MANAGING DESIGN OPTIONS WITH BUILDING INFORMATION MODELING

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ABSTRACT: Building Information Modeling (BIM) proves to be an effective approach for managing design options in a product line, as shown in the case study of K. HovnanianHomes. The business strategy of a production homebuilder is to maintain a series of design options to satisfy a wide spectrum of needs of its customers. The logistics of handling a large number of design options are quite complex as well as making sure that the selected options are compatible to each other. The introduction of BIM has significantly enhanced the management of the process and the options offered as well as streamlined the overall design flow.

This research has two primary purposes: first, to formalize the generic process of generating and managing design options with BIM, and second, to improve its implementation by describing and analyzing current building modeling practices.

KEYWORDS: building information modeling, design options, BIM implementation, design management.

1 INTRODUCTION

Building Information Modeling (BIM) (Bazjanac 2004) provides the opportunity to create different design options for various building components such as the structural system, the exterior cladding, and the interior space (Eastman 1999). With BIM, options can be evaluated based on selected criteria and be assembled for the final configuration (Haymaker et al, 2004). This paper examines the specification and modeling processes for designing with options in the BIM environment. First we analyze an approach to establish the modeling requirements and manage the modeling workflow that builds on the generic framework for BIM project delivery (Panushev and Pollalis, 2006). The process starts with definition of the overall project objectives which drive the design objectives and the building modeling requirements. After the requirements are formalized they are communicated to the modeling team. Our data collection is from field research and is additionally supported by structured interviews of the involved team members.

The BIM environment in this case is a model server (Jeng and Eastman, 1998) based on 3D object information. Previous work (Amor and Faraj, 2001) has indicated the differences of various project information architectures. The object definitions are stored in a single project database and quarried based on certain model configuration criteria. Wang at al. (2007) see the web-service enabled interfaces as means to access the database and propose an approach to create middleware to achieve that. We provide additional insights to the process of using such system in a business environment in order to facilitate future implementation efforts.

Tanyer and Aouad (2005) have proposed a method for enhancing the 3D model based project approach by integrating cost and schedule data to create “what-if” construction scenarios. This improves the decision making process by evaluating complex alternatives which combine elements from different domains. Some form of revision control (Cooper at al., 2005) has to be utilized in order to trace where the underlying information in the architectural models is originating. The decision path (Ozkaya and Akin, 2006) is documented and highly valuable for future design developments. We analyze practical examples of how design decisions of different alternatives are generated, formalized, and used to create building model options.

This research is based on a case study at the New Jersey division of K. Hovnanian Homes (www.khov.com). The company is the sixth largest homebuilder in the US, and has built more than 20,000 homes in 2006. Design options are critical for homebuilders because they provide the opportunity to offer customization and flexibility to their customers. In 2006, BIM was used on approximately 2,000 homes in the Mid-Atlantic region to automate the production of lot-specific documentation for each individual house built in a subdivision. Lot-specific information is required by local authorities in order to issue building permits. It is further used by the homebuilder and its trade partners for construction documentation. There are current efforts to integrate the BIM database with the procurement systems of the company.

2 CASE STUDY BACKGROUND

The BIM software environment involved multiple applications and customizations at K. Hovnanian Homes. The 3D modeling software used is Argos by the Finnish company Vertex Systems. It has object based modeling capabilities and supports open database formats such as ODBC. The 3D model database is managed by an SQL server and is accessible via the company intranet and custom-built on-line interfaces.

The modeling starts with the creation of a base house model which hosts the various design options. Such options include kitchen configurations, window patterns, garage layouts, foundation types and façade finishes. All options are modeled with reference points to the base model so they satisfy all spatial requirements. For a single base model there might be dozens of design options resulting in hundreds of possible building configurations. Each 3D model element is uniquely identified in the database. As the modeling progresses with more and more options, the BIM requires to be "solved" periodically in the database processing system to ensure that there are no interferences between the different options. Finally, a 3D object based master model with all options is created from which the homeowners can select desired components. After an option configuration is identified by the future homeowner it is forwarded to the system and "solved" for a lot-specific set of documents for permitting and construction.

The BIM system is parametric so that some elements could "stretch" to accommodate changing geometry. For example by a single command, without any modification by the BIM modeler, foundation walls could stretch by as much as one foot in order to accommodate various floor deck options. Additionally, parametrically created window trim can automatically adjust to different size windows, with no intervention by the modeler. This reduces the amount of actual modeling that needs to be done in the system.

Another key aspect of the BIM system is the fact that all option selections are collected in object databases, which provides the ability to query for different features of homes built in the past. Thousands of homes have been "solved" since 2002 and K Hovnanian can determine which options have sold well, based on date ranges and which home types are currently selling. BIM has become a great market forecasting tool to project trends so that company management can determine geographically the most popular home size ranges and popular design options.

3 BIM OBJECT STRUCTURE

3.1 *Base model*

The base model (Figure 1) represents a stripped down house configuration which holds the common components and provides reference points for connection to the design options.

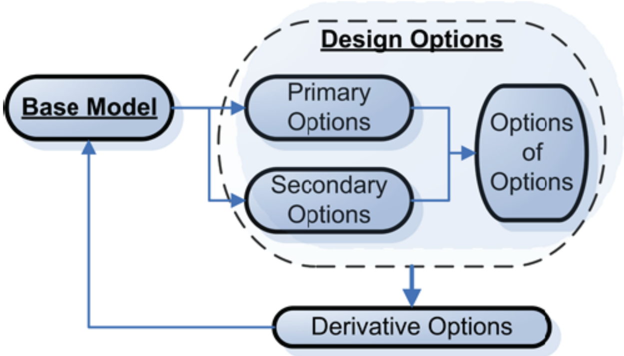


Figure 1. Building Model Structure.

Figure 2 shows a base model at the top right with multiple façade options. The design is driven by the program requirements for each specific community and is defined during the project planning phase. BIM is not used as a conceptual design environment since it is viewed as very detailed and not flexible enough to allow for the full expression of the architect's creativity. However the design teams are aware of the capability of the system and their solutions are based on generic modular concepts. This allows easier modeling of design options and introduction of additional alternatives at later stages of the process.

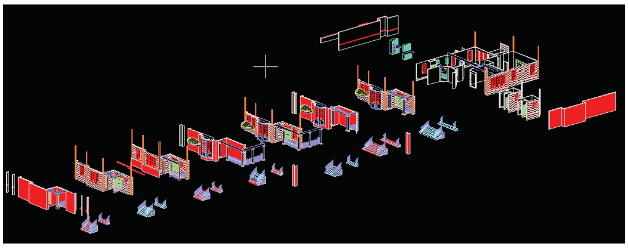


Figure 2. 3D Master Model with Seven Facade Options and a Base Model (Top Right).

3.2 *Design options*

The base model hosts reference points to the primary design options as well as placeholders to accept derivative options. The customer selects the *primary design options* based on his/her direct preferences. These could include kitchen, porch, façade, and garage options. They affect the house configuration and are driven by the architectural design. A unique set of reference 3D points is placed on each option which corresponds to another set of points on the base model. Figure 3 shows how a point from the option reference set corresponds to a point in the base model.

Secondary design options are customer driven and do not affect the space program of the house but have an impact on the overall architecture. For example these can include exterior finishes such as brick veneer or stucco. They are represented in the 3D BIM and can either be individual options or options within the primary design options. They are uniquely identified in the information database.

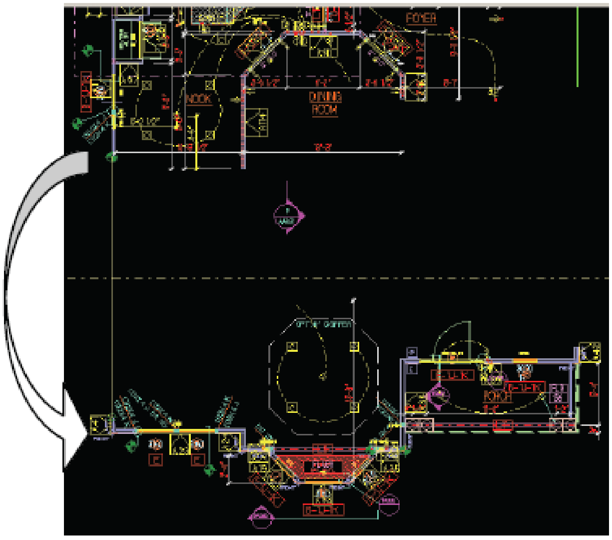


Figure 3. Reference Connection Points (in 2D) between the Base Model (Top) and a Facade Option (Bottom).

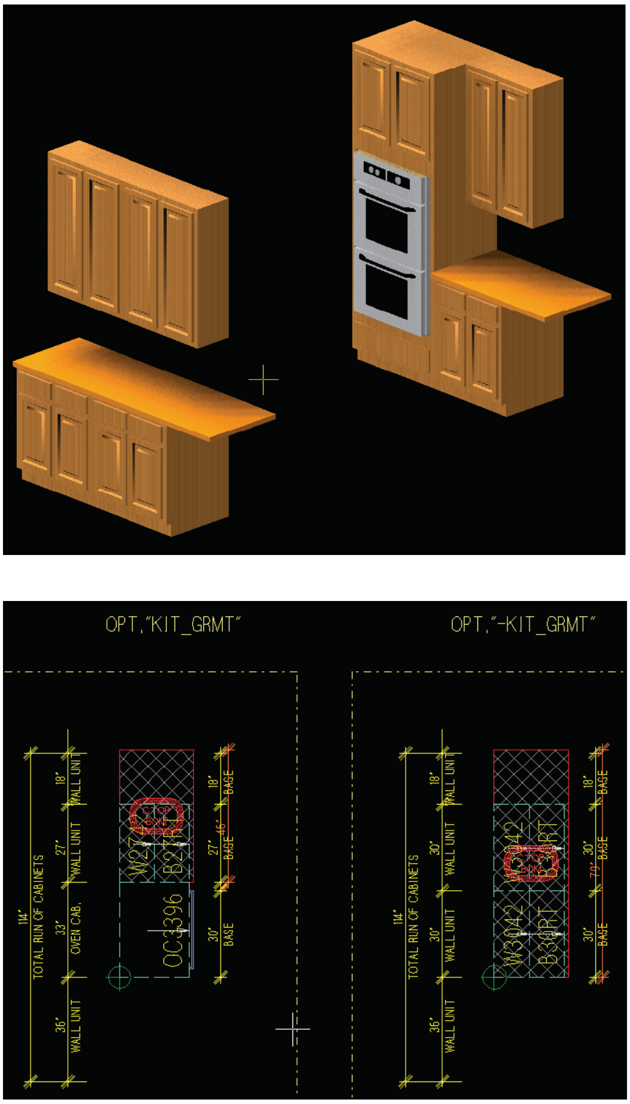


Figure 4. 3D (Top) and 2D (Bottom) Views of Primary Kitchen Cabinet Design Options.

Design options of options represent variations within the other options. They can be nested in any of the primary, secondary or derivative options. They are also based on customer preferences. Examples of these are window types within different façade options.

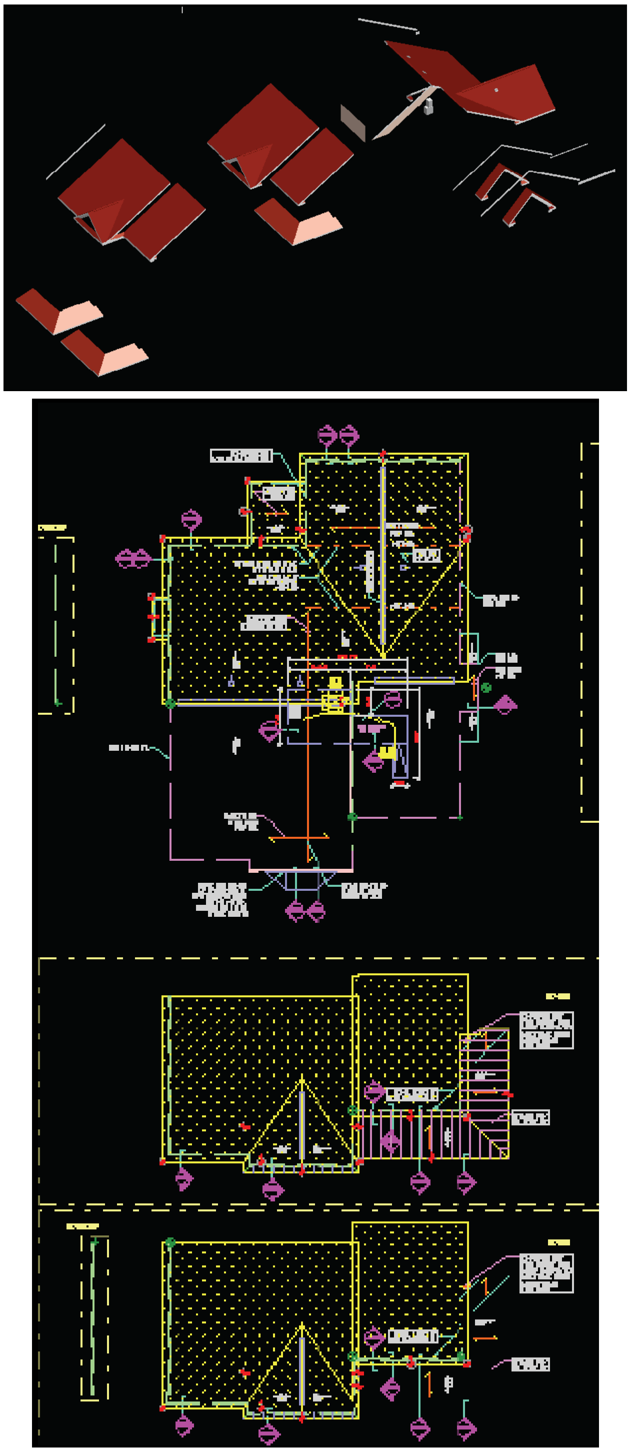


Figure 5. 3D (Top) and 2D (Bottom) Views of Derivative Roof Options.

Derivative options are driven by the selection of primary and secondary design options without direct customer involvement. Their configuration is rule based within the database system and they can affect the overall architectural design. One example for a derivative option is roof assembly (Figure 5) generated by selecting a specific set of façades.

4 ESTABLISING THE MODEL SPECIFICATIONS

The management of this complex data structure is possible because of the BIM environment. The BIM technology provides a single geometric modeling environment and a programmable configuration. The initial options selection process involves architectural, construction and business decisions. We found that a structured approach during the design options definition improves the modeling process because it clearly outlines the BIM and establishes the options dependency. K. Hovnanian uses a two-step process and focuses first on the generic building requirements, and then through design workshops, addresses the individual building features.

4.1 *Generic requirements*

After the general building requirements are established from market research and due diligence, a Community Development Manager (CDM) starts collecting building information from the site manager, the project architect, and the permitting consultant. The CDM generates a document including information about community and project requirements such as the type of building to be designed (e.g. single-family, multi-family, active-adult), number of homes, construction phases, and whether the design will be new or based on previous work. The site manager selects relevant items which will be designed later or influence the overall design such as soil conditions and common community structures (e.g. pools, entrances, fencing, etc.). The project architect identifies the community site and the local applicable codes, as well as the main building features and design options (e.g. ceiling heights, garages, porches, etc.). The permitting consultant specifies the building lot constraints and other local requirements which will affect the design. The CDM collects this information and makes it available to everyone who participates in the architectural workshop meetings.

This approach is greatly facilitates the development of the BIM because it encompasses all major factors that govern the design. During the architectural workshop meetings these factors affect the level of detail specification of the building elements and the design options.

4.2 *Design workshops*

The design workshop meetings are managed by the CDM who coordinates the design and the BIM specification teams. The design team is led by the Design Architect who may not be involved in the building modeling process itself but participates in the definition of all key architectural components of both the base model and the options.

The CDM manages the specification documentation and is responsible for collecting written approvals from the participants on all decisions made at the meetings. In this second phase, he leads the discussion on the specific building configurations, elevation options and exterior materials. The site manager identifies landscaping issues and how utility supply lines might affect the building design. The project architect together with the design architect creates the final base architectural building design and all options. This information is primarily in descriptive text format and might include design sketches of elevations connection details and new building systems. The level of detail in this specification is very high and includes references such as size of bathroom tubs and brand of brick veneer. This information is transferred to the building modeling team to generate a 3D model linked to the company's materials database.

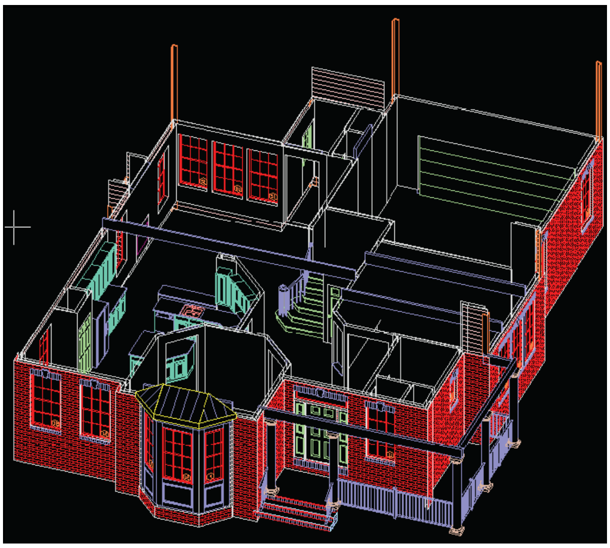
During the initial generic BIM specification phase all participants define the main components of the building which would be modeled later. Those components and their level of detail are matched with the fundamental project objectives coming from non-design sources such as market analysis. During the second phase, at the design workshops, the project becomes more defined by defining additional level of detail to the building specification. This approach follows the generic structure of the BIM delivery framework (Panushev and Pollalis, 2006). Our analysis finds it comparable to the programming and schematic design phases in conventional architectural practice. However in this case designs are developed to a much higher level of detail in order to allow for the development of the building information models.

5 THE MODELING PROCESS

Building modeling starts with creating the base model together with the initial set of primary options. This set of options includes one option of each of the components which are identified to be variable in the model specification. The reference points in the base model are clearly identified so that options can be easily disconnected. The modeler defines all dependencies while rules for element connections are built in to the database.

5.1 *Model "solving"*

After creating one instance of the BIM, the model is "solved" by the database processing system to ensure building components from the design options match those from the base model and verifies that there are no clashes (Figure 6). "Solving" can take relatively long for models with dozens of options. This process is one form of quality control for both the 3D models and the information rules database.



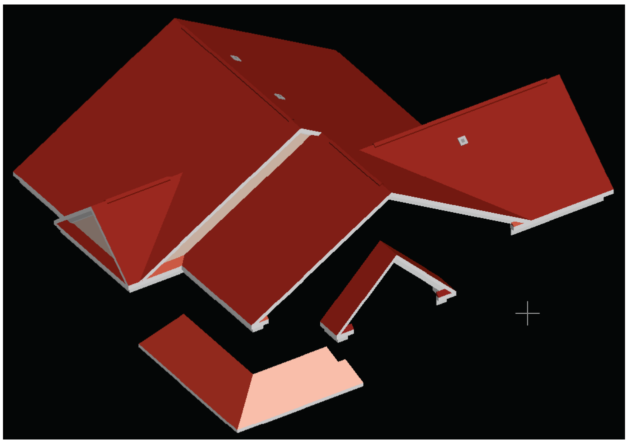


Figure 6. 3D Views of the "Solved" Model Matching Facades (Primary) with Roof (Derivative) Options.

5.2 *Options development*

Once the base model is created, team members focus on developing the specific options. The primary options which define the overall architecture of the house are created first together with the corresponding derivative options. This is necessary because the overall house geometry is hosting the secondary options and the options of options. With the development of new options the model is “solved” periodically to ensure the components match geometrically. If there are clashes the system can generate a report and the modelers modify either the geometry or the “solving” rules.

The “solving” process is a very effective method for continuously checking model integrity as its complexity grows. Similar process could be used on the scale of commercial design where for example an engineer is provided boundary conditions for certain building section and is asked to generate several structural solutions. The BIM environment facilitates the creation of dynamic links between different modules so solutions or design preferences could be easily compared. Key in this process is the early definition of the option variables because it might require models to be built with different driving parameters.

6 MANAGING DESIGN OPTIONS

The most critical part in the management of design options is creating a detailed model specification. K. Hovnanian has developed a process for collecting necessary information and synthesizing it to a format that modelers can use to develop single building components. The main feature of the system is a record trail of all decisions made by the design teams. They are documented with standardized spreadsheets so modelers can easily identify which components and material types should be created in the BIM.

As the section on model specification indicated the requirements documents are “owned” by the CDM, the site manager, the project architect, and the permitting consultant. These standard spreadsheets together with the designer sketches are provided to the modelers to develop the base model and the initial set of options. If needed, the design team might add more options to the model in which case new specifications are generated in the same format.

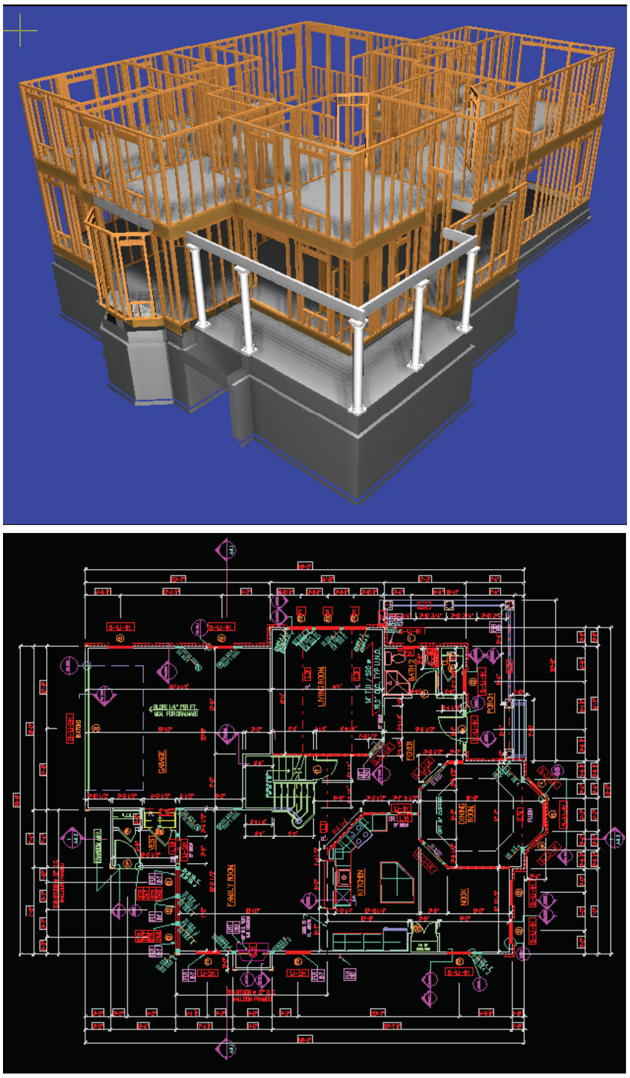


Figure 7. Lot-specific BIM (Top) and Construction Documents (Bottom).

The ability to add new options to existing base designs provides the building owners with enormous flexibility. After all options are generated and a specific configuration selected, the BIM can automatically generate renderings, construction documents, bill of materials, and other information needed for the later stages of construction (Figure 7).

The management of the model specifications is as important as the management of the design options because they provide a record of the underlying decision process behind the BIM. Assigning “owners” to each information set facilitates the management process and provides a point of contact for the modeling team in case additional information is needed. The requirements “owners” serve as the translation group between the design and the modeling teams. This process enables the formalization and synthesis of the design intent.

7 CONCLUSIONS

The paper explores the BIM specification process as a tool for generating and managing design options. In the case study, the conceptual design and the BIM specification processes evolve in parallel. Design architects are not involved in the actual building modeling. However, they participate actively in the BIM specification. We have found that in essence the BIM specification is a formalization of the design intent.

The programming, conceptual, and schematic design phases, as known in architectural practice, provide information for the BIM specification. The output from these phases needs to be structured so that it can be directly translated into the BIM. Hence it is important for design professionals to understand the BIM structure and system requirements in order to provide comprehensive building descriptions. If information is not available, placeholders are created in the model in order to be populated in the later phases of the project. Furthermore software vendors could develop BIM conceptual design tools integrated to the company's information databases at lower levels of detail in order to make decisions early in the design process.

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