THE DEVELOPMENT AND IMPLICATIONS OF POST-FORDIST MANUFACTURING

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"You can have any color car you want, as long as it's black."
Attributed to Henry Ford.

INTRODUCTION

The early twentieth century saw a revolution in manufacturing. By breaking down the process of production into a set of simple steps achieved with the use of specialized machinery, costs of labor could be significantly reduced. Furthermore, if large runs of standardized pieces were involved, the high cost of equipment could be spread out, achieving notable economies of scale. This approach, called "fordism" (after Henry Ford), was most successful in the United States; it demanded certain characteristics in production which are now perceived by most Americans as inevitable in manufacturing and was even influential in areas such as architectural drawing production, housing construction, and land development. Some of the attributes of fordism which Americans tend, even today, to take for granted include a belief that size leads to greater economies; reliance on specialized machinery, which prevent frequent retooling and leads to rigidity in the marketplace; managerial oversight of the line, necessary because individual workers no longer grasp the larger complexities of the system; and privileging of white-collar supervision over the simplified repetitive activities of laborers. Under this structure, with retooling, the skills learned by an individual worker could be quickly rendered obsolete.

Fordism was most successful where the market was relatively homogeneous and could accept an emphasis on low cost over a variety of related products. Elsewhere, wider distribution of income and distinctions of class prevented these economies from dominating the market. While Modernist intellectuals celebrated the potential benefits of universality in Europe and Japan, product differentiation, rather than standardization, remained the norm. Fundamentally, cultural values, educational opportunities, and even resources and technology differed from the U.S. to a degree significant enough that these systems of manufacturing, even where they attempted to emulate fordism, were in fact quite different.

As a result, beyond North America, approaches to manufacturing evolved which addressed the inherent inefficiencies of fordist models. Where fordism accepted the inflexibility of machinery, the necessity of high inventories, and the need for an extensive manager class to project development, maintain systems and to promote standardized output through advertising, neither European nor Japanese systems, particularly at the end of World War II, could rely on the resources and capital necessary for frequent retooling or the idle supplies of material intended to prevent unexpected production delays. (Nor could they rely on a labor surplus among those with technical educations.) Equipment, therefore, was necessarily flexible, allowing a machine to be retooled where one in the States might be idled for long periods of time or even scrapped. Similarly, production was based on the parallel assembly of components, which were ultimately brought together at a final stage, eliminating the need for large surpluses. Recently, this approach began to be recognized as offering advantages over fordism, as it created opportunities for short production runs and innovation. Thus it came to be seen as a distinct approach, now commonly referred to as "post-fordist."

Recently, the United States has also seen post-fordist developments as manufacturers attempt to achieve flexibility and capture unexploited sectors of a more developed and heterogeneous market. However, where Japanese systems of production, for example, emphasize a multi-skilled worker using flexible tools, in the U.S. there has been greater technological development, especially in the area of variable control systems. Some theorists propose that these differences are the result of an emphasis on educating and working with the blue collar line worker in Japan, and innovation through engineering in the United States.[1]

Today, three types of post-fordist production exist: Japanese systems, based on the work of Tai'ichi Ohno of Toyota, emphasize low inventories and a high degree of adaptability in both equipment and labor; European systems grew out of crafts guilds and rely on skilled workers in small plants who may unite to promote innovation or to manage peaks in market demand; and more recent American systems, which have responded to greater diversity in consumer tastes by employing technologies which allow for variable control of the production line. What these systems have in common is a shift from standardization and economies of scale to flexibility and economies of scope, using limited equipment to produce a range of products. Because they have emerged in very different production climates, though, there are important and notable characteristics of each. Since my own experience with production systems is limited to Japan and the United States, I will speak here only of the approaches to customization found in those two areas. Also, as post-fordist systems of production developed in Japan much earlier than in the States, it is possible to discuss opportunities for architects to work with post-fordism, citing a few examples from Japan.

PRODUCTION FLEXIBILITIES IN THE UNITED STATES

Some aspects of post-fordist manufacturing have already begun to affect American architectural practice. The use of adaptable technologies such as laser cutting have made a wider variety of products customizable, including patterned elevator cages, handrails, and light fixtures – all available without additional costs. B. Joseph Pine II, in his book *Mass Customization: the New Frontier in Business Competition*, also considers as American forms of customization specialized services, products which can be modified on site, and the use of modular components. Each is an example which goes beyond conventional standardization. Using these criteria, he includes individually-adjustable furniture by Herman Miller, custom paint mixing, gutters cut to length on site, and modular systems for lighting controls and walk-in coolers as American forms of customization which have been integrated into building production.

But the American approach to customization is most noted for its flexible control technologies and integration of CAD to enhance the speed of product delivery and to smooth the process of making changes. Initially, the numerically controlled production line was not dissimilar to that seen earlier, but through variable control (either NC- or software-based) each product can now be treated individually, and the control system can easily vary color, finish, or other options for goods from the same production line so that each is individualized. This approach naturally has lead to further developments in software programming and the integration of information technology.

New flexibilities have emerged which offer provocative indications of the greater potential for these systems. Most notable is the rapid emergence of "prototypers," who are able to produce solid models of complex shapes from three-dimensional computer models in a matter of days and for only a few hundred dollars. Using these prototypes, casting molds can be quickly fabricated in any shape and to a high degree of tolerance, thus significantly changing the conditions for testing and manufacturing new shapes. The immediate result has first affected the casting of plastics and can be seen in the wide range of telephone casings available, for example. Architects can probably anticipate similar variety emerging first in easily-cast products for the bathroom and kitchen, such as cabinet knobs and tissue holders; in electrical components such as switch and outlet plates; and in a greater range of fastening systems. In the long run, as prototypers lower the cost of services and expand the materials they can work with, the architect may find it practical to produce one-off models directly (including those which might be difficult to fabricate or craft by other means), without the costs associated with crafts-based modeling.

PRODUCTION FLEXIBILITIES IN JAPAN

Japanese production systems, as indicated above, rely on general-purpose machinery run by skilled workers; laborers are constantly being trained in new tasks and contribute to improvements in the line. In addition, Japanese systems are based on a set of isolated segments of the assembly process (which allow the combination of segments utilized to be easily varied) and strong linkages between contractors and sub-contractors, taking advantage of competition between small producers to affect price and to encourage innovation. Some production sites look little different than they might have thirty years ago, but with the help of government and trade organizations, many small subcontractors have been able to access advanced technologies.[2] Nonetheless, the Japanese system places a very high value on input of information from all participants, including the client, management, and the worker, and is able to respond quickly to new demand in the marketplace because of the high degree of versatility implicit in the approach.

Thus, in the Japanese system, an architect can require that a tile, a railing, a corrugated panel or a window mullion have a form which varies from others produced on the same day. The product is simply removed from the production stream at key points, modified to fit the specifications of the architect, and then returned to the production stream, which does not require consistency of the product for further processing. In this way, fabrication takes advantage of economies of scale for most of the process; the additional costs associated with specialization, which are relatively slight, are accepted by consumers who benefit from a higher degree of particularity. This has allowed Japanese producers to maintain a high share of the market both at home and abroad without competing on the basis of price, and has encouraged almost continuous product development.

IMPLICATIONS IN ARCHITECTURE

Looking at the work of Japanese architects, who have had access to mass customization for some time, the larger implications of post-fordist production might be better understood. Japanese architects seem to exploit customization in several key ways:

1) Perhaps most importantly, short production runs allow for niche marketing of technologies which might better serve small populations with special needs; an example of this is a toilet developed by Toto Ltd., which analyzes urine for medical problems.

2) Architects may use customization to create signature elements which reflect the specific theoretic interests of the architect. Examples of this include Isozaki's use of the Marilyn curve in furniture and door pulls, or Kurokawa's recent "fractal" geometries expressed in light fixtures, handrails, and door pulls.

3) Customization may allow the architect to demand a high degree of coordination between parts and to achieve a more refined construction, using consistent spacing or modules, even when working with a variety of independent manufacturers. This coordination is further elaborated on below, using an example from Fumihiko Maki's office.

4) Architects have also used opportunities to individually influence production in order to bring new items to market by altering the form and composition of materials used; the architect is effectively able to move to the beginning of the production process. With production flexibility, new technologies can also be more rapidly delivered to market and tested, without significant start-up costs; thus "expeditionary" marketing is possible, with manufacturers responding in a rapid fashion to evolving demands of the profession. Maki has written of this issue in regard to the development of a stainless steel roofing material for the gymnasium roof at Fujisawa; its rapid and widespread use by other architects demonstrates that this was a product for which many saw a need.[3] I have also written elsewhere about the rapid response to the demands of the architectural market by the glass industry.[4] Below, I briefly discuss the development of low-cost paper tube constructions by Shigeru Ban.

5) Mass customization allows further levels of production, such as structural or envelope assemblies, to be shifted to the factory without compromising design decisions. Japanese architects have found this to not only reduce costs and accidents,

but also to enhance precision and quality control. Both Arata Isozaki and Itsuko Hasegawa have recently written of these opportunities, and they are in part addressed in the discussion below.[5]

6) Finally, the speed of post-fordist systems allows decisions on major components such as elevators to be delayed to a point where they can be more easily coordinated with other areas of design, such as interiors. Some authors feel this shift from inventory storage to "just in time" deliveries indicate that the construction industry in Japan has already refashioned itself to mimic automobile manufacturing.[6] Certainly, frequent "just in time" delivery has proved to be useful in the small Japanese construction site, but it has also been utilized in the United States, most extensively in the construction of the Getty Center in Los Angeles.

In several of these categories, the architect brings values to the manufacturer which might otherwise not be represented. These values include an interest in aesthetic and theoretic issues, but also extend to performance, maintenance, durability, construction costs and quality, and many other issues which concern the practicing architect and may not be readily apparent to others who work outside practice.

WORKING WITH CUSTOMIZATION: TWO EXAMPLES FROM JAPAN

Although most internationally-recognized architects in Japan take advantage of customization in their work, a few simple examples may suffice to demonstrate the benefits of manufacturing flexibility to architects. Fumihiko Maki, in a church recently built in Tokyo, brought together a wide range of components which were altered to fit his aesthetic goals, only a few of which I will discuss. In one case the alteration is significant enough to constitute the creation or discovery of a new product; in addition, light fixtures were specially manufactured to Maki's design.

The Tokyo Church of Christ, completed in September of 1995, is a simple building which achieves its elegance from the care Maki and his staff took in selecting the building's components. The large Trombe wall on the west facade, for example, combines products by Figula Glass and Nippon Kentetsu, both smaller, flexible manufacturers who see their work as supplementing the standardized products of larger suppliers. Maki achieved a soft, even light through the insertion of glass fiber tissue in the inner set of glass panes, and by a finely etched pattern on the exterior glass surface, which was also felt to give the facade a more delicate scale.[7] During design development, Maki's office asked several glass companies about the feasibility of the fine-grained patterns they were considering. The larger firms tended to say that a solution was too difficult for them to achieve, but Figula was able to supply samples and acceptable prices for all but one proposal; this was achieved through the use a computer-directed system to cut patterns on a vinyl protective sheet in preparation for chemical etching.[8] Nippon Kentetsu supplied both aluminum mullions (in the second floor sanctuary) and steel mullions (in the ground floor entry area). Maki's office worked with the manufacturer to develop a wall which offers both the benefits of a Trombe system and could also be part of the structure; the final solution was to fabricate a vertical steel Vierendeel truss which is part of the curtain wall, thus becoming virtually invisible.[9] Below, in the entry area, a mullion which is similar to that in the upper wall has been rendered in steel, giving it a thinner profile while maintaining a high degree of impact resistance.

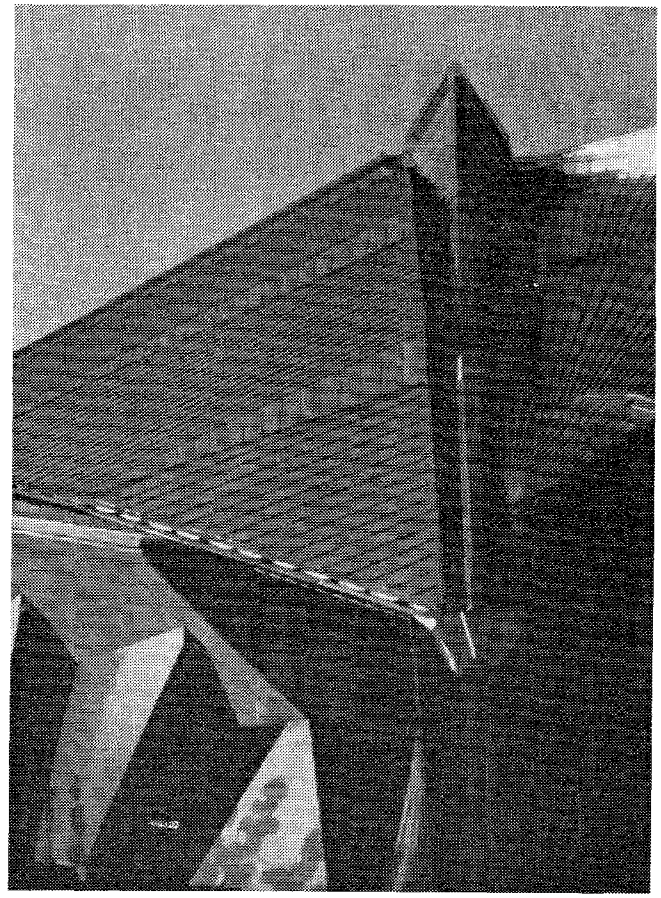

Figure 1. Roofing material developed by Maki for Fujisawa

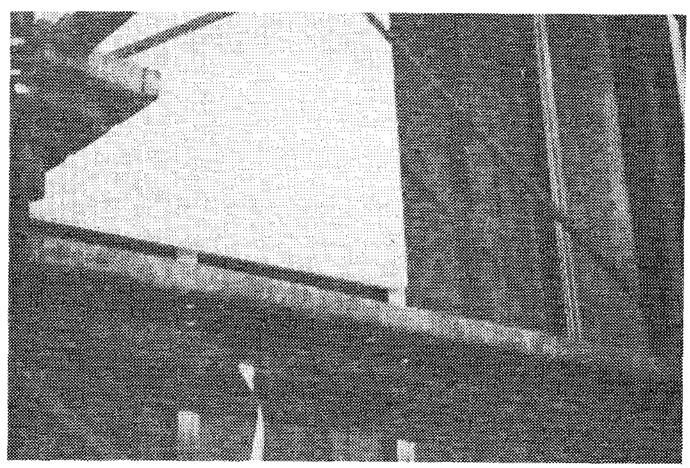

Figure 2. A denticulated material which Maki has used for the interior wall finish

Maki's office also worked with manufacturers to modify materials used as panels in both the interior and exterior. On the rear of the building, a corrugated aluminum panel with an asymmetrical profile was used to give the building greater luminosity; this profile was developed for an earlier project by Maki's office, Hillside Terrace, Phase VI. In the sanctuary, Maki's office also worked with Daimaru Interiors to develop a ridged panel made of a porous sound-deadening material. A

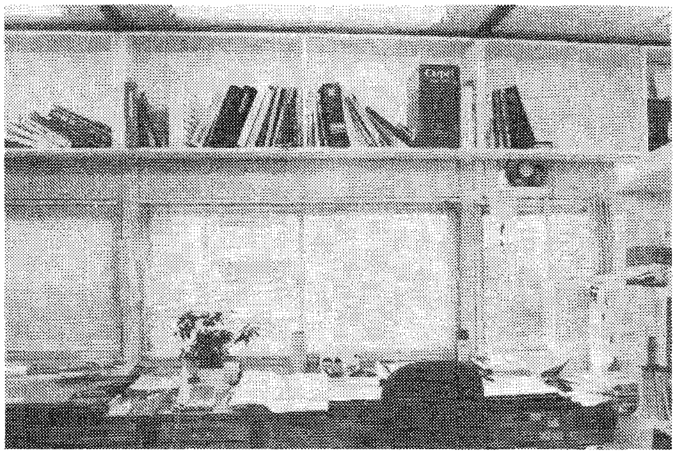

Figure 3. Models of pendant lighting in the job site office

denticulated trim which was produced through pressing and extrusion, Maki's office simply used the material in its extruded "unfinished" (i.e., uncut) form.

Maki's office also designed Wrightian pendant lighting fixtures and wall sconces, working with the manufacturer; the earlier models of these fixtures are shown in the photographs above. The development of these lighting fixtures, though, is also notable because the manufacturer, who had worked with Maki on earlier projects, had grown less enthusiastic about the fabrication of customized products. This was not a technical issue, but a legal one; until recently, any manufacturer in Japan had, by American standards, relatively modest legal responsibility for a product. However, influenced by trends in the United States, Japan has also begun to establish product liability laws. The legal context has hampered innovation in the States and has the potential to have the same effect in Japan.

A second example of exploiting manufacturing flexibility can be seen in Shigeru Ban's development of paper tubes for use as structural components, walls and even small "cubicles" in both high-end and low-cost constructions. While he first got the idea for these materials from cardboard tubes for pouring concrete, Ban has worked with the manufacturer to achieve structural consistency and acceptable finishes for interior construction, and he has also begun to investigate fire- and waterproofing techniques. To date, Ban has used the tubes, in varying sizes, for both furniture and buildings. Lined up vertically, the tubes have been used as structural walls in both a gallery for Issey Miyake and a temporary structure for refugees who lost their church in the Kobe earthquake of 1995. The tubes were also used to build outside walls, offering insulative value, to be used in homes for the same refugee community. Large single tubes have been used by Ban as toilet compartments for a temporary exposition building; smaller, structural components of the same material were shipped to the site inside these tubes. Lastly, working with Vitra, Ban is developing the tubes as a replacement for aluminum tent supports to be used by UNESCO, achieving significant economies.

CONCLUSION

It should not be assumed that post-fordist systems offer only advantages. Fordism was able to achieve the lowest possible price through standardization; while post-fordist systems have reduced much of the cost of specialization, they have not eradicated price differences. Furthermore, customization requires greater time commitment by the architect, both for overseeing production processes and for managing and absorbing information related to opportunities in production. The manufacturer, too, faces greater investments of time, as both the worker and management must maintain a better package of skills through continuous training. Additionally, in the United States, issues of liability (also emerging in Japan), union opposition and regulatory context have undermined support for innovation.

Another area of concern is related to sustainability, as rapid product cycles lead to rapid obsolescence. Consumer demand may lead to quicker turnover of many components considered lasting in buildings today, including elevators, HVAC systems, appliances, and lighting. However, the opportunity to explore new materials with lower embodied energy costs and reduction of the obsolescence of the production line may serve as a balance.

Fundamentally, however, mass customization offers the architect greater possibilities because we serve clients best by designing buildings which fit specific sites and client needs. The opportunities of new manufacturing processes to enhance practice should not be overlooked—especially as our ignorance may prevent us from shaping how new manufacturing processes and architecture interrelate. Several years ago, a Japanese architect from a large construction firm, looking at the context for practice in his country, said, "It has become difficult to boost orders merely by building structures according to design and time schedule demanded by the client, and only those construction companies capable of offering new technologies and services through research and development will continue to exist."[10] In the United States, we also face challenges to conventional practice; those firms which utilized a fordist model in design and document production have shrunk—SOM in Chicago, for example, is less than one half the size it was at its peak—or have altered their structures significantly.

This does not mean that architects in North America should attempt to adopt wholesale the manner in which their overseas colleagues have already addressed post-fordism. Unfortunately, while American architects can learn from study of our colleagues' experiences abroad, the differences in regulatory context, technological advances, and education in the population mean that customization differs in the three regions where it has developed. The opportunities of customization should be explored at home, working with manufacturers who are already invested in new processes of production.

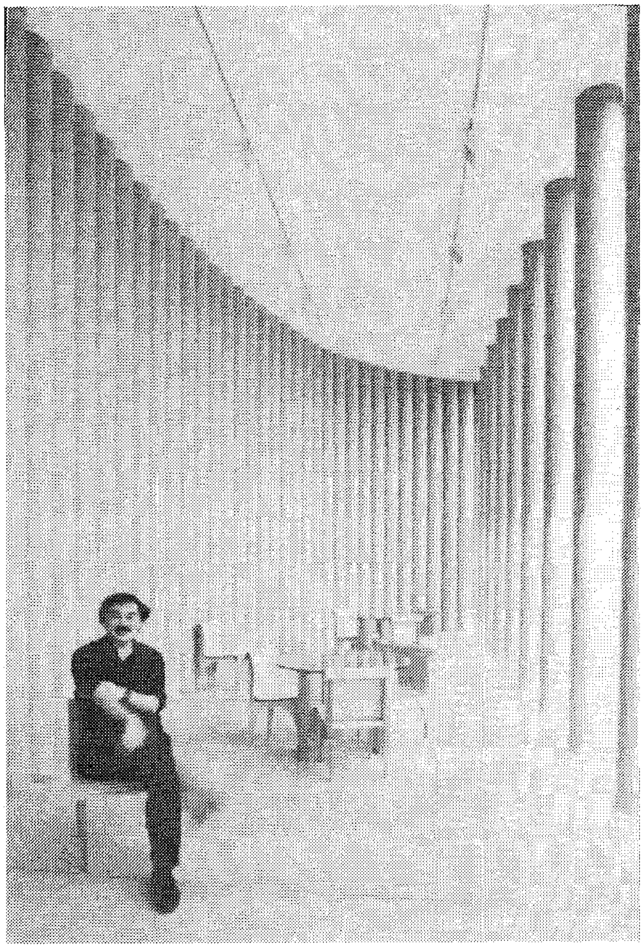

Figure 4. Shigeru Ban in the MDS Gallery

Figure 5. Refugee housing designed by Ban

NOTES

1. Abo, Tetsuo. *Hybrid Factory: the Japanese Production System in the United States.* New York: Oxford University Press, 1994. p. xx.
2. Morris-Suzuki, Tessa. *The Technological Transformation of Japan: From the Seventeenth to the Twenty-first Century.* Cambridge: Cambridge University Press, 1994. p. 225. Morris-Suzuki says that 57% of small-scale manufacturers use numerical controls and 39% have CAD equipment.
3. Maki Fumihiko. "The Roof at Fujisawa," *Perspecta 24.* New York: Rizzoli, 1988. p. 106-121.
4. Buntrock, Dana. "Architecture and Innovation in Japan: the Development of a New Light-modulating Glass," *Proceedings of the Association of Collegiate Schools of Architecture Technology Conference.* January, 1994.
5. Isozaki's use of flexibilities is addressed in *Arata Isozaki: Construction Site: The Japan Architect* 12, Winter, 1993-4. Tokyo: ShinkenchikuSha, 1993. Hasegawa's use of flexible manufacturing is discussed (in Japanese) in an essay entitled "*Kenchikuka to Kozoka no Patonashippu*" ("The Partnership between Architect and Builder"), *GA Japan Environmental Design 12.* January-February, 1995. p. 163-165.
6. *Zusetsu Kenchikuka Shiko Nyukan [Illustrated Guide to Building Construction]* Tokyo: ShokokuSha, 1994.
7. Tomuro, Reiko. (Maki and Associates) Personal interviews. Tokyo, Japan. 18 July 1995 and 28 July 1996.
8. Figula factory visit. Saitama Prefecture, Japan 28 July 1996.
9. Maki wrote earlier this year that the design of this wall required some cleverness. See "*Tokyo Kurisuto no Kyokai*" ["Christ Church of Tokyo"] *GA Japan Environmental Design 18.* January-February, 1996. p. 57.
10. Hasegawa Fumio and the Shimizu Group, *Built by Japan: Competitive Strategies of the Japanese Construction Industry.* New York: Wiley, 1988.

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