# Adapting Affordable North American Wood Frame Construction Homes to Japan

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# Abstract


The primary research question of this study is:

What are the strategies that can contribute to cost reduction of wood frame housing in Japan, based on the technical and design principals of wood frame affordable homes?

During the rapid period of economic growth, from the 1970s to the 1980s, the situation in the Japanese housing market changed dramatically. As they became wealthy, buyers replaced their traditional living style with a western one. The change was so sudden that the Japanese housing situation could not adapt easily the transition from traditional to contemporary styles. As a result, there was a sharp rise in building costs. In addition, because the land prices soared at the time, buying a house became more difficult. This thesis addresses the potential benefits of introducing the concepts used in the building of North American wood frame affordable homes, by showing how, with their efficient building technology, they could be a potential solution for improving the current harsh housing situation in Japan.

The author reviewed the current literature relevant to this subject, including that to the Japanese housing industry, and wood frame construction of affordable houses, then tried to uncover strategies to enable cost reduction of affordable wood frame construction in Japan. In particular, the author sought strategies in cost reduction from the points of view of design and method of construction.

It was found that a number of methods and techniques using the wood frame system in North American affordable homes could help reduce construction costs, and ultimately the price of houses in Japan. The author also found that the Japanese

lifestyles, customs, and building standards do not easily adapt to some ideas and methods used in the construction of North American affordable homes.

# Résumé

La question fondamentale de cette étude serait:

Quels sont les moyens qui peuvent contribuer à la construction de maisons dotées de structures en bois au Japon et ce, basé sur lesb principes techniques et le design utilisés dans les structures en bois des maisons à prix modiques?

Pendant la période de croissance économique allant des années 1970 au milieu des années 1980, la sityation dans le domaine de la construction domiciliaire a énormément changé; c'est-à-dire que plus les acheteurs étaient fortunés plus ceux-ci se tournaient vers un style occidental au détriment du style traditionnel japonais. Le changement s'est effectué de façon si soudaine, que le marché de la construction domiciliaire japonaise n'a pu s'adapter que difficilement. Conséquemment, il s'en suivit une forte montée des prix de la construction. De plus, parce que le prix des terrains augmenta de façon vertigineuse, moins de gens pouvaient s'offir d'acheter une maison. La présente thése se penche sur les bénéfices possibles à réaliser en employant les concepts utilisés en Amérique du Nord dans la construction de maison à structures en bois à prix modiques. Ceci sera démontré par le fait que les techniques de construction efficaces utilisées en Amérique du Nord pourraient s'avérer être une solution possible pour améliorer la situation difficile du marché immobilier résidentiel au Japon.

L'auteur de cette thèse a passé en revu L'information disponible dans ce domaine, de même que celle touchant la sphère de L'industrie japanaise de la construction domiciliaire, ainsi que celle du domaine de la construction de maisons à structures en bois à prix modiques. L'auteur a ensuite regardé quelles stratégies

pourraient être employées afin de réduire les coûts de construction de ces maisons. Il abordera la question du point de vue du design et des méthodes de construction.

Il a été prouvé que certaines méthodes et techniques utilisées dans la construction de maisons à structures en bois à prix modiques en Amérique du Nord, peuvent réduire le coût de construction et conséquemment le prix de la maison elle même, au Japan. L'auteur s'est aperçu que le mode de vie japonais ainsi que les habitudes, traditions et normes de construction ne sont pas toujours compatibles et souvent difficiles à adapter à la maniére nord-américaine de construire des maisons à structures en bois à prix modiques.

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# Chapter 1
# Introduction

## 1.1 Introduction

Japan covers an area of 377,700 sq.km, most of which is mountainous. Only 4% of the total land area is used as sites for housing, factories, office buildings, stores and other facilities. Habitable land, not including forests and bodies of water, accounts for only 33% of the total land mass. As a result, the average population per square kilometer of habitable land is much higher in Japan than in Western countries (Table.1.1).

| | A.Total land (sq.km) | B. Habitable land (sq.km) | C. B/A (%) | Population (million) | Population /A |
|---|---|---|---|---|---|
| Japan | 377,700 | 125,500 | 33 | 122.61 | 325 |
| U.K | 244,900 | 218,400 | 89 | 57.07 | 233 |
| France | 551,500 | 403,200 | 73 | 55.87 | 101 |
| U.S.A | 9,372,700 | 6,514,700 | 70 | 246.33 | 26 |

Table.1.1 Comparison of Habitable Land in 1987 (The Building Center of Japan, 1992)

The most common type of structure in Japanese housing is made of wood. There are about 46 million houses in Japan, and wood structure houses comprise about 68% of them (Matumura,1996). The reason for the high ratio of wooden structures is that wood suitable for use as building material used to be plentiful in Japan. However, nowadays a large percentage of raw wood must be imported from other countries.

It is generally accepted that Japanese houses are very expensive. For example, whereas the average cost of housing in North America is about 3.5 times of the average annual income, the average cost of housing in Japan is about 6.6 times of the average annual income (Matumura,1996). Although the cost includes land price, the construction costs are also high in Japan. While there are many reasons for this, the main reason is that the structure of the Japanese housing industry works as a closed system. There are many big housing construction companies in Japan. As these companies build houses using their own building methods, and materials which they have developed, construction sites do not, in many cases, use standard building methods or materials. For example, the major manufacturer of this closed-system housing is *Sekisui Heim*, a company which produces eighty percent of the total prefabricated housing materials used in the housing industry (Coadrake, 1986) (Fig.1.1). Although this may be good for the companies, it complicates the Japanese housing industry because there are too many systems. Moreover, each method and type of materials can be used and exchanged only within the respective closed-system, and as a result, the costs of houses rise.

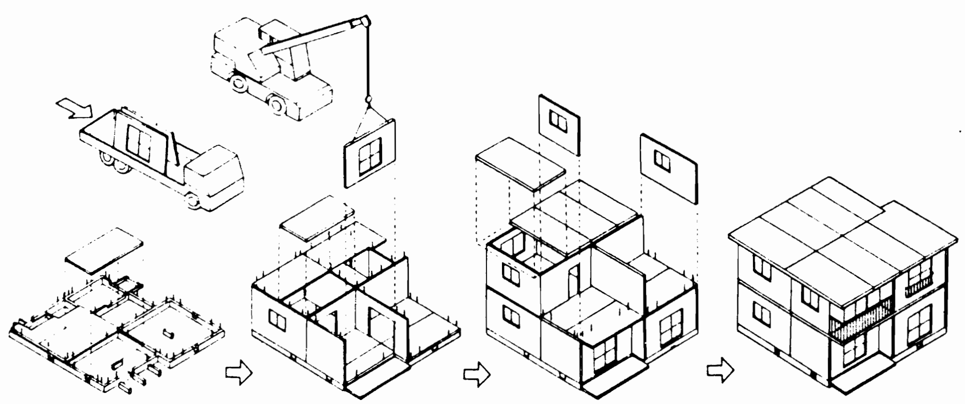


Fig.1.1 Prefabricated House - Concrete Panel (Uchida, 1986)

The Japanese housing market can be divided into three segments: traditional, prefabricated, and wood frame homes. While the traditional home segment accounts for roughly three quarters of the wooden home industry, this proportion is decreasing with the rising popularity of prefabricated and wood frame homes.

The traditional and most conventional method is the post and beam system (Fig.1.2), a method which requires intensive labor and skilled craftsmanship. For example, as the frames of each of the two-stories are built simultaneously, carpenters have to assemble materials under difficult working conditions (Fig.1.3). Besides this, the joints of the materials, such as posts and beams, require skilled carpentry work (Fig. 1.4).

The structure of the post and beam system makes it easy to create openings in walls. For example, in traditional Japanese houses, *Shoji* (wood and paper screens) are used for the walls (Fig.1.5). This is good for Japanese houses during the summer, because of the humid weather; however this method compromises the airtightness of the structure.

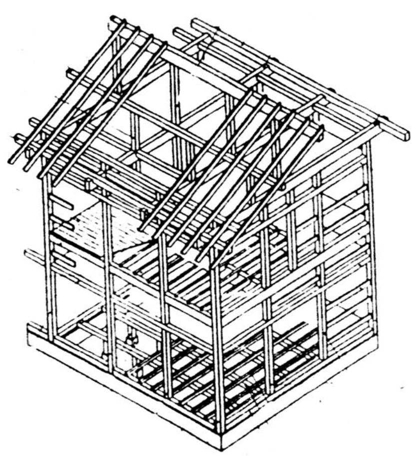


Fig.1.2 Post and Beam System (Takahashi, 1996)

Fig.1.3 Assembling Traditional Home (Takahashi, 1996)

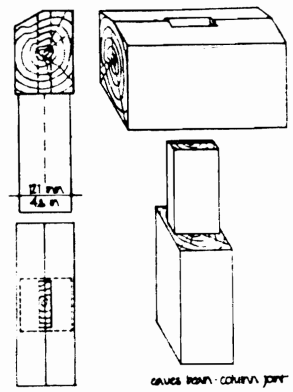


Fig.1.4 Joints in Post and Beam System
(Engal, 1985)

Fig.1.5 Wood and Paper Screen
(Osawa, 1993)

Prefabricated homes are manufactured using standard industrial procedures and are then marketed as attractive homes, usually by big housing construction companies. The number of firms producing this type of housing has been increasing; however, architects tend to argue that these buildings are not “Architecture” at all but merely “Consumer Packages”, because of their lack of design flexibility. In addition, as each construction company uses its own building method and sizes, elements such as door height are not of a universal standard, and thus the closed-system creates confusion within the housing industry.

The wood frame system was introduced to Japan from North America about a quarter of a century ago. Compared to other systems, it has many superior points such as the efficiency resulting from the use of standard materials. In spite of this advantage, the rate of houses built using this system today is only 8% of all wooden houses in Japan (Minami, 1994). Moreover, the building costs are double those of North America. There are several reasons to this, one being that the Japanese government and builders distorted the system when it was introduced, and many aspects of the efficiency which existed in the original system have been lost. For example, using 910mm (3’)×1820mm

(6') panels, such as plywood, instead of 1220mm (4')×2440mm (8') panels is common in Japan. The author believes that modification of the wood frame system in Japan is needed in order for the housing industry to become more efficient and cost-effective.

Japan now consists of two class societies: a land-owning class and a class which will never own land. For land-owners, the price spiral has created unbearable tax-burdens related to inheritance taxes, while the landless are faced with the uninspiring prospect of spending a lifetime in rented accommodation. It seems almost impossible for young people, even those with a university education and a good job, but without land, to purchase a detached-house with a back yard in the suburbs. If they do venture to buy such a house, they will have to pay an extremely high mortgage. On the other hand, if they choose to buy a condominium, or to rent an apartment in town, the mortgage or the rent will still be high, despite the inferior environment. Fig.1.6 shows an example of typical Japanese condominiums whose floor area is about 75 sq.m (870 sq.ft). Generally those kinds of condominiums located in the suburbs of Tokyo are built as mid- to high-rise buildings, with a price range of between \$300,000 and \$500,000 per unit. Although there are only a small number of affordable housing developments in the area, there are a huge number of condominium developments of this kind. In comparison, there are various types of affordable housing developments in North America. Fig. 1.7 shows a prototype of one type of affordable houses in Canada known as the Grow Home. The narrow-front rowhouse 4.3 m (14') with 93 sq.m (1000 sq.ft) of living space on two floors was adopted to maximize land-use efficiency and to minimize infrastructure and heating costs (Rybczynski et al., 1990). This house can be built for \$40,000, and the selling price is about \$70,000 in Montreal, Quebec.

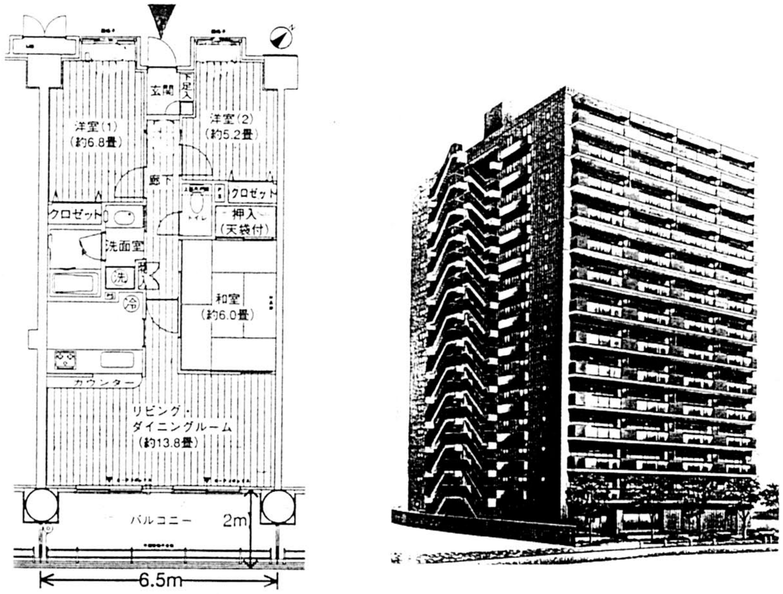
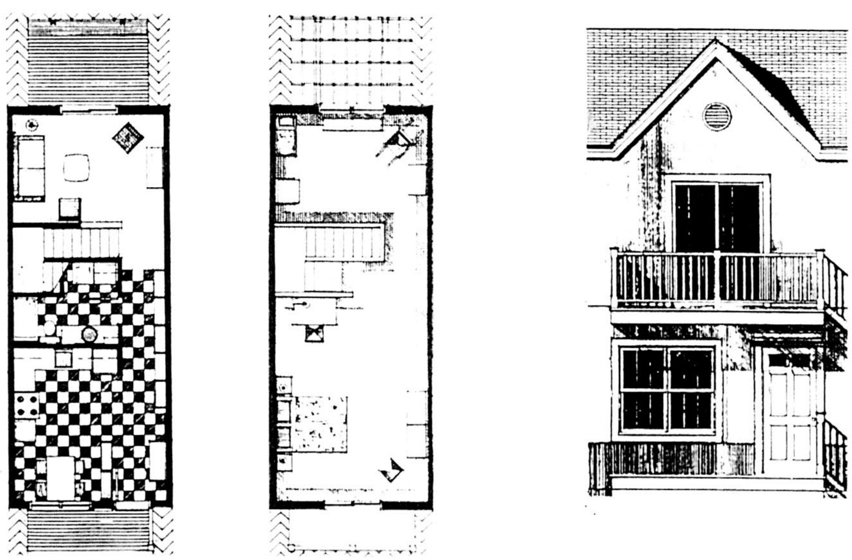



Fig.1.6 Typical Condominium in Japan (Recruit Inc, 1997)



First Floor Second Floor

Fig. 1.7 The Grow Home
(Rybczynski, Friedman, and Ross, 1990)

Construction of the town house, which is a standard dwelling type in North America, would be one of the best strategies for reducing housing prices in Japan. It is characterized by great economy in the use of land, moderate construction costs, and low maintenance and operating costs. In the past, Japan had a long history of town house construction, although nowadays it is not a common dwelling. During the 17th century, there was a kind of town house called "*MACHIYA*" (Fig.1.8) in castle towns. Even now, many "*MACHIYA*", most of which are preserved, can be seen in historical town such as Kyoto. "*MACHIYA*" actually means "town house". Many of its features are similar to those of the current town house. Although the design and function of the "*MACHIYA*" were adequate, their numbers decreased because of their lack of fire-proofing.

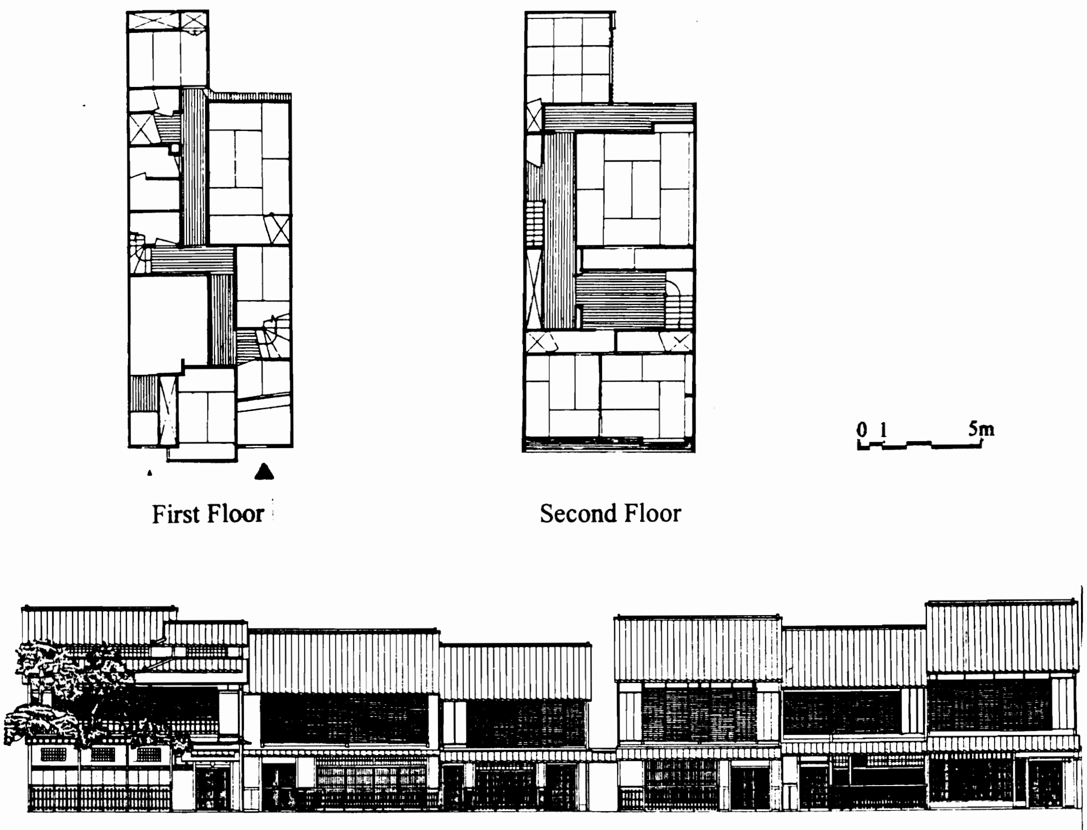



Fig.1.8 Japanese Traditional Town House, "*MACHIYA*" (Yamazaki, 1994)

In the eighteen century another type of town house called "*NAGAYA*", or "Long House", was popular, however, those houses were used as rental properties and were made from poor materials. These houses in which low income people lived were very small and lacked facilities. After World War II a different type of town house called "*BUNKA-JYUTAKU*" (Fig.1.9) appeared. "*BUNKA-JYUTAKU*" whose meaning is

"Culture House" was influenced by the design of town houses of western countries. However, in many cases, their design and concept was distorted by developers, who considered the town house seen in western countries as a new type of "*NAGAYA*". As a result, most "*BUNKA-JYUTAKU*" were not considered to be attractive. Consequently, many Japanese still believe that a town house is cheap and less attractive. However, the author believes that a well-designed town house would be accepted by the Japanese, as the "*MACHIYA*" was accepted a long time ago.

Fig.1.9 "*BUNKA JYUTAKU*" (Huno, 1995)

This paper argues that North American style affordable houses would fit into the Japanese housing environment because their construction does not require a big lot. The concepts of affordable houses, such as the narrow front house, the semi-detached house, and the row house, provide higher density and, therefore, lower cost of land per user. For this reason, the author would like to introduce this concept and study the implications of adapting wood frame construction technology to the Japanese housing industry.

## 1.2 Rational of the Study

The motive for this thesis derives from the author's background. After graduation from university, he joined the Yokohama Branch of Tokyu Construction Co., LTD., a major general construction company in Japan. Since then the author has been engaged in the development of newly developed communities, and the design of custom made homes. Most of the houses which the company design and build are constructed according to the conventional system. However, in the last three years, the ratio of use of the wood frame system has been increasing. One of the reasons is that houses built according to the wood frame system are stronger than those built according to the conventional system. In 1993, Japan had a big earthquake, and many conventional houses collapsed (Fig.1.10). On the other hand, The wood frame houses were hardly damaged at all.

Another reason for the increase in use of the wood frame system use of the wood frame system is that the Yen has gone up in value. Although the Yen is going down reacentry, still the value is much higher than the one in 30 years ago. (e.g. 1998: 1 CND dollar = 90 Yen, 1968: 1 CND dollar = 360 Yen) Since most materials used in building a wood frame house are imported from the United States and Canada, the cost of the materials has fallen. Sales of the so called "Imported House" has been booming in Japan for last 10 years, although the boom started to be curbed reacentry. Many construction companies are making efforts to promote sales of this style of house. Some of them employ North American builders because it is sometimes cheaper and more efficient than paying for the same work when it is done by Japanese builders. Despite this, homes are still expensive. In addition, the import of housing styles from North America causes problems with respect to the harmony with the Japanese environment. The author believe that the Japanese should design and build houses independently, because the North American designs need some adjustments to the Japanese culture. For example, the Japanese still like to make the *Tatami* room (Fig.1.11), which is a traditional floor style, even in a western style house[1]. In order to design wood frame houses well, and to build them efficiently, it is necessary for the Japanese housing industry to understand how to modify the system itself.


Fig.1.10 Collapse by Earthquake in 1993, Kobe (Matumura, 1996)

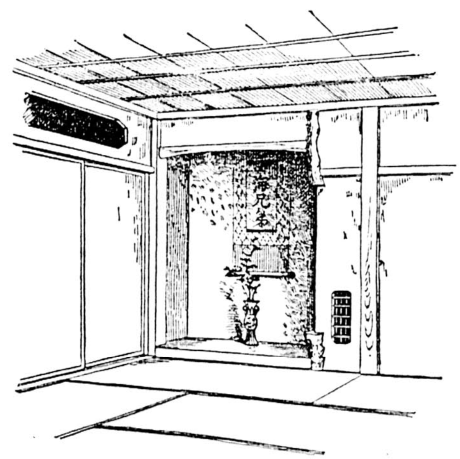


Fig.1.11 *Tatami*-room (Morse, 1979)

Compared to the extremely expensive houses in Japan, North American houses are highly cost-effective. The author believes that significant knowledge can be obtained by studying the methods and the many examples of North American housing styles. From this viewpoint, the author thinks that it is important to study the wood frame construction technology as the first step towards adapting it for use in Japan. In the future, the author hope that the Japanese will be able to design a prototype of housing

[1]The *Tatami* (a mat of woven straw) is widely used as a traditional flooring inside the house. It is normally 90cm (3ft). The size of a room is expressed by the number of tatami mats used to cover the floor

which has a new identity in Japan, by modifying North American housing technology and design.

## 1.3 Research Question

The primary research question of this study is:

**What are the strategies that can contribute to cost reduction of wood frame housing in Japan, based on the technical and design principals of wood frame affordable homes?**

Sub-research questions stemming from this question which further define the study are:

- What are differences between the Japanese low-rise housing industry and the North American one?
- What are the barriers to integrating North American building technology with the Japanese housing industry?

## 1.4 Methodology

In the first parts of this paper, the author will review the current literature relevant to this subject, such as housing industries, and wood frame construction of affordable houses. Next, the author will attempt to find strategies that can contribute to the adaptation of North American affordable wood frame construction to Japan. In particular, the paper will concentrate on finding the possibilities for cost reduction from view points of design and building system.

This thesis will follow the following structure. Chapter two will lay the foundations on which the remainder of the thesis will be built. It will present the characteristics of the low-rise Japanese home-building industry, and the way in which the industry operates. This chapter will conclude with a review of the potential of the Japanese home-building industry to accept new housing systems. Chapter three discusses several design strategies for reducing building costs, and points out how much money Japanese builders and developers can save by adopting planning and design methods used in the building of North American affordable homes. In chapter four, strategies for reducing costs of building wood frame systems will be discussed. This chapter will present factors which influence construction costs, and will identify which North American cost-effective strategies can be adopted to the Japanese housing industry. Finally, chapter five will synthesize and summarize all of the findings.

# Chapter 2
# The Low-rise Japanese Home Building Industry and Its Ability to Accept Changes

## 2.1 Existing Houses in Japan

In 1993, There were about 45,940,000 houses in Japan; the number of households was about 41,220,000 (Matumura,1993). Although the number of houses exceeded the number of households in 1968, it has been said that there are many ways by which houses can be improved. One of these points is that Japanese houses do not last a long time. In all existing houses in Japan, the ratio of houses which were built before World War II is only 5.3%. About 95% of houses were built after World War II, and 53.3% of houses were built after 1976 (Matumura, 1996). In short, about half of the total houses last less than 20 years. This can be attributed mainly to changes in lifestyle and living standards after World War II.

The floor area of a Japanese single dwelling is getting larger every year (Fig.2.1). However, there is a great difference between owner-occupied housing and rented housing, both in size and density. There is also a difference between urban and rural regions in the average total area. For instance, the lowest figure is for Metropolitan Tokyo; 60.3 sq.m (649 sq.ft), and the highest is for Toyama Prefecture; 153.2 sq.m (1648 sq.ft).

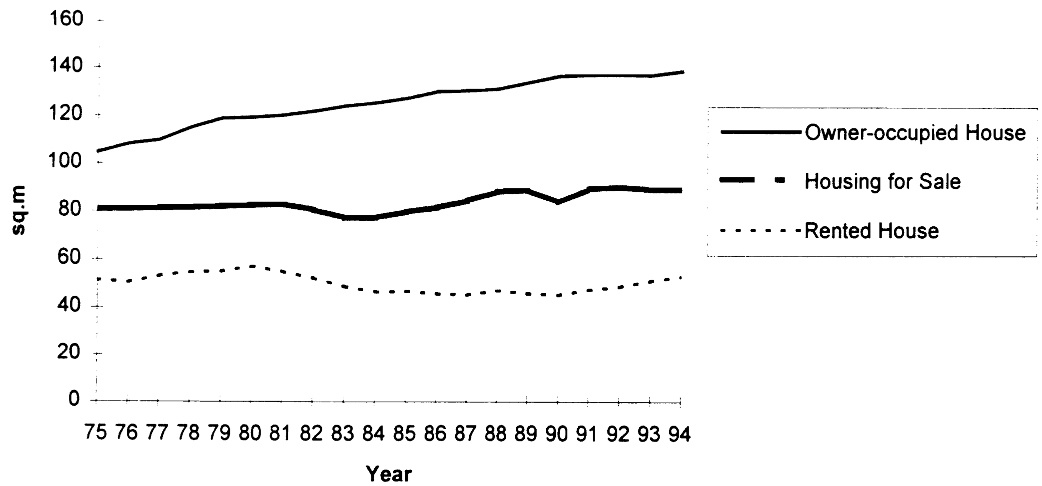



Fig 2.1 Average Floor Area (Ikegami,1995)

The most common building material for existing houses in Japan is wood (68.1%) (Matumura, 1994). However the ratio is decreasing because there is an increase in the number of structures made from steel and concrete. Notably, many prefabricated houses and high-rise condominiums have been built during the past two decades using steel and concrete.

## 2.2 Rapid Rise in Land Prices

In the second half of the 1980s, a considerable rise in the price of commercial land in central metropolitan areas was followed by sharp increases in certain residential areas (Fig.2.2). The increases have caused a housing crisis in metropolitan areas. The price of a 75 sq.m (815 sq.ft) condominium in the Tokyo region was eight times the average annual income in 1990, and as housing becomes further removed from the center of the city, commuting time increases.

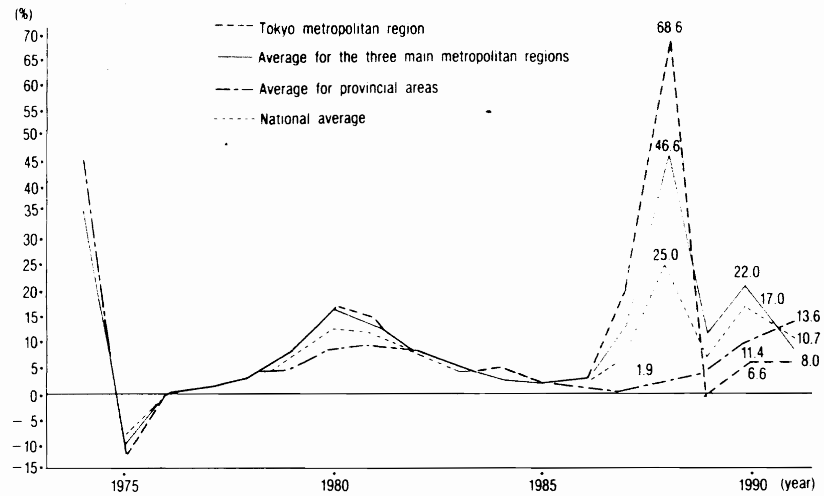



Fig.2.2 Rate of Change of Officially-posted Land Price by Year - Average Price for Residential Land ( The Building Center of Japan, 1992 )

## 2.3 Newly-built Housing in Japan

Every year, the Japanese Ministry of Construction publishes statistics of the number of houses which are built. The statistics show the trend in the housing markets during that year (Fig.2.3). According to the statistics, in 1968, the production of dwellings reached one million for the first time, while 1,850,000 houses, which is the highest number since 1968, were built in 1972. Subsequently, the numbers fluctuated in response to economic influences. The number of houses built in 1994 was 1,561,000: single houses (581,000), subdivided houses (378,000), and rental houses (602,000) (Ikegami, 1996).

In Japan, 'Condominium' generally describes middle- or high-rise dwellings, in which private or governmental companies invest. Nowadays the condominium is a common style of accommodation in Japanese cites. The Japanese Ministry of Construction includes subdivided houses, condominiums and newly built houses in their statistics. The number of units which are built has changed, as Fig. 2.4 shows. Since

1993, the number has increased, because many people, notably young couples, are moving from rented apartments to condominiums with the incentive of low interest rates.

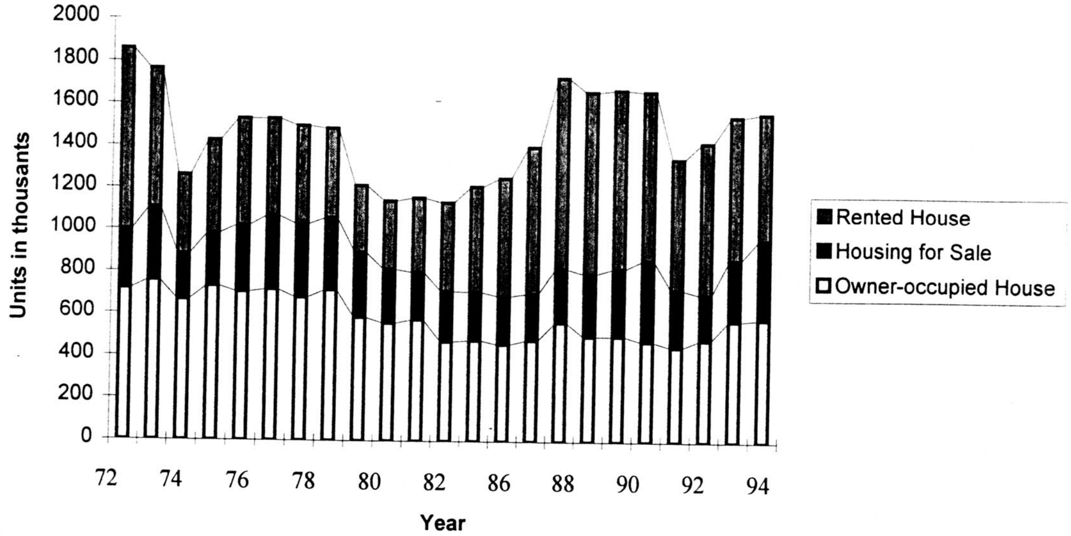



Fig.2.3 Number of Newly Built Houses(Ikegami,1995)

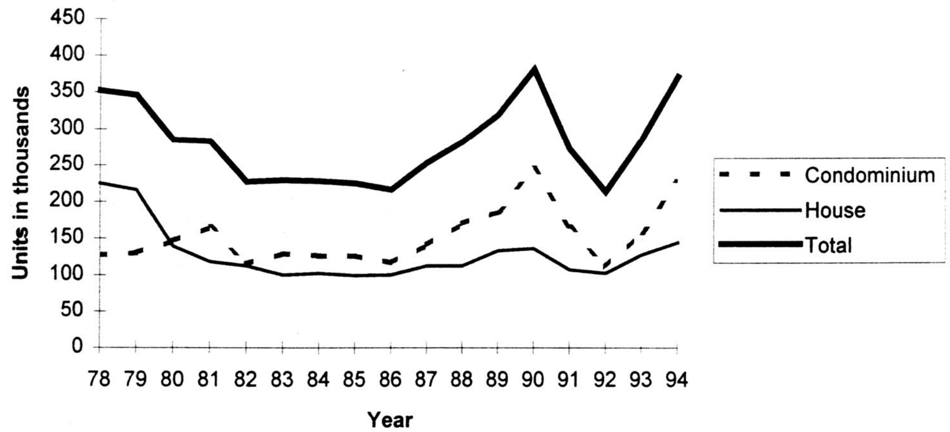



FIg.2.4 Number of Housing for Sale (Ikegami,1995)

## 2.4 Structure of Low-rise houses

There are three common structural systems in Japanese housing: wood, steel, and concrete. The wooden structure has historically been the most common, because traditional housing systems occupied about two-third of all structures in 1970 (Fig.2.5). Since then, the number of wooden houses has decreased because other structures and new systems have been gaining popularity. However, in general, people still have a great attachment to wooden houses.

Wooden structure can be divided in three systems: the post and beam system, the wood frame system, and the prefabricated system. The ratio of houses built like this in 1993 is as follows: on site post and beam system (87%), on site wood frame system (8%), and prefabricated system (5%) (Ikegami, 1996).

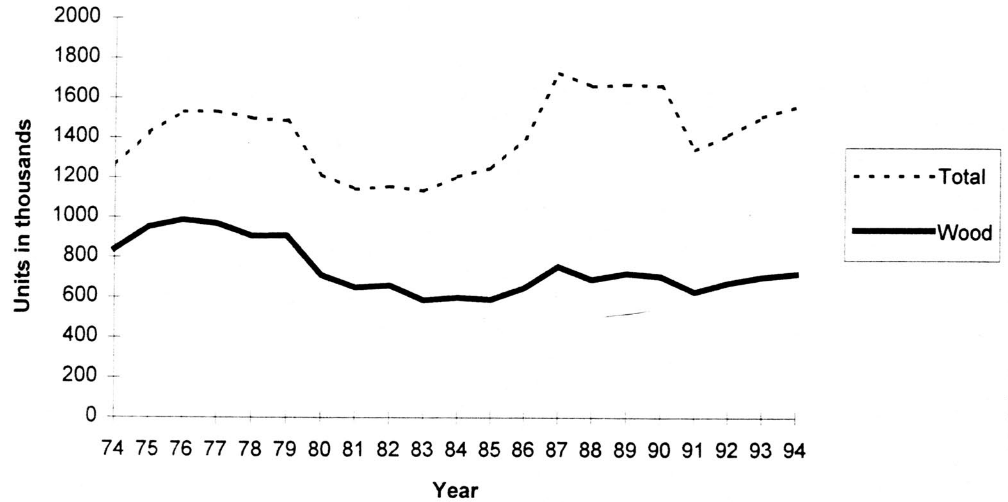



Fig.2.5 The Number of Wooden Houses (Ikegami,1995)

### 2.4.1 The Post and Beam System

The Post and beam system has been developed to accommodate the Japanese lifestyle and climate. The posts and beams are connected by many kinds of joints which the builders make on sites. Because builders did not traditionally use nails and steel joints, their job required great craftsmanship. Although nowadays nails and steel joints are used as supplements to make main connections, much work is still needed in the creation of small joints. For that reason, there is limited productivity with this system. Many conventional builders, as well as small companies still build houses using this system. The builders' conventional views inhibit the development of new methods. However, an innovation of this system has been developed since the 1980s. It is called the 'pre-cut method'. The main characteristic of this method is that joints of posts and beams are made in factories. This method is becoming more popular because it helps to reduce building time, and to compensate for the shortage of skilled carpenters (Table.2.1). The cost of the pre-cut method is still high, but if the costs can be reduced, eventually this method will be useful.

| Year | Wooden Houses (%) | Post and Beam System [Using Pre-cut Method] (%) | Wood Frame System (%) | Pre-fabricate System (%) |
|---|---|---|---|---|
| 1985 | 100 | 93 [ 3 ] | 4 | 3 |
| 86 | 100 | 92 [ 4 ] | 5 | 3 |
| 87 | 100 | 91 [ 4 ] | 5 | 4 |
| 88 | 100 | 90 [ 6 ] | 6 | 4 |
| 89 | 100 | 89 [ 7 ] | 7 | 4 |
| 90 | 100 | 88 [ 8 ] | 7 | 5 |
| 91 | 100 | 87 [ 11 ] | 7 | 5 |
| 92 | 100 | 87 [ 14 ] | 8 | 6 |
| 93 | 100 | 87 [ 18 ] | 8 | 5 |

Table 2.1 Ratio of Wooden Systems (Ikegami,1995)

### 2.4.2 The Wood Frame System

Wood frame houses exist in many points of the world and more than 2 million are built each year worldwide (Hattri, 1996). This suggests that the wood frame system is adaptable to many cultures and climates.

In Japan, the ratio of houses built using the wood frame system compared to other housing systems has been increasing steadily since 1974, when this system was introduced from North America. However, the ratio of wood housing compared to other kinds of housing still remains at 8%, despite its many merits (Ikegami, 1995). One of the reason is that the Japanese housing market is basically scattered . That is to say, houses grouped in clusters, or town houses, which could be produced efficiently, using the wood frame system, are not common in Japan. In addition, in the suburbs of big cities where there is a great demand for houses, lots for large housing developments are scarce. Another reason is that the original productivity and efficiency of the wood frame system was lost because some parts of the system were changed when it was introduced. For example, although the original module of the wood frame system is 16 inches, it was changed to 3 feet because the traditional module in Japan was 3 feet, and as a result, the efficiency was lost.

In recent years, however, the number of houses built according to the wood frame system has begun to increase (Fig.2.6). Buyers tend to like the design of western-style homes because of their resistance to earthquakes, their airtightness, and their fire-resistance. Imported houses from North America and Northern Europe are also popular.

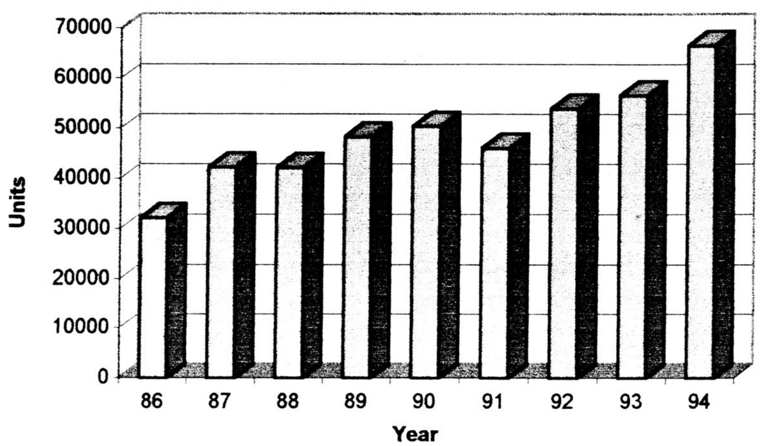



Fig.2.6 Number of Newly-built Wood-Frame Houses (Ikegami, 1995)

In addition, building three-story houses in urban Fire Protection Districts[1] was permitted due to the revision of construction codes in 1987, and three-story wood-frame

[1] The Japanese building codes provides some kinds of fire protection districts.

apartment buildings started to be built. For that reason, it is expected to gain popularity in the future.

### 2.4.3 Prefabricated House

The ratio of prefabricated houses whose main structural materials are produced in factories is 14% of all houses built in 1994 (Fig.2.7). Although the ratio went down in 1993 because of a depression in the rental housing market which constitutes a large proportion of prefabricated houses, it is said that the ratio will go over 20% in the near future (Ikegami, 1995). The reasons for this are that, generally, the quality of houses is consistently high, and companies who sell and build prefabricated houses, have strong commercial strategies, and are highly competitive in the housing market.

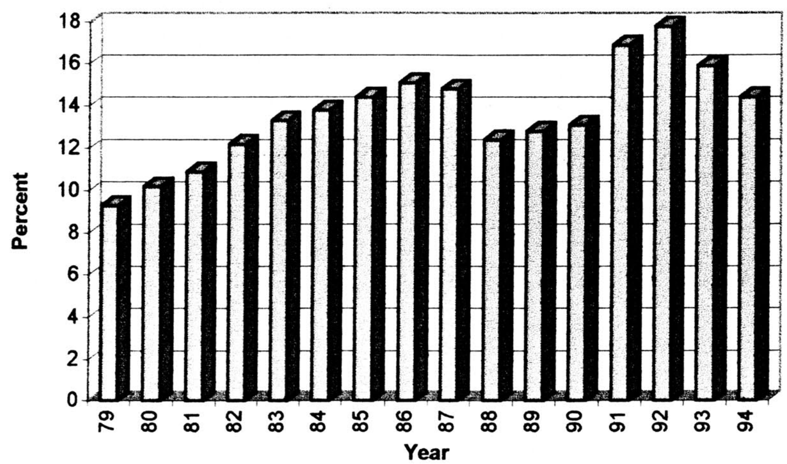


Fig.2.7 Ratio of Prefabricated Houses (Ikegami, 1995)

The system of prefabricated housing is divided according to their main structural materials: wood, steel, and concrete. The ratio of each in 1994 is on Table.2.2.

| | wood | Steel | Concrete |
|---|---|---|---|
| Ratio (%) | 16.9 | 72.6 | 6.4 |
| Number of Houses | 38,000 | 172,000 | 14,000 |

Table. 2.2 Ratio of Structure in Prefabricated Houses (Ikegami, 1996)

#### 2.4.3.1 Wooden Prefabricated House

Wooden prefabricated houses have their walls, floors, and roof panels, made in factories, and assembled at the construction sites (Fig.2.8). Although this system has shown at one time, good productivity, now it is said that productivity and profit are limited because of a lack of variety in designs.

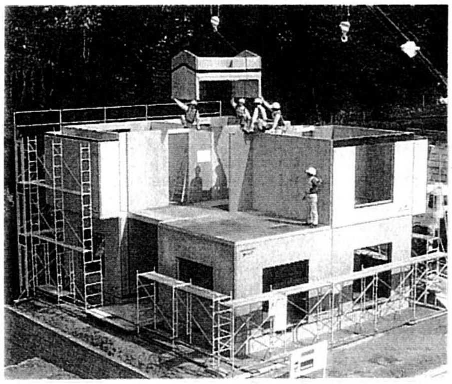


Fig.2.8 Wooden Prefabricated House (Mishima, 1994)

#### 2.4.3.2 Steel Prefabricated House

Light steel is used as the structure of steel prefabricated houses, and light concrete panels are put in the frame to form walls and floors (Fig.2.9). The method is similar to the post and beam system used in wood construction. Length of time which it takes to build is longer than other systems of prefabricated house.

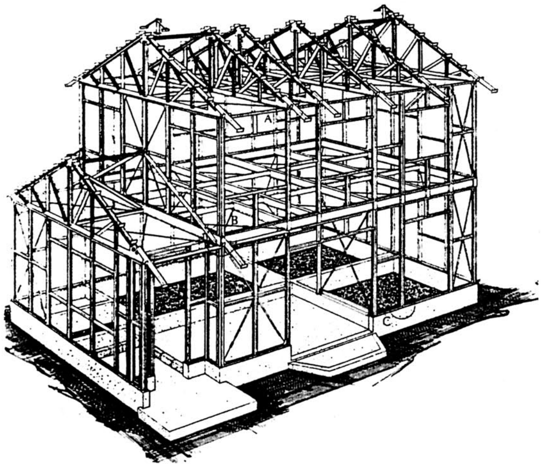


Fig.2.9 Steel Prefabricated House (Mishima,1994)

In another kind of steel prefabricated house, units are made from steel frames (Fig. 2.10) and concrete panels, which are assembled by a crane (Fig.2.11). In this system, about 80% of the building process is completed in the factory. Although this system meets high productivity requirement, the design is not flexible.

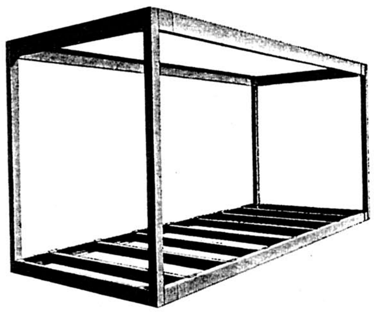


Fig.2.10 Steel Frame (Mishima, 1994)

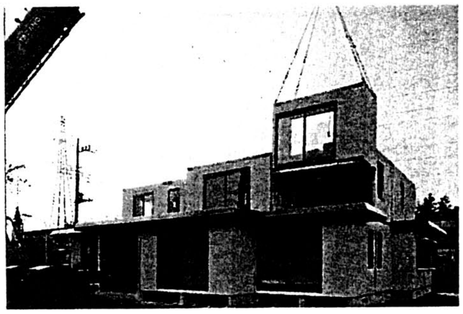


Fig.2.11 Steel Prefabricated House (Mishima, 1994)

### 2.4.3.3 Concrete Prefabricated House

In this system, factory-produced panels which are made of ferro concrete are assembled by crane on the construction site (Fig. 2.12). This system is used not only for low-rise houses but also for middle- and high-rise houses. The merit of this system is in its strength, while the demerit is in its relatively high cost of construction.

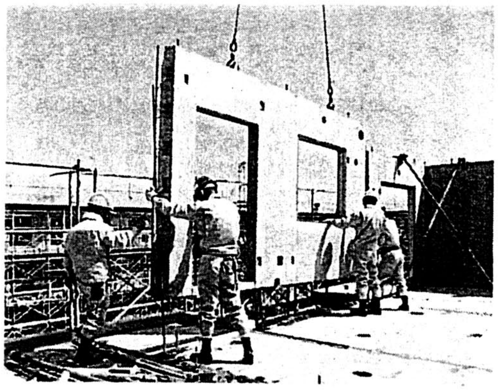


Fig.2.12 Concrete Prefabricated House (Mishima,1994)

## 2.5 Growth of Japanese Housing Industry

It has been only thirty years since the Japanese housing market started to function as an industry. Before the 1960s, when large-scale housing manufacturers appeared, the market was small and scattered, with houses being built only by small-scale builders.

Since the 1960's, the market has rapidly expanded, and in 1994 the amount of money which was invested in housing was about 24,000 billion yen (2,600 billion Canadian dollars) a year (Fig 2.13).

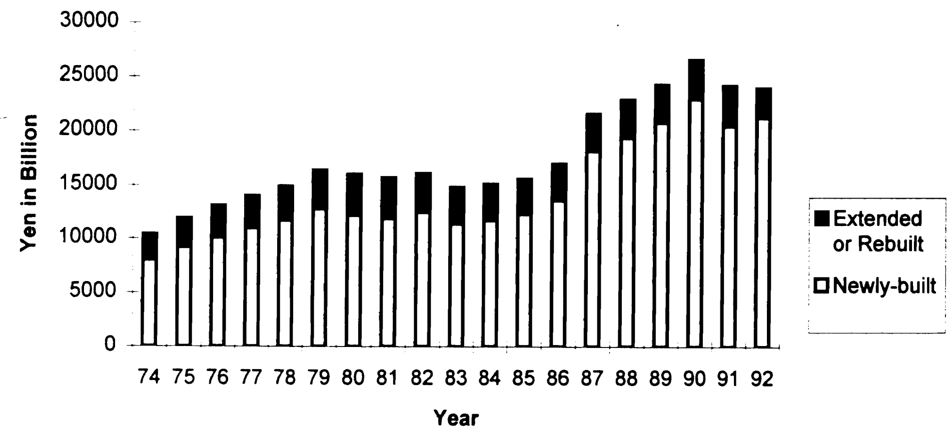



Fig.2.13 Expenditure in Houses (Ikegami,1995)

## 2.6 Relationship in the Housing Industry

Nowadays, custom housing, which land-owners order from housing manufacturers or builders, is the most common in Japan. Those who do not own land buy subdivided housing, which is usually produced by developers and built by general constructors[2], housing makers, or builders. In many case, small-scale builders work as

[2] 'General constructors' in Japan are recognised as companies where design, construction and project development are integrated. Although in the housing industry they mainly built mid- to high-raise collective housing, some of them moved into the general housing maker, designing and building single-family dwellings. There are five majors which employ about 10,000 architects and engineers.

sub-constructors for general constructors, or large-scale housing makers. The relationship between housing manufacturers, developers, and builders is shown on Fig.2.14.

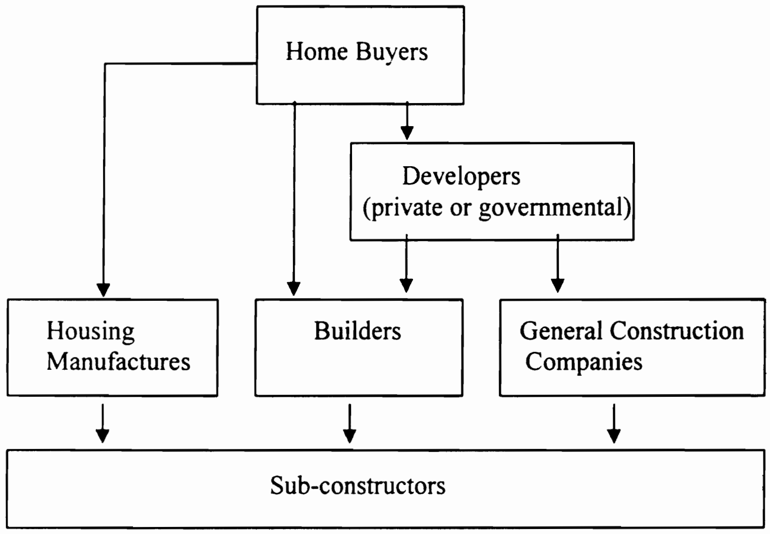



Fig. 2.14 Relationships in the Japanese Housing Industry

## 2.7 Large-scale Housing Manufactures

In Japan there are many large-scale housing manufacturers (Table.2.3). The ratio of low-rise houses which they build in 1994 was about 30%. Although most large-scale housing manufacturers are using systems of prefabricated housing, these are still relatively expensive. They developed their own building systems independently, and the kitchen and sanitary systems evolved through collaboration with building component manufacturers. The top ten of all prefabricated-house manufacturers sold about 246,000 units, which is 89% of all industrially made housing (Ikegami,1995).

Some large-scale housing manufacturers are using the post and beam system and the wood frame system. For example, one of large-scale housing manufacturers, Mitui

Home which was founded in 1974, is the biggest wood frame housing maker in the world. This company imports building materials from Canada where they own a sawmill; wall panels are made in their factory to increase productivity.

| Names of makers | Founded | Employees in 1995 | Unit Production in 1994 | Major Building System |
|---|---|---|---|---|
| Sekisui House | 1960 | 13,977 | 67,577 | Steel-prefabricate |
| Daiwa House | 1955 | 12,377 | 43,591 | Steel-prefabricate |
| Misawa Home | 1962 | 11,044 | 38,143 | Wood- prefabricate |
| National House Industries | 1963 | 3,960 | 26,180 | Steel-prefabricate |
| Sekisui Heim | 1947 | 6,000 | 30,500 | Steel-prefabricate |
| Asahi Hebel House | 1966 | (16,886) ∗ | 14,127 | Steel-prefabricate |
| Sumitomo Forest Industries | 1948 | 4,059 | 7,300 | Post and Beam |
| Mitui Home | 1974 | 2,551 | 9,800 | Wood frame |
| S×L | 1951 | 1,656 | 7,464 | Wood- prefabricate |
| Toyota Automobile | 1969 | (71,000) ∗ | 3,000 | Steel-prefabricate |
| Taisei Corporation | 1969 | (13,388) ∗ | 5,545 | Concrete- prefabricate |

Table 2.3 Major Large-scale Housing Manufacturers (Ikegami, 1995) ∗ Parent Company

Most large-scale housing manufacturers adopted planning, manufacturing and marketing technologies from automobile and home electronic-products manufacturers. Compared to conventional builders, the advantages of large-housing manufacturers are that they have established systems of selling, designing, producing, building, and after-sales service. There are places for exhibiting houses, called 'Housing Centers', Places which are commonly located in the suburbs of cities; 10 to 100 houses are built there. People can see various houses and obtain information. In each house, there is a salesman who shows these houses to clients, and answers their question. Usually these houses are built on large lots, and decorated with well-designed and expensive furniture to improve their appearance. Large-scale housing manufacturers demonstrate their houses, and at the same time, they can find out about new trends by listening to their clients' opinions. After the exhibition, these houses are demolished.

According to the results of a survey undertaken by the government in 1993, the main reasons why people decided to buy prefabricated houses built by large-housing makers are as follows; the houses are good quality (33%), the home-buyer has confidence in famous manufacturers (13%), and reasonable prices (10%). Famous brand names seem to give people confidence and motivate them to buy houses.

## 2.8 Small-scale Builders

Although large-scale housing manufacturers have flourished, middle and small-scale builders occupy more than 50% of the Japanese building industry (Mishima, 1994). They are divided in two groups; in the first, builders have a close relationship with local communities. They design, construct, and sell houses independently. In their local area, their businesses thrive as much as those of the large-scale housing manufacturers. Builders of another group do only construction, and they work as sub-constructors of large companies.

Most of the small-scale builders use the post and beam system. Although they are not as modern or highly industrialized, in a sense, they suit the Japanese housing industry. The reason is that their flexible small-scale job accommodates small infill construction sites, as the Japanese housing market is generally scattered. On the other hand, because their business practices are too traditional, they do not accept new building systems easily. In the last decade, the number of skilled carpenters has been decreasing because young people are not drawn to the profession (Fig.2.15).

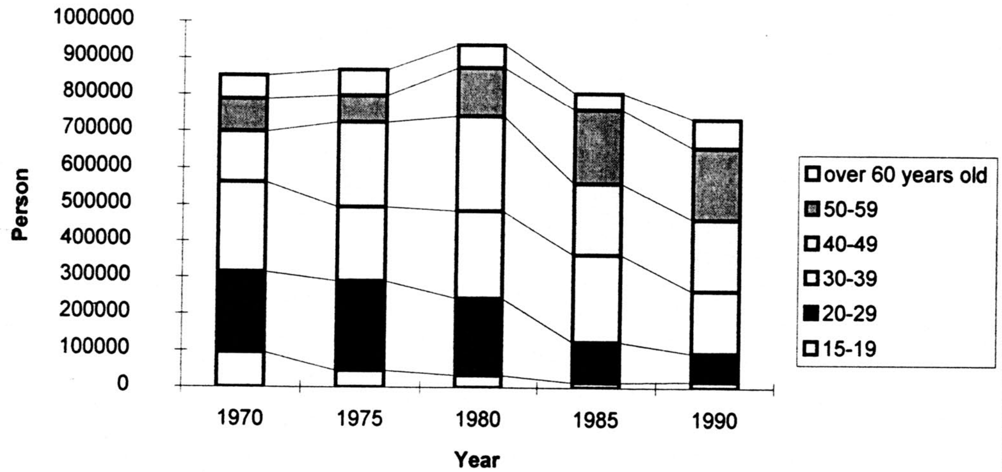



Fig.2.15 Number of Carpenters(Ikegami,1995)

The post and beam system which requires skilled work is no longer advantageous. For that reason, it is evident that small-scale builders need to improve their building systems to make them more efficient. Adoption of the wood frame system would be advantageous to them because it does not need very high skills or large facilities and is much more efficient than the post and beam system. The way in which the system is introduced, and by whom is fundamental in having them adopt it. Some organizations, such as governmental groups, are now involved in promoting new ideas. However, their reluctance to modernize old-fashioned ideas, which characterize many small-scale builders, prevents them from changing.

## 2.9 The Distribution of Building Materials

The distribution of building materials in Japan is complicated because there are many intermediary companies, such as trading firms, wholesale dealers, and building material stores (Fig 2.16).

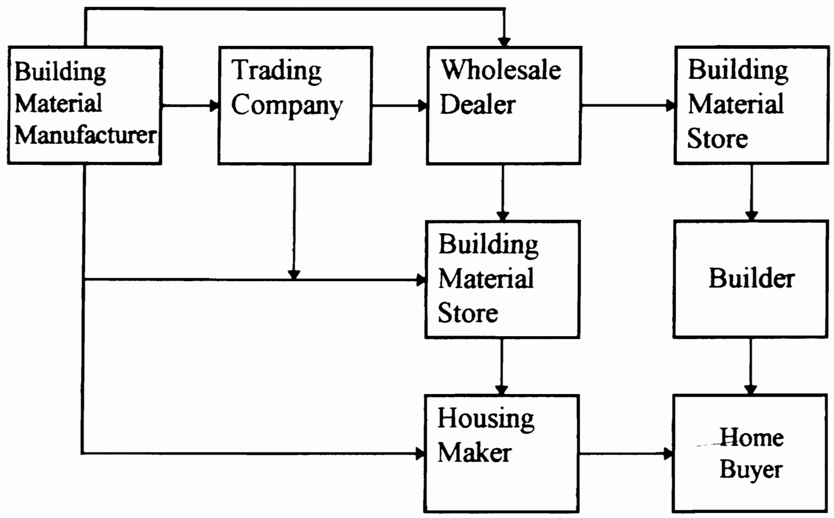



Fig.2.16 Distribution of Building Material in Japan

Since made-to-order houses are most common in the Japanese housing market, various materials are prepared in order to satisfy the diverse demands of users. As a result, many building material and intermediary companies exist. However, this service exists only for construction trade professionals, such as builders, and is not available to the general population.

On the other hand, distribution of building materials in North America is simple (Fig.2.17). In North America, as ready-built wood-frame houses are common, many building materials are standardized. The Home Centers, which are big stores for building materials, are the only major distributors of building materials, and anybody can buy materials there. In addition, there is no big difference between the price for the builders and that charged to the general population.

The long and complicated distribution system for Japanese building materials is responsible for high costs of building houses and prevents people from renovating their houses.

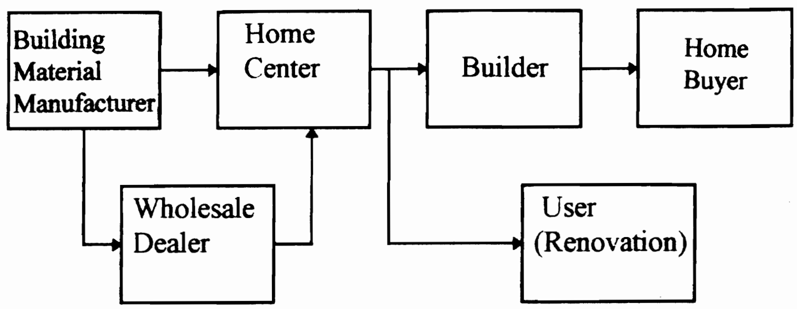
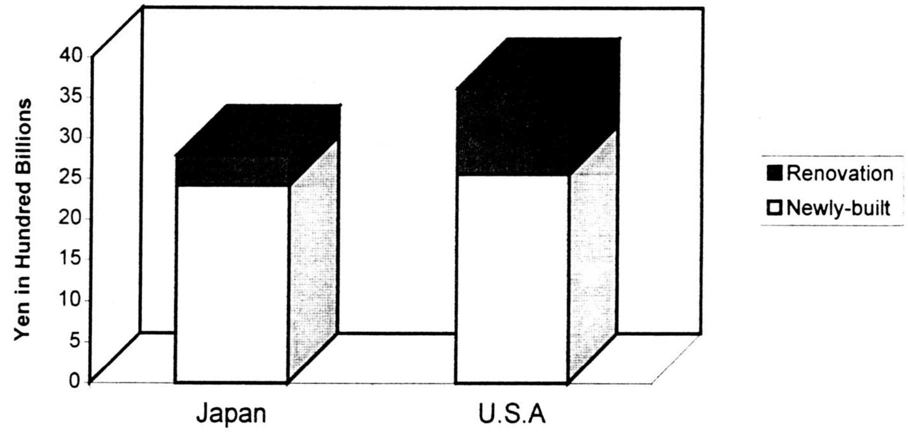



Fig.2.17 Distribution of Building Material in North America

## 2.10 Renovation and Used Houses

Expenditures associated with home-renovation are much lower in Japan, compared to the United States for example (Fig.2.18). Although home renovation by home-owners is very common in North America, this is not the case in Japan. There are three reasons for this. First, as there are many kinds of buildings and finishing systems, and at the same time, too many kinds of products, people are not familiar with renovation procedures. Second, as the distribution system in building materials is complicated, obtaining reasonably-priced materials is not easy for ordinary people. Third, traditionally the Japanese do not like to renovate houses by themselves.




Rig.2.18 Expenditure for Houses (Matumura,1996)

On the other hand, as the building system and the circulation system for building materials is simple in North America, people can easily obtain reasonable products and information about renovation procedures. In fact, renovating houses is a popular hobby in North America.

In addition to the high cost of renovation, the Japanese resale market is small. Fig.2.19 shows the ratio of used houses to newly-built houses in Japan compared to that in the United States. For example in 1993, the number of used houses in the Japanese housing market was about 130,000 units (8%) against about 1,500,000 units of new houses.

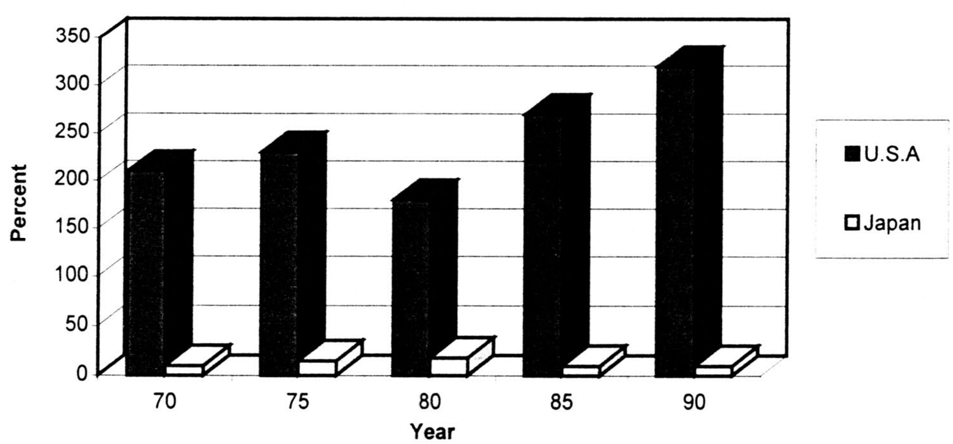



Fig.2.19 Ratio of Used-houses to Newly-built Houses (Matumura,1996)

On the other hand in the United States, the number of used houses on the market is about 3,200,000 units (320%) compared to about 1,000,000 units of new houses. One reason for this is that the Japanese tend to like new houses, and renovating houses is not common.

## 2.11 The Japanese Building Codes and the Fire Regulation

The structure of The Japanese Building Codes is different from those in North America. The Japanese Building Codes come from administrative hierarchic Law. Basic items are provided for by the Building Standard Law, and supplementary items including technical provisions, are covered by the Enforcement Order, Enforcement Regulation and Notifications. For example, the wood frame construction system is based in Article 80-2-1 of the Enforcement Regulation and Notifications in the Japanese Building Codes, and provided on Article 56 as "an exception of wooden structure" because it was a new building system. Only basic items of the wood frame construction system are mentioned in the Codes. Hence, there is another standard of wood frame construction system which is based on the standards in the Enforcement Regulation and Notifications in the Japanese Building Codes, and noted by the Government Housing Loan Corporation.

The comparison of fire statistics between Japan, the United States, and Canada in 1982 is shown in Table.2.4. According to this table, the incidence of fire in Japan is much smaller than the ones in the United States and Canada. Much more caution is exercised in Japan with respect to fire hazards, because when a fire occurs in Japan, the mortality rate is much higher than that in the other countries. The cost of fire-damage in Japan is also higher than that in the United States, or about same as that in Canada.

| | Number of Fire | Number of Dead Parson | Amount of Damage in Million ($) | Rate of Fire[3] | Rate of Dead Parson[4] | Amount of Damage per Parson ($) |
|---|---|---|---|---|---|---|
| Japan | 60,568 | 1,849 | 1,657 | 5.1 | 30.5 | 27,340 |
| U.S.A. | 2,588,000 | 6,137 | 6,819 | 112.1 | 2.4 | 6,911 |
| Canada | 76,199 | 675 | 750 | 30.9 | 8.9 | 29,400 |

Table 2.4 Comparison of Fire Statistic between Japan, U.S.A, and Canada in 1982 (Totani, 1992)

It is not possible to compare these data rigorously, because abilities and systems of fire fighting are different. However, it is obvious and important that in the United States and Canada, where wooden collective houses are commonly built, fire-prevention methods are superior to those in Japan, where wooden collective houses are not common. The differences between the rationale for the regulations in North America and Japan are as follows: In North America, fire starts inside the houses. So a fixed distance is required between windows and the next houses. On the other hand, in Japan, fire begins primarily from outside the houses. Thus, regulations for fire prevention in Japan take into consideration the need for the prevention of the spread of fires caused by earthquakes.

In the Japanese Building Codes, Fire Protection District and Quasi-fire Protection District are fixed as a system of urban planning. According to the building codes of 1995:

> Buildings on Fire Protection Districts must, in principle, be of fireproof construction, while large-scale buildings in Quasi-fire Protection Districts must, in principle, be of fireproof construction, quasi-fireproof construction,

[3] Number / ten thousand people
[4] Number / one thousand of fire

or other construction which has specified fire safety measures on openings, principal building parts, and so on.

This is to say that, depending on the condition of the site, such as the surroundings and the distance between buildings, it is important to make building nonflammable. Most areas for housing are designated as either a Fire Protection District or a Quasi-fire Protection District. For example in these districts, the external walls in portions liable to catch fire (Fig.2.20), which are provided in the code, must be of "Fire Preventive Construction" or of "Earth-plaster-wall-equivalent Construction" (i.e. walls finished with mortar or laminated by gypsum board). Moreover, openings located in portions liable to catch fire, must be fitted with 'Fire Doors'. There are usually aluminum flame windows with wired-glass. Wood frame windows can be used, but only if the external parts are covered by inflammable material, or if they are classified as 'Fire Doors' by the Ministry of Construction.

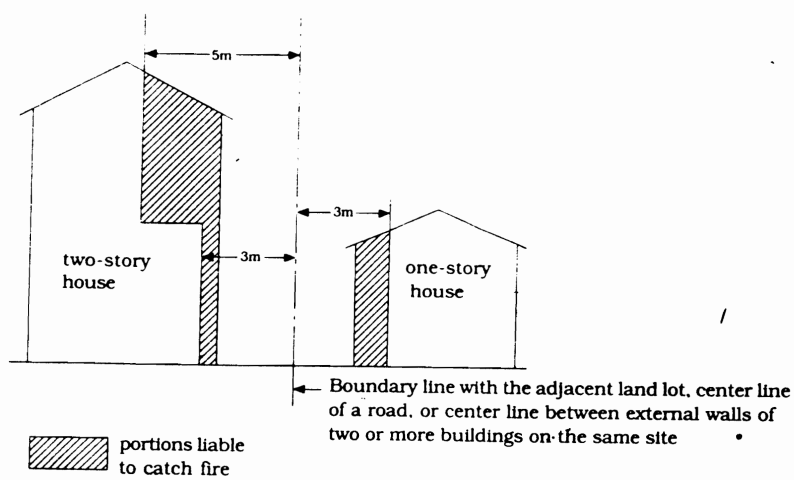



Fig.2.20 Portion Liable to Catch Fire (Building Center of Japan, 1995)

## 2.12 Trends in Japanese Housing Industry

### 2.12.1 Three-story Houses

In recent years, building of three-story wood houses has been increasing (Fig.2.21). The main reason is that a part of the building code was revised in 1987, and it was permitted to build wooden three-story houses in the Quasi-fire Protection District where there is a great demand for inner-city housing. In addition, it became possible to build wooden three-story apartment buildings in 1993.

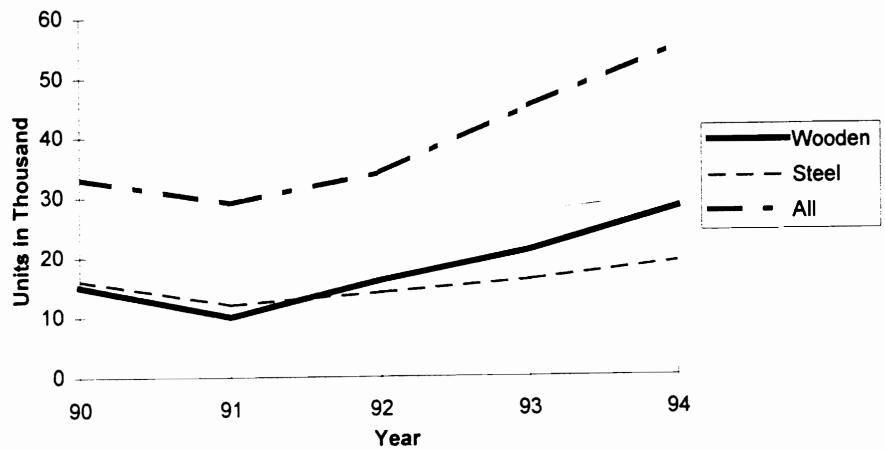



Fig.2.21 Number of Three-story Houses (Ikegami,1995)

In 1994, a new project of three-story housing was built in Osaka city, the second biggest city in Japan. It is called Maple Court housing project which is a joint project, bringing together the Osaka Prefecture Housing Supply Corporation and several Canadian organizations (Fig.2.22). It is believed that this kind of project could deal with urban housing problems in large cities. Moreover, three-story houses are good for using lands efficiently, where, for example, two-family houses combine houses with shops and apartments.


Fig.2.22 Maple Court Housing Project in Osaka
(Osaka Prefectural Housing Supply Corporation, 1994)

The average life span of a Japanese person is the longest in the world: it is 76.57 years for men, and 82.98 years for women (Ikegami,1995). Japanese households still often constitute two or three generations. With increased life expectancy and the increase in population since 1950's in addition to the high cost of land, it is expected that demand for housing will rise.

### 2.12.2 Basement

In 1995, a part of the building code was revised, which allowed for changes in the limit of capacity in floor area. This means that the floor area of the basement, up to one-third of the total floor area of the house, is not factored into the overall total floor area (Fig.2.23). Although constructing basements has not traditionally been common in Japan, after the revision of the code it has become more popular since it increases the efficiency of land use.

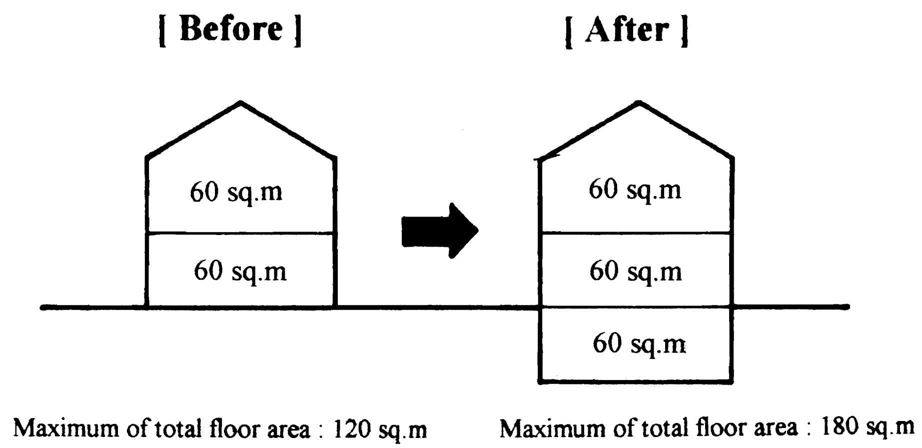



Fig.2.23 Relief of Maximum Floor Area due to Revision of building Code in Japan (Source: Ikegami, 1995)

*Land area : 120 sq.m, Foot print : 60 sq.m, Maximum building coverage rations : 100%

### 2.12.3 Imported Houses and High Heat-insulating Airtight House

In recent years, imported houses have been attracting the attention of people in Japan. These are primarily wooden houses from North America and Northern Europe. The reason for this popularity is that young people in particular, tend to like the design and the quality of Western and European houses. Another reason is that people can buy packages of houses for reasonable price because the yen exchange rate has been rising. For these reasons, many trading companies are advertising high quality imported houses at reasonable prices. However, in reality, the total cost is not so reasonable. To further explain, the packages of building materials are reasonable, but other expenses such as shipping, building, after maintenance, and profits of supplying companies, are the factors that make the total price much higher. Moreover, in many case, Japanese builders are not familiar with these building systems, a factor which increases construction time. In order to take advantage of imported houses, people should be familiar with hidden costs associated with the importation and building of them.

In recent years, high heat-insulating airtight houses have begun to be more popular in Japan because of the comfort and energy saving that they provide. R-2000[5] home system was introduced from Canada, and now it is being modified in order to suit the Japanese climate. Many housing manufactures, insulation material manufactures, and air conditioner producers have been developing new methods since 1987.

## 2.13 Ability of Japanese Home Building Industry to Accept Changes

The ability of the Japanese home building industry to accept new housing systems varies with the market. When it comes to introducing North American wood frame affordable homes to Japan, the author believes that there is much potential for its acceptance it, despite possible difficulties. From a building-method point of view, it is hard to introduce different building systems, as large-scale housing makers have been developing their own systems. On the other hand, small-scale builders, who generally use post and beam systems, have been asked to improve efficiency in their jobs for a long time. For this reason, there is a necessity to move from the post and beam system to the wood-frame system. However, demand for wood-frame houses must increase dramatically, in order to persuade the small-scale builders to change their building system.

From a production point of view, one needs to consider that some problems may arise when introducing North American affordable homes, such as town houses and narrow front homes to the Japanese market. In Japan there are not many town house developments despite their merits: town houses create high density accommodation on

[5] Natural Resources Canada (NRC) and some private companies developed this system.

smaller and therefore less expensive lots. Currently in Japan, single-family dwellings are mainly detached. One of the reasons for this is that the Japanese tend to see a detached house with a garden as a status symbol. Since there is still enough demand for detached houses, developers are more inclined to build them, because they are more profitable.

Another reason is that the concept of town houses is not marketed to its best advantage in Japan. When the wood frame system was introduced from North America in the 1970s, the system of town houses also came to Japan. At the time, town houses were thought of as a new type of urban dwelling, and many town house developments were produced. However, as the system spread, the original concept was changed, and many badly-designed, low quality town houses were built. At the same time, the Japanese were not familiar with the idea of building a community, an important factor in the establishment of a receptive environment for town houses. As a result, people lost interest in town houses, considering them to be of low-quality, and many have given up the idea of living in expensive detached houses and have moved to apartments or condominiums. However, if there are ample functional and well-designed affordable homes available, people who pay high rent and larger downpayments for their dwellings will become interested in these houses. In addition, the demand for affordable homes will grow with the addition of modern amenities, such as basements, a third story and , high heat-insulating airtight construction.

# Chapter 3
# Strategies for reducing costs by design

## 3.1 Introduction

Design and planning have a major impact on the price of housing. In Japan, despite the high land prices, lots for housing are not used efficiently and builders continue to build the same type of detached houses which are not considered cost effective. On the other hand, in North America, there have been many attempts by builders and developers to design low cost housing, and various types of affordable houses do exist. This chapter identifies strategies which reduce the cost of construction through design, and points out how much money Japanese builders and developers can save by adopting planning and design methods used in the building of North American affordable homes.

## 3.2 Floor Plan

The unit planning stage is the first and perhaps the most fundamental stage in the design of affordable houses. The shape of the houses should, ideally, be in a simple, and a cost-effective plan which will provide the best possible economy of use of an enclosed area. Simplifying interior and exterior walls can be an influential strategy for reducing building cost in Japan.

### 3.2.1 Simplicity of Unit Planning

Generally the floor plan design of houses in Japan tends to be irregular and complex. This is the case not only in custom-designed homes, but also in developer-built houses. There is a traditional preference in Japan for houses that are assynmetrical or of an irregular design (Fig.3.1).

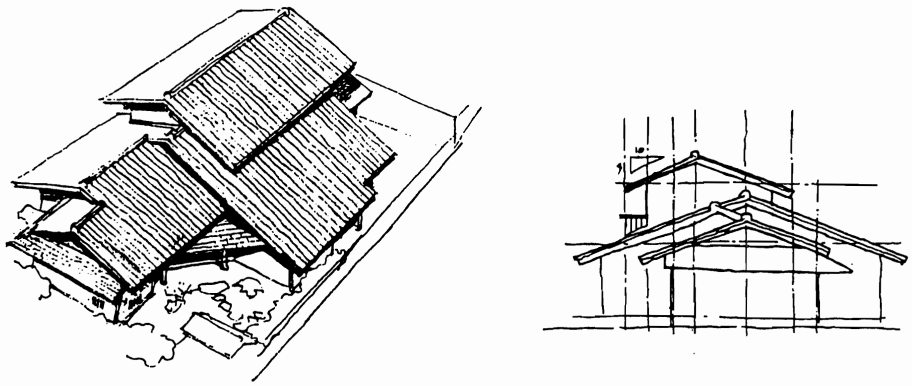


Fig.3.1 Asymmetrical and Irregular Shape in Japanese Traditional House (Yoshihashi, 1995)

Another reason is that the Japanese have designed houses by using modules of 910 mm (3') which is based on the size of the Tatami mat (Fig 3.2). Houses built by using the post and beam system (i.e. the Japanese conventional building system) are comparatively easily designed by following the modules, and the post and beam system can make it easier to design an irregular floor-area plan. This custom has been transferred to the wood frame system, which makes houses complex and costly to build.

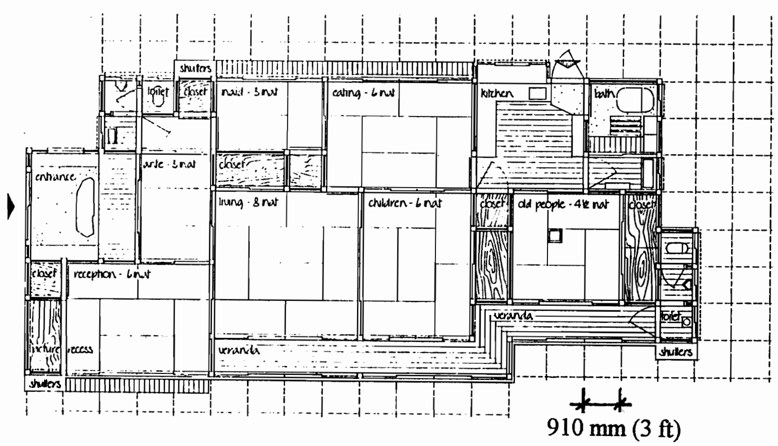



Fig.3.2 Modular System in Japanese house (Engel, 1985).

Designing houses with too many corners also increase the total length of exterior walls. Fig 3.3 illustrates several possible building configurations having the same floor area. As Friedman at al. (1993) explain:

> The required envelope decreases progressively as the plan is simplified to a "T" shape, an "L", a rectangle, square and circle. The latter makes the most efficient use of space, requiring close to 11% less wall than the square for the same floor area. A simple plan costs less to build since there are fewer corners and, most likely, fewer windows. Envelope costs, from the basement to the roof, are reduced, while simple configurations generally require less cutting and fitting of building materials. Consequently, the amount of material wasted is reduced, and the management task is simplified.

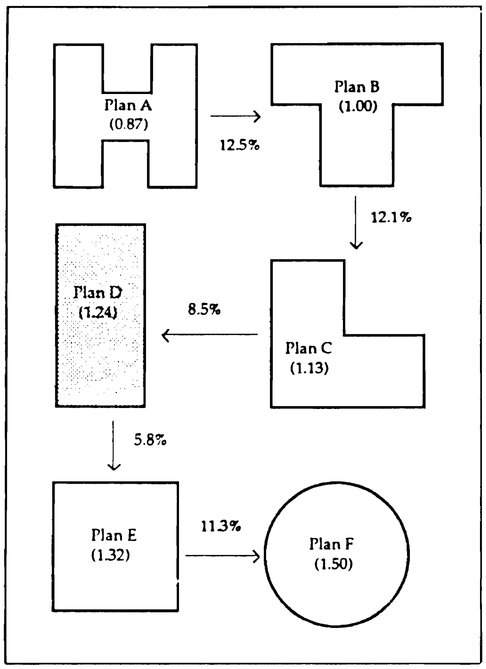
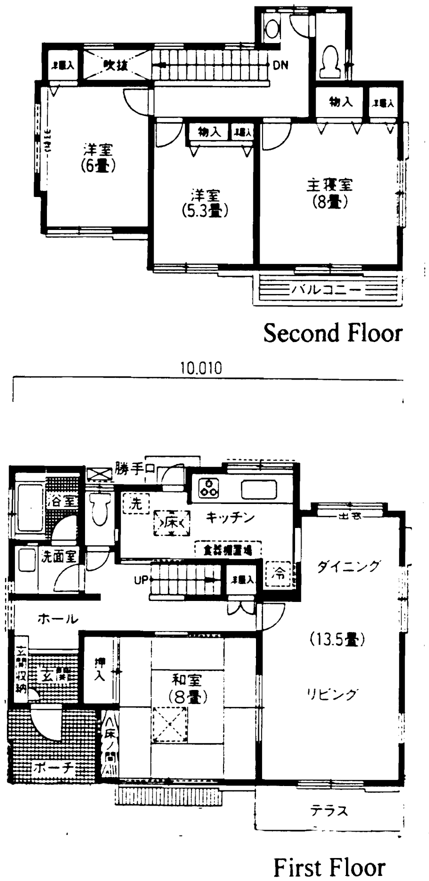



Fig.3.3 **Effect of Building Configuration on Perimeter and Floor Area (Friedman et al, 1993).**

Fig.3.4, and Fig.3.5 show plans of houses whose total floor areas are the same. The house in Fig.3.4 has an irregular plan which is common in Japan. The house in Fig.3.5 has a simple shape which is similar to North American affordable houses. The total floor area of both houses is 115 sq.m (1248 sq.ft). (The garage section, and the upper storage area in Fig.3.5 are not considered.) The length of the exterior wall in

Fig.3.4 is 12 % longer than the one in Fig.3.5 because of the complex shape. When the same type of foundation which has concrete footing - 45 cm (18") width ×25 cm (10") depth - and wall - 20 cm (8") thick ×105 cm (42")depth - is built, the building cost including material and labor is US$ 44.55 per foot (Martin, 1998).



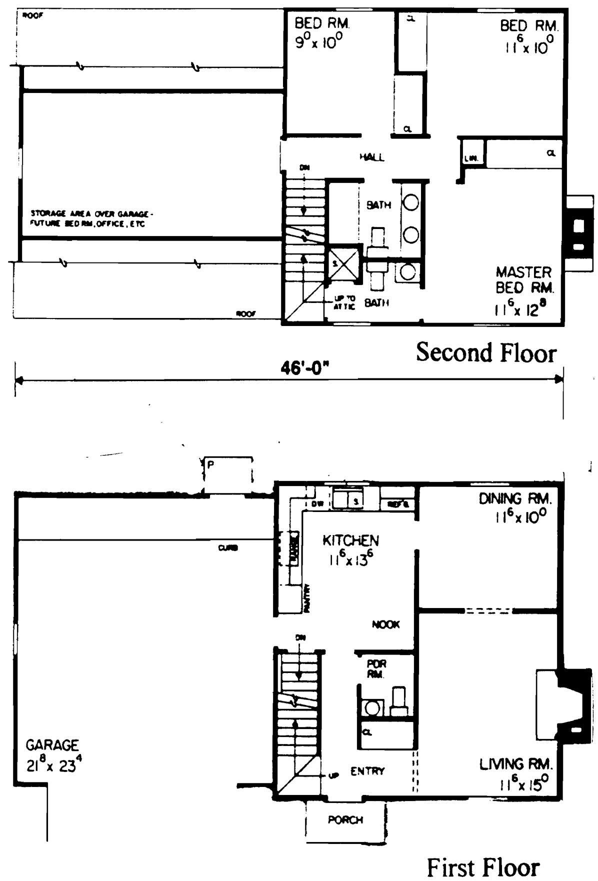




Fig.3.4 Irregular plan in Japan (Source: Tokyu Construction Ltd, 1997)

Fig.3.5 Rectangular Affordable Home in North America (Source: Garlinghouse, 1996)

Likewise, assembling an exterior wall costs US$ 36.22 per foot, including materials and labor, and the contents of the wall is as follows; 5 cm (2") × 15 cm (6") stud walls with drywall interior, 2.5 cm (1") × 15 cm (6") drop siding exterior, 1.25 cm (1/2") gypsum drywall inside face ready for painting, over 15.6 cm (6-1/4") R-19 insulating (Martin, 1998).

Table 3.1 shows a comparison of building costs of which $3,230 (12% of whole costs for exterior wall) can be saved by adopting a simple plan. There are only four corners in the simple plan design, and it allows builders to assemble not only walls but also roofs more easily. Simple-shaped houses can have simple roofs which make it easy to use a pre-assembled truss system, which reduces labor cost. On the other hand, the irregular house plan has many corners and needs a complex roof structure, which in turn means that labor costs are higher. Therefore, in the building of affordable homes, the importance of a simple floor plan is significant, and the Japanese should attempt to adopt simple plans as much as possible.

| | Length of Exterior Walls (m) | Building Cost for Foundation ($) | Building Cost for Exterior Walls ($) | Total Amount ($) | Building Cost Savings ($) |
|---|---|---|---|---|---|
| Irregular Plan | 69.1 [228 ft] | 14,510 | 11,797 | 26.307 | --- |
| Simple Plan | 60.6 [200 ft] | 12,729 | 10,349 | 23,077 | 3,230 [12%] |

Table.3.1 Comparison of Building Costs for Exterior Walls
[ 1 U.S dollar = $ 1.43 (Can) ]

The most expensive part of building a house is the external walls, since they have many elements, such as foundation, wood frame, insulation, exterior and interior finish. The more complex the design of the houses, the more the wall area will increase, and the higher the building costs. However, the Japanese tend to seek new styles, which make even affordable houses complex. Many builders and architects do not adopt a simple square or rectangular plan because they believe these are not attractive.

There is another reason that Japanese do not adopt simple plans. Many architects who are in charge of design in Japan think that the complexity of the design has no effect on the construction cost because the floor area is the same as for a simple design. This misunderstanding derives from the estimating method. The method by which estimation of the cost of houses is done in Japan is unclear. For example, the labor costs of building walls (internal and external) for the irregular plan in Fig.3.4 and those for the simple plan in Fig.3.5 are estimated by the same method. The labor cost of constructing walls is estimated by floor area in Japan, whereas in North America, it is done by length of walls and labor hours. Cost-effective houses need to be estimated precisely, because this is the only way in which costs can be reduced. The Japanese home-building industry needs to adopt the North American way of estimating in order to enable effective cost reduction in the building industry.

### 3.2.2 Open Unit Planning

Open unit planning is widely used in the interior design of houses in North America. The use of open unit planning helps to reduce the total linear feet of partitions, and creates a more spacious feeling, a feature which is especially important in smaller homes. Nowadays, house size in North America is decreasing because of the economic recession and energy saving objectives. Wenting (1995) suggests that "For most programs, downsizing is best achieved by "opening the interior envelope"- or removing walls and consolidating rooms within components without compromising their visual appeal or practical function"

In North America, it is believed that the continuation of social space in a house (e.g. kitchen, family room, dining room, living room, and entrance hall) allows for a big stretch of space. In addition, open unit planning is thought to be desirable functionally. In the 1950s, modernists such as Marcel Breuer suggested that there is no reason for making interior walls inside a house except for between bedrooms. After that, the style of open unit planning came to be used broadly. On the other hand, in Japan, open unit planning is not common and the main living space tends to be divided.

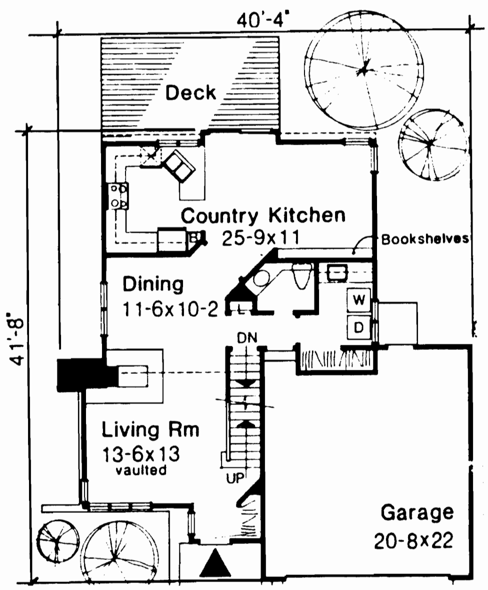



Fig.3.6 Plan with Open Unit Plan Style in North America (Source: Galinghouse, 1997)

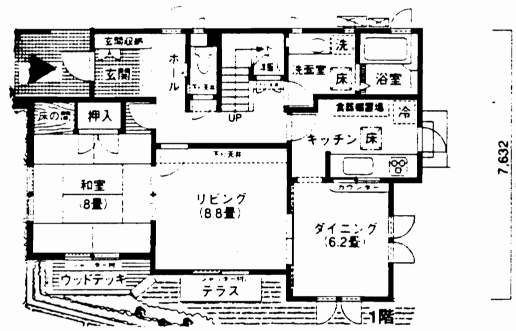



Fig.3.7 Plan without Open Unit Plan in Japan (Source: Tokyu Construction Ltd, 1997)

By adopting open unit planning, the number of interior walls and doors is reduced. The house in Fig 3.6 illustrates the open-plan design commonly used in North America, and Fig 3.7 shows a typical Japanese developer-built house whose rooms are divided. When the garage area is not calculated, the floor areas of both houses on the ground floor are almost the same, about 76 sq.m (834 sq.ft). However, the lengths of interior walls on the houses are very different; the North American house in Fig 3.6 - 17.0 m (56'), the Japanese house in Fig 3.7 - 31.7 m (105'). Because the uses of various room and floors in the houses are different, the necessity for interior walls varies. For example, in the Japanese house, *Tatami* room is used for various functions such as, bed room, family room, and additional living room. Another characteristic of Japanese houses is that the bathroom is always located on the ground floor. Thus, the interior walls of Japanese houses, especially on the ground floor, is longer than the equivalent walls in North American houses.

There are some interior walls which can be eliminated in Japanese houses, for instance, walls dividing a hallway and a living room. Fig 3.8 shows the same house as in Fig 3.7, with some walls eliminated. Table 3.2 illustrates the comparison between the length of interior walls and the percentage of saving between the houses. About 30% of the interior walls can be removed in Japanese houses, to reduce building costs.

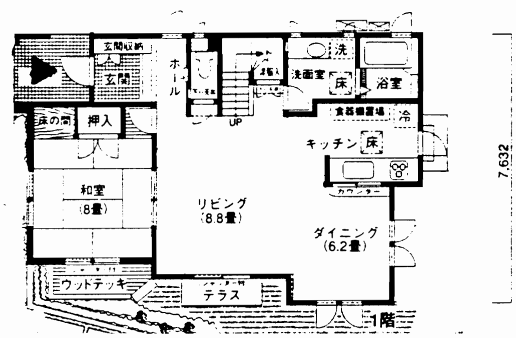



Fig.3.8 Modified Plan in Japan (Source: Tokyu Construction Ltd, 1997)

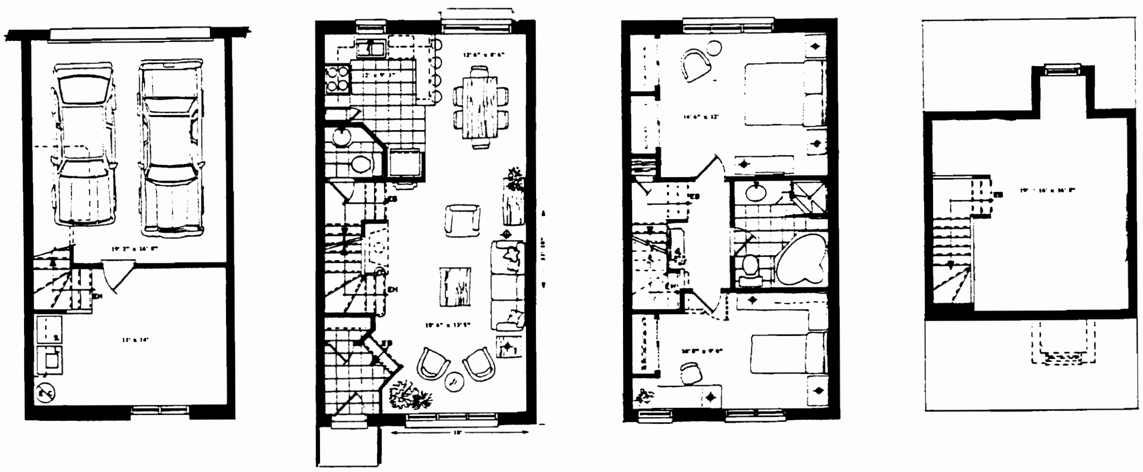
| | Area of the Floor | Total Length of Interior Walls | Percent Savings (%) |
|---|---|---|---|
| Plan in Fig.3.6 | 76 sq.m (834 sq.ft) | 17.0 m (56 ft) | 46 |
| Plan in Fig.3.7 | 76 sq.m (834 sq.ft) | 31.7 m (105 ft) | - |
| Plan in Fig.3.8 | 76 sq.m (834 sq.ft) | 22.3 m (74 ft) | 30 |

Table 3.2 Comparison of Length of Interior Walls

Due to the high cost of utilities in Japan, the use of enclosed space is still more appropriate. For example, people in Japan prefer to heat one room, while air-conditioning the other. In addition, insulation is often deficient in Japanese housing, thus in order to achieve open unit planning, Japanese builders would have to improve the insulation and air-tightness of the houses.

### 3.2.3 Unfinished Space

In North America, selling houses with unfinished space such as a basement or attic, is a common strategy in affordable house development; but it is one rarely seen in Japan. Fig 3.9 shows an example of houses with unfinished space in North America. About 30 % of total floor area (not including garage) is unfinished space in this case. This strategy allows builders to reduce building costs of finishing by about 30 %.



| | | | |
|---|---|---|---|
| Basement<br>[Unfinished]<br>19.9 sq.m<br>(216 sq.ft) | Ground Floor<br>54.4 sq.m<br>(591 sq.ft) | Second Floor<br>54.4 sq.m<br>(591 sq.ft) | Attic<br>[Unfinished]<br>28.1 sq.m<br>(305 sq.ft) |

Fig.3.9 House with unfinished space (Source: Montclair Inc, 1988)

Many Canadians and Americans grow up learning rudimentary carpentry skills as a matter of course (Rybczynski at al., 1993). First-time buyers are ready to buy 'less house' for less money, and finish the house by themselves when means allow. The involvement of residents in the arrangement of their own houses results in pride and confidence in their skills and personal decision-making; it promotes individual creativity, increases the feeling of attachment to their houses, in short, being able to contribute to the shaping of their own space is highly gratifying for the North American home owner.

In North America, many large-scale home-improvement centers which sell various types of equipment and materials do exist in the suburbs, facilitating home renovation by the owners. On the other hand, there are only a small number of substantial home-improvement centers in Japan, it is not common for the Japanese to attempt home-renovation. However, in recent years a do-it-yourself movement has begun to be popular among young people. Therefore, the concept of unfinished rooms is gradually becoming more widely accepted in Japan.

## 3.3 Measure and Module

In Japan, the metric system is used across the board, and most builders are not familiar with the imperial system. However, as materials for wood frame construction are made according to imperial units of measure, builders need begin to adopt it as much as possible, in order to build houses efficiently. Ideally, both units of measures - metric and imperial - should be shown on plans in Japan.

A house should be designed around existing material sizes in order for it to be built cost-effectively. This reduces the amount of offcuts and waste material, and results in optimal material usage. In the wood frame system, the 610mm (2') module is generally the most cost-effective, and provides greater flexibility in design. In North America, structural wood panels such as plywood and oriented strand board are most commonly supplied in 1220mm (4')× 2440mm (8') sheets. Because these building materials are produced in multiples of 1220mm (4'), it follows that a plan that is laid out in multiples of 610mm (2') permits the best use of floor, wall, and roof-covering materials. In Japan, houses are usually designed in a 910mm (3') module because it has been used for the traditional building post and beam system, and originates from the size of Tatami mat, (910mm (3')×1820mm (6')). Therefore, structural wood panels are commonly supplied in 910mm (3')×1820mm (6') sheets which are fit for 910mm (3') module. A 910mm (3') module does not provide the flexibility that a 610mm (2') module does in residential design. As far as wood frame system building is concerned, Japanese house designers can adopt the module which is being used in North America.

In Japan, wall length is designed and scaled from the middle point of a wall to another point at the opposite side (Fig.3.10), while in North America, it is done from a point at the outside of a wall to another point.

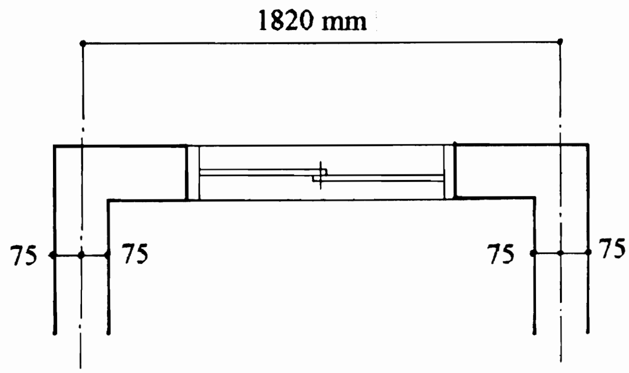



Fig.3.10 Way to Scaling Wall in Japan

Although Japanese builders have been using this method, it creates inefficiency in construction, because many odds and ends of materials are produced. Japanese architects should consider the necessity for efficiency in the construction process when designing houses, and builders also should make efforts to become accustomed to the methods used in North America.

## 3.4 Land Usage and Housing Type

Although land prices in Japan are extremely high, the Japanese housing industry continues to offer the same type of houses which use land inefficiently. Improvement in land usage and housing type could be made by adopting the methods used in planning and building affordable homes in North America.

### 3.4.1 Typical Japanese Detached Houses

The concept of a house situated within a garden has almost universal appeal. In Japan, many still dream of owning a detached house with a garden, even though land prices are extremely high. It seems to be almost impossible for average income-earners to obtain this kind of house in the suburbs of metropolitan areas. Fig 3.11 shows changes in the average prices of developer-built houses in the suburbs of Tokyo in relation to the average annual income. In 1995, the price of a developer-built house was about seven times the average annual income. In North America, it is recommended that a price of a house should be less than triple the annual income of its buyers.

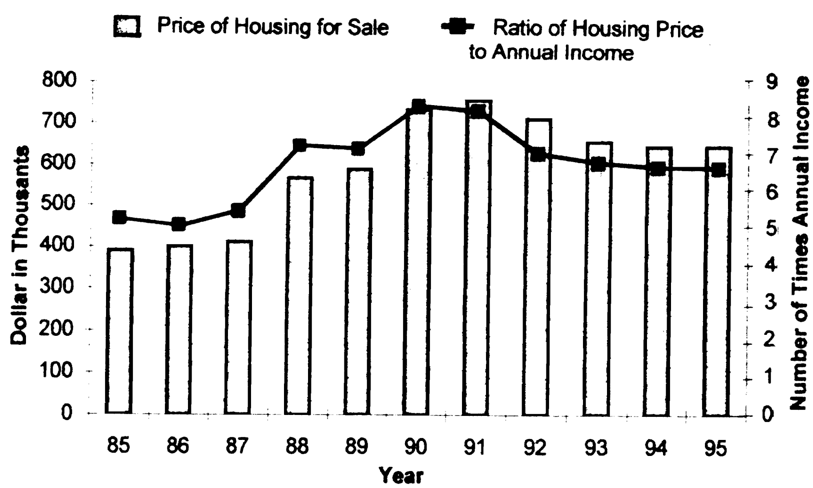



Fig.3.11 Affordablility of Houses in Japan (Source: Senda, 1997)

Fig 3.12 shows a plan of a typical developer-built house which is located about one hour's drive from the Tokyo metropolitan area. It shows the typical rectangular lot with the longer side facing the street. The plans of these kinds of houses are generally similar and lack variety; dining, living, kitchen, bath room, and a Tatami room on the ground floor, three bedrooms on the second floor, and no basement or attic. There is usually an outdoor parking space. Every room except the bathroom and kitchen faces south, accommodating customer preference. This type of house can not be an affordable house, and affordable housing development is rarely seen in this area.

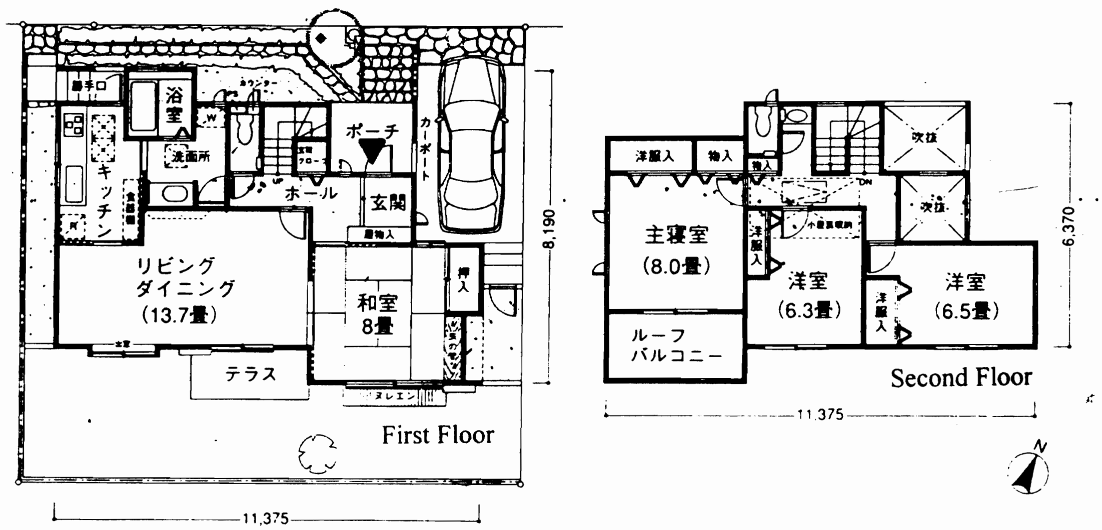



Fig.3.12 Typical Developer-built House in Japan - Land Area : 161.09 sq.m (1733 sq.ft), Total Floor Area : 118.41 sq.m (1274 sq.ft), Price for Sale : About $678,000 - (Source: Tokyu Construction Ltd, 1997)

Fig 3.13 shows several types of detached houses located in a suburb situated about one hour by train from Tokyo, where the land price is approximately $1,800 per sq.m. Plan A shows a type of typical Japanese developer-built house. Plans B, C, and D have several characteristics such as narrower fronts, attics, basements, and inside parking spaces. Although the situations are different, every house has the same size of total floor area and back yard.

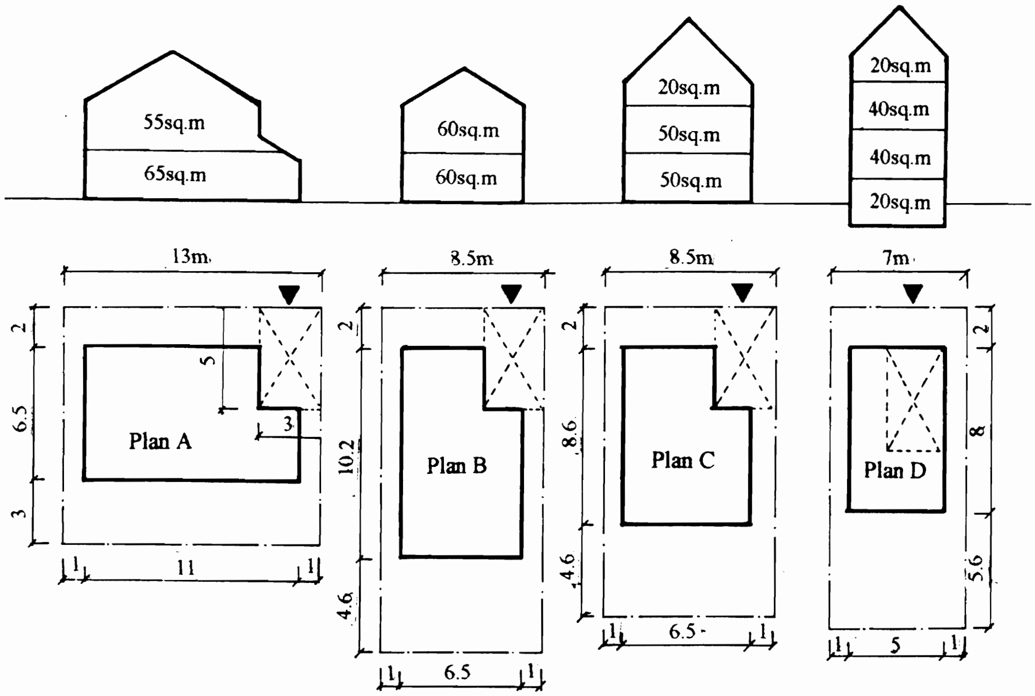



Fig.3.13 Study for Several Types of Detached Houses

| | Land Area (sq.m) | Width of Street-Side in Site (m) | Percent Savings (%) | Land Cost ($) | Land Cost Savings ($) |
|---|---|---|---|---|---|
| Plan A | 149.5 [1625 sq.ft] | 13.0 [43 ft] | --- | 269,100 | --- |
| Plan B | 142.8 [1552 sq.ft] | 8.5 [28 ft] | 35 | 257,040 | 12,060 [4 %] |
| Plan C | 129.2 [1404 sq.ft] | 8.5 [28 ft] | 35 | 232,560 | 36,540 [14 %] |
| Plan D | 109.2 [1187 sq.ft] | 7.0 [23 ft] | 40 | 196,560 | 72,540 [27 %] |

Table.3 3 Comparison of Land Price and Width of Street-Side in Site in Japan
(Land Price: $1,800 per sq.m)

Table 3.3 shows the comparison between land price and length of street-side on site. On plan A, which is a typical Japanese house, the floor area of ground floor - 65 sq.m (708 sq.ft) - is bigger than one on the second floor - 55 sq.m (599 sq.ft) -, resulting in inefficient land use. When the ground floor and the second floor have the same floor area - 60 sq.m (654 sq.ft) - on plan B, land cost will save $12,060. 35% width of street side on the site is saved by adopting a narrow front plan on Plan B and C. Adding a basement and attic achieves drastic land cost saving. Especially, Plan D, which takes parking space in the basement, saves $67,500.

Generally the ratio of land price of land to house price is 7 : 3 in the suburbs of metropolitan Tokyo, whereas it is 1 : 3 in North America (Kumada, 1997). In order to build affordable houses, Japanese developers and builders must give priority to efficient land use rather than to the building of typical detached houses.

### 3.4.2 Semi-detached Houses

The semi-detached house is a dwelling that is attached on one side to a similar dwelling on a divided lot (Fig.3.14). The attachment is made along a common or "Party Wall", which is jointly owned. The main advantage of this type of house is the economy achieved in the construction of the party wall and land.

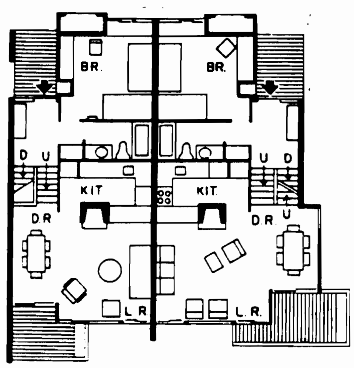



Fig.3.14 Semi-detached House (Chiara, 1995)

Land use in semi-detached housing is more efficient than that of the detached house. Fig 3.15 illustrates a study showing the transformation of detached houses (Plan A and B) in Fig 3.12 into semi-detached houses. It is assumed that basic conditions, such as location of the site, total floor area, and area of backyard, are the same as in last section.

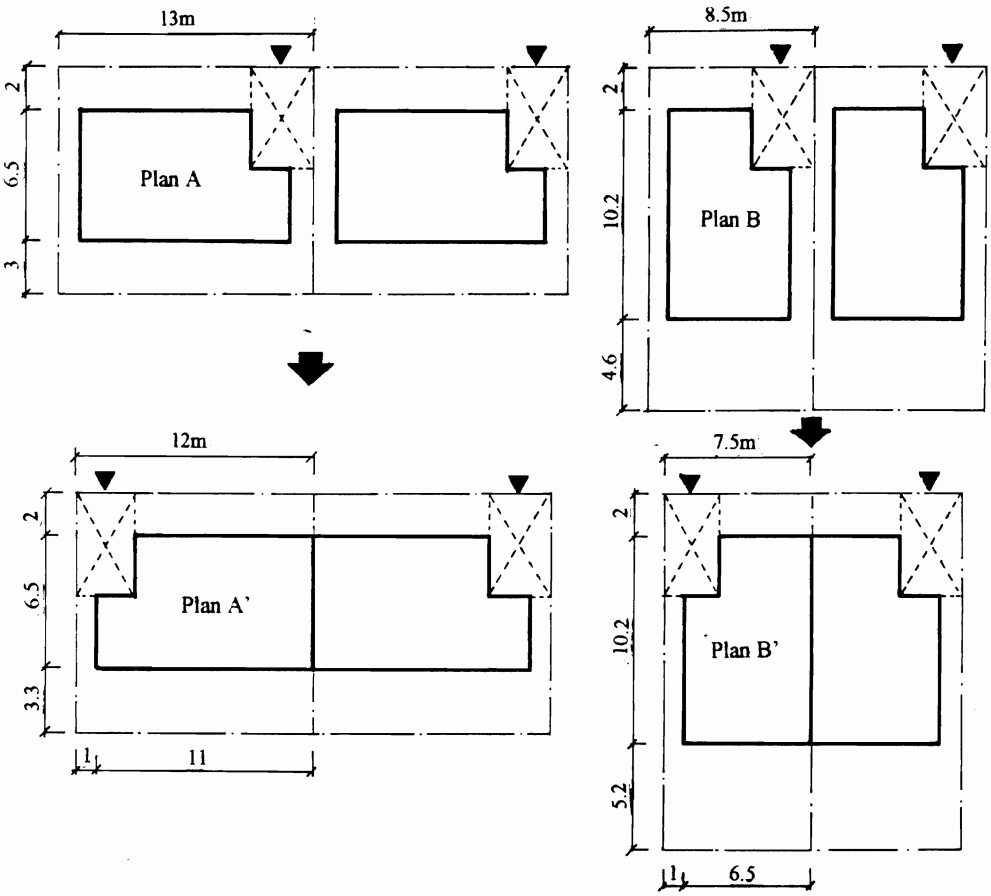



Fig.3.15 Study for Several Types of Semi-Detached Houses

| | Land Area (sq.m) | Width of Street-Side in Site (m) | Percent Saving (%) | Land Cost ($) | Land Cost Savings ($) |
|---|---|---|---|---|---|
| Plan A | 149.5 (1625 sq.ft) | 13.0 (43 ft) | --- | 269,100 | --- |
| Plan A' | 141.0 (1533 sq.ft) | 12.0 (40 ft) | 8 | 253,800 | 15,300 (6 %) |
| Plan B | 142.8 (1552 sq.ft) | 8.5 (28 ft) | 35 | 257,040 | 12,060 (4 %) |
| Plan B' | 130.5 (1419 sq.ft) | 7.5 (25 ft) | 42 | 234,900 | 34,200 (13 %) |

Table.3.4 Comparison of Land Cost and Width of Street-Side in Site in Japan (Land Price: $1,800 per sq.m)

The comparison of land cost and width of street-side in site is shown in Table 3.4. Compared to Plan A, which is a typical Japanese detached house, Plan A' saves

$15,300, while Plan B' saves $34,200 of land costs, because one side yard can be eliminated.

In Japan, this type of housing is rarely seen; however, the semi-detached house has much potential in the Japanese housing market, because the features are very close to those of the detached house.

### 3.4.3 Town Houses

Building of town houses, which is a standard dwelling type in North America, would be one of the best strategies for reducing housing price in Japan. It is characterized by great economy in the use of land, moderate construction cost, and low maintenance and operating costs. It provides each family with its own home and the opportunity to develop a plot of land for its own use. The economic advantage of a long building comes from the elimination of end walls, but there are also savings in land utility. Because no side yards are required, it is possible to build on a relatively narrow lot. The chief advantage of this type of construction is the economy produced by the party walls.

Fig 3.16 shows the effect of unit grouping on exposed wall area. As Friedman, et al. (1993) explained :

> The joining of units into groups of 2 or more can provide significant savings in both construction and energy. Jointing 4 detached units into semi-detached, for instance, reduces the exposed wall area by 36 %. Grouping all four units as rowhouses provides an additional 28 % saving.

From this study it can be said that the same percentages of building costs for finishing outside walls will be saved.

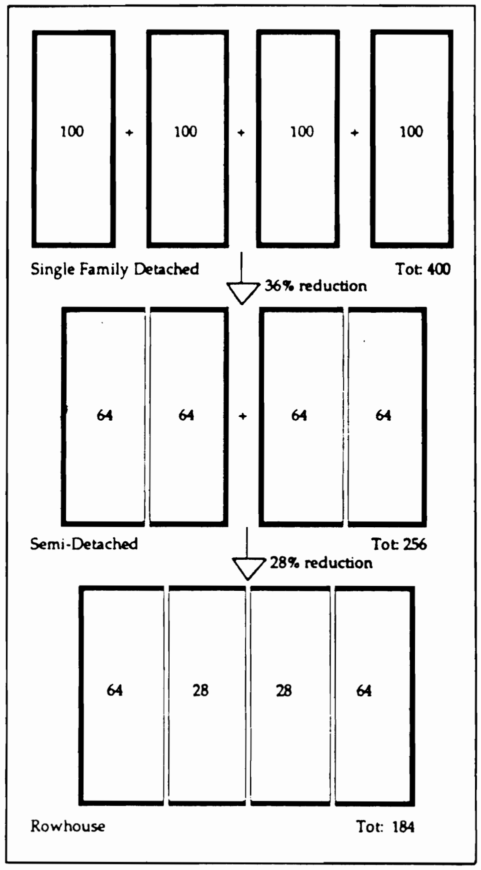



Fig.3.16 Effect of Unit Grouping on Exposed Wall Area (Friedman et al, 1993)

The joining of units into groups can also result in savings on energy. The climate in the Tokyo region varies with the seasons. In winter the average temperature is 3 degrees and there is a very dry wind from the north, and in summer it is humid with an average temperature is 28 degrees. Since costs of fuel and electricity are high, saving on energy is important in Japan. In the same study on narrow-front housing in Fig.3.16, Friedman et al. (1993) explain:

> Heat-loss reductions of approximately 21% can be achieved when two dwellings are attached, and a further 26% savings for the middle unit when 3 or more dwelling are joined as rowhouses. For Montreal, the transition from a detached unit to a rowhouse results in annual savings of $174. In addition to substantial reductions in energy consumption, the joining of units enables efficient use of land and infrastructure (Table.3.5).

| | Heat Loss (Watts) | | | |
|---|---|---|---|---|
| Component | 1 Story | 2 Stories | | |
| | (Bungalow) | Detached | Semi-det | Rowhouse |
| Roof | 558 | 279 | 279 | 279 |
| Walls | 1005 | 1643 | 1005 | 367 |
| Doors and Windows | 1598 | 1598 | 1598 | 1598 |
| Basement | 1560 | 1249 | 780 | 311 |
| Infiltration | 1547 | 1413 | 1250 | 1087 |
| Total | 6267 | 6182 | 4912 | 3642 |
| Annual Energy Consumed (KWh) | 9154 | 9029 | 7174 | 5320 |
| Associated Heating Costs (Montreal) | $429 | $423 | $336 | $249 |

Table.3.5 Combined Effect of Floor Stacking and Unit Grouping on Heat Loss (Friedman et al, 1993)

The town house has important implications for land-use, especially in Japan where land prices are extremely high, and the efficient land-use is vital. Fig.3.17 shows several types of town houses It is assumed that basic conditions, such as location, total floor area, and backyard area, are the same as in previous sections on Fig.3.13 and Fig.3.15. Plan E is a two-story town house, plan F has anattic, and Plan G has an attic and basement with built-in garage. Table 3.6 shows the comparison of land price and width of street-side in site. Compared to Plan A, each type of town house can save 61 % of width of street-side in site because no side yards are required. Moreover, up to $108,900 can be saved on land price by including attics and basements.

To be sure, when the functions between a detached house and a town house are compared, the former is superior to the latter. However, in terms of affordability, it seems that the increase in popularity of the town house, which requires a smaller lot, is inevitable in Japan because of the extremely high land prices.

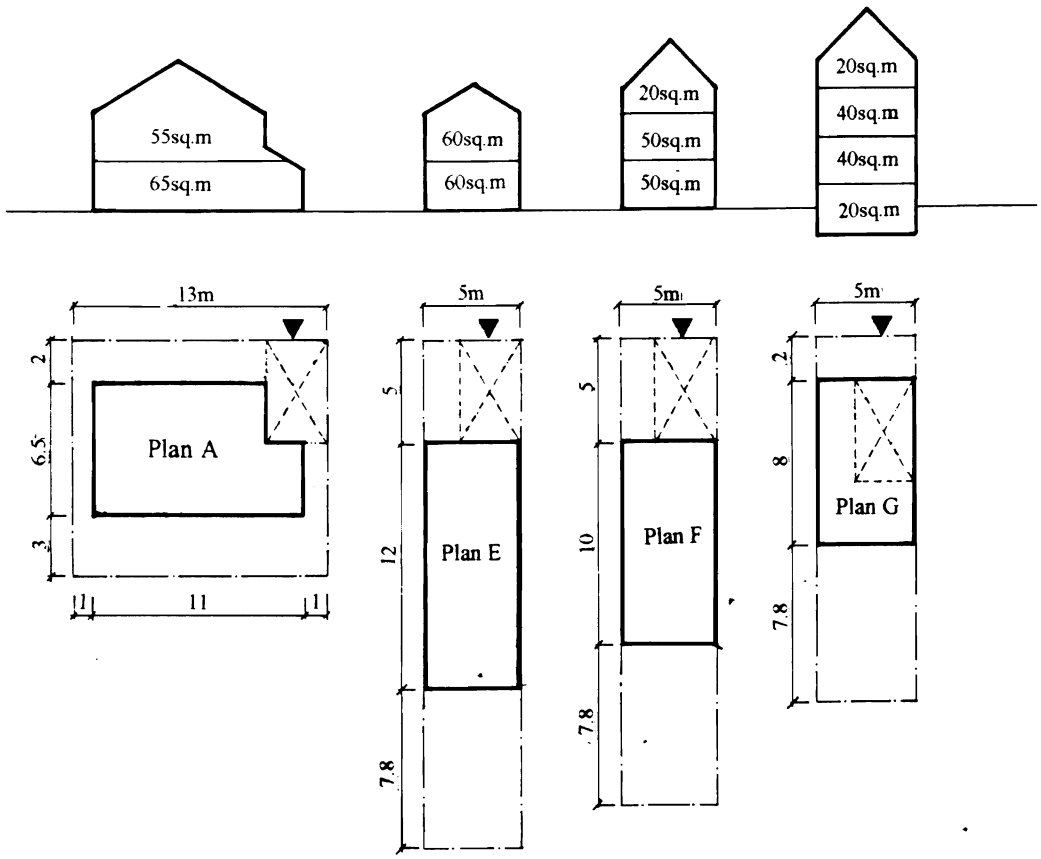



Fig.3.17 Study for Several Types of Town Houses

| | Land Area (sq.m) | Width of Street-Side in Site (m) | Percent Saving (%) | Land Cost ($) | Land Cost Savings ($) |
|---|---|---|---|---|---|
| Plan A | 149.5 [1625 sq.ft] | 13.0 [43 ft] | --- | 269,100 | --- |
| Plan E | 124 [1348 sq.ft] | 5.0 [17 ft] | 61 | 223,200 | 45,900 [17 %] |
| Plan F | 114 [1239 sq.ft] | 5.0 [17 ft] | 61 | 205,200 | 63,900 [24 %] |
| Plan G | 89 [967 sq.ft] | 5.0 [17 ft] | 61 | 160,200 | 108,900 [40 %] |

Table.3.6 Comparison of Land Cost and Width of Street-Side in Site in Japan. (Land Price: $1,800 per sq.m)

## 3.5 Summary

Table.3.7 shows the main results of the data examined in this chapter. Obviously, there is much potential for reducing building costs in Japan by adopting the design methods used in North American affordable homes. Resistance to new ideas could make it difficult for the Japanese to change customs which have been firmly rooted in the country for decades. However, the principals of affordable homes have worked well in North America, and as Japanese housing culture becomes more oriented toward North American styles, it is possible that the Japanese housing industry and home buyers will accept those methods in the near future.

| Matter on being saved | Principal | Percent Saving (%) |
|---|---|---|
| Exterior Wall | Simplifying irregular plan to simple plan | 12 |
| Interior Wall | Adopting open planing | 30 |
| Finishing interior Space | Adopting unfinished space | 30 |
| Lot | Adopting narrow front house | 4 |
| Width of Street-side in site | Adopting narrow front house | 35 |
| Lot | Adopting narrow front house with basement and attic | 27 |
| Lot | Adopting semi-detached house | 13 |
| Width of Street-side in site | Adopting semi-detached house | 42 |
| Lot | Adopting townhouse | 17 |
| Width of Street-side in site | Adopting townhouse | 61 |
| Lot | Adopting townhouse with basement, attic, and inside-parking | 40 |

Table.3.7 Matters on being saved and the Principals in This Chapter

# Chapter 4
# Strategies for Reducing Costs on Wood Frame System

## 4.1 Introduction

In North America, builders continually look for more efficient methods of building houses using the wood frame system, and many new materials (e.g. pre-assembled roof trusses and engineered wood products) have been produced to improve the efficiency of the system by contributing to the reduction in construction costs. On the other hand, in Japan, wood frame systems and the use of materials in building them have hardly changed since the system was introduced in the 1970s. This results in houses whose building costs are generally double those in North America. Although some enhanced methods and materials which are being used in North America do not conform to the Japanese building standards governing the building of wood frame systems, there is still much potential for the reduction of building costs by adopting North American techniques for the wood frame system. This chapter presents factors which influence construction costs, and identifies which North American cost-effective strategies can be adopted to Japanese housing industry. It also studies the extent to which building costs can be reduced by using those strategies.

## 4.2 Foundation

In Japan, where basements are not a standard feature of houses, above ground foundations with crawl spaces are usually built. Because earthquakes are a factor to be considered, foundation need to be reinforced; however, some aspects are overdone. Japanese builders should consider their methods in order to reduce building costs.

According to the Japanese standard on wood frame construction (1997),

> Sills shall be placed underneath the bearing walls of the first floor. Sills shall be firmly fastened to a monolithic continuous foundation constructed of reinforced or plain concrete with anchor bolts having a diameter of 12mm or more and a length of 35 cm or more. The width of the continuous foundations shall be 12cm or more. The height of the continuous foundations from the ground to the top shall be 30cm or more.

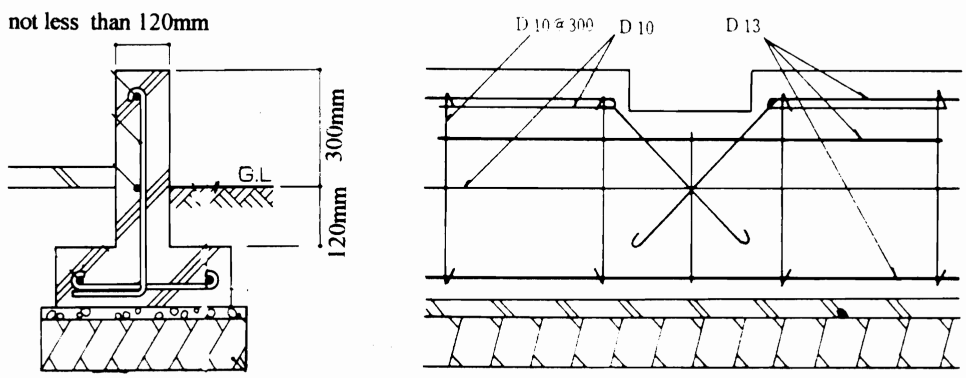



Fig.4.1 Foundation Wall in Japan (Abe, 1984)

Fig.4.1 shows a common foundation wall which is based on the Japanese standard. Generally, the cost of building a foundation in Japan is double or even triple that in North America. One of the reasons for this is that the building standard requirements in Japan are higher than those in North America. For example, reinforcing steel in foundation walls is required in Japan because of earthquakes. Another reason is that Japanese builders tend to build too many foundation walls. Fig.4.2 shows an example of a foundation plan in Japan. Even under the interior non-bearing walls, there are foundation walls. Building too many foundation walls makes the floor framing complex, and increases building costs.

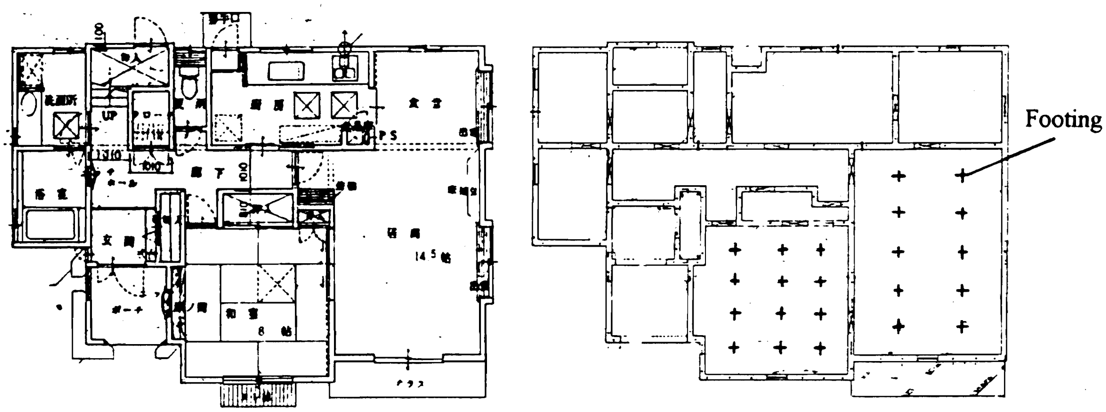



Fig.4.2 Main Floor and Foundation Plan in Japan (Source: Tokyu Construction Ltd, 1997)

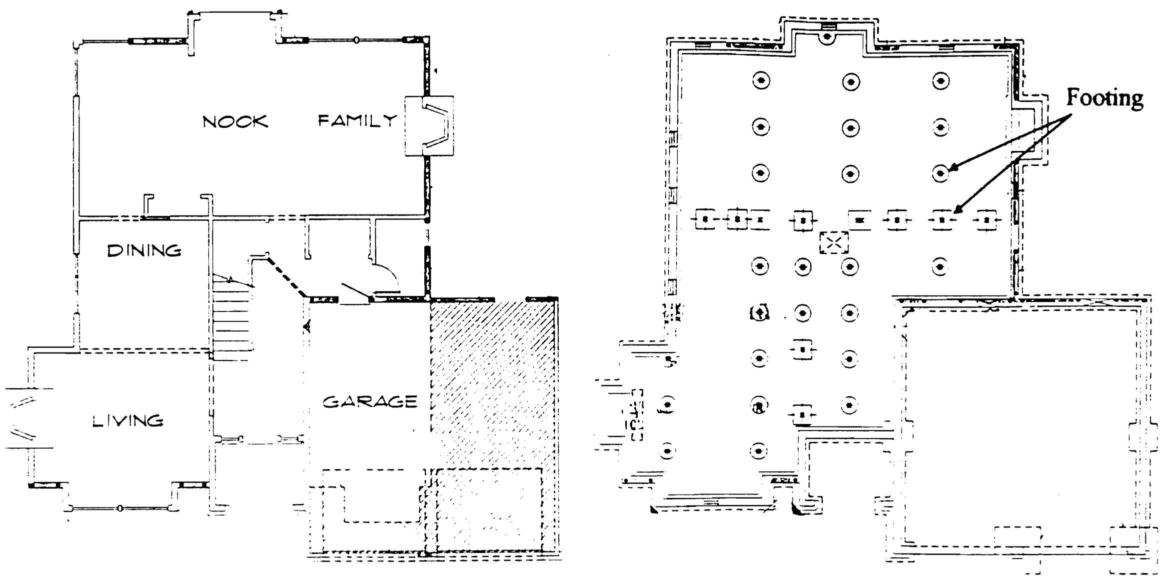



Fig.4.3 Main Floor and Foundation Plan in North America (Source: Mascord, 1997)

On the other hand, Fig.4.3 shows an example of a foundation plan in North America. In North America, foundation walls are usually built only under the exterior walls. In many places, instead of foundation walls, engineered wood products for joists (i.e. I-beams and space joists), which can have a longer span, are used, or footings are built below the interior walls (Fig.4.4). This can not only reduce the cost of the foundation but also allow better ventilation in the crawl spaces and prevent lumber from decaying due to humidity.

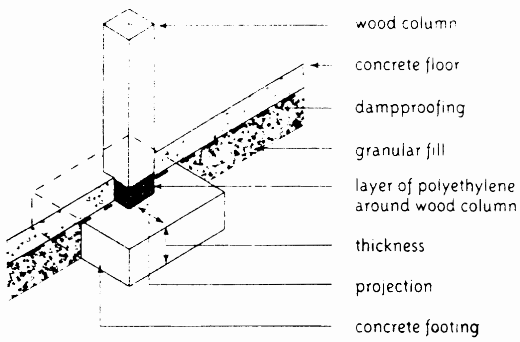



Fig.4.4 Footing (CMHC, 1997)

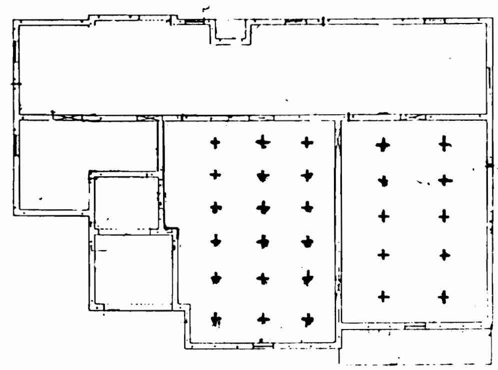


Fig.4.5 Foundation Plan in Japan
(Source: Tokyu Construction Ltd, 1997)

In Japan, the building standard does not require foundation walls under non-bearing walls. Fig.4.5 shows a possible foundation plan in which some foundation walls are replaced by footings in Fig.4.2. About 20% - 17m (56') out of 83.5m (274') - of foundation walls can be eliminated. In Japan, building the foundation wall in Fig.4.1 costs $190 / m (3'-3"), so, potentially $3,230 can be saved on foundation walls (Abe, 1991). Although the number of footings and beams under the interior partitions increases, building footings and beams costs less because building foundation walls needs more materials and requires more labor. In addition, even footings and beams can be eliminated by adopting engineered wood products for joists, which enables the builder to make a longer span on the floor.

## 4.3 Floor construction

Currently, some improvements in floor systems can be seen in North America. New materials for floor framing make it possible to build floors efficiently, and builders are willing to adopt them if these products work better than conventional ones. On the other hand, Japanese builders seem prefer to use conventional ways that cost more.

### 4.3.1 Floor Framing Methods

In Japan there are two floor framing methods in the wood frame system. One is the same as the conventional method in North America. It consists of a wood sill plate, usually 38mm×89mm (2"×4") lumber, anchored to the foundation wall for support, and fastening of the joists and header at the ends of joists (Fig.4.6). Another system is the Japanese conventional method in which 89mm×89mm (4"×4") lumber is often used as sill plates instead of 38mm×89mm (2"×4") lumber, and many footing and beams are needed (Fig.4.7). This method comes from the post and beam system, and is more common because many builders are accustomed to using it. However, this method requires more materials and is more labor intensive. In addition, there is no reason for using 89mm×89mm (4"×4") lumber for sill plates because sill plates bear mainly the vertical load. Generally the price of 89mm×89mm (4"×4") lumber per unit is about triple that of 38mm×89mm (2"×4") lumber. Labor using 89mm×89mm (4"×4") lumber also costs more because of the necessity for drilling holes and bolting it to the foundation.

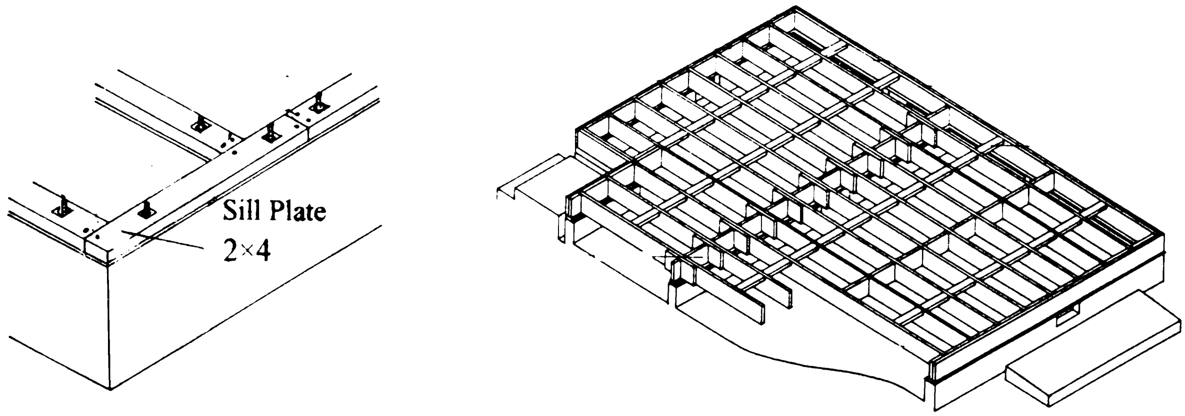



Fig.4.6 Floor Framing in North America
(Nishio, 1996)

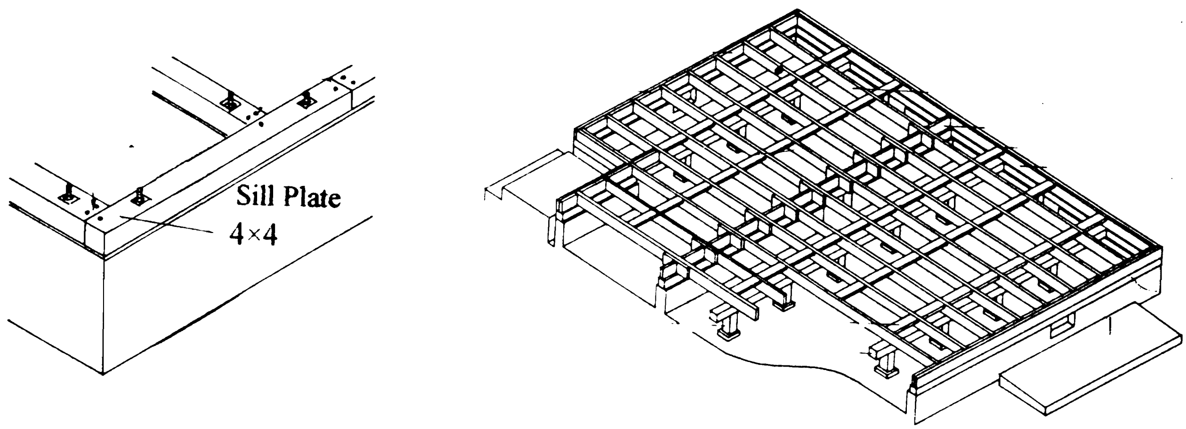



Fig.4.7 Japanese Conventional Floor Framing
(Nishio, 1996)

### 4.3.2 Subflooring

In Japan, boards for subflooring 900mm×1800mm (3'×6'), 12mm (1/2") thickness are commonly used, and spacing of floor joists is 450mm (1'-6"). The building standard requires lumber for receiving subflooring in every space between joists (Fig.4.8). In North America, the size of boards for subflooring is 1200mm×2400mm (4'×8') and spacing of floor joists is generally 400mm (16"). As thicker boards (15mm (5/8") to 25mm (1')), oriented strand boards, or boards with tongue-and-groove on the edge are used (Fig.4.9), lumber for receiving subflooring is not needed. This method is much more efficient in North America than one in Japan because 1200mm×2400mm (4'×8') board is used, which is about 1.5 times larger than 900mm×1800mm (3'×6'), and elimination of lumber for receiving subflooring translates into less labor. Despite the fact that this method meets the building standard in Japan, and could reduce cost, most Japanese builders tend not to adopt it.

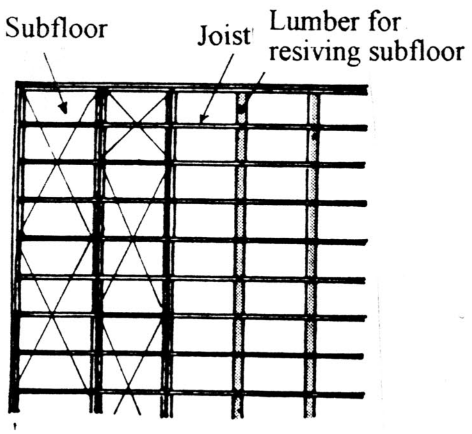



Fig.4.8 Lumber for receiving Subflooring (Suzuki, 1996)

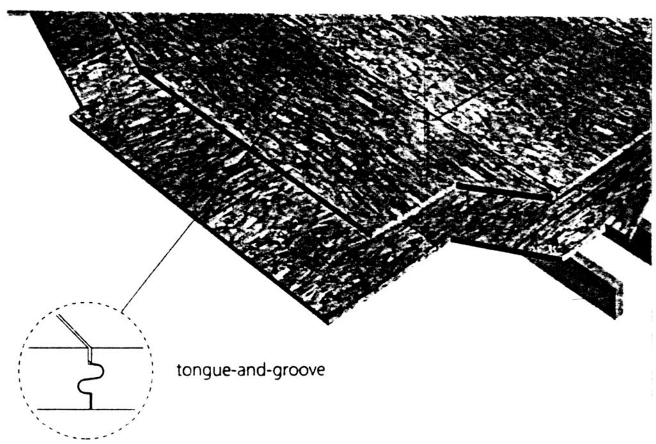



Fig.4.9 Tongue-and-groove on the Edge of Boards (Source: Forex Inc., 1997)

### 4.3.3 Floor Joists

Deciding on adequate floor joists and spacing is very important for cost-effective houses because floor framing occupies a fair part of the home building process. Recently many kinds of floor joists are invented and broadly used in North America. There seems to be much room for improvement in this area in Japan.

#### 4.3.3.1 Spacing of Floor Joists

Joists are selected to meet strength and stiffness requirements. In Japan, 450mm (1'-1/2") on center is generally used for the spacing of floor joists because plans are designed in a 900mm (3') module. In North America, joist spacing of 400mm (16") on center is most commonly used, although for heavy loads or when space is limited, 300mm(1') spacing of shallower joists may be substituted. However, in recent years builders in North America have started to think that deeper joists at 600mm (2') spacing may prove to be more economical. Home Builder (1994) explains;

> In many case, the most cost-effective spacing for structural members, i.e., floor joists, wall studs, ceiling joists and rafters, and roof trusses, is 2 feet. For instance, depending on the design floor loads and the allowable bending stress for a wood species and grade, 2"×10" floor joists spaced at 24 inches on center may carry the same span that 2"×8" floor joists spaced at 16 inches on center could carry. Two 2"×10"s cost less than three 2"×8"s, and there are one-third fewer framing members to be handled and installed than with the traditional 16-inch spacing. The number of fastenings required to attach sheathing or flooring materials to framing is reduced by the same proportion.

A 600mm (2') modular spacing of floor joists is the most cost-effective, and will be a strategy for reducing cost for Japanese builders. Yet in Japan, when joist spacing of more than 500mm (1'-8") is adopted, thicker boards for subflooring must be used. According to the Japanese building standard (1997);

> Floors shall be made of structural plywood with a thickness of not less than 15 mm, or particle boards with a thickness of not less than 18 mm, or of structural panels (limited to Grade 1 as specified in JAS[1] for Structural Panel). Provided, that structural plywood with a thickness of not less than 12 mm, particle boards with a thickness of not less than 15 mm or structural panel may be used in cases where the joist spacing is 50 cm or less.

In North America, thicker boards for subflooring -more than 15mm (5/8')- are generally used. Thicker boards cost more than conventional ones, however, they can

[1] Japanese Agricultural Standard. JAS is provided by The Ministry of Agriculture in order to rationalize productivity, and improve quality of agricultural materials.

eliminate not only some joists but also the amount of lumber used for receiving subflooring in Japan.

### 4.3.3 Wood I-beam Floor Joist system

One of the available common alternatives to conventional floor joists is the wood I-beam (Fig.4.10). The wood I-beam is engineered structured lumber widely recognized in North America as one of industry's innovative solutions to floor framing requirements.

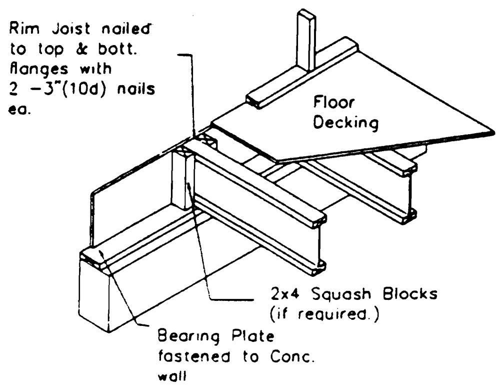



Fig.4.10 Wood I-beam Floor System (Source: Jager Inc., 1997)

Canada Mortgage and Housing Corporation (1997) explains;

> On average, wood I-joists and floor trusses use 20% less material than a conventional floor constructed with dimensional lumber, and may permit a wider spacing between members leading to even further reductions in material requirements.

Although using wood I-beam for floor joists was permitted in Japan several years ago, most builders have not adopted this product for use yet, because they are not familiar with it.

There are some strong points to recommend it. Jager Inc. (1997) explains;

> Manufactured with 38mm×62mm (2"×3") or 38mm×89mm (2"×4") flanges and structurally enhanced Oriented Strand Board webs, wood I-beam will be hard to warp, twist or shrink. The standard depths range from 23cm (9.5") to 50cm (20"), and lengths to 16m (52') are available.

Therefore, compared to traditional lumber, the wood I-beam makes a longer span. Compared to the price of conventional 3.6m (12') long 2×10 lumber which costs $15.84, the price of the equivalent wood I-beam is $16.44, however, these prices will change depending on the size and the time (Jager Inc., 1998). Despite the fact that the price of the wood I-beam is slightly higher than that one of conventional lumber, ducting, wiring and plumbing can be run through the wood I-beams, according to the specification (Fig.4.11), increasing labor efficiency and cost-effectiveness. In addition, the long span capabilities create flexible design options.

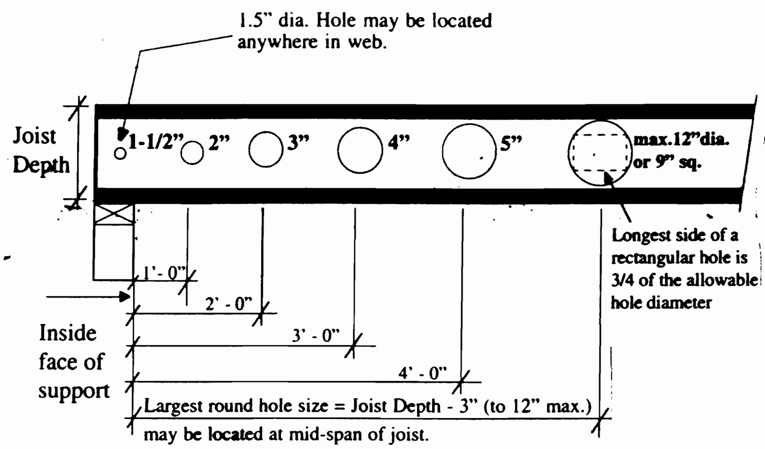



Fig.4.11 Hole Cutting Guideline (Source: Jager Inc., 1997)

### 4.3.4 Space Joist System

The space joist system is a floor framing system which is assembled using prefabricated floor trusses. The use of prefabricated floor trusses is growing rapidly in the residential construction industry in North America. The primary reasons for this are flexibility of mechanical access, greater load carrying predictability, and faster installation time with a minimum of waste. Generally, there are two types of prefabricated floor trusses; one is the wood floor truss made of lumber and connected using glue or metal. Another is the metal floor truss with metal webs (Fig.4.12).

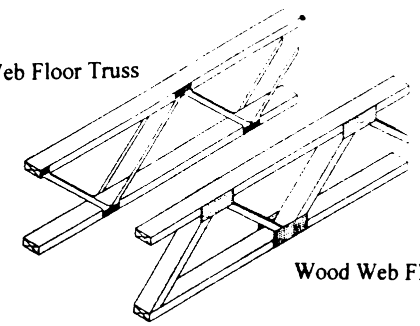



Fig.4.12 Space Joists (CMHC, 1997)

### 4.3.5 Floor Joist Cost Comparison

Table.4.1 shows a comparison of the costs between the conventional wood joist and the wood space joist in North America. Costs shown are per square foot of floor area, based on joists at 16", for a job with 1000 sq.ft of floor area (Kiley, 1998).

| | Material Cost ($) | Labor Cost ($) | Total ($) |
|---|---|---|---|
| Conventional Floor Joist* | 1,960 | 630 | 2,590 |
| Wood I-beam Floor Joist** | 2,000 | 540 | 2,540 |

Table.4.1 Comparison of Costs between Conventional Floor Joist and Wood I-beam Floor Joist (Source: kiley, 1998) [ 1US dollar = $1.43(Can)]
* 38mm × 235mm (2"×10"), ** 223mm (9-1/2")

The total costs of material and labor are almost the same, however, this comparison does not include other labor. Since the space joist features an open web design that facilitates plumbing, electrical, heating and ventilation installations, much of the labor involved in cutting and fitting ducts can be reduced (Fig.4.13). In addition, manufacture wood joists (MWJ) enable a longer span than conventional lumber, consequently, the cost of building a foundation can be cut because the MWJ requires less foundation walls and footings.

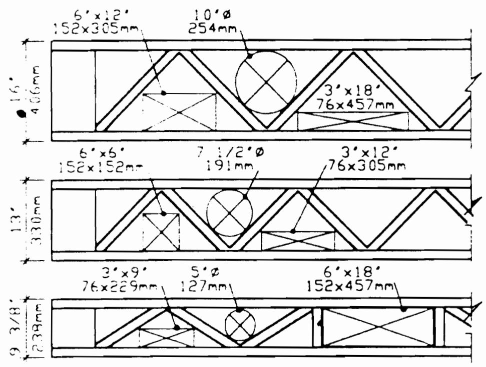



Fig.4.13 Open Web (Source: Jager Inc., 1997)

The price of this product in Japan is higher than in North America, because there is not a large demand for it yet. Nonetheless, it is expected that the demand will rise because of the high efficiency factor, and eventually the price will decrease. Thus, adopting this product and the method will realize considerable cost reduction on floor framing in Japan.

Although the wood space joist is permitted for use in Japan, another type which use a metal connection is not yet approved. However, its light weight (due to the metal connection) results in further labor reduction. So, when they become available in Japan, space joists with metal connections would be another strategy for reducing the cost of floor framing.

## 4.4 Exterior Wall Construction

Conventional wood framing of walls is commonly used both in North America and in Japan. There are some opportunities to reduce both the material and labor costs in conventional wood frame walls. In 1981, the U.S. Department of Housing and Urban Development (HUD) advocated cost-cutting strategies for wall-framing by using methods as follows; 600mm (24") framing, two-stud corner, one-stud partition post, no jack studs, single top plate, and 38mm×62mm (2"×3") interior partition (Fig.4.14). However some methods do not meet the building standard on wood frame construction in Japan.

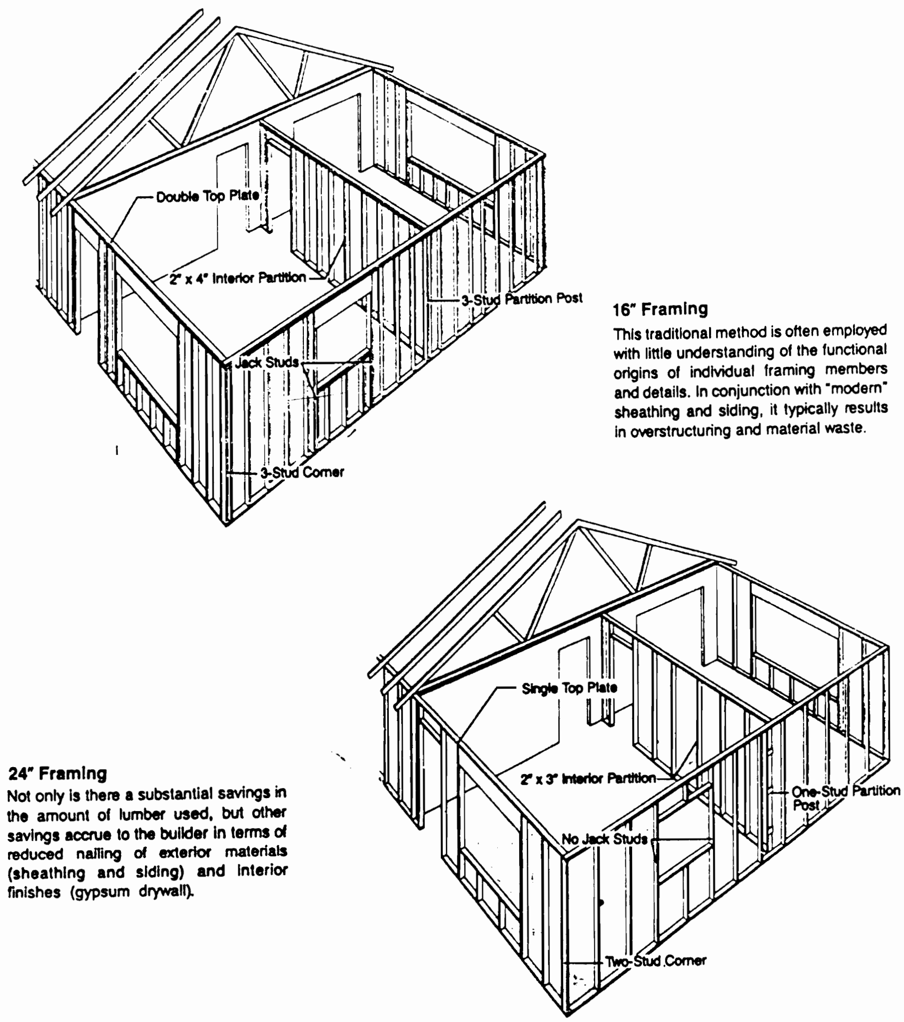



Fig.4.14 Cost-cut Strategies for Wall Framing
(U.S. Department of Housing and Urban Development, 1981)

Building costs can be reduced by increasing the spacing between studs from the standard 400mm (16") to 600mm (24"). In addition, this reduces the fraction of the wall surface taken up by lumber from 14.1% to 10.9% (Friedman et al, 1993). In North America, building codes permit conventional 38mm× 89mm (2”×4”) studs to be spaced up to 600mm (24”) on center in single-story homes and in the second story of two-story homes. In recent years, builders in North America have increased insulation levels in response to consumer demand for energy efficiency. In exterior walls, however, conventional 2”×4” studs allow for only 89 mm(3-1/2”) of insulation. One of the most cost-effective solutions is to use 2”×6” studs that allow room for 140mm (5-1/2”) of insulation. It may be more cost-effective to use 2”×6” studs spaced 600mm (24”) on center rather than 2”×4” studs spaced 400mm (16”) on center.

In Japan, wall-stud spacing of 450mm (18”) is common. Up to 650mm (26”) of wall-stud spacing is permitted by the Japanese building standard. However, there is a restriction. The standard requires that when more than 500mm (20”) of wall-stud spacing is used the stud has to be more than 38mm×184mm (2”×8”) on the ground floor of two-story homes. However, on single-story homes and the second floor of two-story homes, 2×4 studs can be used. Therefore, using 2×6 studs spaced 600mm (24”) on center is not permitted on ground floor’s walls of two-story homes. Nonetheless, it may reduce costs, even if it is used only on the second floor walls.

In North America, a two-stud corner post can be used on exterior corners instead of a three-stud corner post, in order to reduce costs (Fig.4.15). This also eliminates thermal bridges because insulation replaces the studs. In Japan, according to the building standard (1997), “Three or more studs shall be used at the corners and at the intersections of each bearing wall. The studs concerned shall be firmly fastened together in a manner adequate from the viewpoint of structural strength”. Therefore, a two-stud corner post can not be adopted on bearing walls in Japan. Likewise, although blocking in the form of extra studs or ladders can be eliminated at wall or partition intersections by using wood cleat or drywall clip in much the same manner as the two-stud corner too much space in North America, this method is also not permitted by the building standard in Japan (Fig.4.16). The same thing can be said of eliminating jack studs. However, these methods are approved for use on non-bearing walls in Japan, and they will save building costs.

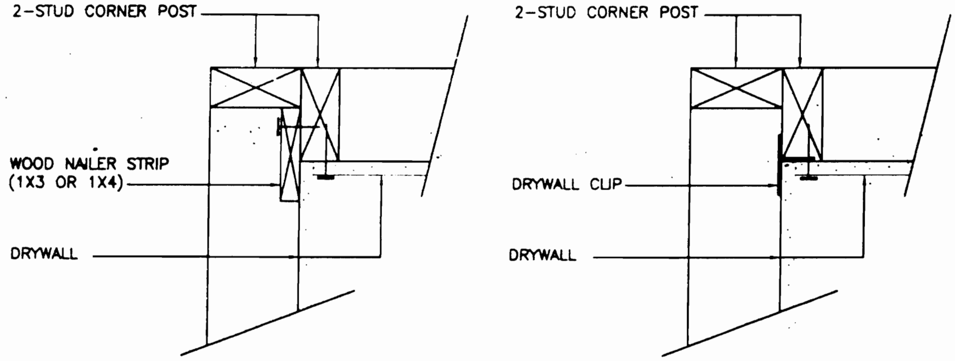



Fig.4.15 Two-stud Corner Post (NAHB Research Center, 1994)

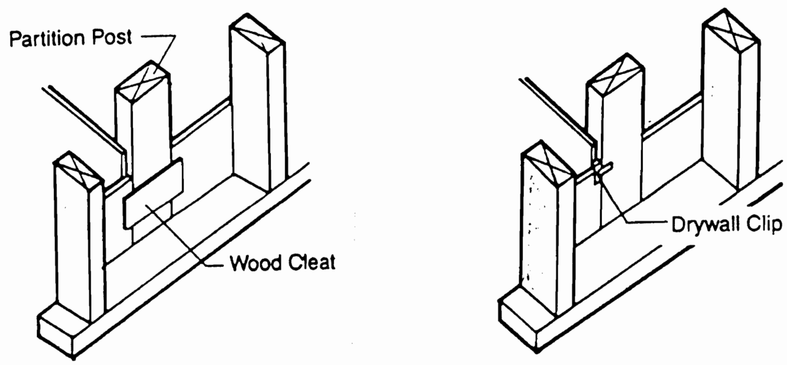



Fig.4.16 Elimination of Studs at Wall Intersection
(U.S. Department of Housing and Urban
Development, 1981)

In North America, top plates can be eliminated where all floor, wall, and roof framing members are aligned vertically and are coordinated on a 400mm or 600mm (16" or 24") module, because building loads are transmitted directly downward through roof rafters or trusses, studs, and floor joists. This reduces the framing component of the wall to 9.4% (Friedman et al, 1993). However, this method is not permitted by the building standard in Japan, in spite of its merit.

Interior partitions are non-load-bearing when roof framing members are designed to bear on exterior walls. Partitions can be 38mm× 62mm (2"×3") studs spaced 600mm (24"). The 38mm× 62mm (2"×3") studs offer ample strength for this non-critical application, and the thinner walls add 25mm (1") to the dimensions of each room. Thus, it is not necessary to double the studs at either side of interior door opening nor to install headers or cripples over the opening. These methods will be strategies for reducing building costs in Japan.

## 4.5 Roof Framing

Residential roof framing usually consists of either conventional joists and rafters or roof trusses. Although in North America, many builders adopt roof trusses due to their high efficiency, in Japan most builders are still using conventional roof framing. The use of roof trusses could contribute significantly to the cost-effectiveness of houses in Japan.

### 4.5.1 Conventional Roof Framing

In the case of conventional roof framing, the gable roof and hip roof are as common in Japan as in North America. For on-site construction, the simplest roof is the gable roof (Fig.4.17). All rafters are cut to the same length and pattern, and erection is straightforward. In the hip roof, shown in Fig.4.18, common rafters are more complex and fastened to the ridge board while hip rafters supply the support for the jack rafters. Even those relatively simple ways of framing are labor intensive. Conventional roof framing, even for a simple roof, is an art that requires a high level of skill (NAHB Research Center, 1994 ).

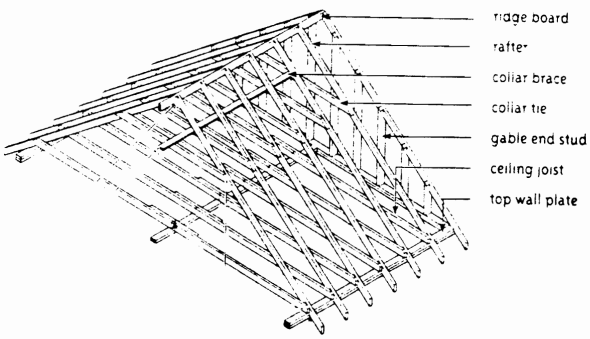



Fig.4.17 Gable Roof used in Japan
(CMHC, 1997)

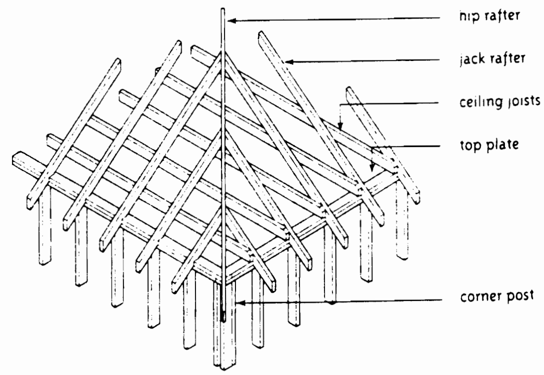



Fig.4.18 Hip Roof used in Japan
(CMHC, 1997)

There are a few strategies for reducing the labor on this framing. First, a 600mm (2') spacing of ceiling joists and rafters may be the most cost-effective if the roof live load meets the requirements. U.S. Department of Housing and Urban Development (1981) explains;

> Builders who thoroughly preplan each aspect of their efforts gain the greatest cost-savings benefits. Modular layouts based on 24" o.c. spacing are key to this effort. Roof lengths should be based on two- or preferably four-foot modules to minimize sheathing material waste and cutting (Fig.4.19).

Second, in order to be cost-effective, rafters should line up with the wall studs. It may not even be necessary to mark rafter positions on the wall plate. Rafter positions also determined the location of the ceiling joists.

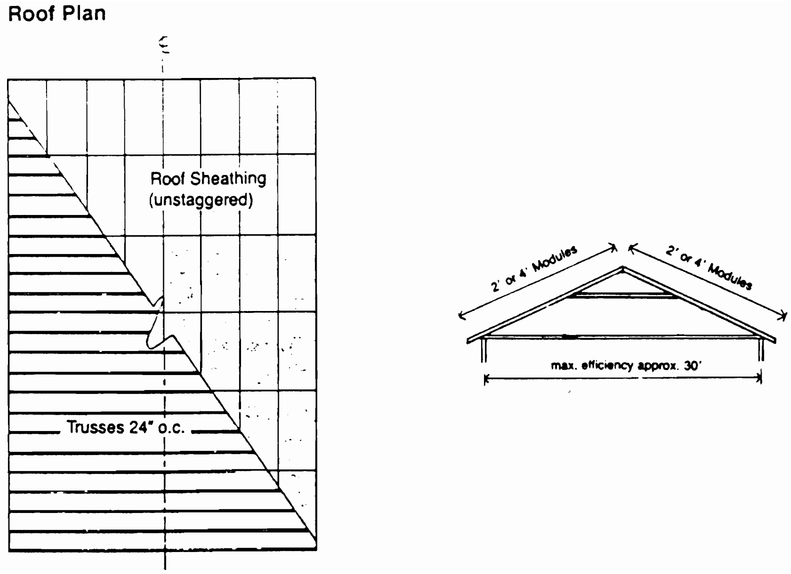



Fig.4.19 Roof Plan on Modular Layout
(U.S. Department of Housing and Urban Development, 1981)

These methods are also available not only when conventional lumber is used, but also for wood I-beams and pre-assembled roof trusses. This is an important point ~~for~~ Japanese builders, because most of them use conventional roof framing methods.

### 4.5.2 Roof Framing with Wood I-beams

Roof Framing with wood I-beams is becoming common in North America because of longer span and light weight. However, it is never seen in Japan (Fig.4.20). Wood I-beams are a desirable alternative to conventional lumber, especially when long rafters are needed.

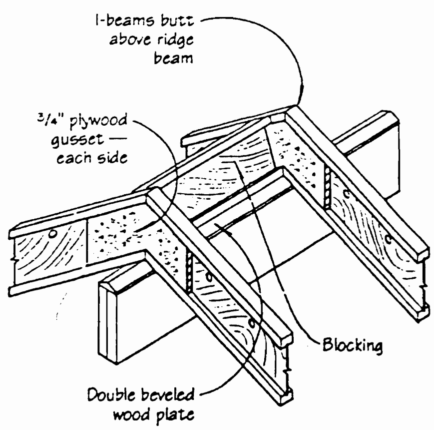



Fig.4.20 Roof Framing with Wood I-beam (Hock, 1990)

One builder in North America who has built several houses by using wood I-beams for roof framing describes his experience regarding cost and efficiency:

> The labor we save handling the lighter I-beam helps outweigh any price difference. On the house we are building now, the TJIs cost about \$500 (U.S dollar)more than solid 2× rafters. But one of these 9-1/2 inch-deep I-beams weighs about half what a 2×10 douglas fir rafter does. This means one man can easily handle a 30-footer. We figure that will save us two days labor for our crew of three on this job alone (Hock, 1990).

In Japan, using I-beams for roof framing has not yet been permitted by the building standard. However, they may be approved in the near future because they are currently approved for use in floor joists.

### 4.5.3 Pre-assembled Roof Trusses

The use of pre-assembled roof trusses in Japan (shown in Fig.4.21) is not common, despite the fact that they offer many advantages, two of which are that they save material and speed up the process of enclosing the house. Pre-assembled roof trusses provides, in one step, a surface for the roof sheeting, a surface for the ceiling finish material, and a space for insulation.

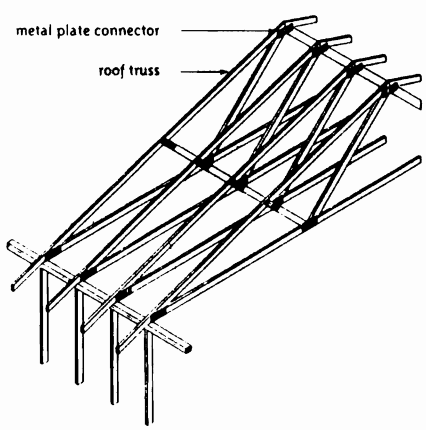



Fig.4.21 Pre-assembled Roof Trusses (CMHC, 1997)

NAHB Research Center (1994) explains:

> Wood trusses are generally the most highly engineering component used in house construction today. They are widely accepted and readily available in most areas. Requiring only basic carpentry skill, wood trusses are easy to install and provide a means of rapidly enclosing the building shell. Trusses adapt to most roof designs, including hips, L-shaped plans, and other variations.

Several basic types of trusses are available, depending on architectural and engineering design factors (Fig.4.22). Gable trusses are the most common, and least expensive type. Scissor trusses are sometimes used to provide a "cathedral" ceiling. They may be mixed with standard trusses in the same roof system to provide a cathedral ceiling feature over a portion of the house. Attic trusses offer a highly flexible design for creating living or storage space within the truss framework. The cost of attic trusses tends to be high because of their construction.

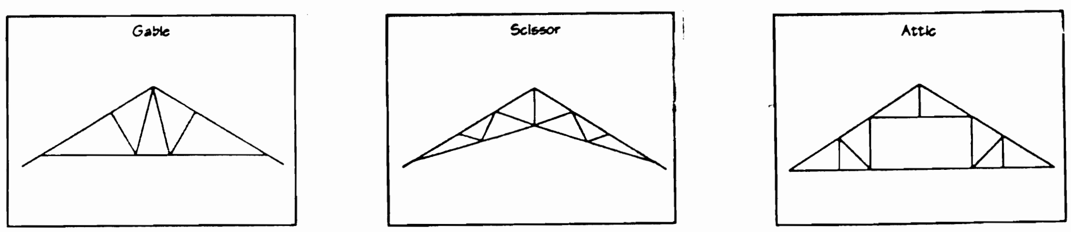



**Fig.4.22 Several basic types of trusses (Paul, 1990).**

The hip truss system, shown in Fig.4.23, has a high initial cost because of its complexity. The costs of valley systems (Fig.4.24) is also high because there is usually only one of any given size in a roof plan.

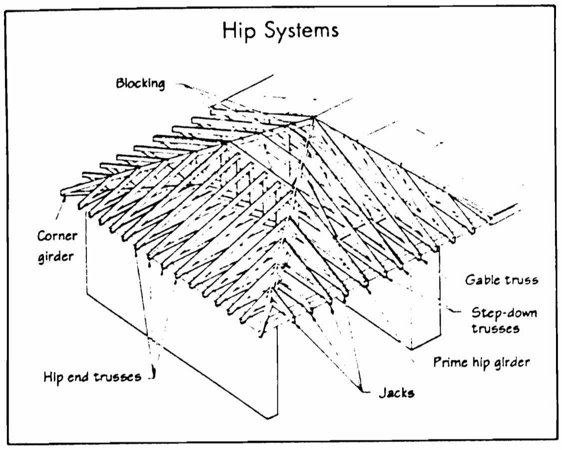



Fig.4.23 Hip Systems (Paul, 1990)

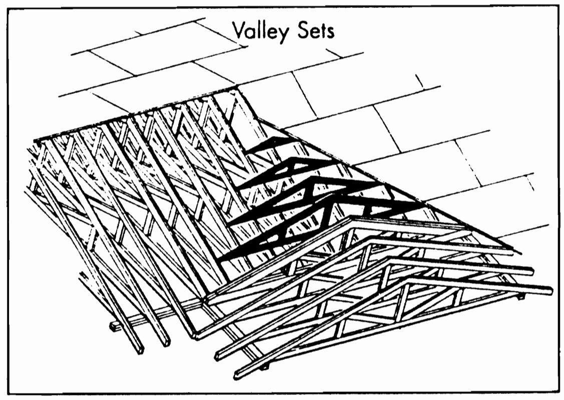



Fig.4.24 Valley Sets (Paul, 1990)

The unit prices vary regionally according to the truss manufacture's location, production capacity, and availability and comparative costs of local framing lumber and labor. Paul (1990), an manufacturer of pre-assembled trusses in North America, estimates their products and explains:

> The greatest savings using roof trusses is still with a simple gable roof. Take a 26'×40'- foot ranch as an example. Our truss package for this house runs about $800 (U.S dollars) delivered. The material for conventional framing, figuring 2"×8" rafters and 2"×6" joists, would run nearly that much before cutting and installation. Also, the conventional framing would require nailing rafters and joists.

Table.4.2 shows a comparison of the costs between a pre-assembled roof truss and conventionally framed roof. Whereas material of pre-assembled roof trusses costs 25% higher than one of a conventionally framed roof, labor costs associated with pre-assembled roof trusses are about 40% on a conventionally framed roof. In North America, about 10% of building costs associated with roof framing can be cut by adopting pre-assembled roof trusses.

| | Material ($/0.3sq.m (sq.ft)) | Labor ($/0.3sq.m (sq.ft)) | Total ($/0.3sq.m (sq.ft)) | Percentage Saving (%) |
|---|---|---|---|---|
| Conventionally Framed Roof* | 1.80 | 1.30 | 3.10 | - |
| Pre-assembled Roof Truss** | 2.26 | 0.54 | 2.80 | 10 |

Table.4.2 Comparison of Costs between Pre-assembled Roof Truss and Conventionally Framed Roof in North America (Kiley, 1998) [1 U.S dollar = $1.43 (Can)]

* Based on straight gable type roof with 6"in 12" rise or less. Framing includes 2"×8"common rafters at 24" on center.

** Based on conventional roof truss - 2"×4" top and bottom chords - 24"on center, any slope from 3"in 12" to 12" in 12".

In Japan, use of pre-assembled roof trusses is gradually increasing, however, in spite of the advantages, use of engineered roof trusses is not common. One of the reasons is that builders are not familiar with engineered roof trusses. Another reason is that only a small number of manufacturers produce them. According to a manufacturer who produces engineered roof trusses in Canada, "About 90% of builders are using engineered roof trusses in Canada (Jager Inc., 1998)." In other words, using engineered roof trusses is indispensable in order to reduce building costs. This would also be true for Japan.

## 4.6 Summary

Since Japan has earthquakes, the Japanese building standard on wood frame systems is more strict than that in North America. However, Japanese builders tend to build houses which are stronger than necessary. This is particularly true in the construction of the foundation. This chapter showed that about 20% of foundation walls can be reduced by eliminated unnecessary foundation walls, or adopting footing and longer-span floor joists.

Japanese builders tend to adhere to conventional methods, and have introduced some (i.e. conventional floor system and 900mm ×1800mm (3'×6') module), which have been used in the post and beam system, into use when building with the wood frame system. Those methods do not work well from a point of view of efficiency. On the other hand, builders in North America have always attempted to seek new products and materials to ameliorate the wood frame system. Although some methods and products are not permitted by the Japanese building standard regulations, many of them, such as engineered wood floor joists and pre-assembled roof trusses, will help to realize the goal of cost reduction in Japan.

# Chapter 5
# Conclusions

## 5.1 Summary of Findings

The findings of this thesis have demonstrated that a number of methods and techniques using the wood frame system in North American affordable homes can help reduce construction costs, and eventually the price of houses in Japan. On the other hand, the author also found that the Japanese lifestyles, customs, and building standards do not easily accommodate some ideas and methods used in the construction of North American affordable homes.

In chapter three, several design strategies for reducing building costs were demonstrated. The floor plan design in Japan tends to be irregular and complex; designing houses with too many corners increases the total length of exterior walls, and elevates building costs. This thesis has compared an irregular floor plan common in Japan, and a simple plan, which is similar to that used in North American affordable homes. The author found that when floor areas are the same, 12% of building costs of exterior walls can be saved by adopting a simple floor plan.

In North America, an open plan design, which reduces interior partitions and creates a spacious feeling, is widely used in the design of houses. On the other hand, the main living space in Japanese houses tends to be divided. This research showed that 30% of interior walls in Japanese house could be eliminated with an open approach to unit planning.

The Japanese housing industry continues to offer the same, traditional styles of houses which use land inefficiently, in spite of the fact that land prices are extremely high. This study has found that improvement in land usage and housing type in Japan could be made by adopting the methods used in planning and building affordable homes in North America. With regard to detached houses, between 4% and 27% of land costs can be reduced by adopting narrow front housing, and by building a basement and an attic. In addition, up to 40% of land cost can be saved by modifying conventional Japanese detached houses to townhouses as is the case in North American affordable homes. At the same time, about 40% less width on the street-side in site will be needed for the townhouse, thus a significant amount of infrastructure will be saved.

In chapter four, strategies for reducing costs of building wood frame systems were presented. In Japan, the building standard required is more strict than the ones in North America because of the threat of earthquakes. However, Japanese builders tend to be over-cautious when taking measures against earthquakes; for instance, they often build too many foundation walls, even under the interior non-bearing walls. This study showed that about 20% of foundation walls are not needed in Japan when the simple North American method of building foundations is used. In addition, simpler foundations could be constructed using engineered wood products for joists, enabling a longer floor span.

In North America, builders who seek cost-effective methods began to use spacing of 600mm (2') for structural members such as walls, joists and roof-rafters, instead of conventional spacing of 400mm (16"). In Japan, where the spacing of 450mm (1'-1/2") is common, the North American method could be applicable in some cases, although there are some regulations which prohibit this (i.e. lumbers and boards of larger dimension have to be used). The 600mm (2') spacing is highly cost-effective. For example, two 2"×10" lumbers cost less than three 2"×8" lumbers, and there are one-third fewer framing members to be handled and installed than with the 400mm (16") spacing.

Engineered wood products for floor joists, such as wood I-beam joists and space joists, are common in North America, although they are not used frequently in Japan. Wood I-joists and floor trusses use 20% less material than a conventional floor constructed with dimensional lumber. In addition, those products permit a wider spacing and make labor more efficient because of the lighter weight and the easier plumbing installation. The price of those products in Japan is higher that in North America. However, it is expected that the demand will rise because of the high efficiency, and consequently, the price will decrease.

In North America, elimination of studs at wall corners and intersections is a strategy for reducing costs. It also eliminates thermal bridges because insulation is replaced with studs. Although this method is not permitted by Japanese building standards, it can be used for non load-bearing interior walls in Japan, similar to the method of using 2"×3" studs instead of 2"×4" studs.

Although in North America many builders use pre-assembled roof trusses which are less labor-intensive, in Japan most builders are still using conventional roof framing. This study has found that about 10% of building costs on roof framing can be cut by adopting pre-assembled North American roof trusses. Although the savings through use of pre-assembled roof trusses in Japan have not been estimated, using the trusses would become essential in Japan as an efficient way to save on labor costs.

## 5.2 Conclusion

In the previous chapters, the author has discussed the characteristics of the Japanese housing industry and how the industry can reduce building costs by adopting methods of North American wood frame construction, especially design and construction techniques.

In Japan, the notion of affordable homes has not been developed. At present, the goal of Japan's housing policy for urban dwellers states that the price of a house should be five times the annual income of the average wage earner (Hasegawa, 1996). However, that goal is still too difficult for people who earn an average income to achieve. In North America, such a ratio would not be considered affordable, and house prices are usually less than three times the annual income of the average wage earner. In Japan, people in their forties who are able to build custom-made houses in Tokyo or in any major metropolitan area, have the benefit of already owning land. However, the average person is not privy to this option. Most Japanese housing developers do not attempt to provide affordable homes, and many people are content with living in small condominiums and apartments, or just give up hope of owning their houses. The recent economic depression in Japan has made it more difficult for people to own a house, so it is time for the Japanese to reconsider the idea of affordable homes.

The Japanese housing market is facing an inevitable increase in the demand for attached and multifamily housing, both low-rise and high-rise. This can be explained in part by the severe shortage of suitable lots for residential developments within acceptable commuting time of places of employment. While owning a detached house is still the dream of most households, the extraordinarily high housing prices and long distances to work are making this dream unattainable in major metropolitan areas.

The main reason for the high price of houses is the high land price. However, there are several ways to overcome the difficulty of building houses on expensive lots. For instance, many methods of using land efficiently which are demonstrated in this study (e.g. narrow front house, semi-detached house, and townhouse), are common in North America. These methods have been developed through numerous experiments with different housing styles, and are realistic alternatives for conventional detached houses in North America. In Japan, the "myth" of the virtues of the detached house is still strong, and in many cases, most people just do not know the advantages of narrow-front houses and townhouses. In particular, they are not aware that the cost reduction is essential due to the high land price. This thesis has demonstrated how much land, and consequently cost, can be reduced by adopting design principles of affordable homes.

The North American housing industry has always attempted to find more efficient construction methods. On the other hand, the Japanese housing industry has striven for high quality housing rather than affordability, and consequently has pointed buyers in the wrong direction. Kendall pointed out some problems that exist within the Japanese housing industry (1995);

> The current housing problem in the minds of most people in Japan is achieving housing quality. The concept of quality, however, is difficult to define. Furthermore, to some, quality is synonymous with high cost and the inverse is therefore true: low cost means low quality. Product manufacturers and the entire distribution system has promoted this idea and overcharges. The buying public has "bought" this equation of high quality and high cost housing and housing products. Companies have built on the long tradition of high value placed on appearances, rather than on matters of practicality, safety, economy, or longevity. . . . . Some believe that Japanese housing products are of a higher quality (and thus

> higher cost) than necessary. Also, interesting studies have been done illustrating the rapid increase in a variety of product lines and types of products within each line. A visit to any showroom of a major supplier of bathroom equipment and fixtures provides an indication of the attitude toward these products and the acceptance till now of excessively high prices, and variety. It is clear that high housing prices in Japan are not only a result of artificially high land prices.

In recent years, as the Japanese economy began to slow down, the demand for conventional detached housing has been decreasing, and affordable condominiums are in demand, despite the fact that these condominiums do not have the same amenities as houses. It is time for some kind of housing in Japan that provides an alternative to conventional detached house and condominiums, that is, affordable housing in Japan. The author believes that the Japanese housing industry should be aware that there are many strategies for reducing building costs that will provide cost-effective quality houses by adopting the building methods used in North American affordable homes.

## 5.3 Future Research

This research was limited to investigations of strategies for cost reduction through of design and construction methods. The scope of the study did not allow for a deeper analysis of all the issues. However, another important issue, construction management, should be considered in order to uncover strategies for reducing building costs.

Many people think that the most important factor in the difference between building costs in Japan and North America is the cost of materials. However, this is not the case. Although building materials in North America are cheaper than the ones in

Japan, the difference is not significant. In fact, the most important factor is the cost of labor. In other words, inefficient construction management in Japan results in higher labor cost, which in turn, raises the building costs.

Generally, if the same houses are built in Japan and Canada, the building cost in Japan, including builder's profit will be double that in Canada. Fig.5.1 shows an example of the difference in building costs between Japan and Canada. Whereas the cost of materials in Japan is 80,000 dollars (40 % of the building cost), the cost in Canada is 55,000 dollars (60%). The difference is 25,000 dollars. Because in Japan, many building materials are imported, the costs are necessarily higher. On the other hand, whereas the labor cost in Japan is 80,000 dollars (40%), in Canada it is 25,000 dollars (25%). It means that the labor cost in Japan is more than triple that in Canada. Nonetheless, there is not much difference between hourly wages in Japan and Canada. For instance, the wage of a carpenter in Japan is about 244 dollars (22,000 yen) a day (about eight working hours), thus about 30 dollars per hour. In Canada, it is about 25 dollars per hour. So, the difference between them is not significant. Indeed, the cause of the high labor cost in Japan is lower productivity.

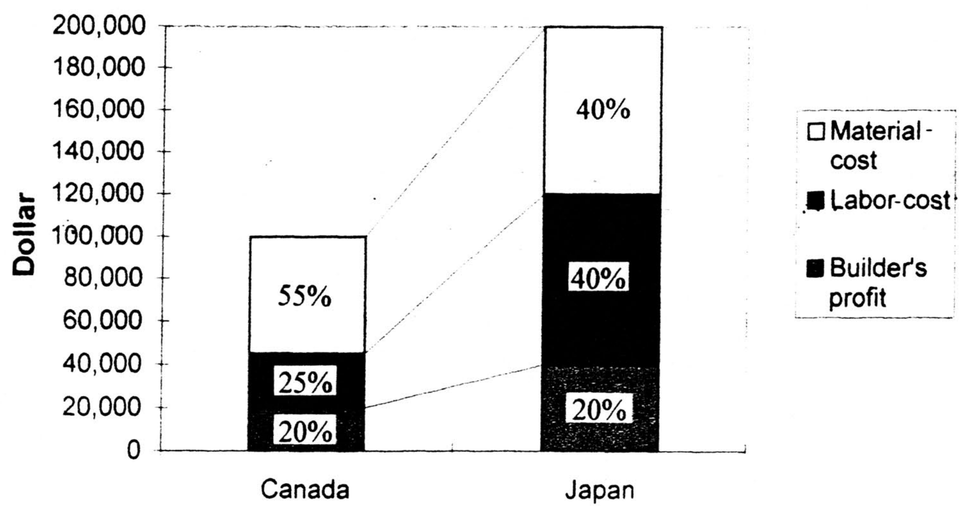



Fig.5.1 Comparison of Building Cost (Kurose, 1994)

In many cases, the term for constructing a house whose total floor area is about 150 sq.m (1615 sq.ft) is about 60 working days in North America. However, in Japan it will take about 120 working days (Totani, 1995). One of the reasons is that Japanese builders do not use efficient methods such as using I-joists and pre-assembled truss systems, methods and systems which reduce working time. Another reason is that workers in North America are specialized. For example, a framing carpenter and a laborer for the installation of drywall are two different occupations in North America. However, Japanese carpenters do framing, installation of wallboards and even interior carpentry. Specialized workers in North America can naturally work more efficiently.

It is important for construction managers to dispatch workers properly, especially on framing in developer-built housing projects. Considerable cost reduction may therefore become possible. When many houses are built on one site in North America, framing teams are used, but, this system is not seen in Japan. In this system, three kinds of teams are organized; a 'deskwork team', a 'pre-assembling team', and a 'framing team'. Members of the 'deskwork team' draw and check working plans, such as sections of frames, and manage materials and time. Members of the 'pre-assembling team' cut lumber and assemble wall panels and roof trusses. The 'framing team' is comprised of three groups, for example, a floor framing group, a wall framing group, and a roof framing group. Each group works to a schedule and moves on to different stages as the work progresses. A framing table (Fig.5.2) as a place of pre-assembling and a forklift track (Fig.5.3), which carries and lifts materials, are often used in this system.

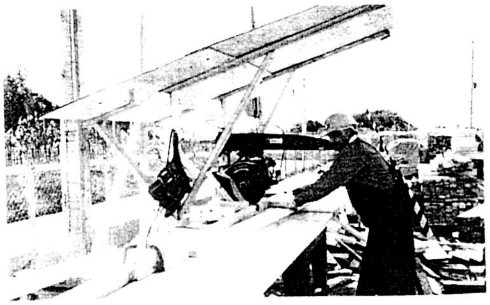


Fig.5.2 Framing on Table (Kobe City Housing Supply Corporation, 1995)

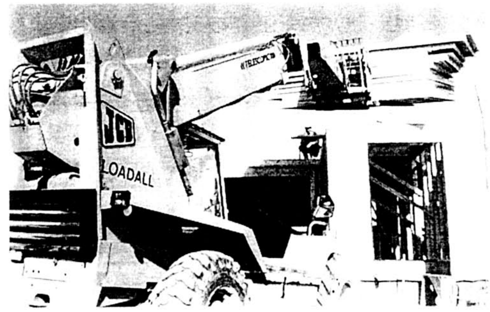



Fig.5.3 Forklift Track (Kobe City Housing Supply Corporation, 1995)

Fig.5.4 explains the process employed in this system. In North America, this kind of "Team Work" is also used for interior finishing such as drywalling. These systems are organized and managed by construction management. Japanese builders should adopt this way of construction management in order to dispatch workers properly, especially on framing in developer-built housing projects.

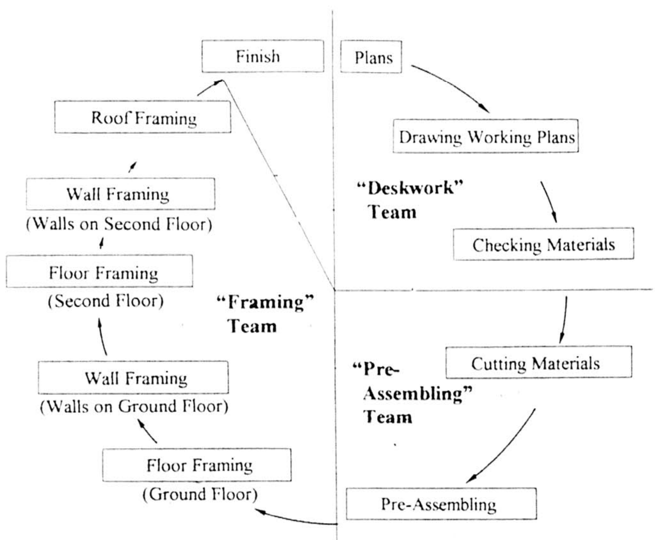



Fig.5.4 Process of Framing by Team
(Kobe City Housing Supply Corporation, 1995)

Japanese builders should apply these methods, understanding that well-carried construction management may reduce building costs. In Japan, high labor costs and low productivity are a result of the construction management whose concept of the relationship between time and cost is very vague. In short, there is no effort made to reduce costs by shortening construction time. For example, schedules for construction are very approximate and tend not to be followed. The reason is that Japanese supervisors who make the schedules and manage building sites do not have enough knowledge about construction systems. In many cases, they leave important things such as time and labor management for the carpenters and other workers. On the other hand, supervisors in North America generally have enough experience of the construction system and its management to lay out and impose efficient work schedules.

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