BIM-Based Plan Modeling System at Preliminary Stage for Residential Real Estate Projects

Tianfeng He[1], Jiarui Lin[1], Zhenzhong Hu[1], Jianping Zhang[1], Weidong Jia[2], Jing Su[2]

1 Department of Civil Engineering, Tsinghua University, Beijing, China 100084; Tel: 086-010-62782706; Email: htf12@mails.tsinghua.edu.cn
2 China State Construction Land Co.,Ltd, No.15 Sanlihe Road, Haidian District, Beijing 100037, Tel: 086-010-88321008; Email: su_jing@cscec.com

ABSTRACT

The preliminary stage of a residential real estate project is of great importance but also is known to be with poor efficiency. However, residential real estate project contains numerous built standard units such as dwelling units and floors. By introducing BIM, this research tapped the full potential of this advantage to improve the performance of the preliminary plan modeling in residential real estate projects. This research proposed a standard-unit-based modeling approach which contains 3 main steps: 1) standard unit management, 2) rapid plan modeling and 3) in-time estimation. By integrating functions such as intelligent standard unit boundary revision, sun analysis, multi-level and information-based model visualization, a prototype system was developed based on this approach, and was applied to a real estate project in Xian, China. The results indicate that this approach has the potential to improve the efficiency and quality of preliminary plan.

INTRODUCTION

Preliminary stage aims at defining budget and other requirements for further design. It is the stage when critical features that impact a project's profitability and performance are normally decided (Hsu et al. 2000). It is also the most flexible phase when plans are free to justify with low cost (Stumpf et al. 2009). However, most efforts were paid to support either upstream works such as investment planning, or downstream works such as performance analysis. Several researches had been summarized by Cavieres (Cavieres et al. 2011) who emphasized that there was a strong need of redistribution of efforts towards early knowledge integration and computational support. Wang (Wang et al. 2002) and Macleamy (Macleamy et al. 2007) also mentioned the great need at preliminary stage for more suitable tools and more efforts.

Residential real estate project has a distinctive characteristic that makes it a lot different comparing with other real estate project. It contains numerous

successful and popular house units and dwellings, which are also called standard units in China. Standard units consist of rich geometric and economic information, which brings new solution to preliminary planning (Lin 2012). Successful cases include public rental housing in Hong Kong and Singapore (Sim 2003 and Xue 2013). Top housing estate developers in mainland China such as Vanke and CSC Land have already begun to explore their own way to use standard units.

However, traditionally useful information of standard units is fragmented in drawings and documents separately, making utilization of such information difficult. This inconvenience in data retrieval also results in lack of efficiency and accuracy when making decisions. As a result, nowadays preliminary plans are always made depending on decision-makers' experience, which has been criticized to be with fairly poor efficiency with low estimation accuracy and visualization level.

Building information modeling (BIM for short) and building information model (also BIM for short) focus on a digital representation of the geometric and non-geometric data of a facility (National Institute of Building Science 2007). Functioning as a single data repository, BIM ensures the capacity to store different types of information including geometric information, economic information and ecological information of a standard unit. Such information can be used for better visualization and estimation. Thus, BIM provides a perfect solution for preliminary plan modeling and evaluation.

In this research, a standard-unit-based BIM modeling system was developed to improve the efficiency and accuracy of the preliminary plan modeling process. A review of related works in this area, a BIM-based plan modeling approach and the prototype system are presented in the following sections.

RELATED WORKS

As the result of a general lack of early design development support (Cavieres 2011), preliminary plan has attracted many initiatives across the globe. Cheung (Cheung et al. 2012) proposed a multi-level modeling and estimation process for schematic BIMs. Donn (Donn et al. 2012) developed the COMFEN tool for flexible non-residential buildings design with in-time estimation. Other than academic researches, Onuma Planning System, a commercial software application, specializes in building conceptual design, providing functions like multi-scale modeling, space configuration and in-time estimation. Trelligence Affinity is another early-stage focused design tool which is famous for its capacity of specifying, automatically tracking and checking user's requirements (Khemlani 2012).

Even though these tools and systems specialize in conceptual design, they do not make use of the idea of standard unit. CITYPLAN 6.5 (ZZSOFT 2013) specialized in urban planning and can perform massing exercises and layout designs using standard units. However, the freedom to change and use standard

unit model is relative low. And most importantly, it is not a BIM-based tool which makes it quite difficult to extend its function and corporate with other BIM software.

Other than such defects, those tools are designed for designers, not for owners. Shen (Shen et al. 2012) mentioned the considerable gap between owner-oriented and designer-oriented software. This research, on the contrary, concentrates on the needs of real estate developers who pay little attention to what exactly the design is. They focus on whether the plan will address all needs within budget and other requirements. For this purpose, a standard-unit-based rapid modeling system is more pragmatic than one with detailed modeling functions.

PLAN MODELING APPROACH BASED ON STANDARD UNIT

This research proposed a standard-unit-based plan modeling approach as a solution to tap the full potential of rich information provided by standard units. This approach consists of 3 main steps.

The first step is to build standard unit databases. Geometric data such as the location and profiles and non-geometric data such as cost, price, and construction duration are stored in the databases. The hierarchic structure of standard unit which represents the relationship among floor, flats, rooms, windows and doors are also included. As for a certain project, standard units imported from other projects may not meet various specific demands. Some necessary revisions for those units are needed. For this purpose, this research proposed a headquarter-project database structure. The headquarter database stores successful standard unit models that have already been approved by professionals. And each new project has its own project database for storing both original standard units and revised ones. If one project is regarded as successful and its experience worth sharing, selective standard units from that project can also be introduced back into the headquarter database.

The second step is to provide standard-unit-based rapid modeling tools for each of the 3 parts that each preliminary plan modeling process contains. Firstly, the standard unit revision tool includes functions like editing room boundary, setting flat price and floor cost etc. This research uses plane figure to represent standard unit containing room, dwelling unit and floor. Several intelligent standard unit boundary revision techniques have been designed and realized. Those techniques automatically combine or split walls and recalculate the position of both doors and windows according to certain revisions. Secondly, the building template configuration tool enables creating building templates by setting floor count, floor height and configuring related standard units. Finally, based on these building templates and other building modeling tools, the plot planning tool provides basic functions to do mass exercise, such as building template positioning, and creation of commercial buildings with custom profile. 3D-visulization is also provided for both building templates and the plot plan.

The third step is standard-unit-based in-time estimation. Supported by the

rich information provided by standard units, estimation will get strong improvement on its efficiency, accuracy and variety. Such estimation functions include sun analysis, income and outcome estimation, visualization of economic and other statistics etc. If user revises a standard unit, all building templates and plot plans consisting this unit will automatically change, ensuring the consistency and accuracy of the plan model. This research also optimized the algorithm and procedure of some estimation functions for better utilization of standard units' information. The estimation results in turn help user revise the plan or choose the best plan. The richer information standard unit model contains, the more powerful functions and interfaces system can provides, and the more profitable the final preliminary plan will be. Fig. 1 illustrates the standard-unit-based preliminary planning and modeling approach.

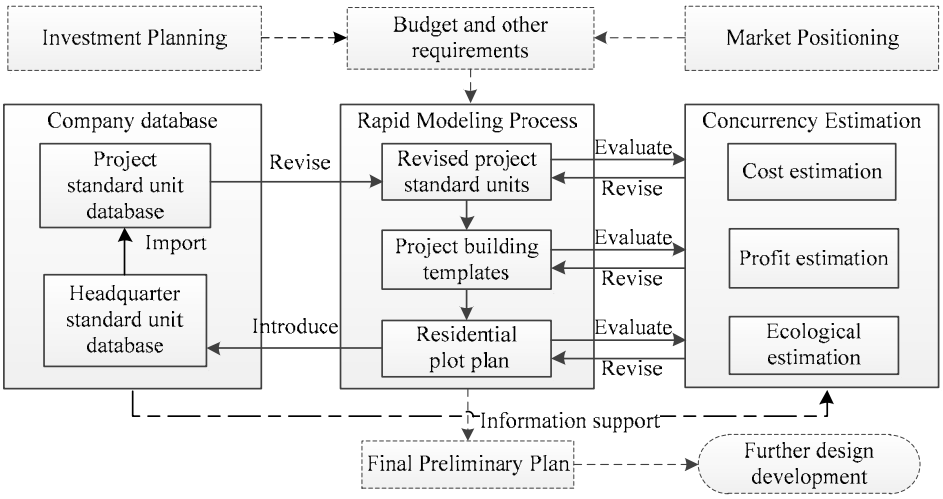


Fig. 1. Standard-unit-based preliminary planning and modeling approach

PROTOTYPE SYSTEM AND APPLICATION

In this research, a prototype system has been developed based on the approach mentioned before. For the purpose to store standard unit BIMs and support the visualization, the system is developed based on an existing 4D-BIM platform developed by Zhang (Zhang et al. 2011). The prototype system is client-server (C/S) structured, providing supports for the headquarter-project database structure and its permission management.

According to the 3 main steps of standard-unit-based approach, this prototype system consists of 3 main modules: 1) standard unit management module; 2) rapid modeling module; and 3) in-time estimation module. It has been applied to a residential real estate project called Kaiyuan Yihao in Xian, China. It is developed by CSC Land Co., Ltd with a total floor area of about 1 million square meters.

The standard unit management module is designed for standard unit

database management with model preview and search tools. Fig. 2 shows the user interface of this module. In this project, our BIM team built standard unit BIMs using Autodesk Revit Architecture according to several CSC Land's successful projects. Information like room area and boundary was automatically retrieved, while other information like price, project location was provided by the users themselves. Such information was stored in database as the representation standard unit BIMs.

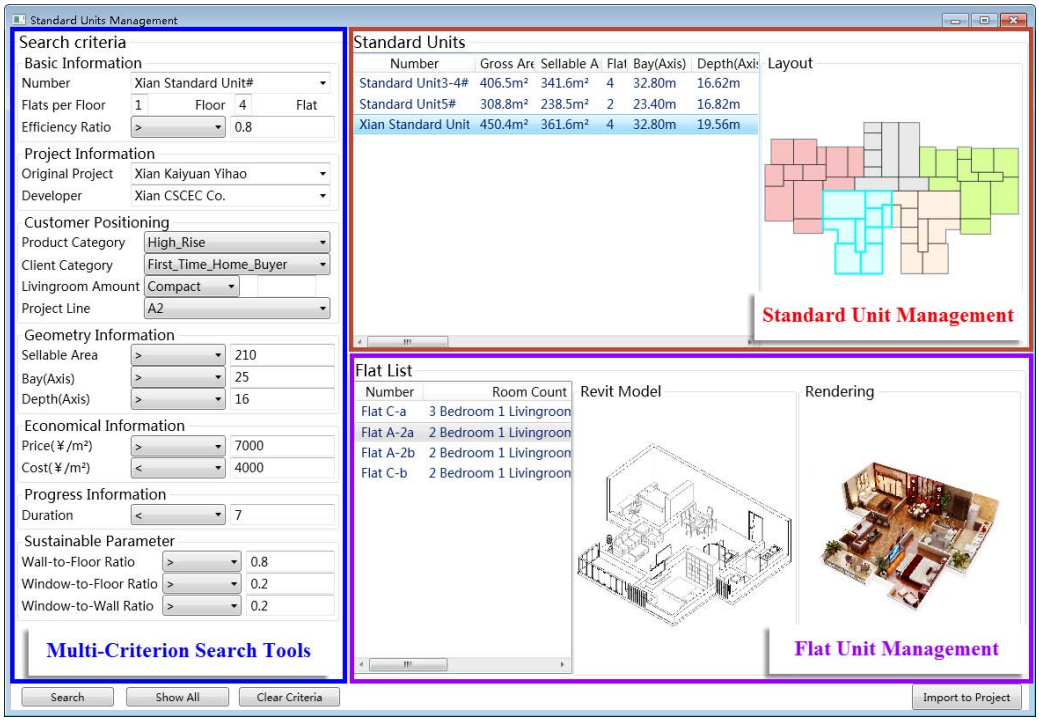


Fig. 2. Standard unit management user interface

Rapid modeling module defines 3 steps to build a preliminary plan model. First, standard units introduced from headquarter database are revised, such as modifying the room size and position, to suit specific needs of new projects. Then, revised units are used to resemble building templates using the building floor configuration tool. In this project, we selected 5 standard units from headquarter database that meet the requirements defined in upstream works. These units were imported into the project database. By slightly adjustment, 8 revised units were created along with corresponding building templates. Functions of precise position of building templates and other customized buildings were also designed and realized to establish one alternative preliminary plan model. Fig. 3 illustrated the full process.

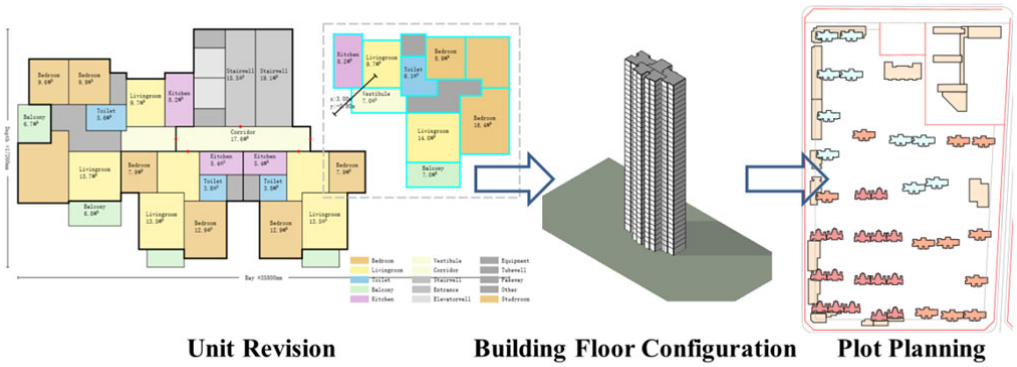


Fig. 3. Standard-unit-based rapid modeling process

In-time estimation is integrated into rapid modeling user interface for better interaction. Economic and environmental summary can be automatically calculated once model changes. The preliminary plan model is visualized in 3D views with colors changing according to unit types, construction phases and prices (as showed in Fig. 4). These tools were applied to 3 preliminary plans made through rapid modeling focusing on small-unit, large-unit and a relative balanced plan. 3D plan models were generated and relative information was estimated. Fig. 5 shows the sun analysis comparison among the 3 plans.

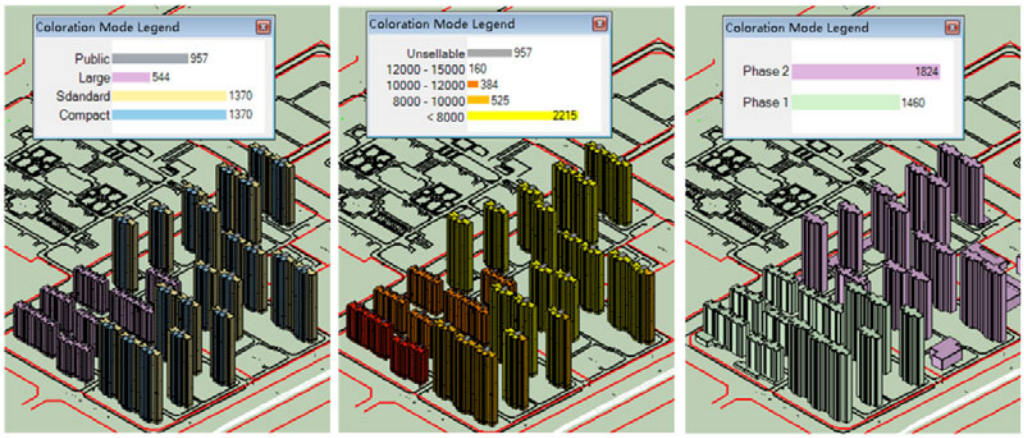
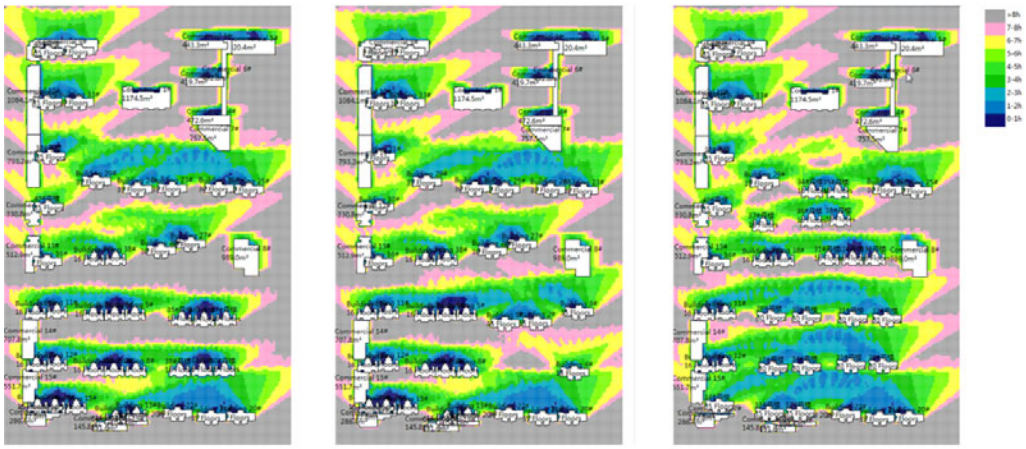


Fig. 4. Visualization in 3D view colored according to information

The application of this prototype system and approach has received positive feedback. By interviews to the users, we were convinced that there was a significant improvement in efficiency of preliminary planning with a relative higher level of visualization and accuracy estimation in some disciplines.



Large-Unit-Focused Plan Balanced Plan Small-Unit-Focused Plan

Fig. 5. Sun analysis comparison among 3 different plans

CONCLUSIONS AND FUTURE WORKS

The merit of this approach lies in its capacity to do rapid and flexible modeling with in-time estimation by utilizing standard unit BIMs. A standard-unit-based plan modeling approach was proposed and applied to a residential real estate project. A prototype system with three modules was developed to support better plan modeling and estimation during the preliminary stage of residential real estate project. The application indicated that there was a significant improvement in efficiency of preliminary planning with a relative higher level of visualization and accuracy estimation in some disciplines.

In the future versions of this system, as it is developed based on Tsinghua University's 4D-BIM platform, it can be augmented to integrate more functions such as construction scheduling, sale scheduling, 4D simulation and resources management etc. The concept of digital delivery will also be applied so that the developers can deliver the preliminary plan model instead of design task documents for further design, which will improve knowledge sharing and information integration among different building stages.

ACKNOWLEDGEMENT

We are grateful for the support provided by the National High-tech Research and Development Program of China (No.2013AA041307) and the National Natural Science Foundation of China (No.51278274)

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