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A Comparative Assessment of the North American and Japanese 2x4 Residential Construction Systems

ABSTRACT

Despite Japan's relatively small size, residential housing starts have exceeded those in the US throughout the 1990's, totaling 1.57 million units in 1994. However, the cost of residential housing in Japan is substantially higher than in other developed countries. In an effort to address this problem, the Japanese Ministry of Construction (JMOC) recently announced an action program to reduce the cost of residential housing 33% by the end of the century. Numerous factors have been cited as contributing to the high cost of residential housing in Japan, including high labor costs and low labor productivity, a lack of skilled carpenters familiar with the 2x4 system, non-standardized building materials, a lack of competition in the construction industry, restrictive building regulations, high building material costs, inadequate construction management systems, and an inefficient and extended distribution system for imported building materials. Many industry observers in both the US and Japan feel that one way to reduce residential construction costs would be through the adoption of North American 2x4 construction technology as an alternative to the more traditional but less efficient post-and-beam construction technology.

US construction professionals familiar with the Japanese construction industry indicate that the small segment of Japanese contractors currently building 2x4 houses have modified the 2x4 system to fit their traditional construction system. These modifications have resulted in a hybrid construction technology that fails to achieve the production and cost efficiencies inherent in the North American system. Exploratory interviews with building professionals who have worked on residential construction projects in both the US and Japan identified a number of areas where the Japanese 2x4 construction system differs from its US counterpart in terms of these efficiencies. The primary areas where significant differences were noted included foundations, interior wall finishing, ceiling framing techniques, finish carpentry, labor specialization, and project management skills.

In order to take full advantage of the efficiencies inherent in the North American 2x4 construction system, it is important that Japanese designers, contractors, and carpenters develop a basic understanding of the North American 2x4 system. This implies that the transfer of 2x4 technology should occur at a variety of skill levels within the Japanese residential housing industry. At a minimum it is important that four groups be included in any 2x4 technology transfer programs: designers/architects, carpenters, construction site supervisors, and project managers.

The process of effectively transferring 2x4 construction technology requires that US contractors and carpenters be allowed to work with their Japanese counterparts. However, the perceived and real difficulties involved in obtaining work visas for US construction professionals in Japan have effectively restricted this component of technology transfer. A review of existing policies related to the issuance of work visas for US construction professionals and skilled workers

would support total technology transfer and provide benefits for both the residential construction industry and home buyers in Japan. This strategy would provide the basis for rationalizing construction costs and management systems within the Japanese residential construction industry.

INTRODUCTION

Japan, with a population of 125 million, is approximately the size of California. Despite its relatively small size, however, residential housing starts in Japan have exceeded those in the US during the 1990's, totaling 1.57 million units in 1994 (Anonymous 1995a). While wood has been the dominant building material in Japan, its share of the residential housing market has declined from 79% in 1965 to 46% in 1994 (Anonymous 1995a). Traditionally, the primary construction technique for wooden housing in Japan is the post-and-beam method, a costly and labor-intensive construction technology (JETRO 1992).

In an effort to respond to the prohibitively high cost of residential housing around urban areas, the Japanese Ministry of Construction (JMOC) has recently announced an action program to reduce the cost of residential housing by one-third by the end of the century (JMOC 1994). According to JMOC, this cost reduction can be achieved by improving labor productivity, rationalizing the distribution channels for building materials, reducing regulations to promote market competition, and achieving international mutual recognition of building codes.

In contrast to post-and-beam home construction, which has declined in recent years, 2x4 housing starts have increased over the past decade. However, rather than adopting the North American 2x4 system unchanged, the Japanese have modified the system to fit their traditional construction system. These modifications have resulted in a hybrid construction technology that fails to achieve the production and cost efficiencies inherent in the North American system.

The Japanese 2x4 Housing Market

The North American 2x4 platform frame construction technique was first introduced into Japan in 1974 (JETRO 1988). Despite the cost and production efficiencies inherent in the system, several factors have contributed to its relatively long introduction period. Japanese carpenters possess little experience with the 2x4 construction method and have been reluctant to change from the traditional post-and-beam construction method. Also, the Japanese residential construction industry utilizes non-standard, smaller-size building materials and spacings when adapting the North American 2x4 system. Another factor, the high cost and difficulty of obtaining JAS (Japanese agricultural standards) approval for imported building materials, has restricted the use of 2x4 construction, particularly for residential housing funded through Government Home Loan Corporation (GHLC) mortgages (Magnier 1994). This is an important point because more than 40% of residential mortgages in Japan are obtained through GHLC financing.

However, despite its relatively small market share, 2x4 housing is a growing segment and is slowly gaining popularity in Japan. For example, the number of 2x4 housing starts in Japan totaled 64,000 in 1994, a 14% increase over the previous year (Anonymous 1995b). Additionally, the ratio of 2x4 starts to total housing starts in Japan has grown from 1% in 1980 to 4.1% in 1994. A recent report by the Japan 2x4 Building Association predicts that the market

for 2x4 homes will increase at an annual rate of 10% from 1995 to 2000 to reach a level of 100,000 housing starts per year (JETRO 1993).

In 1992, the Japanese External Trade Organization (JETRO), during interviews with Japanese housing industry specialists and consumers, found that 2x4 homes were perceived to be structurally superior to traditional post-and-beam homes in terms of earthquake and thermal performance (JETRO 1992). In addition, some regulations of Japan's Building Standards Law concerning the construction of wooden houses have recently been eased. For example, the maximum allowable floor space for wooden houses was increased from 2,000 m^2 to 3,000 m^2 in 1993, a change that should facilitate the construction of three-story, multi-family wooden apartment houses, a fast growing sector in the housing market (JETRO 1993). Both of these events indicate that public acceptance of 2x4 housing is growing in Japan.

Residential 2x4 construction costs in Japan are substantially higher than those encountered in the US. According to a recent study by JMOC, the construction costs (excluding land costs) for similar homes built with similar materials are approximately 2 to 2.5 times higher in Japan than in North America (Nakamae 1995). Among the reasons cited for this cost differential were higher labor costs and lower labor productivity, a lack of skilled carpenters familiar with the 2x4 system, non-standardized building materials, a lack of competition in the construction industry, restrictive building regulations, higher building material costs, inadequate construction management systems, and an inefficient and extended distribution system for imported building materials (Nakamae 1993; The Journal 1994; Magnier 1994; Nakamae 1994; Nakamae 1995; Watanabe 1995; Eastin and Rahikainen, in preparation).

The Japanese 2x4 Housing Industry

The largest Japanese industry association for 2x4 housing contractors is the Japan 2x4 Home Builders Association (JETRO 1993). The combined membership of regular and associate members in the Japan 2x4 Home Builders Association includes 744 companies, 360 of which have built at least one home. Perhaps more importantly, the top company accounted for almost 35% of 2x4 starts while the top five companies accounted for 46% of 2x4 residential housing starts in 1992 (Table 1).

Despite the relative newness of 2x4 housing in Japan, consumers have expressed an interest in 2x4 housing based on its Western appearance, extensive use of wood in construction, structural integrity (particularly its resistance to earthquake damage), spacious design, good quality, and lower price (Parker 1994; Nakamae 1995; Watanabe 1995). Lower prices represent a particularly important marketing variable for influencing perceptions of 2x4 housing because Japanese consumers have become very price conscious during the recent recession. The importance of lower prices was emphasized in a recent article in the *Nikkei Weekly* where several Japanese home buyers were asked about their perceptions of western-style homes with respect to traditional Japanese-style housing designs (Nakamae 1995). Buyers responded: Western style housing "would be meaningless to us unless its price is at an affordable level. If it remains

Table 1. Japanese 2x4 home builders ranked by size, 1992.

	Company	Units sold
1.	Mitsui Home	11,600
2.	Sekisui Kagaku	4,800
3.	Taihei Jutaku	2,900
4.	Sanwa Home	2,000
5.	Sekisui House	1,700
6.	Sumitomo R. E. Home	1,450
7.	Iwatani Jutaku	1,440
8.	Kinoshita Komuten	960
9.	Tokyo Home	900
10.	J. R. Home	850
11.	E. D. Home Plaza	820
12.	Daiken Home	800
13.	Mitsubishi Asset	800
14.	Towa	700
15.	Iwakura Home	565
16.	Taisei Jutaku	320
17.	Kanebo House	280
18.	Hokushu Housing	260
19.	Hokudai Homes	150
20.	Nihon Homes	100
21.	Northwest Home	60
Total		**33,455**

Sources: Collected from Japan Housing Industry Journal, Washington State Department of Community, Trade and Economic Development.

expensive, it will be just for a limited group of people with Western tastes" and "We would probably choose a Japanese house, which we are more accustomed to, unless western-style homes were much cheaper."

Objectives and Methodology

In response to a request from the US Consulate in Osaka and the Washington State Department of Community, Trade and Economic Development, researchers from the Center for International Trade in Forest Products (CINTRAFOR) and the Department of Building Construction, both located at the University of Washington in Seattle, worked cooperatively to identify Japanese modifications to the North American 2x4 residential construction system, assess the impact of these modifications on Japanese construction costs and production efficiencies, and provide a series of recommendations for facilitating the efficient transfer of North American 2x4 construction technology to Japan.

Qualitative empirical data was obtained through a series of exploratory interviews conducted with US and Japanese architects, contractors, and carpenters possessing residential construction experience in both countries. The exploratory interviews were guided by a research

questionnaire that was pre-tested by six reviewers, including three construction professionals, an international trade specialist and two University of Washington faculty members (one in marketing and the other in building construction). Participants for the project were subjectively chosen based on their construction experience in both Japan and the US and their expressed willingness to participate in the study. The sample frame for the survey included 11 participants with training and experience in the following disciplines: architecture (3), residential contracting (3), building material consolidators (2), construction site supervisors (4), and carpentry (4). Although it was our initial intent to tape record each interview, given the continuing nature of their business transactions, each of the participants expressed a reluctance to have their responses taped. In deference to the participants, notes were taken during the course of the interview by each of the three investigators and the results of each interview were transcribed and consolidated immediately following the interview to facilitate analysis. The interview results were analyzed qualitatively to meet the following research objectives:

- identify specific areas where Japanese carpenters and contractors have modified North American 2x4 residential construction technology.
- identify specific areas where the North American 2x4 construction method is more cost-effective than the Japanese adaptation.
- provide a series of strategic recommendations to facilitate the transfer of North American 2x4 construction technology to Japan in such a way as to take into account Japanese cultural factors while retaining the cost and production efficiencies inherent in the North American system.

COMPARISON OF US AND JAPANESE 2x4 CONSTRUCTION TECHNIQUES

Numerous differences between US and Japanese 2x4 construction practices were identified, primarily in the areas of construction technology, labor specialization, and project management. In comparison to the US, Japanese construction methods can be refined in order to increase both cost and production efficiencies. The following paragraphs describe the most notable differences identified during the course of the interviews with US construction professionals.

Construction Technology

Foundations: The process employed by many Japanese contractors in setting a foundation system includes five basic steps: soil preparation, spreading of a rock base, pouring of the concrete for the perimeter and interior foundation walls to a sub-grade level, pouring a mud or "rat" slab, and pouring of a thin layer of mortar (1-2 cm) on top of the foundation walls to bring them to final grade level.

The respondents observed that, in most cases, foundation systems for residential homes in Japan are over-designed and inefficiently constructed. The quantity of concrete used in foundation walls is excessive because foundation walls are placed under all interior load-bearing walls while a two- to three-inch thick concrete rat slab is poured under the entire house. The rationale behind the rat slab is to provide a physical barrier for pest control and to facilitate drainage.

These features substantially increase construction cost for foundations, particularly given the fact that the price of concrete in Japan is approximately two to three times higher than in the US.

Poured-in-place foundation walls are constructed under both exterior and interior walls. Providing foundations for interior walls appears to be the Japanese equivalent to the US practice of using wood posts over concrete pad footings to support interior load-bearing walls. Japanese and US foundation systems also differ in the number and placement of ventilation spaces in the foundation walls. The purpose of ventilation openings is to facilitate the free flow of air throughout the foundation to prevent the build-up of moisture, thus reducing the occurrence of wood rot and degradation. Building codes in the US require a specific number of ventilation openings per foundation. While the Japanese also require ventilation openings, the use of interior foundation walls substantially restricts the flow of air throughout the foundation, thereby reducing the efficiency of ventilation.

US and Japanese foundations also differ in that Japanese foundations are not poured to a finished height. Rather, they are poured to a sub-grade level and after the concrete has cured they are raised to the final grade. To reach final grade, concrete forms are literally nailed onto the foundation walls and a thin layer of mortar (1-2 cm) is poured onto the top of the foundation. The purpose of this second pour is to provide a smooth, level surface in preparation for placing the sole plate. This two-step method of pouring foundations is an expensive process which is performed in a single pour in the US. Most respondents also observed that there is poor adhesion between this thin topping layer and the main foundation wall and that the topping layer possesses little structural integrity and is subject to cracking. In fact, several respondents noted that the topping layer readily separated from the foundation and that they were able to lift it off of the foundation.

US building codes generally require that crawl spaces be a minimum of 18 inches above the grade of the soil. In Japan, it appears that there is no minimum crawl space height, a fact that restricts access into the crawl space where plumbing, electrical and mechanical services are usually located. These utility services are generally installed in the crawl space prior to the setting of the floor joists and sub floor covering. Because the service connections have already been located, carpenters are required to cut the subfloor materials to fit around the service connections, a labor-intensive and expensive task.

The final difference with respect to foundations concerns the fact that in Japan the exterior surface of the foundation wall is frequently covered with a thin layer of cement. This treatment, while it serves no structural purpose and is apparently merely for appearance purposes, does increase the cost of the foundation substantially through increased labor and material costs. In summary, while both foundation systems provide adequate structural support in residential applications, the costs associated with the Japanese method are substantially higher than the US method due to increased labor and material costs.

Structural Framing: The building professionals interviewed noted that the most obvious differences between the US and Japanese 2x4 systems relate to the Japanese preference for

smaller-sized building materials. Japanese carpenters prefer to build on the 3x6 tatami system, whereas North American carpenters utilize the 4x8 module. Based on the area covered per sheet of plywood or drywall, the North American system is more efficient, since a 4x8 panel covers 78% more wall/ceiling area than does a 3x6 sheet. It has often been argued that Japanese carpenters are older and prefer the smaller-size materials because they are lighter and easier to handle. However, two Japanese contractors who possessed construction experience in the US indicated that they had encountered little trouble working with the larger-sized panels once they learned the proper carrying technique. Obviously using the larger sizes allows carpenters to increase their productivity and provides for more efficient material usage.

Several respondents noted that Japanese carpenters often use more lumber when framing a house. This occurs in floor and ceiling applications as well as in the framing of roof systems. Floor joists are often double framed in an effort to increase their stiffness while dropped ceilings are frequently used to reduce noise transmission from upper-level rooms into lower-level rooms. Both of these practices require greater amounts of lumber, thus increasing material and labor construction costs. Also, roof trusses are seldom used in Japan. Carpenters prefer to frame a roof with a rafter system, a practice that is very time- and labor-intensive. The pitch of Japanese roofs is significantly steeper than roofs in the US, thereby necessitating safety measures (such as roofing scaffolding) that severely reduces the productivity of carpenters. Finally, several respondents noted that Japanese carpenters often do not employ the correct technique for tying the house down to the foundation, a process that is critical for ensuring that the house does not shift during natural disasters such as typhoons and earthquakes.

Blocking is also used routinely in areas where it serves no structural purpose and would not be used in North America. Blocking refers to the placement of small pieces of wood between and perpendicular to wall or ceiling studs. Examples of superfluous blocking being used occur at the end of plywood and drywall sheets, for cupboard installation and inside closets where shelving will be installed. The installation of blocking is very labor- and time-intensive thus incurring significant labor costs while slowing down the entire construction process.

Many Japanese 2x4 homes are constructed using higher grades of lumber than would be used in the United States. Part of the reason for this is the GHLC requirement that all building materials used in a GHLC-mortgaged home possess a JAS grade stamp. Another factor is the Japanese desire to utilize higher grades of lumber. Much of the lumber used in Japanese home construction is J grade, a classification which differs between North American mills but usually consists of higher grades. This preference for higher lumber grades can increase the cost of framing a 2x4 home by 10-15% without significantly increasing its structural performance.

A more subtle difference between Japanese and North American carpenters relates to the philosophical approach each employs during the rough framing task. North American carpenters possess a production mentality, working as quickly as possible, constantly seeking to develop new techniques to increase their efficiency. In contrast, Japanese carpenters approach the task of rough framing in the same manner that they would use when framing a traditional post-and-beam house. Rather than working to increase efficiency, they concentrate on ensuring that each

component of the framing system is accurately cut and that the entire wall system fits together accurately. North American contractors who have observed Japanese carpenters framing-in a 2x4 house have noted that they approach the framing task as if the stud wall system were an exposed component of the house, rather than hidden behind a layer of sheet rock and paint. While this attention to detail certainly does not detract from the structural performance of the home, it also does not increase its structural performance and the time spent fitting the system together significantly increases labor costs.

Other differences in the framing process relate to regulatory issues. For example, new homes financed through a GHLC mortgage must be constructed according to GHLC regulations and incorporate GHLC-approved building materials. GHLC regulations require that all building materials must be JAS/JIS (Japanese industrial standards) approved, including even the types of nails used and their pattern of spacing. For example, in the United States drywall is usually hung using 6 inch by 12 inch nail spacing while the Japanese regulation requires a 4 inch by 8 inch spacing. As a result, drywallers in North America install 47 screws per sheet of drywall while their Japanese counterparts are required to install 92 screws per sheet. Not only does this regulation increase the labor and materials costs associated with hanging drywall, but it also has cost implications during the interior wall finishing process because of the large number of nail dimples that must be spackled.

Finally, an enormous amount of scaffolding is erected around the residential structure and roof area. This is due partly to safety considerations and partly to minimize the impacts of construction on neighbors. Not only does this represent a substantial expense throughout the entire construction process, but it also restricts the ability of carpenters to move building materials efficiently around the job site. In contrast, carpenters in North America have developed much simpler and effective methods to provide access to the upper levels of the home during the construction process without unduly restricting access to the job site.

Drywalling: The Japanese have not developed an efficient method for dealing with the drywalling and interior wall finishing components of residential construction. While there are some specialized drywallers and tapers in Japan, in general this task is performed by carpenters. In most cases it appears that carpenters possess little skill in hanging, taping or finishing interior walls. As opposed to the North American system of applying a high-quality, smooth or textured finish to interior wall, most Japanese interior walls are often poorly finished and covered with a vinyl wallpaper covering. While this vinyl wall covering is fairly effective in covering finishing defects in the short term, over time these defects are telegraphed through the wall covering and become readily apparent.

As mentioned earlier, drywall sheets in Japan more often than not come in 3x6 sheets. This difference in material size, in conjunction with the lack of specialized drywall crews, translates into a significant reduction in productivity on the Japanese side. Several respondents noted that a US crew can drywall an average Japanese house in two and a half to three days (excluding

taping), whereas a Japanese crew of carpenters would typically require about ten days to drywall the same house.

Finish Carpentry: Several respondents pointed out that Japanese carpenters lack the necessary knowledge of US finish products to install them correctly. Examples of finish products for residential applications would include stair packages, pre-hung doors and windows, and cabinets. Knowledge regarding the installation of these products is critical with respect to the performance of the products and the overall quality of the house. In addition, many of these products are supplied in an unfinished state and it is attendant upon the carpenter to stain and apply the final finish to the product. This also was identified as an area where Japanese lack of knowledge regarding North American products had a negative impact on the quality and performance of the final product.

Labor Specialization

Another factor that adversely impacts the cost structure of Japanese 2x4 housing is the lower productivity and higher wage structure of Japanese carpenters. Three recent studies in Japan have investigated the comparative productivity of Japanese carpenters with respect to their US counterparts (Nakamae 1994; Nakamae 1995; Watanabe 1995). The conclusions of these studies indicate that, on average, the productivity of Japanese carpenters ranges from one-third to two-thirds that of US carpenters. As a direct result of lower productivity, one study found that labor costs accounted for 10.6 million yen of total residential construction costs in Japan as compared to 3.7 million yen for a similar project in the US (Table 2). If accurate, this information implies that construction labor costs in Japan can be almost three times as high as those in the US.

Several factors have been advanced to explain the lower productivity of Japanese carpenters. First, the various stages of construction work are not well coordinated and Japanese construction crews often do not have site supervisors who schedule the different phases of a project. Similarly, the critical path method (CPM) utilized by project managers in the US to coordinate different aspects of the construction process is not widely utilized by small- to medium-size

residential housing contractors in Japan. Second, construction workers in the US tend to specialize (*i.e.*, framing, roofing, hanging and taping wall board) while in Japan a larger proportion of work is performed by a single crew of carpenters. Third, Japanese carpenters are not particularly knowledgeable about the North American 2x4 construction method. In particular, Japanese carpenters do not possess a detailed understanding of the structural framework of a 2x4 house and its role in transferring loads to the foundation of the house. As a result, Japanese carpenters tend to revert to post-and-beam methods when uncertain of a framing detail. This in turn tends to result in excessive material usage and higher construction material costs. For example, when framing a roof system, Japanese carpenters often use two ridge beams where a US carpenter would use a single piece of lumber.

Table 2. A comparison of residential construction costs in Japan and the US (in millions of yen, with percentage of total cost in parentheses).

	Japan		US	
Building Materials (Total)	10.605	(37%)	5.621	(40%)
Construction	8.355	(29%)	4.721	(34%)
Fixture installation	2.250	(8%)	0.900	(6%)
Labor (Total)	10.605	(37%)	3.747	(27%)
Construction	8.355	(29%)	3.147	(23%)
Fixture installation	2.250	(8%)	0.600	(4%)
Design Fees	1.560	(6%)	4.290	(3%)
Business Expenses	5.694	(20%)	4.579	(30%)
TOTAL COST	28.470	(100%)	13.950	(100%)

Notes: For equivalent houses (164 m^2) constructed in Sendai and a suburb in Seattle. Exchange rate $1 = Y100. Original source: Japanese Ministry of Construction. Adapted from "Interest in imported housing highlights domestic inefficiencies," *Nikkei Weekly*, February 6, 1995.

Another factor contributing to lower labor productivity in the Japanese residential construction industry is the fact that Japanese homes tend to be custom-made and located in dispersed locations. In the US most residential housing consists of on-site construction in residential housing developments where the economies of scale obtained from working on multiple homes contribute to cost efficiencies and increased labor productivity. Also, in the US the widespread use of 2x4 construction has led to wide standardization in building techniques, while in Japan diverse construction methods are used and standards differ greatly. These differences in construction practices reduce the production and transportation efficiencies characteristic of construction methods in the US

Cultural factors also play an important part in determining the productivity of Japanese carpenters. Very few young people enter the carpentry profession and, as a result, the average age of a carpenter in Japan is approximately 54. An important implication of this demographic trend is that very few older Japanese carpenters have received training in the 2x4 platform framing method and, in fact, many have expressed a reluctance to learn this system. Rather, Japanese carpenters focus on acquiring the skills required to construct traditional post-and-beam homes, skills which emphasize craftsmanship and woodworking techniques. In contrast, while US carpenters are trained in a basic set of woodworking skills, their training focuses more on developing their ability to work with speed and efficiency. As a result, there is a distinct difference in the manner with which carpenters in each country approach the construction of a house. This difference is best characterized by the speed and efficiency that US carpenters bring to the job. For example, several respondents noted that US carpenters can frame in and close a 1200 square foot (33.3 tsubo) house to weather in about 24 man-days while it takes a Japanese crew approximately 40-48 man-days to complete the same task.

A final factor that impacts the productivity of carpenters in Japan is the absence of incentives for carpenters, who are generally paid by the day or week, with wages usually based on length of employment. In contrast, US carpenters are often paid on a differential wage system that takes into account worker skill, experience and productivity. In addition, US carpenters are sometimes paid on a piecework basis, thus providing them with a further incentive to increase productivity. Finally, the familiarity of US carpenters with the 2x4 system allows them to develop innovative solutions to design problems which may not have been detailed on the construction drawings. Japanese carpenters, with their lack of experience with the 2x4 system, do not exhibit a similar ability to innovate on the job.

Project Management

A third important factor that was found to differ between the way that the 2x4 construction system is implemented in North America and Japan relates to the application of project management principles. Given the overall contribution of project management to the cost and production efficiencies found in the North American system, the application of these skills is critical to the effective implementation of the North American 2x4 system in Japan. As practiced in the United States, project management includes the following distinct, but interrelated, elements:

a. Mobilization (site logistics and organization)
b. Procurement (building materials, equipment, and tools)
c. Scheduling (from site preparation to labor to material acquisition to construction)
d. Cost control
e. Value engineering
f. Project close-out and demobilization

Although the principles of project management are commonly applied on commercial, industrial, and heavy construction projects in Japan, their application within the residential construction industry is minimal. Not only does this lack of implementation have a substantial impact on the cost structure associated with residential construction projects, but it results in cumulative negative impacts during the course of the project as unnecessary costs and inefficiencies incurred in early stages of the project affect tasks performed in later stages. Interviews with US construction professionals identified a number of areas where the application of project management principles could reduce project costs while increasing construction efficiencies. For clarity, these comments will be summarized and organized to correspond to the project management elements presented above.

Mobilization: The lack of a mobilization plan contributes to a chaotic and disorganized construction site operation where building materials and equipment are haphazardly located on the site. As a result, the contractor is often forced to relocate materials around the site before they are eventually incorporated into the job. This process of repetitive relocation and stacking of building materials and equipment adversely impacts production efficiency and is an inefficient use of labor that needlessly increases production costs.

Procurement: Project managers in North America constantly strive to minimize construction costs. One area where they have been particularly successful is in the logistics of handling building materials on the construction site. In contrast to Japan, where the on-site movement of building materials is primarily accomplished through manual labor with little or no mechanical support, North American managers have largely mechanized the process. For example, extender fork lifts are commonly used to move pallets of building materials onto and around the construction site, and conveyors are generally employed to lift materials onto the roof of the house. It is interesting to note that in those cases where Japanese managers do utilize mechanized equipment to assist in the movement of materials on the construction site they frequently employ small cranes, a solution deemed to be too expensive by US contractors.

Scheduling: Beginning a construction project without a realistic and practical project schedule to guide the project means that the site supervisor and work crews often operate on an *ad hoc* basis. Similarly, the lack of specification of individual task durations and target completion dates causes site work to proceed in an uncoordinated fashion that delays the project. In the North American system, project scheduling assists in the proper sequencing and coordination of the work effort, thus reducing construction delays.

Cost Control: The introduction of cost controls into the residential construction process is, to a large degree, dependent upon the implementation of a realistic project schedule. Proper scheduling of a construction project allows the project managers to monitor construction costs as they occur and to anticipate future costs in time to develop effective strategies.

Value Engineering: The concept of value engineering is based on encouraging each member of the construction team, from laborers to managers, to identify ways to increase the efficiency of the construction process. In North America, each member of the construction team (with the possible exception of apprentices) possesses a strong understanding of the 2x4 system and is encouraged to identify new and creative methods to accomplish a job more efficiently while reducing construction costs. This process is performed within the context of a construction contract thus providing an incentive to reduce construction costs while safeguarding the quality and safety of the construction process. Although value engineering is most effective when applied during the design phase of a construction project, significant cost reductions can be realized during the construction process.

Many Japanese project managers possess a traditional architecture or engineering background while their counterparts in the US generally have a construction management background. This difference in training results in Japanese managers being less familiar with residential construction techniques, which contributes to delays in the decision-making process and reduces the effectiveness of workers and subcontractors on the project site. Interviews with several building professionals indicated that delays in on-site decision-making were largely responsible for delayed construction schedules and increased project costs. They also noted that the lack of project management skills results in constant construction delays and interruptions. As a result, it is considered essential that any transfer of North American 2x4 technology include training in project management skills.

RECOMMENDATIONS FOR TECHNOLOGY TRANSFER

Although a small number of firms are currently building 2x4 homes in Japan, very few Japanese carpenters and architects possess an intimate understanding of how the 2x4 system works. Indeed, the North American 2x4 system requires more than just a knowledge of framing techniques. It consists of a series of components extending from land planning to structure maintenance (Figure 1).

Within the US residential construction industry, the paradigm for the development of construction skills has generally involved the development of individual skills through a gradual progression from apprentice to journeyman to foreman to superintendent. Given this paradigm, the role of the carpenter represents the basic building block upon which increased knowledge and understanding of the 2x4 construction system is based. It is only after individuals have acquired this base level of knowledge that they can realistically progress to the more advanced levels of site supervision. The process of effectively transferring this construction technology to Japanese carpenters requires that US carpenters be allowed to work with their Japanese counterparts.

The perceived and real difficulties involved in obtaining work visas for US carpenters in Japan have effectively restricted the effective transfer of this technology to Japanese carpenters by limiting their opportunities to work with their US counterparts. The increased availability of work visas for US construction professionals would provide at least two immediate benefits to Japanese contractors. First, it would provide an opportunity for Japanese authorities to verify the credentials of applicants to ensure that they possess the requisite combination of knowledge, skill and experience in 2x4 residential construction that would allow them to function both as carpenters and technical trainers. In addition, the process would facilitate a more efficient transfer of technology by encouraging US companies to send qualified carpenters to work on projects in Japan.

The US consulate in Osaka has expressed an interest in working with the Japanese government to facilitate the process of obtaining work visas for US construction professionals and skilled workers. The Japanese Ministry of Justice is currently reviewing the policy for issuing skilled worker visas.

In order to take full advantage of the efficiencies inherent in the North American 2x4 construction system, it is important that designers/architects, carpenters, construction site supervisors, and project managers develop a basic understanding of the North American 2x4

Figure 1. A schematic representation of the North American 2x4 residential construction system.

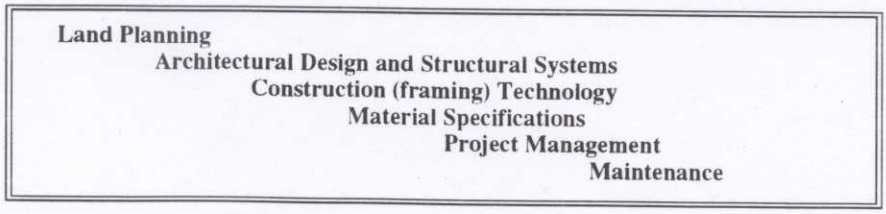

Table 3. Strategic recommendations for transfer of the North American 2x4 residential construction system to Japan.

	Primary Method	Secondary Method
Designer/Architect	Classroom	On-site work
Carpenter	On-site work	Seminar
Site Supervisor	On-site work	Classroom
Project Manager	Classroom	On-site work

construction system. This implies that the transfer of 2x4 technology should occur at a variety of skill levels. However, given the very different functions and requisite knowledge bases required, different programs should be developed for each group to effect technology transfer efficiently. For example, while it may be appropriate for carpenters to acquire basic skills on the job site, it is probably more appropriate for project supervisors to develop project management skills within a classroom/seminar environment. As a result, the recommended technology transfer program involves separate strategies for each of the four groups identified (Table 3).

Educational programs currently operating in the US provide training in the 2x4 residential construction system. However, the effectiveness of these programs in providing training to Japanese construction workers is limited by a number of factors including the high level of expense involved, cultural factors, and the reluctance of Japanese firms to send large numbers of employees overseas for extended periods of time. A more efficient method for technology transfer might involve developing cooperative education/training relationships between appropriate US and Japanese building associations, vocational technical institutes and universities. These cooperative relationships would provide the basis for facilitating the two-way exchange of building construction technology at a variety of levels. For example, the inclusion of technical institutes and universities would allow for a spectrum of training programs ranging from basic carpentry techniques to project management.

SUMMARY

A review of existing policies related to the issuance of work visas for US construction professionals and skilled workers with a view toward increasing their accessibility would help to ensure that qualified carpenters and site supervisors are available to work on projects in Japan. This would provide broad support for total technology transfer, providing benefits ultimately for both the Japanese residential construction industry and home buyers. Interested organizations in the US, in cooperation with the Japanese government, could be called upon to develop a program to review the technical qualifications of US construction professionals and skilled workers applying for work visas. Technology transfer could be effected by implementing an integrated system of theoretical and practical classroom and worksite training of Japanese construction professionals by their US counterparts to rectify the incomplete understanding and mastery of US 2x4 construction technology in Japan. These strategies would facilitate the effort to provide the Japanese residential construction industry with the necessary skills to implement North

American 2x4 technology efficiently as the basis for rationalizing construction costs and management systems.

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