IT TOOLS AND HOUSING

A Design System Approach to Mass Customizing Industrialized Homes in Japan

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Abstract

Today's housing manufacturers in North America claim that they can customize a home to the same extent as conventional homebuilders. Their design process for the creation of customized homes, however, does not reflect the advantages of industrialization of housing, in which mass-production of housing components helps reduce the design and production costs, while in-factory production ensures a steady supply of quality products.

'Mass Customization' is a seemingly contradictory term, for how can one combine mass production and customization? In 1987, this revolutionary concept was first introduced in North America, recognized as a means to produce customized products on a mass basis. In many industries, the concept of mass customization is applied to product design in order to satisfy the unique demands of each consumer. The housing industry is no exception. Today, Japanese housing manufacturers have already succeeded in mass customizing industrialized houses, and their high-quality, reasonably priced homes have a good reputation.

This paper examines how Japanese housing manufacturers apply the mass customizing approach to improve their products, and the public's perception of industrialized housing. The authors surveyed five manufacturers on their mass customizing techniques by visiting their manufacturing plants in order to analyze their production capability. The authors found that the manufacturers have developed a 'mass custom design system' in order to totally coodinate their design, production and marketing approaches. This paper describes the principles of the design system and its effect on the delivery of industrialized housing.

Mass Customizing Homes

Buying a new home is a significant investment usually undertaken only once or twice in a lifetime. Therefore, today's consumers are cautious and selective when buying a house, because it must satisfy their personal requirements in terms of customization, product quality and affordability. In order to meet the housing demands of today, Japanese housing manufacturers have been practicing a unique way of mass-producing customized products—their design and production approaches can be referred to as "mass customization" (Davis 1987 & Pine II 1993).

Mass customization is a relatively new concept that has taken years of research to put into practice. The concept of mass customization was anticipated in 1970 by Alvin Toffler, but it was not until 1987 that the term itself was first coined by Stanley Davis. In 1993, B. Joseph Pine II developed a general strategy for mass customizing products and services. Today, Japanese housing manufacturers have brought the concept into full play, mass customizing their homes.

Mass customization is an oxymoron. The term is composed of two opposite notions: mass production and customization. The mass production of housing is effective in reducing construction costs, as well as in increasing product quality. In general, the higher the rate of the in-factory completion of the house, the shorter the elapsed time for the construction, which reduces the production costs (Hutchings 1996). In addition, the quality of the components of the home can be maintained under optimum conditions inside the factory, where the materials are not exposed to outside climate. On the other hand, mass production usually produces identical, monotonous homes that hardly correspond to the market demands for personalized design. Custom design, on the other hand, is an influential factor in satisfying homebuyers' individual requirements; however, customization increases design costs (Smith 1998). Mass customization is not a 'trade-off'—it does not require one to choose between mass production and customization. It is rather a situation in which the disadvantages of one system are 'offset' by the advantages of the other; it is "the paradox of the simultaneity of opposites" (Davis 1987).

One of the most effective methods of mass customization is to create modular components that are mass-produced but can be

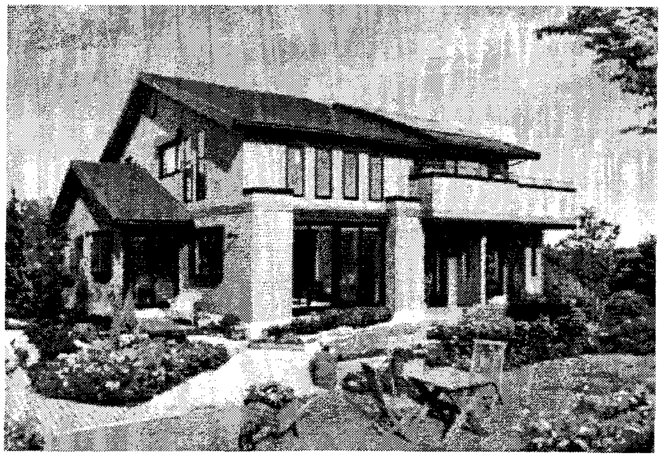

Fig. 1. A typical prefabricated house in Japan (Source: Daiwa House Industry Co., Ltd. 1999)

configured into a wide variety of end products. This method minimizes costs, while maximizing individual customization (Pine II 1993). Also, Japanese housing manufacturers produce a number of modular components, while developing communication tools that effectively adapt the client's choices to housing. As a result, the manufacturers have succeeded in mass customizing their homes, having enjoyed a good reputation for their industrialized housing, which the public had perceived as inferior until the mid-70s, since the manufacturers focused only on mass-producing their products with little thought to the design quality (Fig.1).

Mass Custom Design System

By the 1980s, the 'high quality' of products had become a requisite for market entry. The concept of quality had developed from a focus on reliability, in the 1970s, to a demand for personalization of products. In general, today's consumers are no longer satisfied with generic, ready-made products; rather, they prefer to purchase customized products that meet their immediate needs (Anderson 1997). Today's Japanese housing manufacturers focus on the custom design of dwelling units, mass-producing a variety of housing components, which end users are given the freedom to choose from. However, although custom design helps upgrade housing quality, it also leads to an increase in design costs, while the market still demands affordable homes. By using a mass customizing approach, Japanese manufacturers have succeeded in avoiding a conflict between the demands of customization and the increase of design costs (Pine II 1993).

To bring the concept of mass customization into full play, Japanese manufacturers have developed a 'total coordination' approach to their design, production and marketing. In particular, their design techniques are well integrated into a system that is composed of two design-support sub-systems: product (P) and service (S). In other words, the system can be referred to as a 'mass custom design system' (MCDS) and explained by using an analogue model as follows:

MCDS = f (PS)

The service sub-system concerns communication techniques that lead users to directly participate in customizing their new home, while the product sub-system covers production techniques to encourage housing suppliers to mass-produce housing components. Both sub-systems can be considered as the indispensable functions of mass-producing customized homes. In general, mass production of housing components is regarded as an effective method of reducing production costs (Sekisui Chemical 1998a). Moreover, the higher the rate of in-factory completion of housing components, the more the product quality can be maintained under optimum conditions inside the factory, where materials are not exposed to adverse outside climate (Hutchings 1996). Moreover, the elapsed time for the production, which influences the product's costs, is fully controlled.

The Service Sub-System

In customizing products, 'user participation' is considered important, and therefore manufacturers provide design support communication services for their clients. During the design stage, manufacturers encourage clients to participate in customizing their home in three ways: by giving catalogues to the client, by visualizing the client's image of the house, and by estimating the product's costs (Daiwa 1999). Before actually making a contract with the client, manufacturers offer these services as part of their design

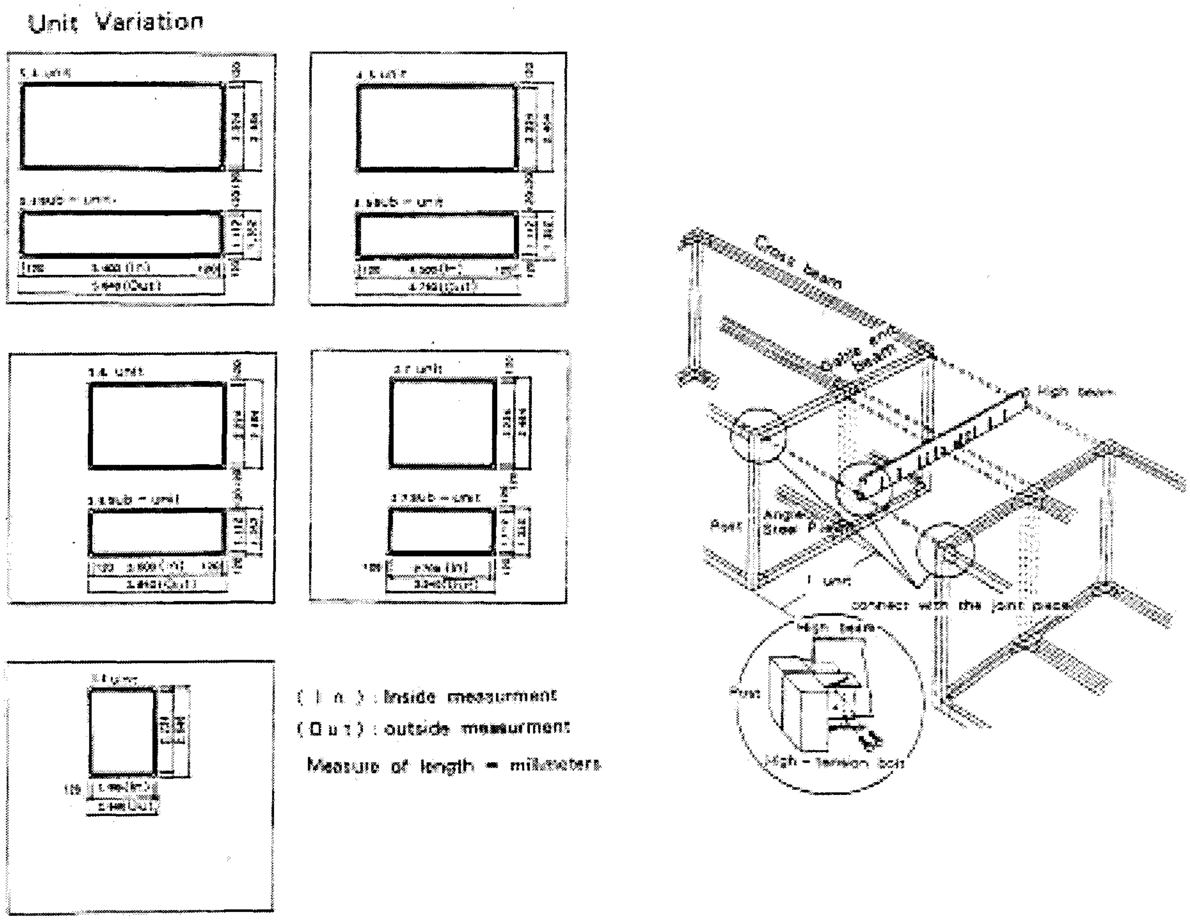

Fig.2. Structural unit variation (Source: SekisuiChemical Co., Ltd. 1998a)

consultation process, which normally takes place in the company's display house located in the Housing Park or in the salon of the Housing Information Center. A Housing Park offers a collection of display homes built by a variety of housing companies, located in commercial centers readily accessible by transit or train. The scale of the parks varies in size; however, 20 to 40 model homes are usually built in the park. The Housing Information Centers also function as exhibition and design consultation areas.

In general, during the design stage, the manufacturers provide the client with three types of catalogues that concern the company's commodities, specific-housing types, and component selection. The housing component selection catalogue corresponds to the housing styles, and helps the client choose the standard components for the exterior and interior arrangements of the home. The catalogue describes the material, size, color, texture and functions of each component; however, it does not include any prices. In addition, manufacturers use a computer-aided design (CAD) system for the creation, modification, analysis and optimization of a design. Furthermore, as the virtual image of the house is erected, based upon the housing components selected by the client, the manufacturer provides a cost estimate. Once the client is satisfied with the plans, the manufacturer will finalize the design and, at last, enter into a contract with the client (National 1997).

The Product Sub-System

An important part of mass customization is that the user directly determines the configurations from choices given as client input during the design stage. This could hardly be achieved without the standardization of housing components for the structural, exterior and interior arrangements. The concept of component standardization can be illustrated with Lego® building blocks. A number of simple, modularized blocks can be connected in a variety of ways, because of their interlocking tabs and holes.
Likewise, Japanese manufacturers offer a variety of housing components to their clients and then encourage them to participate in combining the components to design their new home. These are visually arranged in a component selection catalogue to enable clients to easily choose from the many options. Housing components can be divided into three categories: structural, exterior and interior. The structural components are used to construct the housing models that determine the number and size of each room, while the interior and exterior components serve to coordinate both the decorative and the functional elements that customize housing.

Structural Components

This category often applies to modular homes, because a panelized housing system does not define spatial limitations with its size and volume of interior space. However, most prefabricators who produce panelized components still adopt a conventional modular system based on the size of a "tatami" mat (909 mm by 1818 mm) to a room layout of their products, so that the number of tatami mats determines the size of each room. On the other hand, prefabricators who produce unit components precisely standardize the size and volume of each structural unit component that is simply a box-shaped frame made of either steel or wood. Spatial variation of housing can be achieved by the combination of standard units (Fig.2).

Sekisui Chemical, for instance, produces modular components, standardizing nine basic units. Toyota also manufactures unit

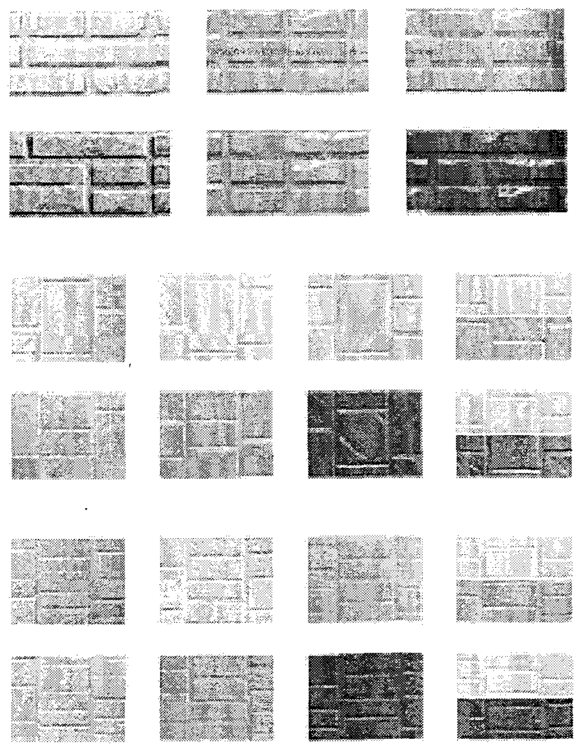

Fig.3. Exterior wall variation (Source: Toyota Motor Co. 1998)

components, providing three basic units. The width of the units ranges from 5,700 mm to 4,800 mm, and 3,900 mm, while the depth is basically 2,400 mm; however, half-sized units are also available for each. In addition to these units, Toyota offers two extensions to further increase the variation of housing forms.

The manufacturers expand the variation of spatial arrangements with a few numbers of structural unit components for which the size and volume of each are standardized. According to Toyota and Sekisui Chemical, there are roughly 8-10 standard unit components in use that include half-sized units and additional modules. By combining these standard unit components, manufacturers can produce a great number of individualized housing forms to meet clients' spatial requirements.

Exterior Components

The exterior of a house is vital to first impressions and also enhances a sense of ownership. A house's identity is defined by its external design features such as roofs, walls, openings, verandas, balconies, and entrances. In order to customize their products, Japanese prefabricators offer a variety of external components to meet clients' preferences.

In general, two types of roofs are commonly offered: a pitched roof and a flat roof. The former is a more conventional roof shape, and has a classic appeal. The latter is also becoming popular because efficient land use is essential, and a flat roof is as a multifunctional space and can be used, for example, as a garden. In order to increase roof variation, the manufacturers provide several types of roofs with different shapes, colors, and textures. As well, exterior walls vary mainly in color and texture. Many manufacturers apply walls made of ceramic-based materials that can be molded into certain types of walls, as though the house is built of brick or stone (Fig.3). The wall surface is more articulated by coating, weather-resistant acrylic resin often used to burnish the surface of the wall.

Interior Components

Interior components are more diversified and are designed to coordinate the living environment for each client. The main interior components are the kitchens, sanitary facilities, storage, interior finishes, staircase, and amenities. To meet the varied client requirements, the manufacturers allow freedom in interior design and, at the design stage, introduce a complete selection catalogue that enables clients to customize interior components.

The kitchen's layout must be carefully designed in order to provide a convenient place for cooking, serving, storing, and cleaning. Sekisui chemical, for example, provides two kitchen types: I-shaped and L-shaped. The former is the simpler shape, where the sink is central and counter space extends horizontally on either side (Fig.4). The space is large enough for two people to use at the same time. The L-shaped kitchen is also designed to allow the user ease of movement while cooking, but provides a shorter distance from the sink to the refrigerator and stove. As for kitchen variation, Sekisui

Fig.4. I-shaped and L-shaped kitchen variation (Source: Sekisui Chemical Co., Ltd. 1999)

Chemical provides eleven styles for the I-shaped and nine styles for the L-shaped. Such variation is mainly achieved by using a variety of partitions to separate the kitchen from the dining room. These partitions come in four styles: open, open hatch, hatch, and separation. The manufacturer also offers fifteen different colors for kitchen furniture. In addition, many other options are available for the sink, oven, dishwasher, and storage.

A house is required to have enough storage space for users to store their family's belongings. Usually, 10 to 20% of the floor area is used as storage space for clothes, cookware, bedclothes, books, foods, cookware, and household utensils. Sekisui Chemical illustrates the usability of storage, dividing the uses into two types: concentration and diversion. The former concerns belongings that are used seasonally and then stored away. The latter involves those items that are frequently used, and therefore each room needs such storage spaces to allow for easy access. Once clients understand the spatial needs for the storage space, under the manufacturer's guidance, they will select the rack systems as well as the entrance- and laundry-storage systems from a catalogue. In

Fig.5. Rack system variation (Source: Sekisui Chemical Co., Ltd. 1999)

addition, storage is often placed under the staircase and in the attic in order to use indoor space more efficiently.

Racks are designed to fit every room and function as both concentration and diversion storage spaces. The location of these racks is determined according to the client's spatial arrangements and needs. Rack variation is based on the volume that determines the capacity for storing, the shelf combination, and the door variation. Sekisui Chemical carefully categories their rack systems into 11 types, and, with some exceptions, most types can extend to a certain size based on modules. For the horizontal extension, Sekisui Chemical standardized the width of racks at intervals of 900mm, 1,000-1,200mm, 1,300mm, 1,800mm and 2,200mm, while the depth are also fixed by 400mm, 600mm and 900mm modules (Fig.5). In total, Sekisui Chemical offers 81 configurations and 48 door arrangements to satisfy clients' tastes and storage requirements.

As is the Japanese tradition, people usually keep all shoes on the entrance shoe shelves. Even though the entrance space is limited, entrance storage is required to have sufficient space for all forms of outerwear. Sekisui Chemical presents several types of entrance storage spaces: a waist-height shelf with a counter on the top, a counter shelf with storing spaces below and above the counter, and a tall shelf without a counter. Configurations and door colors increase the variety of options. The manufacturer also produces two basic shelf units of 440mm and 760mm in width. In combination with the two units, the widths of the shelves can be extended to 1200mm, 1520mm, and 1960mm. In addition to these, Sekisui Chemical provides 16 colors for doors and 4 colors for full-length mirrors to help customize the entrance storage.

Laundry space is required to be large enough to enable the user to launder clothes and store all the necessary laundry cleaning materials that are usually kept in the space. As a result, a laundry space is usually filled with shelves for detergents and other small articles, as well as a washer, a dryer, and a washstand. However, these items are conditional, because each household differs from the other in terms of the user's needs and spatial limitations. Sekisui Chemical divides their laundry space into five storage arrangements. Normally, they put one or two shelves above the washer space, and selectively, one tall shelf can be placed on either side of the upper shelf. As for the shelf doors, clients can choose from 11 colors. A staircase serves as a link between the levels, and is designed with consideration for safety in terms of the shape, length, and pitch of the stairs, which are determined by the

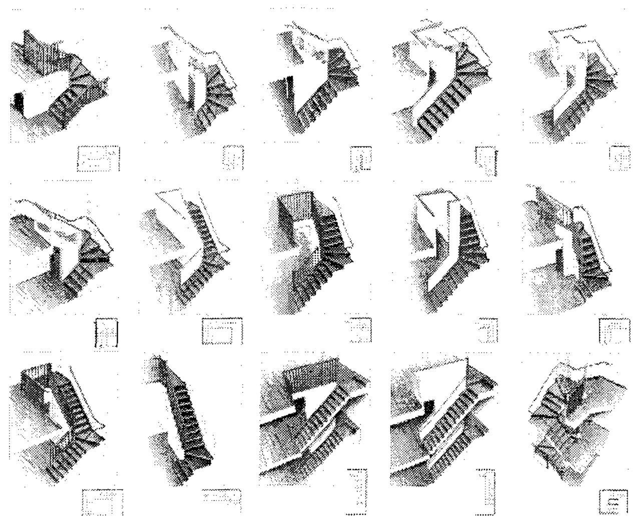

Fig.6. Staircase unit variation
(Source: Sekisui Chemical Co., Ltd. 1999)

height of risers and the depth of treads. Also, staircases must be safe enough to be used by people of all ages. Handrails are often put in place to prevent users, especially the elderly, from falling, and to help them climb up the stairs. As well, the treads must be non-skid. Japanese prefabricators offer a variety of staircase designs: I-shape, J-shape and U-shape. Each manufacturer differs as to the length and pitch of the stairs; in particular, such manufacturers as Toyota and Sekisui Chemical that produce modular homes standardize staircase units to fit their specific housing types. Sekisui Chemical, for instance, produces 18 different staircase units that correspond with one specific housing type (Fig.6). The location of the staircase is not predetermined. Instead, during the design stage, clients choose a staircase type from a catalogue and then decide on its location.

Mass Custom Design

The manufacturers' design approach can be referred to as 'mass custom design' (MCD) which is a result of the combinations of three basic design elements of housing: the volume (V), exterior (E) and interior (I). In addition, the manufacturers usually provide optional equipment (O) in order to improve the quality of the housing. In principle, these housing components must be mass-produced, but the home itself can be customized by the user's direct choices of such components. Furthermore, the design approach can be explained by using an analogue model as follows:

MCD = f (V, E, I, O)

Furthermore, the exterior and interior designs include sub-categories such as the roof, walls, doors, windows, balconies, and front entrance arrangements for the exterior, as well as the kitchens, sanitary facilities, bathrooms, washrooms, toilets, storage, and finishing arrangements for the interior. In addition, the variety of sizes, materials, colors, and textures available for each component, as well as the variety of amenities offered, help expand the number of variations. Consequently, in order to meet clients' individual requirements, the manufacturers are able to provide thousands of housing variations for their clients without producing model homes that are designed on a speculative basis.

The Cost Performance Approach

Japanese housing manufacturers have succeeded in mass customizing homes, and have increased productivity by adapting integrated inventory systems and automated production lines. Most manufacturers have acquired ISO 9000 and 14000 series that certify the quality control of their products, as well as the companies themselves. However, it still remains a paradox that the industrialization of housing cannot help to provide affordable housing. A housing survey conducted in 1997 by the Government Housing Loan Corporation in Japan showed that the construction cost of a site-built wooden house in Japan was estimated at 2,193 \$/m2 (Cdn. \$) on average, while a prefabricated house was at 2,375 \$/m2. This result shows that a prefabricated house is approximately 8% more expensive than a site-built house.

On the other hand, Japanese housing manufacturers have been producing 'better quality' homes for about the same price as conventional homes. In fact, their products are quality-oriented in

response to the marketing strategy called 'cost
contributes towards increasing the price of housing, while upgrading the quality to a great extent.

Housing affordability is considered a crucial factor in determining whether or not the buyer actually proceeds with the purchase of the house. For this reason, the Japanese cost performance approach may not be applicable, unless consumers regard housing price as of secondary importance to quality. Moreover, according to the market needs and the company's capability in mass-producing housing components, the component variations within the product sub-system need to be re-arranged. In principle, the proposed mass custom design system helps both local homebuilders and housing manufacturers produce mass custom homes that can directly meet the housing demands of today.

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