from the client's evolving demands during construction. Therefore, it is necessary to determine the costs during the decision-making process for interior design items in an apartment unit plan. This study implements a decision support system for a large-scale apartment building project in which the clients can make cost-based decisions that meet their requirements, while the builders can control both resource planning and interior design construction costs. To perform a cost review for a housing project with a uniform apartment plan, it is necessary to manage the information for the basic apartment plan constituting the interior information. In this study, we developed an information model to support cost-based decision making in the interior design phase. An interior design object library was developed by analysing the relationship of the housing project hierarchy and interior information attributes. The proposed model was validated in an example study to show that the model could support the decision-making process of various project participants by providing real-time cost information when the interior design was created or changed.*

KEYWORDS*: Interior design, Information model, Decision support system, Housing project, Cost management*

1. INTRODUCTION

In a large-scale housing development project with hundreds or thousands of uniform apartment unit plans, unexpected cost overruns can occur when the interior item changes because even one small change in the apartment unit plan has a follow-on effect on hundreds or thousands of apartments when they are built. In general, interior designers consider the overall concept, colour and style according to floor plans, spaces and elements. However, because they generally do not consider the construction work required, the construction and design characteristics are not connected, and the cost and design properties are controlled separately. This is why the real-time management of cost change is not included in the decision-making process. It is therefore necessary to consider the cost when making decisions on interior design items for an apartment unit plan (Lee et al., 2007).

Rapid advances in information technology are changing the nature of most human activities (Bennett, 2000) and are generating new requirements for clients such as the owner/developer in large-scale housing projects. The clients' requirements are stated in ongoing communications among project participants in the early phase of a project and become embodied in the design phase, during which design alternatives must be selected to meet the clients' requirements while satisfying them in a realistic way. A decision support system for selecting design

alternatives is intended to represent design information, document design rationale and manage design changes (Geoffrion, 1987). Many studies on the design phase have focused on the cooperation between various participants such as the architects, engineers and contractors (A/E/C) (Demirkan, 2005; Kalay et al., 1998; Khedro et al., 1994; Lee et al., 2001; Mokhtar et al., 2000), but few studies have examined cooperative systems or decision support systems in which the end-user or client participates in the selection of interior design specifications. In addition, it is unusual to propose a process or database function that accepts and manages the extensive interior design information generated by too many alternatives.

Integrated project systems would help streamline project activities by allowing downstream disciplines to access design information. With this, they could evaluate the design and assess the impact of design decisions on downstream project activities early in the design process (Halfawy and Froese, 2005). It is possible to calculate real-time cost information with precision if the relevant interior design information is integrated and reflected in the design. The calculated cost can then serve as important information to let the owner/developer and various other participants make accurate estimates for the projects they perform.

This study aimed to devise a system that allows clients to make cost-based decisions suited to their own interior design specifications and that enables the builder to plan resource requirements and budget costs. We describe an information model that supports cost-based decision making in the interior design phase. To do this, we derive the space hierarchy for a large-scale housing project. We also propose a method for building a library of interior design information based on the space hierarchy and interior information. The proposed model is validated using an example study analysis to show how it supports the decision-making process of various participants in the interior design phase by providing real-time cost information when the interior is initially planned or later changed.

2. BACKGROUND

2.1 A Concept of Cost-based Interior Design

The space information generated in the architectural design stage is not separate from the interior design, or the cost and work information generated in the interior design stage. As seen in Fig. 1, they are closely related. In this study, an interior design information model was suggested to identify the relevant pieces of information in the interior design stage, combine it according to a conventional information model and allow for cost-based interior design decisions.

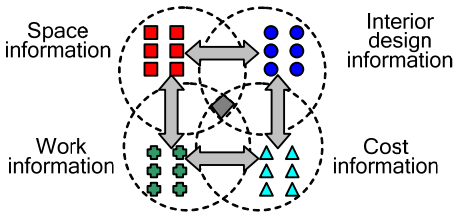


FIG. 1: Information relationship diagram

As shown in Fig. 2, the interior design progresses through the stages of conception, modelling, review, finalisation, detailing, drafting and costing, in that order. Interior designers working on projects come up with design concepts, perform space modelling, review results, fill in details of the finalised design and draft the results, all to calculate the costs for estimates.

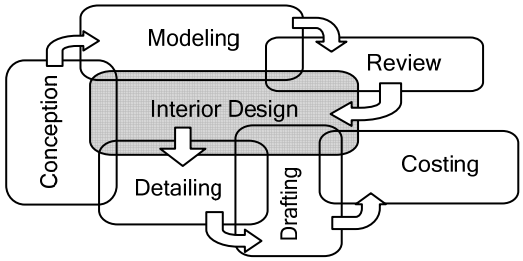


FIG. 2: Interior design phases

In the existing interior design procedure, owners/developers first produce ideas or requests. Then interior designers propose designs and alternatives, and the results are initially reviewed without any consideration of cost. In the detailed design stage, the owner/developer does review the interior design accompanied by costs. However, the procedure is a long one, and is subject to many problems in feedback concerning alternative design proposals (Lee et al., 2007).

Parametric cost estimation models have been developed (Kim et al., 2004). Regression, or multiple regression analysis as it is usually called, is a very powerful statistical tool that can be used as both an analytical and predictive technique for examining the contribution of potential new items to the overall cost estimate reliability (Hegazy et al., 2001). It is not appropriate, however, when describing nonlinear or multidimensional relationships with multiple inputs and outputs (Huyn et al., 1993). In addition, it is difficult to use parametric methods when the number of alternatives tends be infinite, based on the different items of the design.

Therefore, we propose a procedure in which designers use an interior design object library (IDOL) to select an interior design item based on cost. At that point, the total cost for the interior can be reviewed. The builder's constructability review and the suppliers' availability review of the interior design are not included in this study, but the design information stored in the interior design information model can be used in the construction phase.

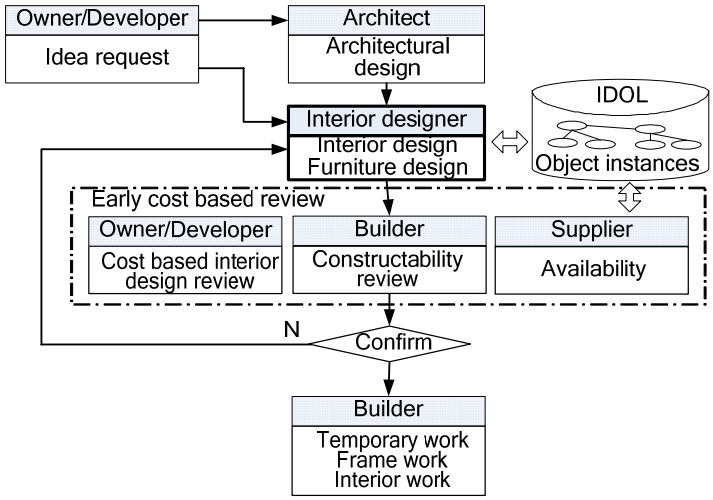


FIG. 3: Proposed cost-based interior design procedure

2.2 A Model for Representing Interior Design Information

Various approaches have been proposed to provide structure to product models. Early efforts included the A/E/C building systems model (Turner, 1990) and the general A/E/C reference model (GARM) (Gielingh, 1998). The major standardisation effort in product modelling today is ISO-STEP from the International Standards Organization (Hegazy et al., 2001), and in recent years, researchers in the A/E/C industry have devoted considerable attention to the representation of design information and the management of design changes.

Researchers and practitioners have been investigating improved integration, that is, the continuous and interdisciplinary sharing of data, knowledge and goals among all project participants (Hegazy et al., 2001; Luiten and Tolman, 1997). The architectural information model proposed in these studies manages the creation, modification and exchange of the spatial design information created for all participants in the process for A/E/C purposes (Hegazy et al., 2001). Other studies have proposed building information models from various different perspectives. Anwar (2005) studied methods of structural analysis, modelling and design with structural mechanisms for major members (e.g., foundation, column, beam, wall, slab) in building structures using a structural information model. Choi et al. (2007) provided a building data model including building components such as building, plan, space, ring, wall skeleton, surface and column, for structured floor plans. Fig. 4 shows the building project hierarchy (BPH) of a building information model.

In this study, the structured floor plan (Choi et al., 2007) was used as the basis of the interior design information for housing projects. The structured floor plan is roughly divided into private space and public space. Its major components are surfaces such as floors, walls and ceilings, and non-surfaces such as furniture, windows, doors and lighting fixtures. These are the major components of private space for an apartment unit plan and serve as the primary focus of this study.

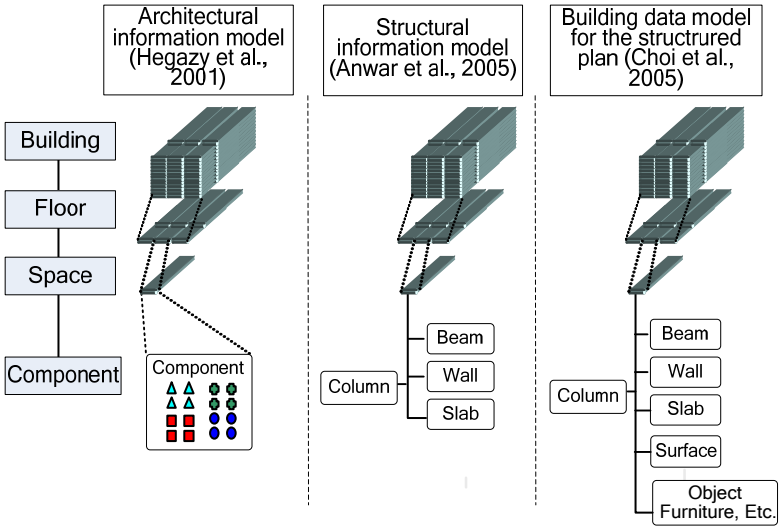


FIG. 4: Building project hierarchy according to the building information model

3. NEED FOR AN INTERIOR DESIGN DECISION SUPPORT SYSTEM

3.1 Communicating with Clients in Deciding Interior Design Specifications

The evaluation of design alternatives is an important ongoing phase in the design decision stage and when producing new design concepts. Participants select the best design alternatives using a variety of evaluation methods (Lee et al., 2001). Usually, expert users such as designers, engineers and technicians select the design alternatives (Demirkan, 2005).

Most design decisions are made intuitively without predicting the actual performance with respect to a variety of parameters such as lighting, energy and comfort (Reichard and Papamichael, 2005). In addition, design decisions are made by expert project participants without regard to the requirements of the occupants in terms of space, element colour, pattern, texture and materials. Consequently, the clients frequently change the interior design when they review the feasibility study and plan the target cost. The added cost, time delay and construction waste generated by such changes lead to claims and waste resources. Therefore, a decision support system must allow client input when the interior design specifications are selected.

As shown in Fig. 5, the owner/developer's requirements lead to design alternatives for each room, and the alternatives are incorporated in space (i.e., the unit plan) in the interior design stage. Also present at this stage is a deluge of cost information, which makes it difficult to generate and manage the costs that predominate in project. Such a problem is also linked to the communication difficulties among the project participants such as the owner/developer, interior designer and builder.

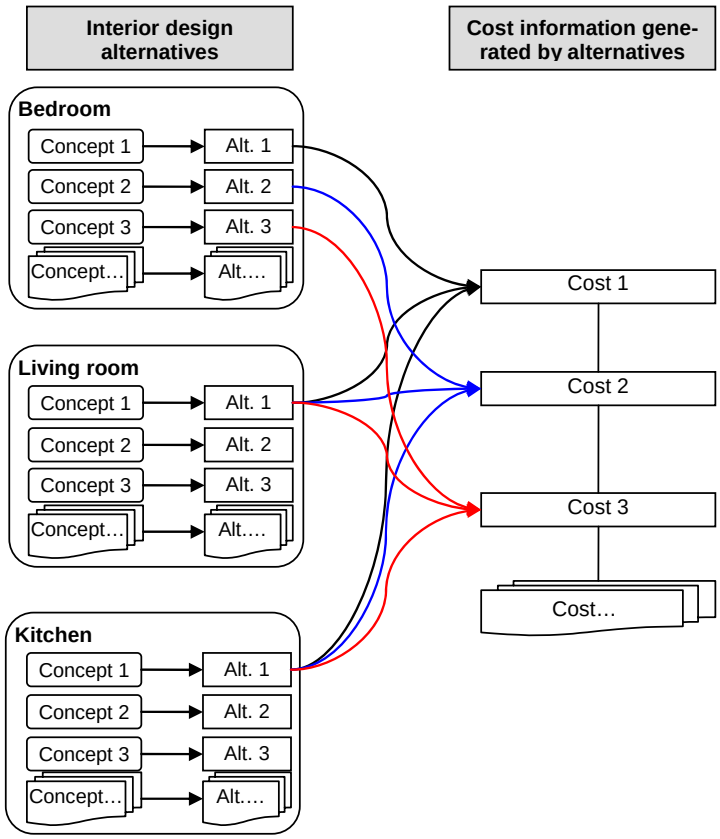


FIG. 5: Cost information generated by interior design alternatives

3.2 Providing a Cost Baseline when Selecting Interior Design Specifications

In general, interior designers consider the overall concept, colour and style according to floor units, spaces and elements. They often do not consider the work items involved in construction. As a result, the construction and design characteristics are not connected, and the cost and design properties are controlled separately. It is important to manage project costs and time management when evaluating a construction project. Project cost management deals with the procedures to ensure that the project is completed within the approved budget. The Project Management Body of Knowledge explains project cost management as a four-phase process consisting of resource planning, cost estimation, budget establishment and cost control (Project Management Institute, 2000). By linking this with the project work breakdown structure (WBS), we propose a cost baseline to control costs during the design phase, which enables the builder to examine resource and cost planning during the interior design phase of a project. Our system reports the changes that a client makes to the interior design, which affect resource planning in the WBS and alter the costs.

3.3 Managing an Interior Design Object Library for Integrating Design and Cost Information

During the detailed design stage, a vast amount of largely interrelated design information is generated. This information should be adequately communicated among the various professionals involved in the design to enable them to make mutually compatible decisions (Mokhtar et al., 2000). Much research has suggested using an integrated building model to identify, classify and structure the building elements and components using standard classification methods (Dawood et al., 2003). Almost all existing models including the RATAS system by Björk (1989) place the design systems at an upper level of the hierarchy. Other models such as that of Garza and Alcantara (1997) incorporate multiple BPHs from the same building. We propose an alternative BPH representation to unify the storage and manipulation of building data and avoid redundancy. As illustrated in Fig. 6, the proposed BPH has five levels.

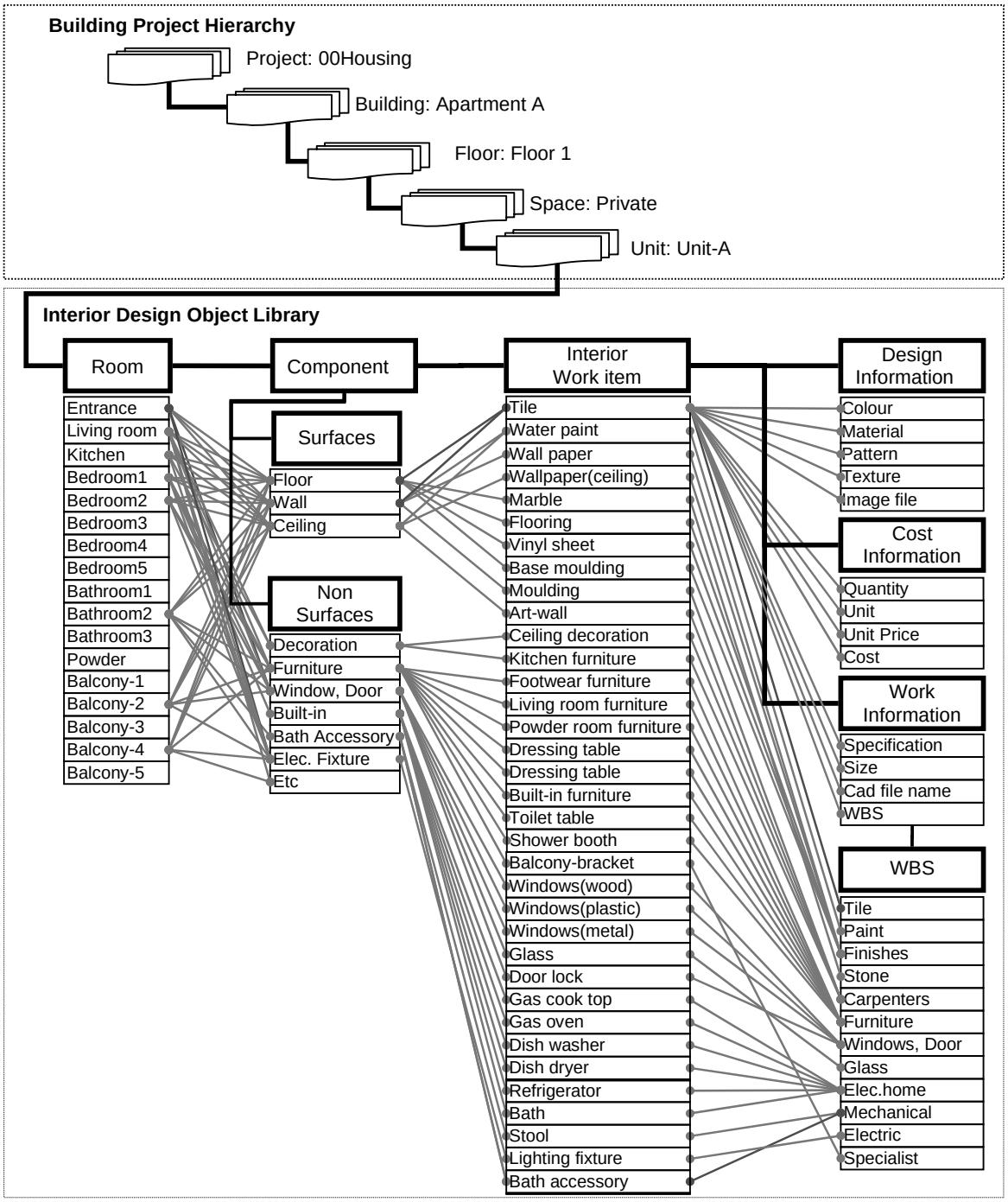


FIG. 6: Relationships with interior design objects (work items), spaces, unit, room, component, and design, cost, work information

To control costs during the interior design phase, interior design information, process characteristics, and cost information must be interrelated. To control the information on the finishes work item generated through the interrelation of the construction and design characteristics, we developed an IDOL. We used a relationship analysis to examine several completed apartment projects to identify interior design objects. The relationships involve spaces, rooms, components (surfaces and non-surfaces), work items, and design · cost · work information, as shown in Fig. 6. A work item is defined as an interior design object that is integrated with the proposed BPH. For work items, the IDOL includes the surfaces and Non-surfaces design information (colour, material, pattern,

texture, image), cost information (quantity, unit, unit price, cost), and work information (specification, size, cad file, work breakdown structure), as shown in Fig. 7. Surfaces include floors, walls and ceilings, while non-surfaces include furniture, windows, doors and lighting fixtures. These are the major components of private space for an apartment unit plan and serve as the primary focus of this study.

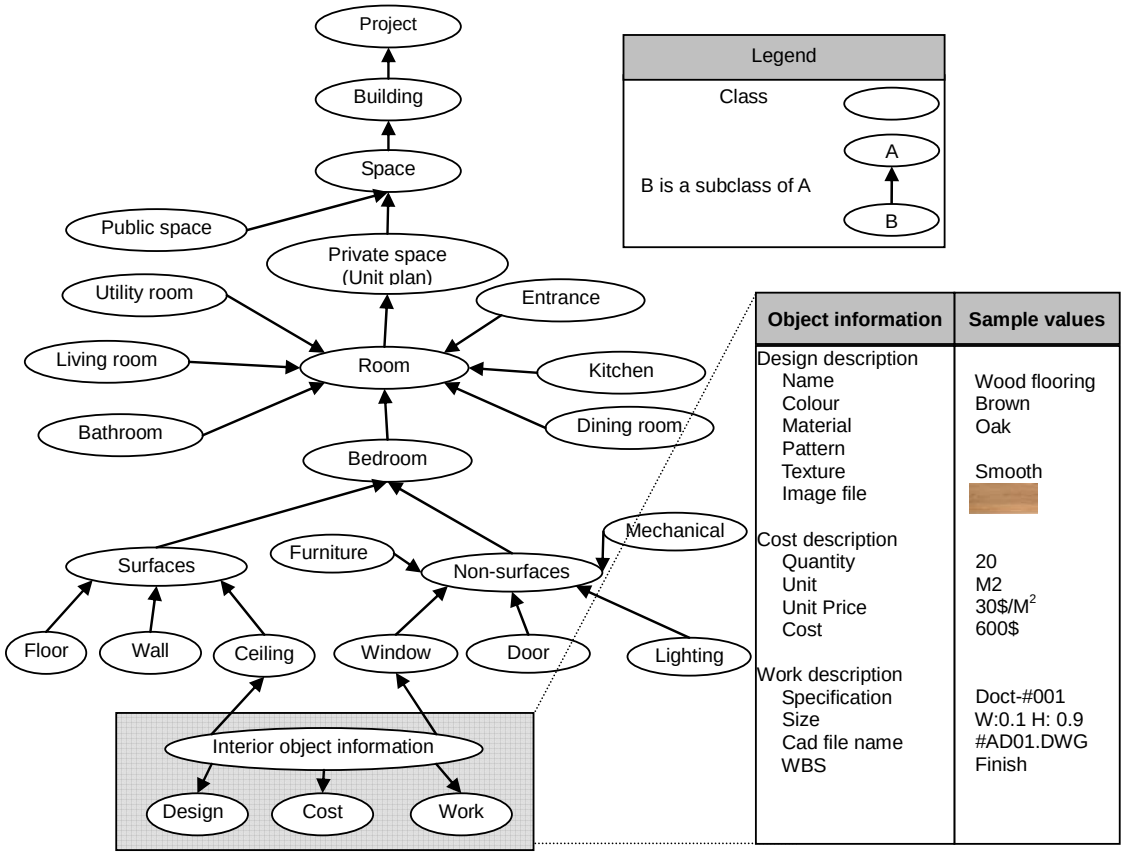


FIG. 7: Hierarchy schematic for interior object information

In this study, the structured floor plan (Choi et al., 2007) was used as the basis of the interior design information for housing projects. The structured floor plan is roughly divided into private space and public space, as shown in Fig. 8.

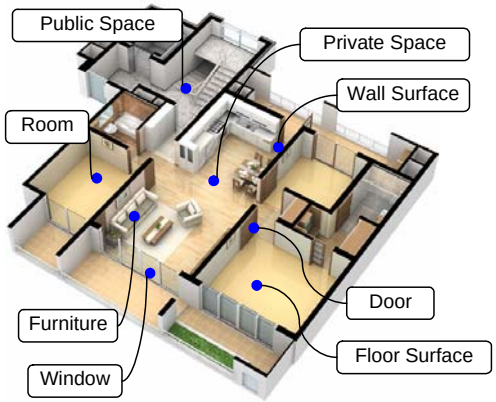


FIG. 8: Basic components of the unit plan

Once the information is integrated, it can be used by each project participant for his or her particular responsibilities as Fig. 9 suggests. For example, the interior designer reviews the costs and plans several different design alternatives for each room based on the unit plan. The owner/developer can review the project costs for each interior design alternative, and the builder will be able to prepare resource and budget plans for each WBS.

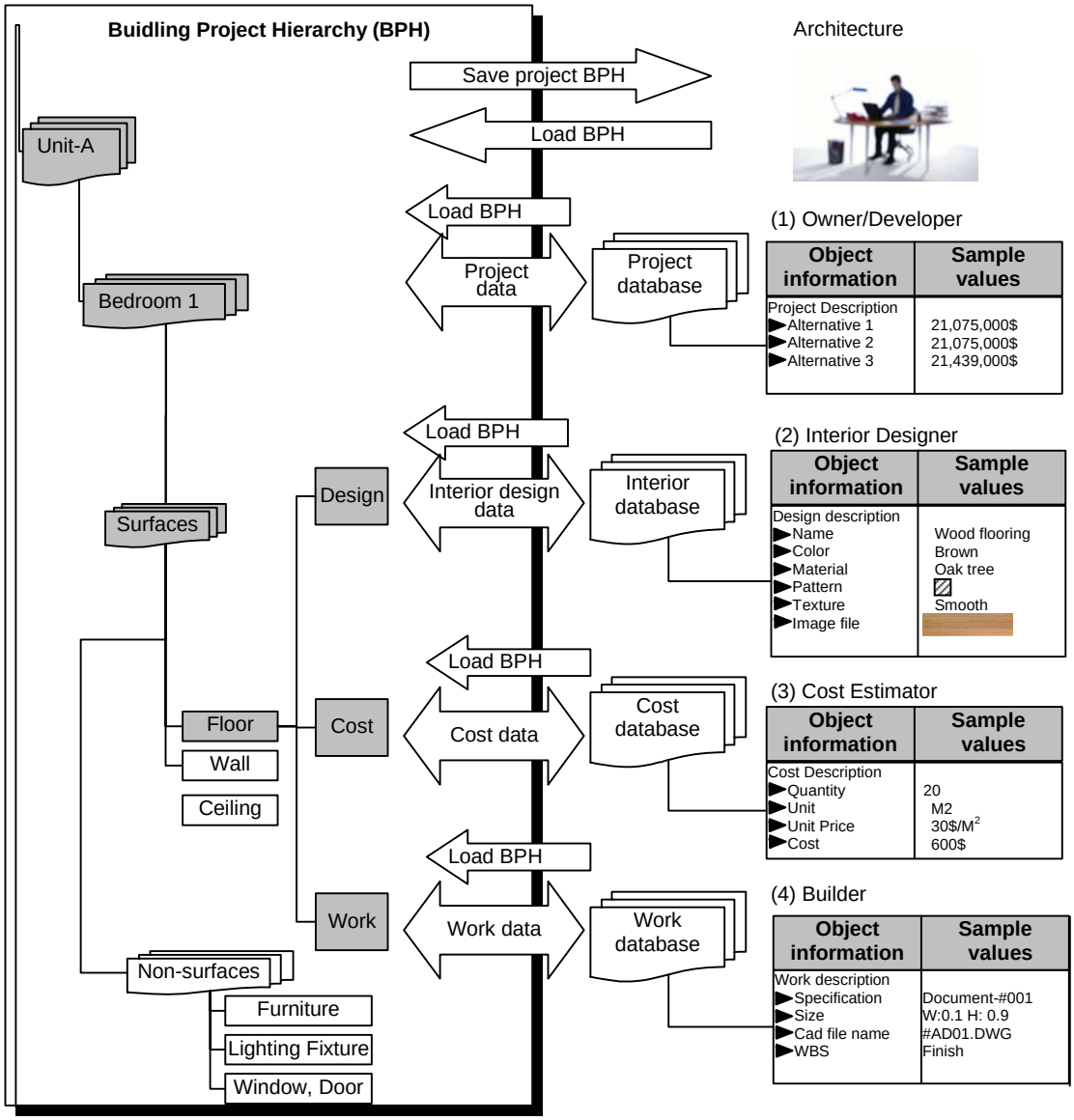


FIG. 9: Multidisciplinary use of the building project hierarchy and the interior design object library

4. SCHEMATIC AND COMPONENTS OF THE INTERIOR DESIGN DECISION SUPPORT SYSTEM

4.1 Schematic of the Interior Design Decision Support System

The Interior Design Decision Support System suggested here is capable of controlling interior design costs and supporting client decisions. This is achieved by referring to resource consumption plans from the early phases of a project, and by implementing and using the IDOL database to link the construction and design characteristics for interior design. The procedure involved is shown in Fig. 10, and the components of the system are described in the following section.

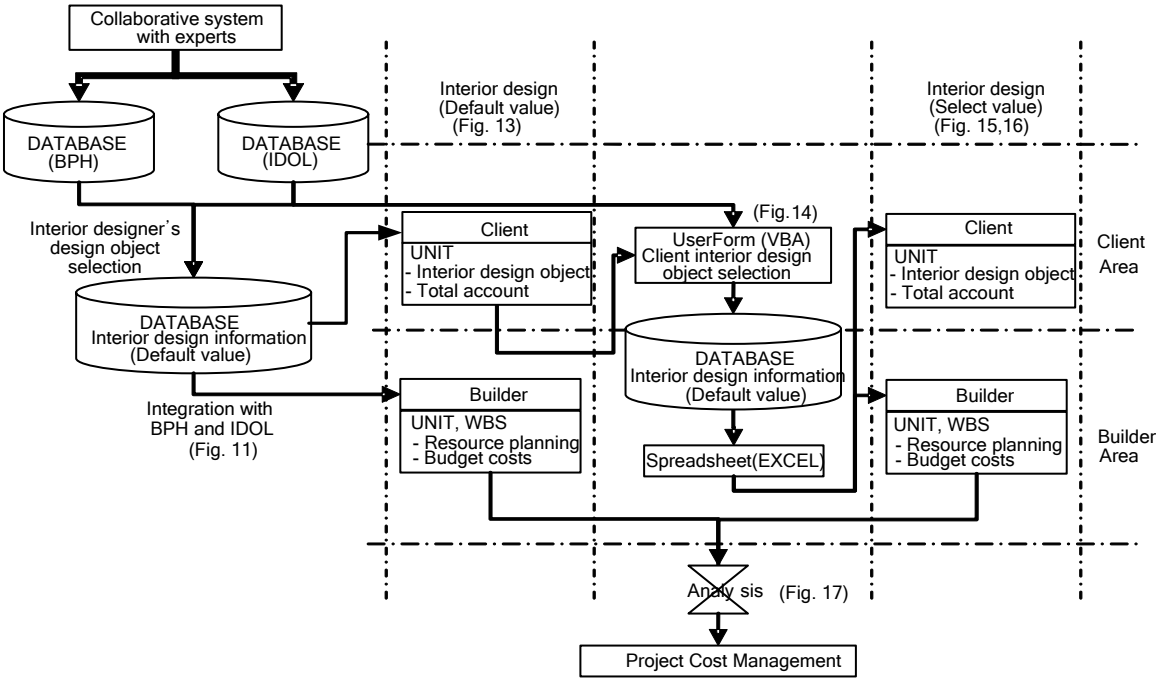


FIG. 10: Schematic of the proposed Interior Design Decision Support System

4.2 Components of the Interior Design Decision Support System

4.2.1 People

The main users of the Interior Design Decision Support System are the client, the interior designer and the builder, who participate in the decision-making process. The interior designer has the responsibility for the interior design process. Once the interior designer selects the default values for the IDOL, clients can change the colour, pattern, texture and material by viewing images of the interior design objects. They can also examine costs, one of the unit measures, on a real-time basis.

As shown in Fig. 10, after receiving a BPH from an expert group involving A/E/C, the interior designers select the default values for the IDOL. Then clients are given the task of making selections from the IDOL. With help from a cost estimator, construction costs are estimated for the selected interior design, and in addition, the particulars of the changes in the IDOL are updated and controlled.

4.2.2 Decision-making Procedure

After the A/E/C group produces the BPH during the detailed design phase, interior designers select the design objects from the IDOL and set the default values for the interior design. Targeting these default values, the clients use the decision support system and make decisions by selecting interior design objects to their requirement from the IDOL. Clients can make decisions either under the constraint of fixed costs (e.g., simply changing the colour of wallpaper), or with the option of variable costs to change the design items.

4.2.3 Information Model

The underlying data of the Interior Design Decision Support System are related to the work involved and the costs of the interior specifications. As stated previously, the information on interior design decisions comes from the creation of the IDOL and its integration with the project BPH. As shown in Fig. 6, the BPH consists of five levels: the project, building, floor, space and unit plan. It also tracks the cost for the quantity of the components determined by a cost estimator. As shown in Fig. 11, the proposed BPH and the IDOL produce interior design information that is integrated after being selected by the client. Here, the IDOL holds the elements such as work items, specification, image, colour, material, unit, unit price and work breakdown structure. The interior design

information (the selected value) generated here is displayed and used to meet the requirements of the client and builder.

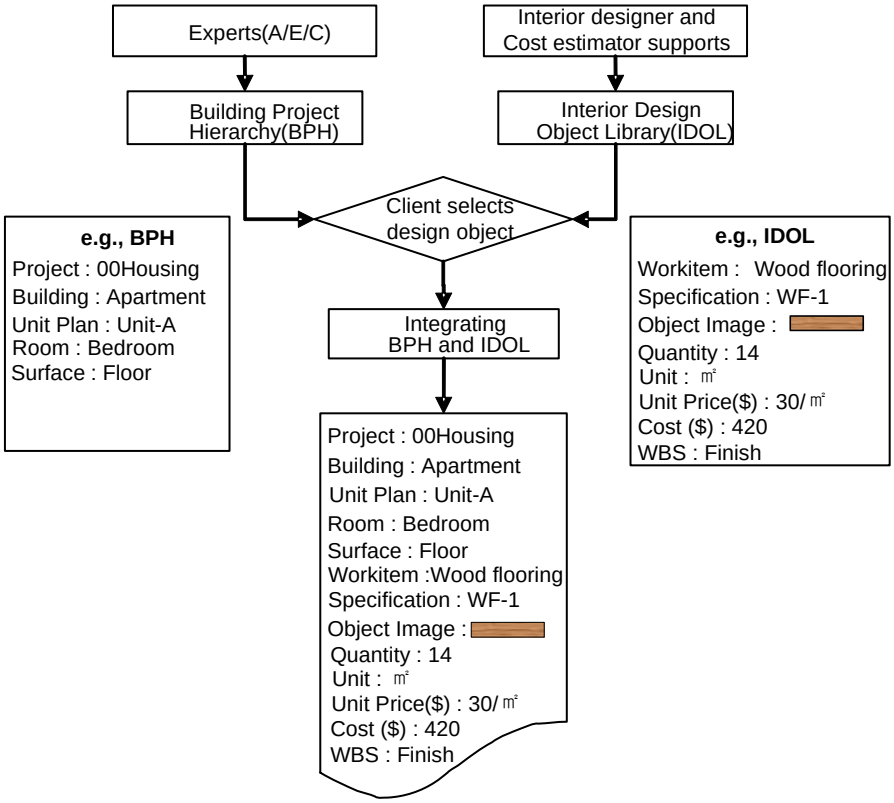


FIG. 11: Integrating the BPH and the IDOL

As seen in Fig. 12, an information model was suggested to integrate the BPH and IDOL that supports cost-based interior design decisions.

4.2.4 Implementation Tools

Spreadsheets are widely used as a tool for the development of many decision support system products. Sim Engine, for example, is a spreadsheet-based simulation modelling and analysis system built on top of Microsoft Excel (Lia et al., 2004). We propose that our Interior Design Decision Support System be implemented using Access for the database, with a Visual Basic application (VBA) for the graphical user interface (GUI) and Microsoft Excel for the output. VBA was used to implement the user interface to support the decisions concerning selected values for the interior design. The interior design information (i.e., the values selected by the client) created this way is displayed using Excel.

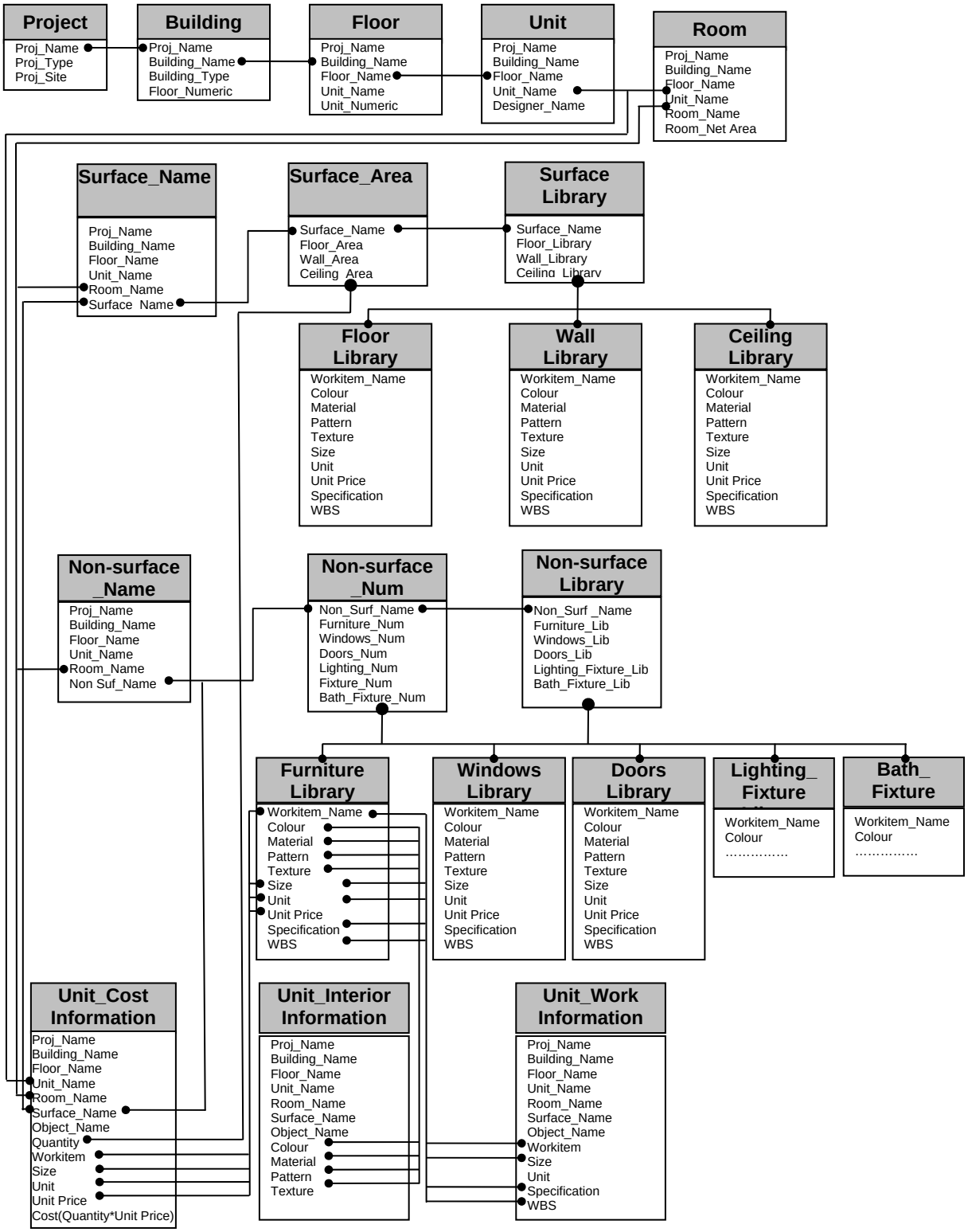


FIG. 12: Interior design information model

5. EXAMPLE STUDY AND APPLICATION

In the early phases of the detailed design for a project, the BPH is implemented in cooperation with an expert A/E/C group. After the interior designer and cost estimator set the default values for the interior design information (i.e., interior design objects and costs), the changes in the costs are examined in accordance with the client's cost-based selection of interior design objects. For this study, the applicability of the proposed interior design information model was validated with an example study of the interior design of a housing project involving 1,000 apartment units built on the same unit plan, each of which had a floor space of 100 m^2.

5.1 Establishing the Interior Design Information (Default Values)

To set the values for the interior design objects and costs in the early phase, the BPH of the target project is configured in co-operation with the A/E/C experts, and the default values of interior design objects are created with the help of the designer and cost estimator. The cost of each unit is established when the interior designer inputs the interior design for the units using design objects from the BPH, and the cost estimator inputs the cost estimates for the selected interior design. Figure 13 shows an example of the default values set by the interior designer for each element in relation to the BPH (00Housing, Apartment A, Floor 1, Unit Plan A, Bedroom).

Default (1)	Information	Floor	Wall	Ceiling	Decoration	Doors	Fixture	Total
	Interior work item	Wood flooring	Wallpaper	Wallpaper	Moulding	Wood door	Lighting fixture	
	Specification	WF-1	WP-1	WP-1	MD-1	0.9*2.0	LF-01	
	Object Image							
	Quantity	14	28	14	15	1	1	
	Unit	M^2	M^2	M^2	M	EA	EA	
	Unit Price ($)	30	5	5	3	250	150	
	Cost ($)	420	140	70	45	250	150	1,075
	WBS	Finish	Finish	Finish	Decoration	Doors	Electric	

FIG. 13: Interior designer-selected values (default values)

5.2. The Client Selects the Interior Design Objects

The client makes decisions with the support of the IDOL database, which is linked to the default values. As design objects are selected, the cost is changed accordingly. Using the basic default values, the client selects the interior specifications that their requirements. Two scenarios for changes can be simulated involving the fixed and variable costs.

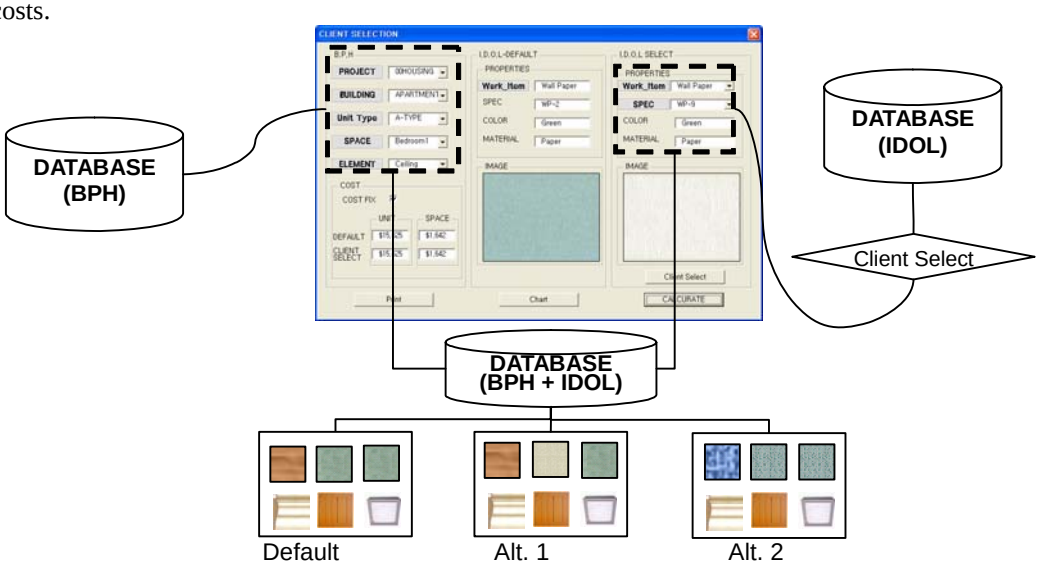


FIG. 14: Decision making the alternatives in IDOL database

5.2.1 Fixed Cost Example

When the client selects the fixed cost condition, he or she can decision making the alternatives provided in the

IDOL database, as presented in Fig. 14. The results of these decisions are displayed on a spreadsheet, as shown in Fig. 15. For example, when the client changes the wallpaper pattern, the interior design objects change, although no change in the cost is indicated. Nevertheless, the client can still choose from a variety of alternatives. The information generated in this example is then used in resource planning and project cost management.

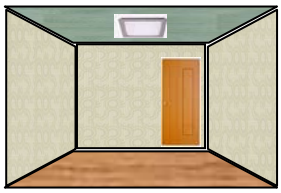
Alternative 1	Components	Floor	Wall	Ceiling	Decoration	Doors	Fixture	Total
	Interior work item	Wood flooring	Wallpaper	Wallpaper	Moulding	Wood door	Lighting fixture	
	Specification	WF-1	WP-2	WP-1	MD-1	0.9*2.0	LF-01	
	Object Image							
	Quantity	14	28	14	15	1	1	
	Unit	M^2	M^2	M^2	M	EA	EA	
	Unit Price($)	30	5	5	3	250	150	
	Cost ($)	420	140	70	45	250	150	1,075
	WBS	Finish	Finish	Finish	Decoration	Doors	Electric	

FIG. 15: Options for the client-selected values under the fixed cost scenario

5.2.2 Variable Cost Example

Alternatively, the client can select finishes and confirm the final costs on a real-time basis. These decisions are made by selecting from alternatives proposed in the IDOL database when selecting the variable cost option. As Fig. 16 shows, when the client changes work items for the floor, wall and ceiling, the cost changes from $1,075 to $1,439.

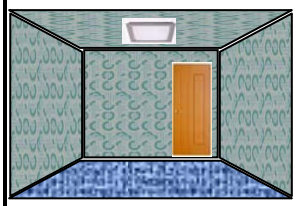
Alternative 2	Components	Floor	Wall	Ceiling	Decoration	Doors	Fixture	Total
	Interior work item	Carpet tile	Wallpaper	Wallpaper	Moulding	Wood door	Lighting fixture	
	Specification	CT-2	WP-3	WP-3	MD-1	0.9*2.0	LF-01	
	Object Image							
	Quantity	14	28	14	15	1	1	
	Unit	M^2	M^2	M^2	M	EA	EA	
	Unit Price($)	50	7	7	3	250	150	
	Cost ($)	700	196	98	45	250	150	1,439
	WBS	Finish	Finish	Finish	Decoration	Doors	Electric	

FIG. 16: Options for the client-selected values under the variable cost scenario

A system example study was run using the default values proposed by the interior designer using the fixed and variable cost options. The change in cost is the difference between the cost of the interior design objects proposed by the interior designer, and the cost of those selected by the client. Under the fixed cost scenario, the client changed the design of wall objects without changing the costs relative to the default values set by the interior designer. With the variable cost option, changing the wood flooring to tile carpet and the wallpaper material from paper to fabric increased the cost to $1,439 from the default value of $1,075.

5.3 Application for the Client and Builder

Considering the needs of the client/builder described in Section 3, the interior design objects selected for the target project are integrated for each space and WBS, and the results are displayed for the client and builder. When examining the costs, the client can also check the interior design total project cost by decisions made concerning the unit interior design. The builder can make a project interior construction cost plan and resource consumption plan according to the WBS. The following detailed summaries are produced for the client and builder.

5.3.1 Application for the Client

As shown in Fig. 17, the developer or owner can establish a baseline cost of $21,075,000 against which to compare the alternative proposals. Alternative 1 has no cost impact compared to the baseline, while Alternative 2 would increase the project cost by $364,000 due to the interior changes.

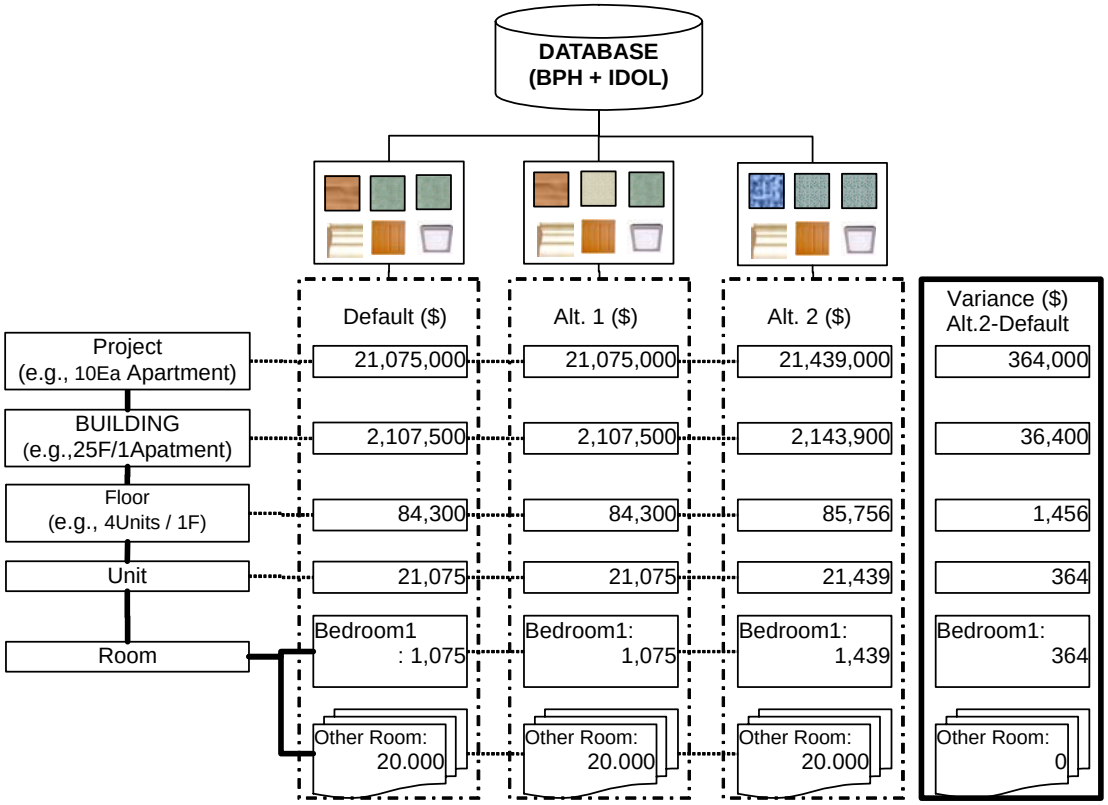


FIG. 17: The total costs according to the changes

5.3.2 Application for the Builder

Based on the client's decisions, the builder is provided with cost and resource data according to the WBS (e.g., finishes, doors, windows and furniture), displayed as the amount per construction type as shown in Fig. 18(a). The builder or other agents can also use work items from the spaces as shown in Fig. 18(b).

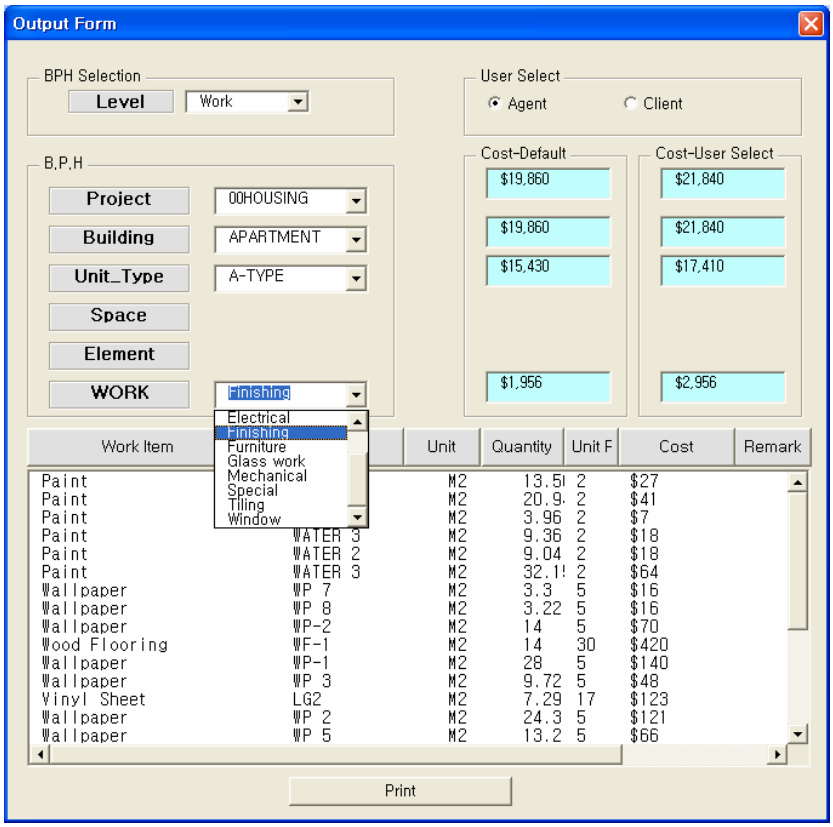


FIG. 18(a): Work breakdown structure according to the default interior design and client-selected items

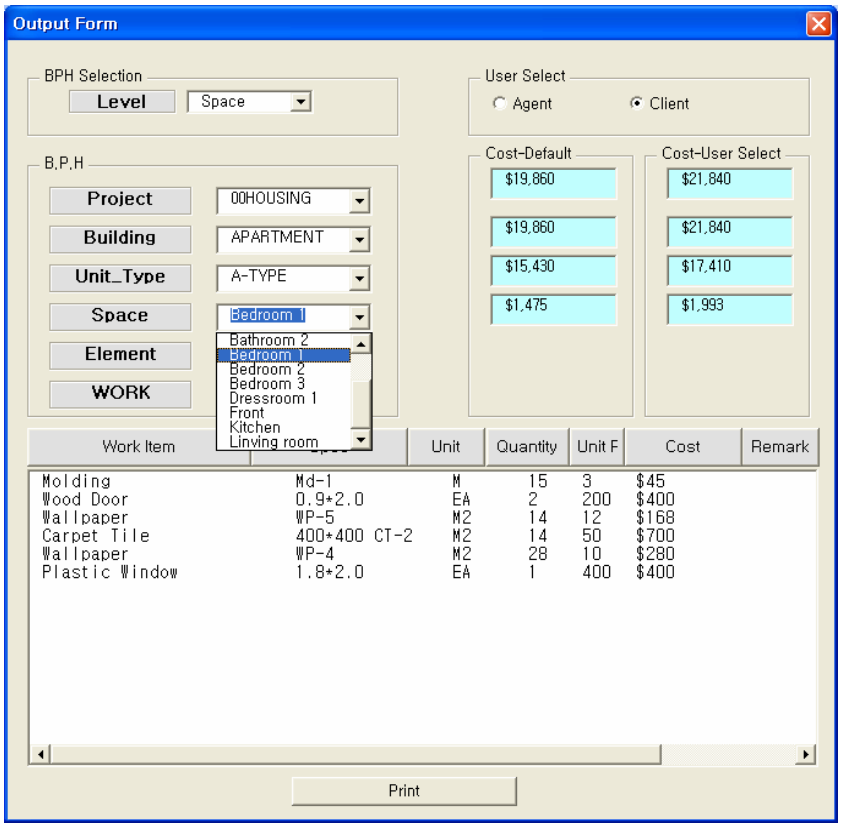


FIG. 18(b): Space resources according to the default interior design and client-selected items

The design objects and costs generated here are used as data for managing project costs in the WBS as shown in Fig. 19. By analysing the costs according to the different spaces (Fig. 19(a)) and work (Fig. 19(b)), the builder can make a construction cost plan and resource consumption plan in accordance with the WBS. From the perspective of project cost management, the default cost proposed by the interior designer and the costs determined by client selection can increase the estimate accuracy of the project costs in the early phases of a project.

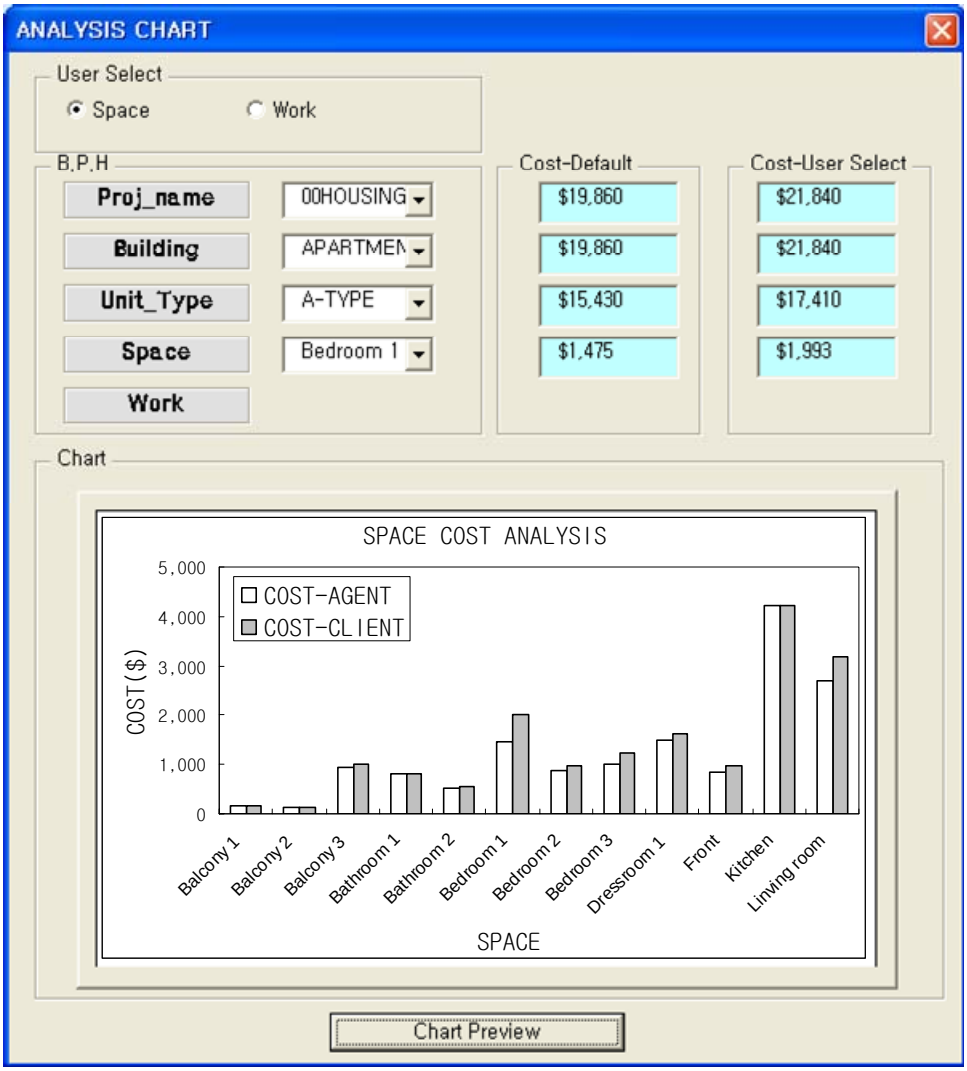


FIG. 19(a): Cost analysis charts according to spaces

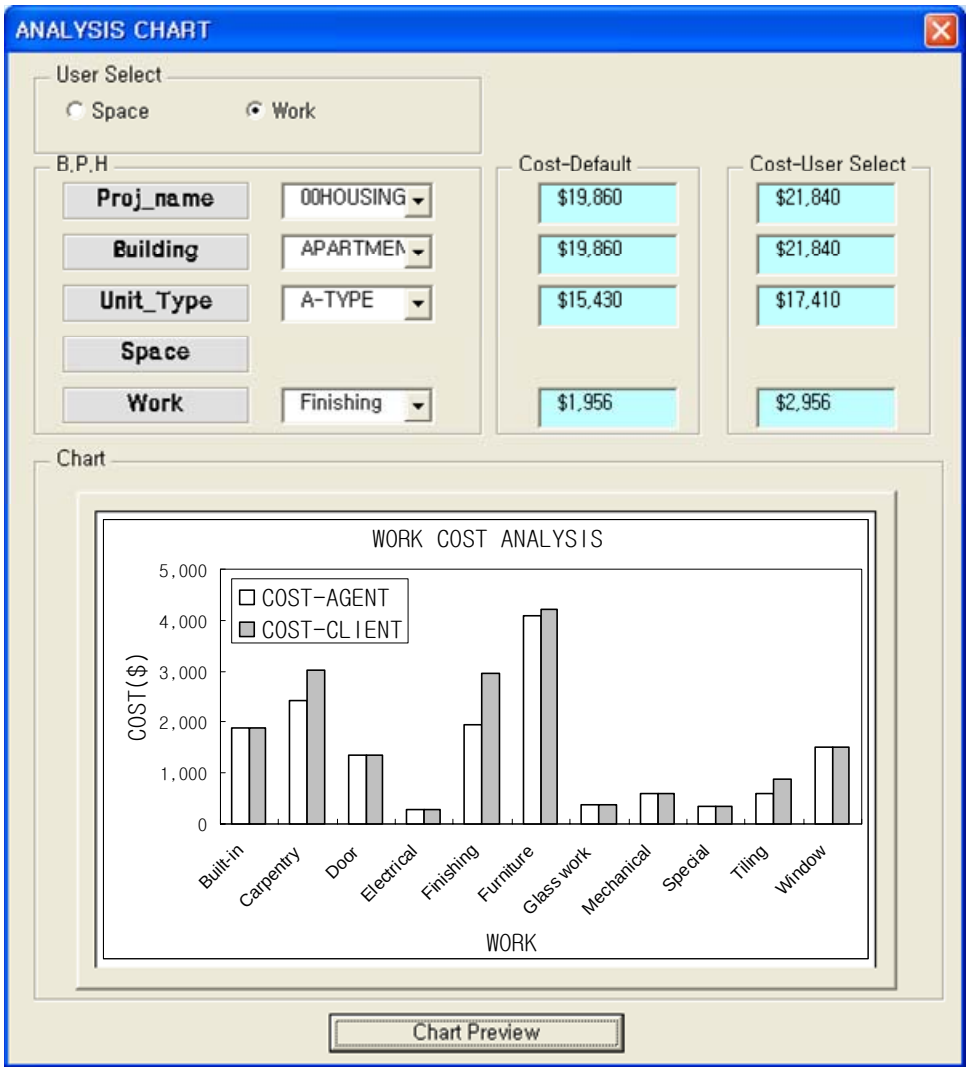


FIG. 19(b): Cost analysis charts according to works

6. CONCLUSION

We proposed an interior design decision support system that enables clients to participate in the early phases of the interior design for a housing project. This allows them to select objects (e.g., colours, patterns, material) for the interior design based on the unit measure of costs with input from various A/E/C experts. This also allows the interior designer and cost estimator to check the costs accordingly. The proposed system was implemented using the BPH and IDOL. In an example study, interior design objects and default costs were proposed while examining the fixed and variable cost options.

This study examined how client decisions made during the early design phases and based on restrictions in the interior design can affect a project. An analysis of the results confirmed that our interior design decision support system leads to client satisfaction with the interior design, while enabling clients to manage project costs by providing a cost baseline. Overall, this increases the accuracy of early estimates made during the project concept phase.

Cost and time are both very key indicators for assessing project performance. In the earlier phases of large-scale housing projects, the review of construction costs is important (Kim et al., 2004).

It is not appropriate to state that high-cost interiors designs are good and low-cost ones are not. However, making interior designs or design changes without any consideration of the cost is a source of serious problems for the interior designer and other project participants, especially the owner/developer. Moreover, despite considerable information on costs for alternative proposals selected by interior designers, existing procedures have many problems as seen in a review and feedback of these alternatives.

To address these problems, we investigated various alternative proposals for surfaces (floor, wall and ceiling) and non-surfaces (furniture, windows and doors) on a unit plan basis for large-scale housing development projects, and provided an interior information model. The model was validated through an example study to show how it could be used in the decision-making process by various participants in a construction project. The proposed model is useful in providing a total interior cost review and cost baseline for the developer/owner, a means for cost-based decision making by interior designers, and the interior material information required by builders.

Future studies will focus on the automation of quantity surveying and graphics to reinforce the use of Internet-based decision support systems. In future studies, further subdivision of the design objects characteristics will be necessary, as well as the development of a system that enables clients to make interior design decisions by changing layers, a subject outside the scope of the present study. Additional work is also required to enable interior designers to use the information provided by vendors and suppliers directly, and to provide the information for the procurement phase without any additional processing.

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Acknowledgement

This research was supported by a grant (# 06E01 Virtual Construction System Development) from 'Advanced Technology Collaborated Construction' Program funded by Ministry of Construction & Transportation of Korea

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