A Choice Model of Consumer Participatory Design for Modular Houses

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The paper describes the relationship of client’s requirements and available design options of the proposed system by examples of its current prototype. By integrating the nature of modularity in prefabricated housing design, a proposed web-based design system will provide information filtering questionnaires to assist customers in selecting appropriate design components. A methodology has been developed that can generate design options based on the client’s needs and available modular components from selected product suppliers making it possible to simulate the final design before processing orders for assembling and manufacturing.

Keywords: Customer participation; questionnaire approach; design knowledge representation; housing delivery process.

1. Introduction

The design of industrialized housing has been a pre-occupation in architecture since the start of the industrial revolution in the nineteenth century. In the first half of the twentieth century, architects attempted to solve the housing shortage by introducing a production process based on the assembly line. The assembly line was initially developed for the automobile industry by Henry Ford, but soon became a paradigm for the housing industry (Duarte, 2001). Currently, the construction of a new site-built home in the U.S. typically consists of 80% field labor and 20% material costs (Larson et al., 2004) – an extraordinarily high labor component compared to other industries. With prefabrication technology, the improvements of quality and efficiency are accomplished because factories can offer better working conditions, automation of many tasks, fewer scheduling and weather-related problems, and simplified inspection processes.

If mass production and prefabrication methods of the assembly line were the ideal of architecture in the early twentieth century, then mass customization and the development of digital technology are the recently emerged paradigms of the twenty-first century. The development of the digital revolution has already prompted the shift towards mass customization. In this new industrial model, computer-aided manufacturing facilitates variations of the same product. Mass production was all about the economy of making things in quantity, but mass customization does not depend on serial repetitions to be cost effective. It is about cultural production as opposed to the industrial output of mass production (Kieran & Timberlake, 2004). The Internet has
increased the opportunities to apply the concept of mass customization to customer interaction by tailoring the content to individual needs. Within limited design parameters, customers can determine what options they wish by participating in the flow of the design process from the beginning. This concept has already been implemented in the computer, clothing, and automobile industries, but it has not been fully integrated in architecture, especially the housing industry which is more directly related to personal life style. The industry lacks a process that will lead to the customization of homes that respond to the unique values and needs of the occupants.

Today’s information technology has become even more interactive and powerful than at the end of the last century. Integrating a participatory home design concept with web technology to create an online interface can become the design platform by which the clients can make more choices and establish a better communication with architects and/or manufacturers. Face-to-face meeting time between architect and client is always limited and time consuming, while a computational web-based design approach is infinitely patient and always available (Larson, Tapia, & Duarte, 2001). One of the problems that prefabricated housing industries failed to address in the twentieth century was the lack of variability and an individual identified design (Kieran & Timberlake, 2004). How prefabricated housing design can be evolved from mass repetitive production level to mass customization level to meet flexibility and variability is the primary issue to be explored in this research.

2. Background

2.1. Current approach of consumer participatory design in modular houses

Sears mail-order kit houses, from 1908 to 1940, can be viewed as the first customer-tailored mass product in the housing industry (Thornton, 2004). Sears provided a house plan catalog with the added advantage of modifying houses and hardware according to buyer tastes, and shipped the appropriate precut and fitted materials to the customer’s site. With today’s technology, the internet is the perfect medium for the dissemination of domestic design. Many pattern book companies now have big websites offering thousands of house plans stored on databases searchable by type, style, square footage, average cost, number of bedrooms and so on (Davies, 2005). Some websites also provide the design tool for customizing exterior and interior finishes after the clients have selected the base model from a house plan catalog.

2.2. Problem statement

Although the engagement of internet with pattern book concept can create a power of e-commerce for the housing industry, the end result of web surfing may or may not fit the client’s spatial needs. Unlike the other industries (shoes or watch), a suitable house design is not only judged by its appearance or architectural style, but also involves a series of architectural programming phases. Figure 1 demonstrates that by reversing the sequence of choosing a product image to get spatial features and functional details, a knowledge-based questionnaire can be a new format to collect client’s input. The interactive web interface will provide suggested design solutions based on client’s needs. The main goal of this research is to investigate the possibilities of customizing mass housing by internet and prefabrication technology beyond the finish material selecting process.

3. Methodology

3.1. Conceptual framework

In order to achieve the goal of mass customizing prefabricated modular housing, the conceptual design model must combine the results of two important parts: data collection of client’s requirement and prefab system design combinations. The web-based prototype can simulate the interaction between clients and the adoptable systems. The evaluation part
can include a series of case studies to demonstrate and revise the data-input method within the design interface. Finally, the resultant design can generate building specifications prepared for manufacturing (figure 2). This research will be more focused on input methods of the end-users instead of architects for finding suitable design solutions of prefabricated housing.

3.2. Digital questionnaire

The proposed digital questionnaire model links a series of pre-established answers that define the architectural implementation from its database, and the users will receive real-time feedback to evaluate room layout and home design solutions from the digital interface. From general spatial need to detail preference, there are four different levels of questionnaire to be developed as the programming of this prototype system: (1) Generate a list of required spaces, (2) Determine each room size and relationship of plan by function, (3) Define the detail layout of individual spaces and the development of the plans and elevations, and (4) Customize material and color selections for exterior and interior components, figure 3.

The first series of questions are trying to identify the household profile. By answering the household type and how many people in your new home can generate the basic requirement of spaces and sleeping arrangement. Furthermore, the questionnaires of life style, space adjacency preference, architectural options, and site context can help clients to provide more information and reflect the detail of spatial needs in a short period of time. For example, the eating style of the client’s family may determine the size, layout, and location of the dining area. If the client needs to work at home quite often, a home office or a den has been considered. All human-machine interactive results can be viewed as design references. The clients have a right to revise any modular component during the design trade-off process. Finally, i_Prefab advisory system will provide available design suggestions from its database. The matrix of figure 4 shows the integration of four different levels of the digital questionnaire and four different categories of the modular house system. This matrix of information then becomes the framework of constructing the database for the i_Prefab website interface.

4. System prototype and usage scenarios

In order to show how this proposed model works, a prototype simulation is developed to provide the modular housing design consulting and customization for the consumer as a simplified web-based application in the early phase of housing delivery process. A series of new concepts and methods like decision tree visualization, digital questionnaire as
the data collection, and different levels of design suggestion can be integrated as a prototype to apply in a real case. The text information on the right window of the interface includes questionnaire, explanation and multiple choices for client to input. The graphic information on the left window is the visualization output from the advisory system. The information window on the upper-right corner indicates the status of design process. Overall, the intent of this interface design is trying to keep simple and intuitive.

4.1. Design process I: List of required spaces
The first page is an introduction to provide a big picture of the i_Prefab advisory system and basic instruction of creating a personal account. After the client creates an account with user name and password to login, the first step of the design interface is gathering the client’s information to generate a list of required spaces. There are three tasks in the information gathering step: A. Household Profile, B. Life style, and C. Activities at Home.

The first question tries to define the household profile in the new home. The household profile here indicates the major occupants for the new house and does not related with family profile. The content of question will base on the answer of the previous question. In some cases, this question tries to determine the future needs of the room requirement. For instance, a young couple plan to have children will affect how many bedrooms in the list of required spaces.

Once the system gathers enough information from the user’s household profile, a basic list of required spaces will be generated as a reference. The following questions will ask the life style of living members in order to create the additional list of extra needed space (figure 5, left image). By the end of this programming phase, the system provides a checklist for selecting any activities or functions which need to be included in the new home (figure 5, right image). This is the last question in the Level 1 Questionnaire with a form of checking list to avoid any missing required space that does not address in the previous questions. All of the activities or functions within the house can be translated as physical spaces.

4.2. Design process II: Plan layout and room size
Compare to Level 1 design process, Level 2 Questionnaire is more focus on the building geometry and space adjacency. There are three sub-categories under Level 2 design process: 2A-General Site Context, 2B-Life Style, and 2C-Room Size. As mentioned previously, collecting data of site context is important because it can avoid the problem that a suggested design option does not fit the site boundary. Figure 6
left image shows that the first question in this phase is to gather the general site context information by simplified three options: urban site (narrow lot), suburban site (wide lot), and undecided location (show both conditions).

The questions followed by the general site context are related with the issue of space adjacency. By asking what is the first space to see when the client enters inside of the house can determine the first room module's location. Once the system has the first module located as a reference point, the rest of the modules can be easier to locate based on the room adjacency preference. After answering all space adjacency preference questions, the visualization window will provide a design suggestion in the form of a diagrammatic floor plan (figure 6, right image).

4.3. Design process III: Room layout and design

The building geometry and floor plan boundary have been decided before moving to this phase of design process. The task of this phase is to provide the alternative content of individual spaces. The options of different room layout have been treated as replaceable and compatible “space tiles”. The four different kitchen layouts in figure 7 left image is an example for showing the graphical layout in the visualization window and feature explanations in the client’s input window. The different kitchen layout may reflect the different cooking and living style from the clients. Besides that, the system also provides a choice option of future expansion. It is important to concern about this issue since the configuration of household profile may be changed.
after a couple years. Figure 7 right image demonstrates two expansion options: vertical and horizontal with the precise modular components as a reference.

4.4. Design process IV: Finishes and appliances
Once the building geometry, wall openings, and roof forms have been decide, the rest of the customization options are about the finishes and appliances. First of all, the finishes indicate any surface material or color for exterior and interior building components. The concept of customizing building elevation materials or interior finishes have been proposed and even implemented in the existing modular housing vendors. The reason to include this method is to proof that the i_Prefab advisory system can achieve this level and even better. Figure 8, left image, simulates the proposed modular house design model with a human scale perspective for the client to preview their future house. Exterior siding materials and colors can be customized by a simple mouse click. Moving from the exterior to the interior, each room has a simple perspective with ID numbers to identify its space element, like floors, walls, ceiling, doors, trim, curtain track etc. (figure 8, right image). After the client selected the desired finishes, the interior perspective will show as a real-time rendering to represent the finishes.
4.5. Design collaboration and evaluation

In order to transform the client selection design information and the evaluation process by professionals (architects and engineers) with the fabrication process by the manufacturer, the virtual design geometry should be represented as an information-contained object, not just a graphic entity. Figure 8 demonstrates the pre-design diagnostic website (left image) which is available anywhere with internet connections. All design suggestions are represented as a virtual building online and the digital design model with customized client-input data is then transformed into a Building Information Modeling (BIM) application using Autodesk Revit or a similar program (figure 9, middle image). After professional review, the BIM digital design model includes all of the construction information and is ready for the coordination with manufacturing and the assembly of the building components in the factory. The digital design model also can be exported from the Revit application to Google Earth (figure 9, right image) to position directly with the exact site information and provide the client with a review of the house as a four-dimensional experience. Overall, the diagram shows the expectation of housing delivery process from web-based programming to digital design collaboration and virtual environment simulation.
5. Conclusion

The results of this current phase of research establish an open-ended framework of a decision support system by dynamic questionnaire to find design solutions for future reference. The objective is to bring prefabricated modular houses to the next level to meet the goal of mass customization with digital technology. The interpretation of translating the client’s need to match different spatial configurations of the design models from the selected prefabricated modular housing vendors is a little subjective based on architect’s assumption. However, this is an online recommendation to replace the limited face-to-face first meeting time between architects and clients. Revising the modular unit to be more flexible and client responsive is the feedback to the modular housing architects and vendors. It is obvious that costs can be reduced in the architectural design and engineering consulting phase. Moreover, the factory-made modular houses can save the material waste and time spent on the construction site with tremendous labor cost. The future direction will be focused on the output format for manufacturing and the bi-directional linkage between the advisory system and Building Information Modeling applications to make seamless design collaboration in the housing delivery process.

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References