A Proposed Design System Model for the Delivery of Mass Custom Homes: Learning from Japan's Prefabricated Housing Industry

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Abstract:
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 customisation, product quality and affordability. Housing manufacturers in North America claim that they can customise a home to the same extent as conventional homebuilders. Their design process for the creation of customised homes, however, does not reflect the advantages of industrialisation 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 Customisation' is a seemingly contradictory term, for how can one combine mass production and customisation? In 1987, this revolutionary concept was first introduced in North America, recognised as a means to produce customised products on a mass basis. In many industries, the concept of mass customisation 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 customising housing, and their high-quality, reasonably priced homes have a good reputation.

This paper examines how Japanese housing manufacturers apply the mass customising approach to improve their products, and the public's perception of industrialised housing. The authors surveyed five manufacturers on their mass customising techniques by visiting their manufacturing plants in order to analyse 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 industrialised housing.

Keywords: Housing, Prefabricated Housing, Industrialized Housing, Customization, Mass Production, Mass Customization, Design Management

MASS CUSTOMIZING HOMES

Mass customization is a relatively new concept that has taken years of research to put into practice. The concept was introduced 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. Therefore, in this study, five major housing manufacturers in Japan were examined thoroughly in terms of their mass customization approaches (Table 1).

TABLE 1. Company Profile

Company Name (1)	Plant Location (2)	Production (3)
Daiwa House Industry Co., Ltd.	Nara	Steel hybrid panelized housing
National House Industrial Co. Ltd.	Shizuoka	Steel hybrid panelized housing
Resco House Co., Ltd.	Ibaragi	Concrete panelized housing
Sekisui Chemical Co., Ltd.	Saitama	Wood and steel modular housing
Toyota Motor Co.	Yamanashi	Steel modular housing

Table 1: *Company profile*

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 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).

Figure 1: *A typical prefabricated house in Japan.*
Top: The exterior
Bottom: Interior open space arrangements of the living and dining rooms
(Source: Daiwa House Industry Co., Ltd.)

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 catalogs 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 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, manufacturers provide the client with three types of catalogs, concerning housing types, technology and component selection. The first two catalogs are usually provided during the marketing stage, while the component selection catalog is used during the design consulting stage. The housing component selection catalog corresponds to the housing styles, and helps the client choose the standard components for the exterior and interior arrangements of the home. The catalog 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

In this study, five major manufacturers were examined; however, their communication approaches during the design stage were quite similar. Therefore, the trends within two of the manufacturers, such as Sekisui Chemical and Toyota, were re-examined in order to identify their communication techniques during the design stage.

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 catalog 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. Tatami mats made mainly of straw are Japanese traditional flooring mats of a standardized size, used to describe the size of a 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.

Sekisui Chemical, for instance, produces modular components, standardizing nine basic units (Fig. 2). Toyota also manufactures unit 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.

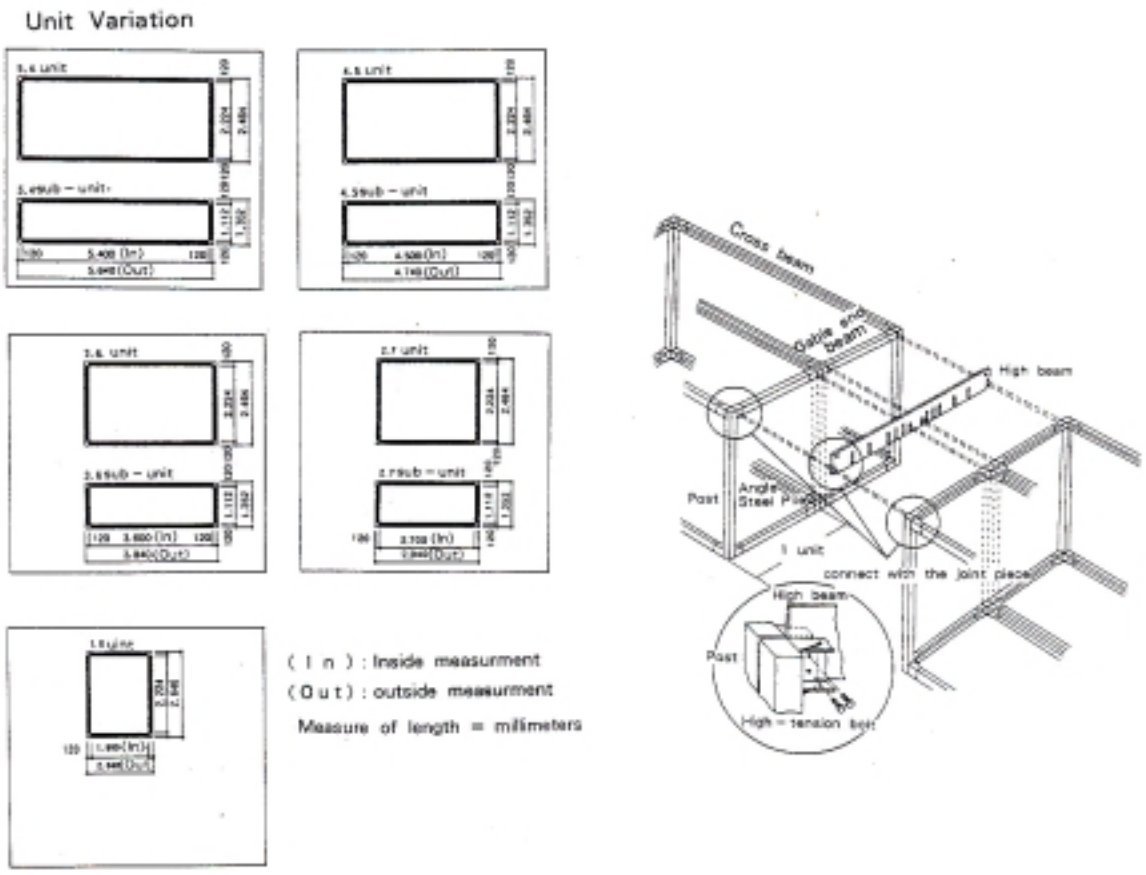

Figure 2: *Structural unit variation*
(Source: Sekisui Chemical Co., Ltd. 1998)

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 the sections covering exterior components, Toyota's component selection catalog will be used. The catalog covers four types of their products: Meleze Premier, Meleze, Chene, and Foret (Toyota 1998).

Roofs

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. Toyota, for instance, produces two types of pitched roofs (gable and hipped) with an overhang of 450mm, 600mm, or 900mm. In addition, they also offer five different slate materials.

Walls

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. Toyota offers six colors for brick-type walls, eight colors for sandstone-type and Oya tuff stone-type walls, six colors for Teppeiseki stone-type walls, and five colors for general masonry-type walls.

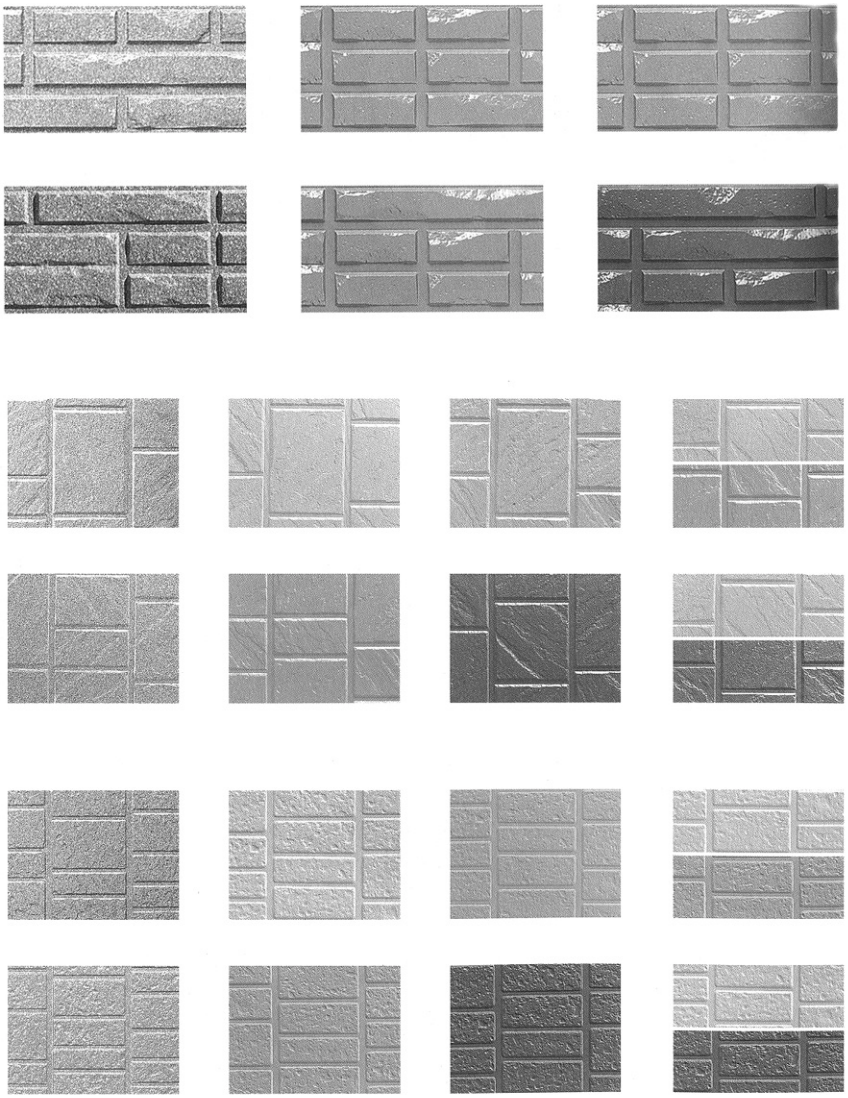

Figure 3: *Wall Variation*
(Source: Toyota Motor Co. 1998)

Windows

Windows not only create a sense of identity on the housing facades, but also allow each room to gain access to natural light and ventilation. The larger the window, the larger the room looks, because one focuses on the outside; however, the larger the window, the higher the rate of heat loss. In order to improve the heat insulation property of windows, insulating glass and sash are preferred by most manufacturers. Toyota's catalog categorizes windows into five types: large-sized bay windows, bay windows, patio windows, waist-height windows, and small windows. Also, Toyota provides additional windows to fit specific locations such as kitchens and bathrooms.

Balconies

Verandas and balconies are prominent features of any home's exterior, and can function as gardens, hobby spaces or laundry rooms. Japanese people frequently prefer to dry their laundry outside in the sunshine rather than use dryers and therefore the location of verandas or balconies is important. In the case of Toyota, the size of the veranda is determined by the combination of structural units, and the overhang of balconies is standardized to be 900 mm from the surface of the external wall. The appearance of verandas and balconies is harmonized with the wall materials selected by the user. In addition, each housing type has its own style of balusters and balustrades (Fig. 4).

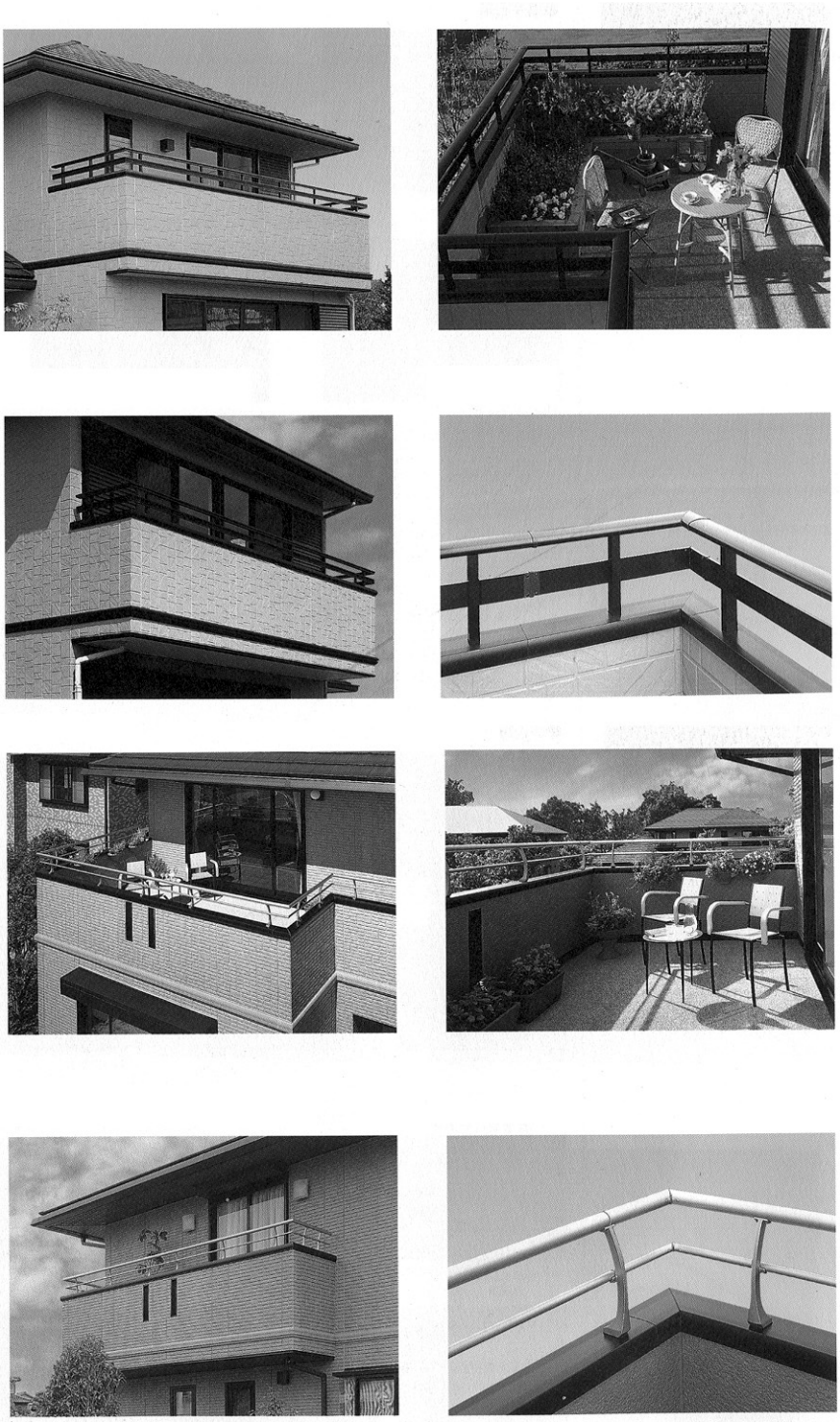

Figure 4: *Veranda and balcony variation*
(Source: Toyota Motor Co. 1998)

Entrance Doors

The entrance is another important decorative feature of a house. Toyota provides two types of entrance doors, aluminum and heat-isolating steel, which are used in three types of their products (Meleze Premier, Meleze, and Chene). The aluminum door expands into five additions: single-swinging lattice doors, double lattice doors, double decorated doors, double-slit doors, and double quasi-fire-preventive doors. There are also three types of heat-isolating steel doors: double doors, single-walled doors, and double-walled doors. As an additional option, some of these doors can be equipped with a remote control key system.

Front Entrance

Japanese people usually take their shoes off at the entrance, when entering a home, so that the entrance must have sufficient space for taking off shoes and storing them. The inside floor is normally built a few steps higher than the entrance floor level. Toyota provides two types of front entrance configurations: flat and alcove. In order to decorate entrance façades, a variety of eaves are used, and the location and size of the entrance also influence the design. To enhance the façade variation of the entrance, Toyota offers entrances with eaves, with roof-shaped eaves, located under the overhanging balcony, and under the veranda with eaves.

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 and amenities. In this section, the variety of interior components will be reviewed, based on the Sekisui component selection catalog for their products known as 'Two-U home'. To meet the varied client requirements, Sekisui Chemical allows freedom in interior design and, at the design stage, introduces a complete selection catalog that enables clients to customize interior components (Sekisui Chemical 1999).

Kitchens

The kitchen's layout must be carefully designed in order to provide a convenient place for cooking, serving, storing, and cleaning. Sekisui, for example, provides two kitchen types: I-shaped and L-shaped (Fig.5). The former is the simpler shape, where the sink is central and counter space extends horizontally on either side (Fig.6). 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 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. Sekisui Chemical also offers fifteen different colors for kitchen furniture. In addition, many other options are available for the sink, oven, dishwasher, and storage.

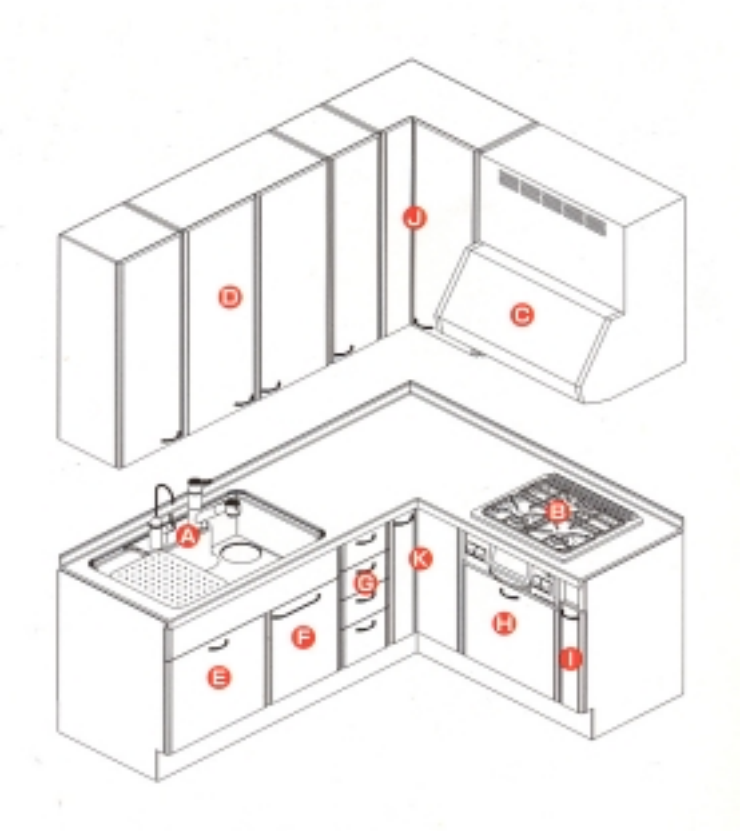

Figure 5: *I-shaped and L-shaped kitchen types*
(Source: Sekisui Chemical Co., Ltd. 1999)

Figure 6: *I-shaped and L-shaped kitchen variation*
(Source: Sekisui Chemical Co., Ltd. 1999)

Sanitary Facilities

Sanitary facilities include bathrooms, washrooms and toilets, and are essential for everyday life. In Japan, these facilities are usually separated by permanent partitions, and are designed for people of all ages to use comfortably and safely. Most prefabricators use barrier-free design strategies for sanitary facilities, especially for the elderly. For instance, Sekisui equips bathrooms and toilets with handrails.

Bathrooms

A bathroom consists of many components: a floor, ceiling, shower, bathtub, counter, storage, walls, doors, windows, lights, fans, and metal work. The variation in the bathroom is mainly in

the size, color, texture, and additional equipment. Sekisui Chemical produces three types of bathrooms: Ageless, New Wide and New Custom. They also offer clients a choice of 14 colors of bathtub and counter. In order to improve users' choice, Sekisui Chemical increases bathroom variation with optional equipment such as emergency call buttons, wide handrails, and shower-sliding hooks.

Washrooms

In Japan, a washroom does not usually have a toilet—the area is normally used only for hand washing. It consists of a washstand, racks and mirrors. The racks are arranged according to the side of the bathroom and the choice of door color allows for a sense of variation. Sekisui Chemical produces three types of washrooms: Ageless, Refiny, and Basic. In general, the Ageless washroom has a modern appearance, while the other two types are more traditional, and have laminated wood doors. In order to enrich the variation of the racks, the user can choose from a wide variety of colors and sizes (Fig.7). The size variation is essentially created by means of horizontal extension of the racks, mirrors, and counter.

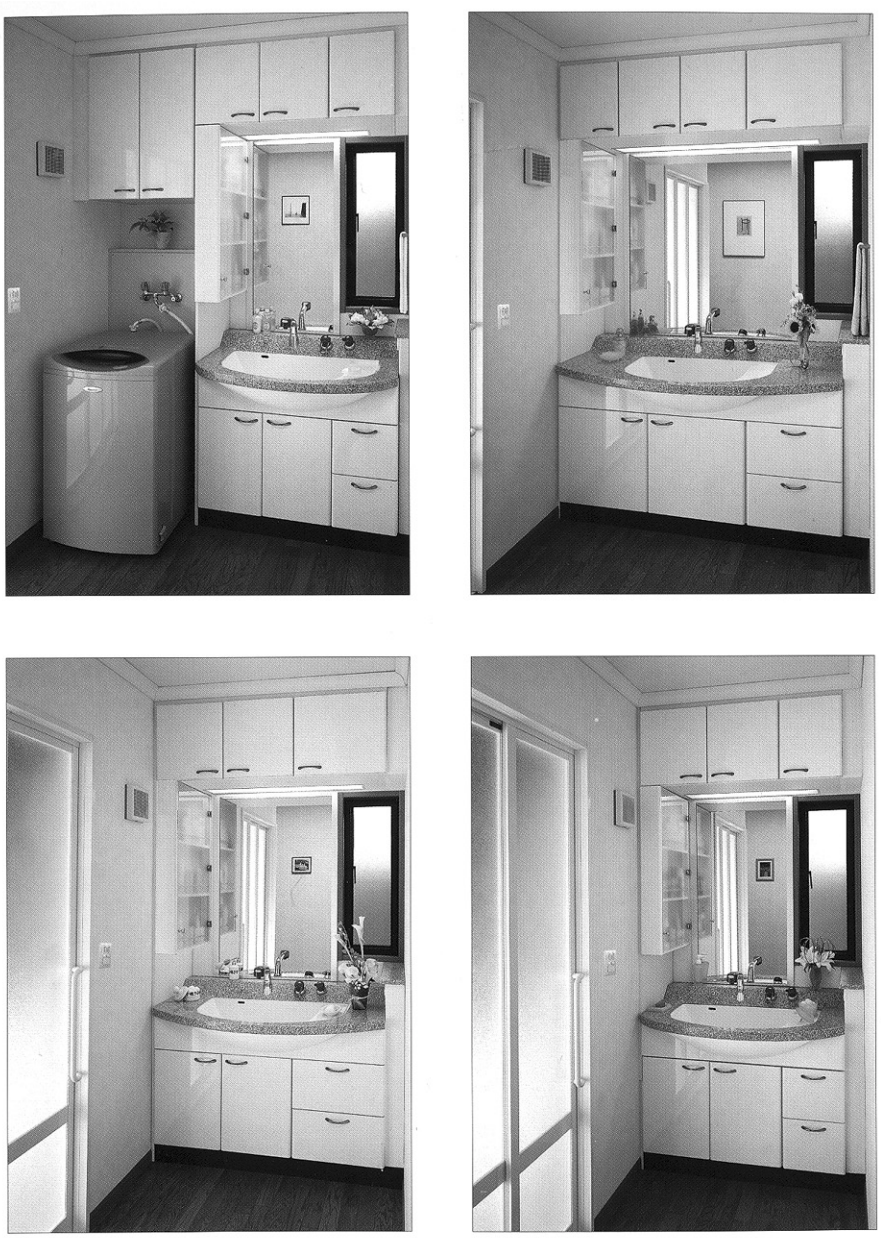

Figure 7: *Washroom variation*
(Source: Sekisui Chemical Co., Ltd. 1999)

Toilets

In Japanese homes, the toilet is usually separate from the bathroom and is similar to the North American 'powder room'. It is a small space with a toilet, washstand, and mirror. Using barrier-free design techniques, the prefabricators ensure toilets are comfortable, safe, and equipped

with handrails to help the user's vertical motion. In addition, they provide electric toilets with such functions as heating, cleansing, drying and deodorizing. Some electric toilets are equipped with a moveable seat that helps the user to sit down and stand up. Sekisui Chemical's toilet rooms come in two sizes, standard and wide. They also provide, as standard equipment, a spot heater that is strong enough to instantly warm up the small toilet room when needed.

Storage systems

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 catalog. In 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.8). In total, Sekisui Chemical offers 81 configurations and 48 door arrangements to satisfy clients' tastes and storage requirements.

Figure 8: *Rack system variation*

(Source: Sekisui Chemical Co., Ltd. 1999)

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. Sekisui Chemical 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.

Interior Finishes

Sekisui Chemical has been practicing their own design approach, and gives clients the opportunity to coordinate the interior space of their new home. They provide two styles of rooms, Decorating and Shaping, with four colors (ecru, medium, dark and light) for flooring and molding materials. The Decorating style is designed to represent the elegance of Western classic ambience, while the Shaping style is simplified and modern. In addition to these two styles of rooms, Sekisui Chemical also produces a Japanese-style room. Most clients like to have at least one room in their house designed in this traditional way.

Flooring

Flooring helps decorate the interior of a house, and flooring materials such as wood, carpet, and tatami are preferred in Japan. Flooring varies mainly in color and texture (Fig.9). In wood flooring, the combination of wood boards that differ in size also helps increase flooring variation that the user can select. In addition, Sekisui Chemical provides more selections in wood flooring, with eight decorated floors in four basic colors, and, in total, they offer 32 types of wood flooring to their clients.

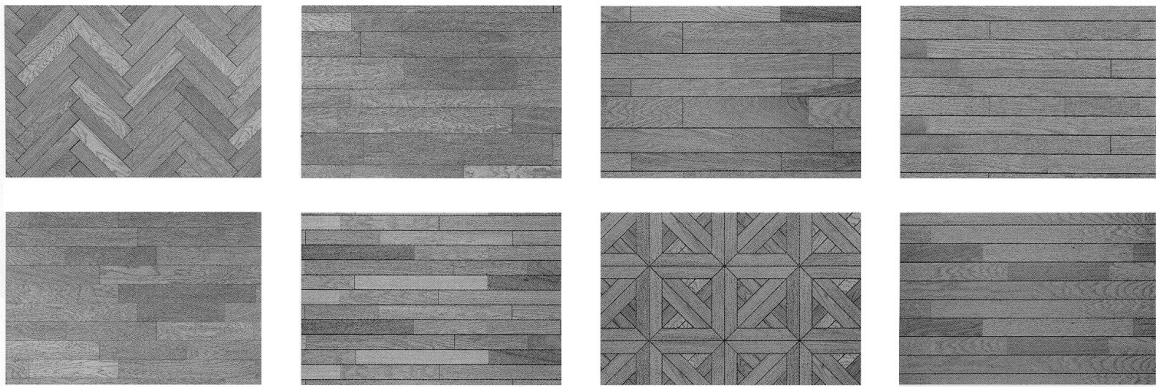

Figure 9: *Flooring variation*
(Source: Sekisui Chemical Co., Ltd. 1999)

Interior doors

Interior doors not only provide visual and acoustical privacy when closed, but also allow for natural ventilation when opened. Two types of doors are normally used: swinging and sliding. Swinging doors suit most rooms and are relatively easy to install; however, they require a certain space for opening and closing. In order to use the limited space efficiently, sliding doors are more effective. The parallel sliding system for the opening and closing of sliding doors does not require much space. In terms of the variation of interior doors, Sekisui Chemical provides, in total, 24 prototypes of interior doors that are applicable to two types of their interior arrangements called Decorating and Shaping. Most of the doors are swinging doors, but the manufacturer also provides one sliding door among them. These doors vary in size and decorative pattern, some of which have transparent windowpanes that allow for a visual link to adjoining rooms. In addition, Sekisui Chemical offers four colors for the laminated wood doors. Therefore, in total, 96 interior door styles are offered.

Staircases

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 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.10). The location of the staircase is not predetermined. Instead, during the design stage, clients choose a staircase type from a catalog and then decide on its location.

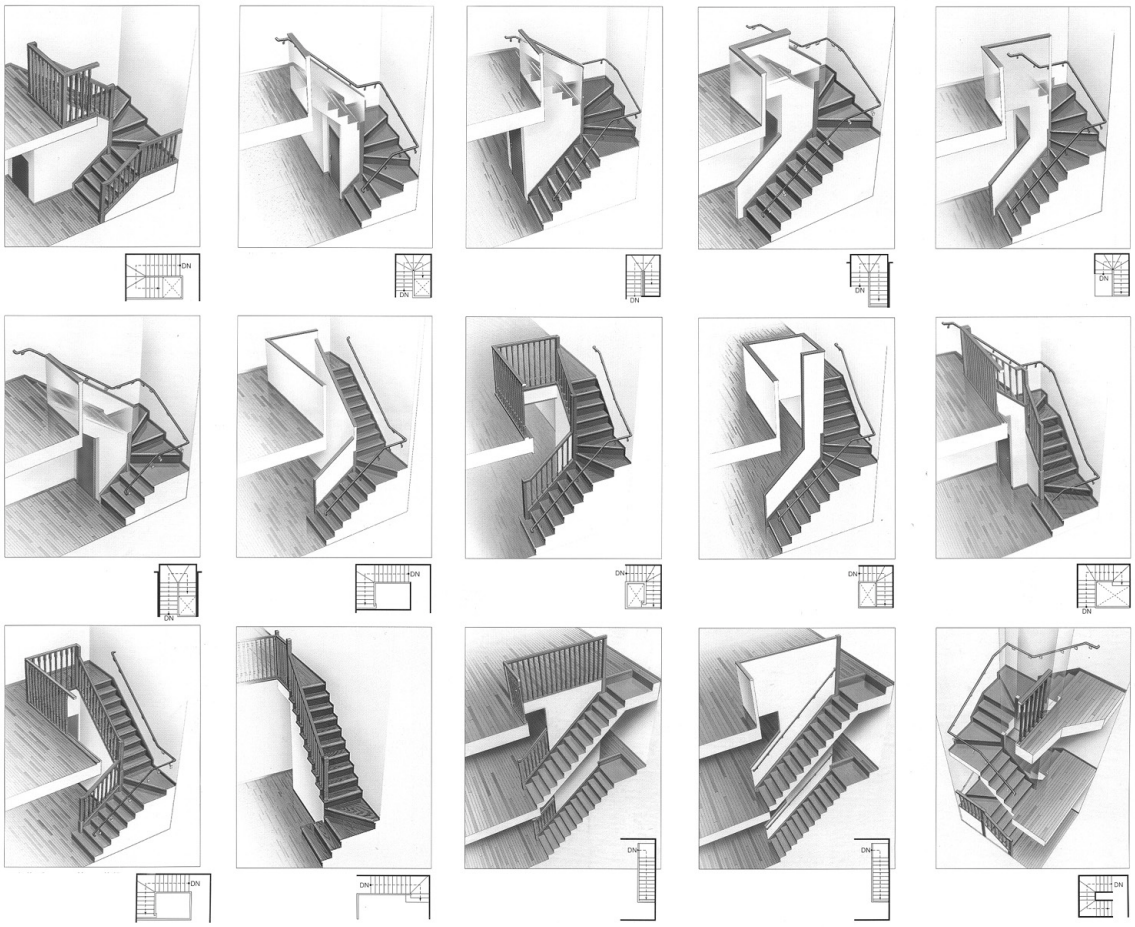

Figure 10: *Staircase unit variation*
(Source: Sekisui Chemical Co., Ltd. 1999)

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 analog 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 $/m^2 (Cdn. $) on average, while a prefabricated house was at 2,375 $/m^2. 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 performance." This marketing strategy is often used in the automobile industry as well (Sekisui Chemical 1998a). Even though today's automobiles can be produced with lower production costs than those in the past, their selling price does not seem to be affected dramatically by the high productivity and cars are still regarded, in general, as expensive. On the other hand, the standard items offered on new cars, such as air conditioning, a stereo set, automatic transmission, airbags, remote-control keys and adjustable mirrors were only offered as more expensive options on older models.
Therefore, it is clear that the quality of the newer model is much higher than that of the old model. The housing industry is no exception. The quality-oriented production contributes toward producing a high cost-performance home, which, as standards, contains modern conveniences installed optionally in conventional housing, in order to improve the housing

quality, while the selling price of prefabricated housing is slightly higher than that of the conventional housing (Suzuki et al. 1995). In Japan, there is a tendency for today's housing manufacturers to compete to improve the quality of their products, rather than to merely reduce the selling price, even though they have drastically reduced their production costs (Sekisui Chemical 1998a).

Clearly, the product quality, which appeals to many homebuyers during the decision-making process, has been drastically improved by the manufacturers. In fact, according to a survey conducted by the Japan Prefabricated Construction Suppliers and Manufacturers Association (JPA), 49% of the 3,500 surveyed households, who purchased prefabricated housing in 1998, answered that the product quality with regard to safety, durability and amenities of housing was the primary factor that prompted them to buy a prefabricated home. In addition, 7% of the buyers regarded the price of prefabricated housing as relatively low (JPA 2001). These results indicate that their cost performance marketing approach is successful in the sense that housing price is considered of secondary importance to quality in the purchase of a prefabricated home.

CONCLUSION

Japanese homebuyers often attach importance to two basic factors in the buying process—quality and price. Also, the elapsed time for the design and construction, as well as the after-purchase maintenance services, are influential factors in a buyer's decision to select a housing supplier. In order to meet the housing demands of today's market, Japanese manufacturers have applied the concept of 'mass customization' for their housing design, and have eventually developed a total coordination approach to design, production and marketing.

Furthermore, the manufacturers' design techniques are well integrated into a system, which can be referred to as a mass custom design system (MCDS). It is composed of the product and service sub-systems to produce mass custom homes. The system was explained by using an analog model as follows: MCDS = f (PS). The product sub-system (P) covers the production techniques that encourage housing suppliers to mass-produce housing components, while the service sub-system (S) refers to the communication techniques that lead users to participate in customizing their new home. In consequence, the two design-support sub-systems function as the key elements that make the manufacturers successful in mass-producing customized homes that satisfy today's consumers.

Although the manufacturers have already succeeded in producing mass custom homes, the selling price does not seem to reflect their production efforts. In fact, their products are slightly more expensive than site-built homes. The higher prices are explained by their marketing strategy known as ‘cost performance.’ Originally, a mass custom design (MCD) approach was explained by using an analog model as follows: MCD = f (V, E, I, O). In order to upgrade the quality of housing, the cost performance marketing approach encourages manufacturers to install standard equipment (SE) that used to be offered only optionally. In consequence, the manufacturers do not reduce their selling price. Therefore, such an addition needs to be made to the original model. Thus, the model can be modified as follows: MCD = f (V, E, I, O) + SE. This implies that such standard equipment 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 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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