CASE STUDY OF USING USER PRE-OCCUPANCY EVALUATION METHOD IN FACILITATING DESIGNER-CLIENT COMMUNICATION

Weilin Shen [1] and Qiping Shen [1]
[1] Department of Building and Real Estate, The Hong Kong Polytechnic University
Email: shenallan@vip.sina.com

ABSTRACT
There are constant interactions between the clients and designers during the briefing and early design stage in a building project. Problems usually stem from the fact that clients cannot fully understand the habitual representation of the design, such as 2D drawings, due to their limited comprehensive in three-dimensional space. Another problem is also the lack of a framework to guide the inexperienced clients to review the design solution systematically. This paper introduces a case study of using a User Pre-Occupancy Evaluation Method (UPOEM) in a campus project. In this case study, this UPOEM is compared with the traditional designer-client communication method on the effect of improving clients' performance. The result of this case study indicated that the UPOEM provided a potential to improve the clients' performance at understanding the future built environment as well as design review.

KEYWORDS

Virtual prototype, BIM, Pre-occupancy evaluation, designer-client communication, architectural design.

INTRODUCTION

There is a considerable gap between the designer and clients, which is, unlike architects, clients (including end users) are usually not trained and their comprehension in the three-dimensional space is limited. The difficulties for inexperienced clients to read drawings affect them to specify the brief (Barrett, 1999). Problem also stems from the fact that clients cannot imagine how the design will be emerged after construction phase (Lertlakkhanakulet al., 2008). In addition, it is rather difficult for them to imagine how their organization being accommodated in the new built environment (such as movement patterns), this may lead to dissatisfaction after the design solution is finalized.

Kiviniemi (2005) found that there is a lack of mechanism for designers to record, manage and track changes of the clients' requirements during the design stage. Problem also emerged from the clients' perspective, which is there is a lack of a systematic method to guide them to define, manage their requirements and review design against requirements during the communication with designers.
In order to solve the problems mentioned above, a User Pre-occupancy Evaluation Method (UPOEM) has been established to improve the clients' performance in two aspects:

First, virtual reality technologies are applied in the UPOEM to improve clients' understanding of their built environment. A virtual environment which can demonstrate both the building and users' activities in the built environment will be established. The reason of simulating end users' activities is that the buildings usually play a key role of accommodating user's organizations and equipment, and enable their activities. The end users' activities decide the allocation of spaces. Therefore it is expected to visualize the end-users' activities can improve clients understanding of the design solutions.

Second, a requirements and feedback interface is designed to facilitate the clients to manage requirements and review the design. This interface is intended to remind clients of the requirements of the given design solution, and guide them to evaluate the design against these requirements. Both the requirements and

evaluation results are recorded as the attributes of each room will be saved in a database during the development of the design process.

This paper is a case study conducted in a campus project, for the aim to compare the effect of this method on enhancing clients' performance during design-client communication with conventional methods.

LITERATURE REVIEW

User activity simulation

Since participants' behavior have impact on the building design, the user activity simulation research are conducted to simulate and predict occupants' activities in a given building to evaluate the building performance like evacuation, circulation, building control system, energy saving, and space usage. In the field of building performance simulation, behavior research is mainly focused on control-oriented user behavior, i.e. the interaction between the occupants of a building and environmental controls, like windows, lights, heating systems (Fritsch & Kohler, 1990; Hunt, 1979; Mahdavi & Mohammadi, 2008; Nicol, 2001; Zimmermann, 2006).

Stochastic processes were selected by some researchers as the basis of occupants modeling methods in buildings, such as Markov chains (Page 2007; Yamaguchi et al.,2003) or Poisson distributions (Wang, 2005). Some other researchers designed different user profiles in the modeling process. Abushakra et al.,(2001) developed an advanced form of input in building simulation programs with regard to occupant presence named diversity profiles. These diversity profiles described the presence of occupants and the corresponding lighting loads. Reinhart (2004) developed a model named Lightswitch-2002 to predict the interaction of occupants with lighting and blinding systems based on an adapted version of Newsham's stochastic model (Newsham, 1995), while the major part of the profiles in Lightswitch-2002 are still fixed and these profiles are also repeated for all workdays. SHOCC (Bourgeois, 2005) provided a platform for the integration of advanced behavioral models for a whole building energy simulation, which based on the Lightswitch-2002 algorithm. Tabak (2008) argued that the full complexity of real human presence in built environment was not reproduced in the previous methods, and then he developed a system called USSU to mimic the behavior of real occupants when scheduling activities in the office building. This system aims to produce data about activities of members of an organization, so as to improve the performance of building simulation tools. However, the system requires a large amount of user input data, and has no connection with the 3D virtual environment. Based on the Tabak's activity scheduling method, Zimmermann (2010) designed an agent-based method to model and simulates the individual behavior of occupants in building, for the purpose of simulating energy consumption.

Requirement management methods

For the aim to support clients to develop requirements and review design solutions, clients' requirements and feedback interface is designed in the UPOEM. This section therefore introduces the related requirement documentation methods or hierarchies. Most of the time, the documentation of client requirements is in form of traditional building program, which is generated mostly by interviewing clients, owners, and end users. In many cases, the original client requirements are not clear, and designers have to turn them into more accurate requirement descriptions or requirement attributes (Whelton and Ballard, 2003). Kamara (2002) summarized several structured requirements capturing and documentation methods, including Quality Function Deployment (QFD), Client Requirements Processing Model (CRPM), Total Quality Management (TQM), and Failure Mode and Effects Analysis (FMEA). As for the research about requirements hierarchies, there are also a lot of relevant works. The International Centre for Facilities (ICF) has published several volumes documenting their standards for Whole Building Functionality and Serviceability (WBFS) since 1992 (ICF, 2009). The purpose of these standards is to help organizations to define their functional requirements for the buildings and serve as a checklist together data and evaluate the existing buildings from the portfolio management or tenant viewpoint. Though the WBFS provides a high-level, strategic view for evaluation of building, it has no connection between requirements and design tools. On the other hand, EcoPro, a software application developed by VTT (Technical Research Centre of Finland), is intended to help building owners to define the sustainability requirements for their building projects (Kiviniemi, 2005). Kiviniemi then designed a building requirement IFC specification based on the

requirements hierarchies of the WBFS and EcoPro. The research aims to manage requirements information during design process and provide the possibility of linking requirements to the objects in the design. A solution for cascading requirements which simplifies the database structure significantly is also identified. However, there is still no attention given to the clients for collecting their feedback against these requirements. In this context, Kiviniemi's requirements specification has become part of the research basis for the requirement documentation method used in UPOEM. In addition, a feedback questionnaire is used with the requirements specification together to facilitate the clients to review design solutions in this study.

DESIGN OF UPOEM

Components of UPOEM

The architectural design process usually starts from a design brief containing the user information and requirements, such as a space program. The preliminary design proposal is created by the designer in the early stage, and then modifications are made based on the clients' feedback (this process is connected by grey arrows in Figure 1).

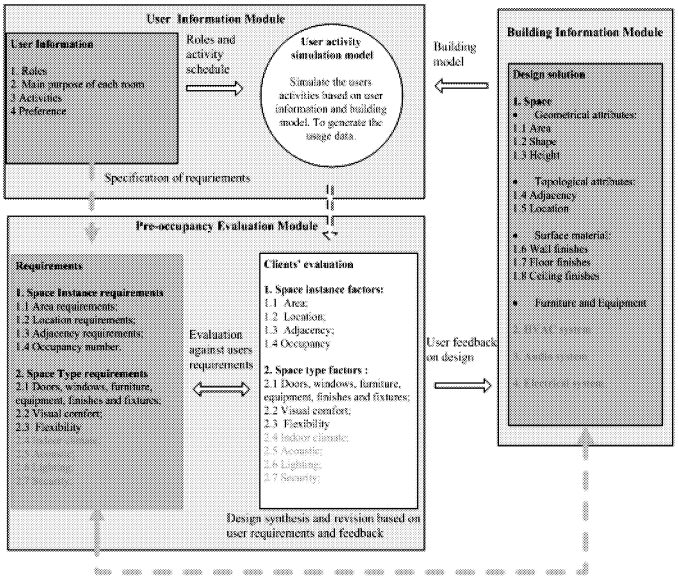

Figure 1 The design of UPOEM

In the UPOEM, another two processes are added: (1) user activity simulation; and (2) pre-occupancy evaluation (illustrated by white color in Figure 2). UPOEM is composed of three following modules:
Building information module: the purpose of this module is to use BIM tools to build up the building model according to the design given by designer;
User information module: this module is intended to collect end users' information, facilitate them to specify their activities and simulate their daily activities in the building model;
Pre-occupancy evaluation module: this module aims to conduct a pre-occupancy evaluation based on the virtual environment, and collect clients (including end users)' requirements and feedback.

Procedure of applying UPOEM

The UPOEM is applied to support the architectural design consultation meeting which mainly involves designers and clients. This method is used after preliminary outline proposal is given by the designer. The frequency of such meetings depends on the scope of the specific project and duration of its design period, and would possibly last until the design solution is finalized. There are four main steps to implement the UPOEM in practice (shown in Table 1):

Table 1 Steps to implement the UPOEM in designer-client communication meeting

1. Preparing the building information model	In this step, the building model is built via BIM tools based on the drawings given by architects. When clients give feedback on the design, the building model needs to be updated for further evaluation.
2. Specification of user activities	After the preparations of building model, end users are requested to specify their activities and the functional spaces they will use in the future working environment (support by relevant consultants) via user organization information module.
3. Simulation of the user activities	When the building model and user information are ready, the activity simulation model will be generated based on this information.
4.Pre-occupancy evaluation	The clients' feedback or further requirements are collected in this step via the pre-occupancy evaluation module.

If the clients discovered unsatisfied requirements or developed further requirements in Step 4, the feedback and design solution will be sent back to designers for revision, and the whole process starts from Step 1 again.

Implementation of UPOEM

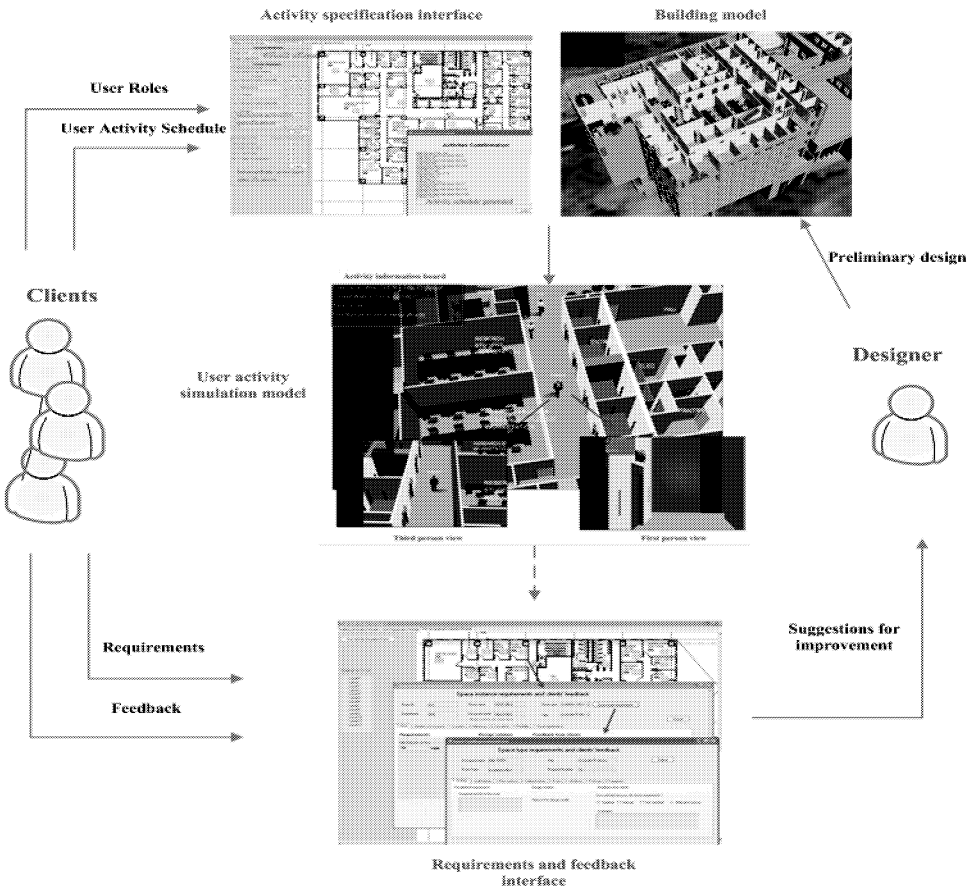

Figure 2 The implementation of UPOEM

The implementation of UPOEM starts from the designer's preliminary design of a building (Figure 2). This preliminary design contains information as building envelope and interior layout of each floor. As the development of the building, more details can be added such as furniture, equipments and MEP information. This preliminary design is generated by the BIM tools (e.g. Revit), and then imported into other software for the integration with environment and human simulation.

The activity specification interface is designed to collect end-users' organization information, which includes roles and daily activities. The end-users are requested to specify their skeleton activities (activities depend on the workflow of the individuals in the organization and can be divided into planned (e.g. fixed lectures) and unplanned skeleton activities.) by inputting start time, end time, activity type and location. They are also need to specify their intimidate activities (activities have a strong relationship with the psychological and physical needs (e.g. get a drink) but less depending on a person's role.) by inputting the daily frequency of each activity. An algorithm is written to schedule these skeleton activities and intermediate activities into one complete daily activity schedule.

Based on this activity schedule, one individual end-user's daily activity is simulated in the building model. In the same way, group of end-users' activities can be also demonstrated in the virtual built environment. Then a user activity simulation is generated as shown in Fig.3. Different functions are provided to support users to understand their activities in the building model as well as the building model itself. For example, first person view, third person view and overview are available for observing the model. Non-graphical information is also provided, such as, an activity information board is designed to tell the users the current time, walking distance, and the next activity they will conduct. In addition, the annotation of room name or function is added into the virtual environment. The purpose of this user activity simulation model is to enhance the visual experience of clients (including end users).

When the users have obtained understanding of the built environment, they can use the requirements and feedback interface to review the pre-defined requirements and specify more requirements in terms of spatial factors (e.g. size, location, adjacency, circulation, and flexibility) and visual factors. At the same time, a questionnaire is compiled with each type of requirement to collect the users' feedback. They can give comments at different levels such as satisfied, fair and unsatisfied. They can also give comments directly. These requirements and feedback are stored as the attributes of each room in a database. Therefore the designer can retrieve this information while the design development process.
By using UPOEM in the designer-client communication, the clients are expected to have better understanding of their future built environment than facilitated by traditional method (e.g. 2D drawings or 3D effect drawings). They are also expected to have better performance at expressing their requirements and reviewing design solutions when communicate with designers.

CASE STUDY

A case study is designed to implement the UPEOM in a campus project, and compare its effect on enhancing clients' performance with conventional designer-client communication method.

Design of the case study

A method of comparative experiment is used in this case study. It is intended to compare clients' performance in two circumstances: one is supported by conventional communication method and the other is facilitated by UPOEM.

In conventional communication, the representation of design solution is 3D model, which is created by Revit Architecture. Another software Design Review is used to present the 3D model. In the communication process supported by UPOEM, the user activity simulation model could enhance users' virtual experience, and the design review process is facilitated by the requirements and feedback interface, therefore the clients are expected to have better understanding of the design, and will give more comments on the design (if the design solutions do have deficiencies).
Thus the primary hypothesis to be tested by the experiment is: Clients used the UPOEM during the communication with designer will generate larger numbers of suggestions for improving the design solutions than conventional method. The definitions of "suggestions for improving the design" are specified as:

- Unsatisfied requirements uncovered during the design-client communication;
- Further requirements specified during the designer-client communication.

Two groups of end users were invited (Group A and B) to communicate with the architect to discuss the layout design of one level in a campus building (the 7th floor of the new project 'Phase 8' in the Hong Kong Polytechnic University). There are 10 end users in each group, which covers the main roles of the department accommodated in this floor. Besides, there are 1 designer and 1 facilitator. All of these end users are selected randomly but constrained by two criteria: (1) have no or less architectural design experience; and (2) have never seen the drawings used in the experiment before.

Each group of end-users will attend one designer-client workshop. During the workshop, they are required to review two drawings (task 1 and task 2) with the designer together. These two drawings are two different versions of one office layout, containing the information of architectural layout and basic furniture arrangement. Task 1 is the first version of the layout given by designer, and Task 2 is the 7th version after several revisions based on campus development office's comments. Both of these two tasks have several design deficiencies in space planning.
In the first workshop, the Group A was invited to evaluate task 1 using conventional method, and then task 2 was reviewed via UPOEM; in the second workshop, Group B reviewed task 1 via UPOEM first, and then task 2 was evaluated by 3D model. The duration of design review of each drawing is limited to 20 minutes, including both time of reading drawing/model and giving comments.
The reason of applying cross-comparison method is to avoid one group of end users reading the same drawing twice (Table 2). In this case, each group will use different method to review different drawing each time.

Table 2 Cross-comparison approaches

	Group A	Group B
Task 1	3D Model	UPOEM
Task 2	UPOEM	3D Model

Procedures of the two methods

Procedure of applying UPOEM

1. Pre-workshop preparation:
The end users are invited to specify their activities in one working day. They may be asked to describe a "busy" day, so more scenarios can be simulated in the model. Then the user activity simulation model is generated, which can simulate this 10 users' daily activities on one working day. The activity scenarios (presented in forms of animation) include desk work, meeting, use of copy machine, use of pantry, and movement between different rooms.
2. Introduction
The architect or facilitator will briefly introduce the design solutions in terms of spatial function, and let the end-users have a general understanding of reason behind the design.
Application of activity simulation model
Participants are trained how to use the user activity simulation model to observe their daily activity and the building model. Then they review the model under the help of the facilitator.
3. Evaluation
After observing the activity model, end users are asked to evaluate the design and give comments via the requirements and feedback interface of the pre-occupancy evaluation module. A video camera is used to record the verbal comments generated during the workshop.

Procedure of using 3D model

1. Introduction
The architect or facilitator will briefly introduce the design solutions in terms of spatial function, and let the end-users have a general understanding of reason behind the design.
2. Review of the 3D building model
The end users are trained to observe the 3D building model via software (Design Review), and evaluate the design solution under the help of facilitator.
3. Evaluation

After observing the building model, end users are invited to express their feedback on the design. Blank papers are prepared for them to write comments. A video camera is used to record the verbal comments generated during the workshop.

Variables and measures

Independent variables of the experiment are the two method applied: (1) the conventional method using 3D model; and (2) the UPOEM. Dependent variable is the number of suggestions for improving the design.

5. Research findings

Table 3 shows the different performance of two groups of end users. In the process of reviewing task 1, the end users of Group A generated 20 suggestions for improving design, while Group B generated 3. Because these suggestions were not normally distributed and the two groups of suggestions are independent, the nonparametric Mann-Whitney (M2) mean rank tests were used to test the significant difference. The statistical analysis showed significance p=0.019 < 0.05. In the process of reviewing task 2, Group B, who using UPOEM, generated larger suggestions than Group A, the significance p=0.019 < 0.05. Therefore the hypothesis was supported in this experiment.

Table 3 Results of the comparative experiment

		Group A (10)		Group B(10)	
Task 1	Unsatisfied requirements	UPOEM	12	3D Model	3
	Further requirements		8		0
	Total		20		3
	Mean		2		0.30
	Standard deviation		1.63		0.67
	Mann-Whitney (mean rank)		13.55		7.45
	Significance	p=0.019<0.05a			
Task 2	Unsatisfied requirements	3D Model	2	UPOEM	11
	Further requirements		0		0
	Total		2		11
	Mean		0.20		1.10
	Standard deviation		0.42		1.10
	Mann-Whitney (mean rank)		7.40		13.60
	Significance	p=0.019<0.05a			

a Significant at the 0.05 level.

Discussion

Comparing conventional 3D building model supported designer-client communication with UPOEM supported designer-client communication, the findings are as follow:

1. Compared with the conventional method, by using UPEOM, clients can generate larger numbers of suggestions for improving the design;
2. According to the questionnaire survey of client's feeling of using the UPOEM, it appears that the UPOEM provided a better virtual environment for the clients to understand the design solution in terms of spatial issues, such as, size, connection, location, adjacency, as well as appearance. Their willingness of involvement is also improved;
3. Also refer to the results of the questionnaire survey, it is found the requirements and feedback interface can help the clients to specify requirements and review the design solutions compared with the conventional method.

CONCLUSIONS

This paper introduced a case study of applying a User Pre-Occupancy Evaluation Method (UPOEM) in a real campus project. In this case study, the UPOEM is compared with the conventional designer-client

communication method which was supported by 3D models. The findings of the case study indicate that, the UPOEM can enhance the clients' understanding of their future built environment, and help them to express requirements and feedback on the design solution. The UPOEM built up a platform for supporting the designer-client communication in the briefing and architectural design stage. It also provided a potential for integrating more building and user information to conduct a pre-occupancy evaluation in the virtual environment.

REFERENCES

Abushakra, B., Sreshthaputra, A., Haberl, J. and D. C. (2001). Compilation of diversity factors and schedules for energy and cooling load calculations. Texas, USA.

Barrett, P. (1999). Better construction briefing. Malden Mass: Blackwell Science.

Fritsch, R., & Kohler, A. (1990). A stochastic model of user behaviour regarding ventilation. Building and Environment, 25(2), 173-181.

Hunt, D. (1979). The use of artificial lighting in relation to daylight levels and occupancy. Building and Environment, 14(1), 21-33.

ICF. (2009). ASTM Standards for Whole Building Functionality and Serviceability (3rd ed., p. 250).

Kamara, J. (2002). Capturing client requirements in construction projects. London: Thomas Telford Ltd.

Kiviniemi, A. (2005). Requirements management interface to building product models. VTT PUBLICATIONS. Stanford University.

Lertlakkhanakul, J., Choi, J., & Kim, M. (2008). Building data model and simulation platform for spatial interaction management in smart home. Automation in Construction, 17(8), 948-957.

Mahdavi, A., & Mohammadi, A. (2008). Occupants' operation of lighting and shading systems in office buildings. JJournal of building performance simulation, 1(1), 57-65.

Nicol, J. (2001). Characterising occupant behaviour in buildings: towards a stochastic model of occupant use of windows, lights, blinds, heaters and fans. Proceedings of the seventh international IBPSA conference (pp. 1073-1078).

Page, J. (2007). Simulating occupant presence and behaviour in buildings. Lausanne,Switzerland: École polytechnique fédérale de Lausanne.

Wang, D. (2005). Modeling occupancy in single person offices. Energy and buildings, 37(2), 121-126.

Whelton, M., & Ballard, G. (2003). Dynamic States of Project Purpose: Transitions from Customer Need to Project Requirements--Implications for Adaptive Management. 11th Annual Conference of the International Group of Lean Construction 2003.

Yamaguchi, Y., Shimoda, Y., & Mizuno, M. (2003). Development of district energy system simulation model based on detailed energy demand model. Proceedings of the seventh international IBPSA conference.

Zimmermann, G. (2006). Modeling and simulation of dynamic user behavior in buildings-A lighting control case study. Proceedings of the 6th European conference on product and process modelling (pp. 309-316).

Zimmermann, G. (2010). AGENT-BASED MODELING AND SIMULATION OF INDIVIDUAL BUILDING OCCUPANTS Gerhard Zimmermann. Fourth National Conference of IBPSA-USA (pp. 269-276). New York City, New York.