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ROBOTICS AND HIGH-TECH

AN ADVANTAGE OF JAPANESE CONTRACTORS

by

HITOSHI HASEGAWA

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Signature of Author____
Department of Civil Engineering
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Certified by____
Yechiel Rosenfeld
Thesis Supervisor

Accepted by____
Ole S. Madsen
Chairman, Department Committee on Graduate Students

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Submitted to the Department of Civil Engineering on May 20, 1986 in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering

ABSTRACT

This thesis analyzes the construction industry in Japan and the United States based on the statistics for the last twenty years to uncover the similarities as well as the differences.

In the first part of this thesis, Japanese construction industry in the national economy is analyzed in comparison with the U.S. construction industry. Input-output analysis is employed to illustrate structural differences between the construction industries in the two countries and structural changes from the time horizons.

The second part analyzes the individual construction establishments to identify the structure, organization intra-industry dependency in the construction industry paying regard to the size of the company in particular.

The third part describes the peculiar roll of large size general contractors in Japan. Their features are discussed both from intra and inter industry perspectives. As a case study, development of construction robots by them are discussed.

This thesis concludes with their technology oriented strategy, based on their characteristics uncovered in this thsesis, to enter into overseas market.

Thesis Supervisor: Yechiel Rosenfeld

Title: Visiting Assistant Professor of Civil Engineering

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CHAPTER 1 INTRODUCTION

The construction industry plays an essential role in the national economy. Its output accounts for great proportion of Gross National Product and serves and accommodates people for a long period as a fixed asset. Its production process involves a lot of intermediate input from various industries and creates a lot of employment.

The construction market is considered to be a demand-push market and is affected seriously by the national economy. However, due to the constant upward economy after the World War II and the government policy to increase public construction during the recession, the construction industry in Japan had never experienced serious recession until the first oil crisis.

From the nature of construction, it used to be considered as a regional and domestic industry. Nevertheless, as the technology involved in construction becomes more complex and the size of a project increases, international construction began to play important role.

Construction firms in Japan, however, stayed in the domestic market until the first oil crisis. There were several minor reasons why they were relatively reluctant to go into international markets, such as language problems, cultural problems, geographical and various risks. However, the major reason is that they did not have the necessity to go out to expand their business due to the active domestic market.

After the first oil crisis, general contractors found a shrinking domestic market and lots of resources both human and assets accumulated during the 50's and 60's on hand. Thus, general contractors first seriously considered to go out into international market to make up for the shrinking domestic market.

It was fortunate that the international construction market was very active especially in the OPEC countries due to the escalating oil price, in that it forced Japanese construction firms to enter into this overseas market. The recessive domestic economy in Japan, at this time, further encouraged this international expansion.

Judging from the amount of contract, general contractors appeared to had successfully launched into the international market. Since the early 80's, however, as the active construction investment in the Middle East ended by the Iran-Iraqi war, they have had the hardest time ever.

In December 1985, one book, entitled as Kensetsugyo no Mirai Senryaku (Future Strategies of Construction Firms), was published by a group of members working for Shimizu Corporation. Surprisingly, it soon became a nationwide best selling book. It proposes several strategy to survive in the construction industry on the recognition that the construction industry is now suffering the hardest time ever. The public's concern about this book reflects the seriousness and magnitude of problem facing the construction industry.

The motivation of this thesis is basically the same as this book. This thesis, however, focuses what we presently have rather than what we should have in order to uncover the strengths and weaknesses of general contractors in Japan.

The purpose of this thesis is to identify the characteristics of general contractors in Japan and to propose strategies to expand their business into the international construction market.

The organization of this thesis is shown in figure 1.1. Topics are changed from broader ones to more specific ones as each chapter proceeds. In chapter two and chapter three, the construction industry is analyzed as a sector of the national economy. The framework of Input-Output analysis is employed in chapter three. Chapter four discusses the structure in the construction industry, focusing the size of construction firms and their roles in particular. Chapter five focuses the big five general contractors in Japan to identify their characteristics. Chapter six discusses construction robots developed by them as a case study and to propose a strategy to develop construction robots. In chapter seven, their activities in the overseas construction after the first oil crisis are analyzed. Finally in chapter eight, a strategy to expand into foreign construction markets is proposed.

Figure 1.1 Organization of the Thesis

Subject	U.S.A.	Japan	Case Study
Introduction		Chapter 1	
The Construction Industry in the National Economy	Chapter 2	Chapter 2	
Input-Output Analysis	Chapter 3	Chapter 3	
Structure in the Construction Industry	Chapter 4	Chapter 4	
Big Five General Contractors in Japan		Chapter 5	
Construction Robots Developed in Japan			Chapter 6
Overseas Construction		Chapter 7	
Conclusion & Further Study		Chapter 8	

CHAPTER 2 CONSTRUCTION INDUSTRY IN NATIONAL ECONOMY

2.1 Introduction

In the next two chapters, the construction industry in Japan is analyzed as a sector of the national economy for the last two decades mainly in comparison with that of the United States. The second chapter discusses the role of the construction industry in the framework of the national economy such as gross domestic product, fixed capital formation and construction investment. The third chapter employs Input-Output tables to analyze structural changes in the construction industry and to find similarity and difference between the two countries after World War II. Analysis in this chapter is based on System of National Account (SNA) and National Income and Product Accounts (NIPA's), which are national account systems of Japan and the United States. Fundamentals of these account systems are provided in appendix 1 at the end of this chapter.

2.2.1 Construction Industry in Japan

After World War II, Japan's economy grew very rapidly. The construction industry also continued to expand and modernize at an increasing speed favored by Japan's nationwide needs for socioeconomic reconstruction, rehabilitation and redevelopment. From the mid 40's to the mid 50's, the construction industry had developed mainly to restore the lost national wealth through World War II, which was almost 25 percent of the national wealth before the war. [Miura, 1977, pp.17] It was not until 1955 that accumulated assets reached the level of 1940. From 1955, Japan's economy went into a so called "High Growth Era". Its GNP had increased at a real annual compound rate of 8.4 percent, 10.0 percent and 11.3 percent between the years 1955 and 1960, 1960 and 1965, and 1965 and 1970 respectively. As a result, Japan's GNP had risen from the seventh among liberal countries to the second to the United States in 1967.

This rapid economic growth had been supported and had supported the high rate of fixed capital formation. All through this period, the ratio of Gross Domestic Fixed Capital Formation to Gross Domestic Product (GDFCF/GDP) had been almost 30 percent of which almost 70 percent had been construction investment in nominal terms. Therefore, the ratio of construction investment to GDP had been about 20 percent during that period. This rate is the highest among developed countries and almost twice as much as that of the U.S..

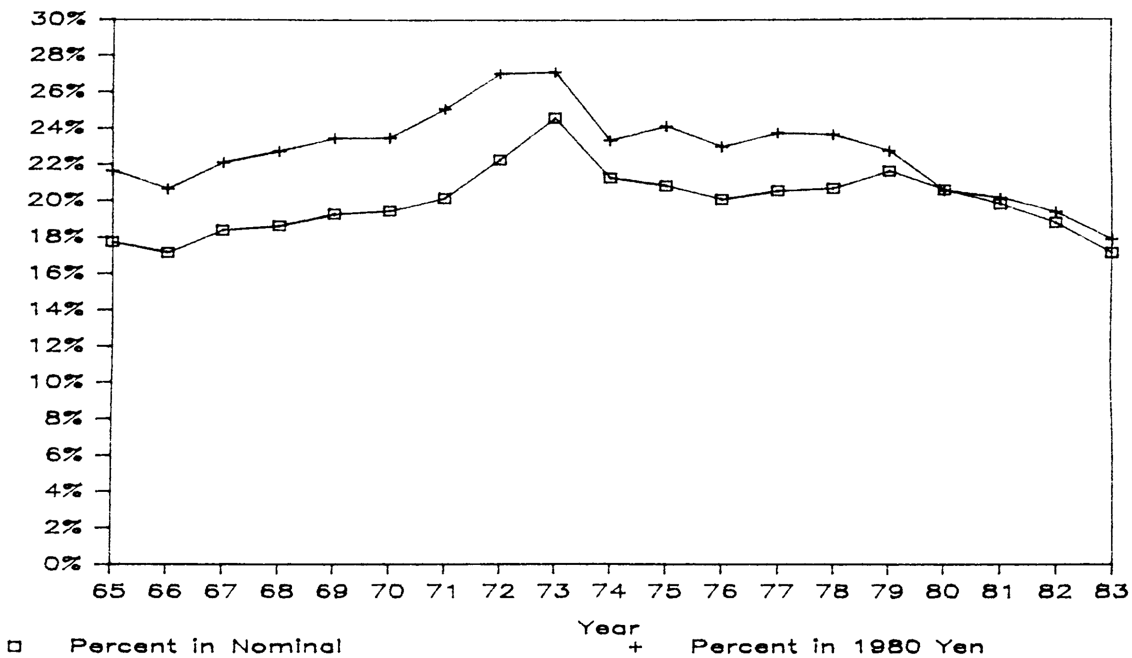
Table 2.1 GDP and Construction Investment (1970)

Country	Unit	(A) Construction Investment	(B) GDP	(A)/(B) %
JAPAN	B.YEN	14634	73238	20.0 %
U.S.A.	B.DOLLAR	95	986	9.6 %
U.K.	B.POND	4059	51365	7.9 %
W. GERM.	B.MARK	105	675	15.6 %
FRANCE	B.FRANC	98	782	12.4 %
ITALY	B.LIRA	7792	57937	13.4 %

Source: Year Book Construction Statistics 1979, 1980

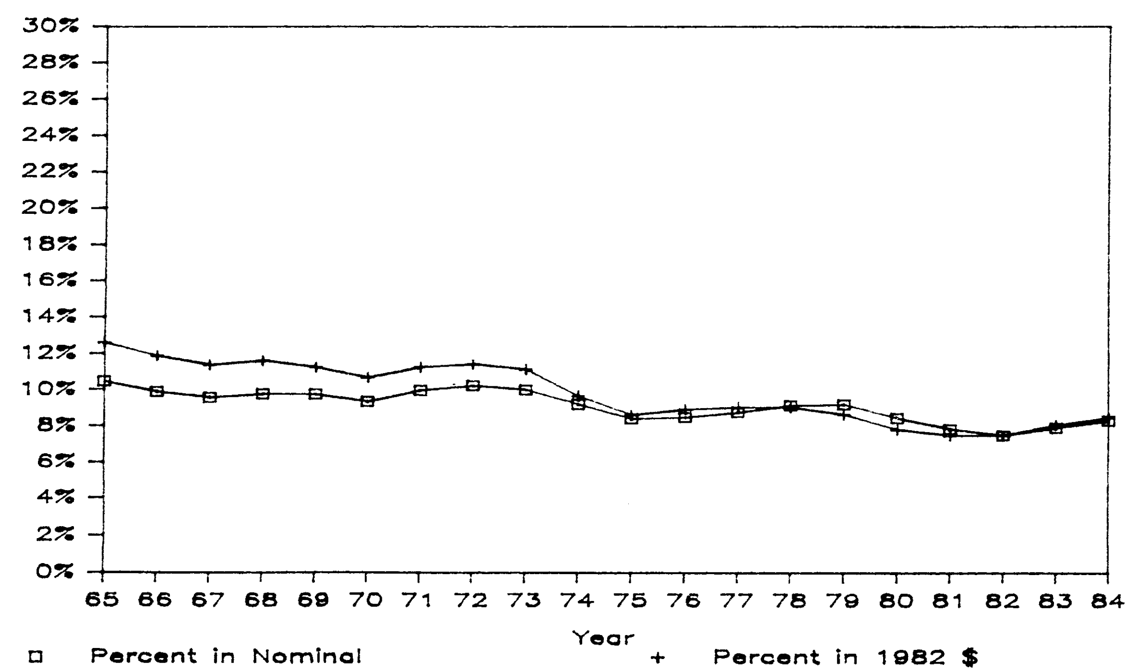
This high rate of construction investment remains the same until 1980 in nominal terms. (Figure 2.1) This exceptionally high rate of construction investment as a part of GDP can be explained by the low accumulation of capital assets in Japan. With all this high rate of construction investment, the accumulated capital assets both in residential buildings and social infrastructure are still far behind the average of developed countries. (Figure 2.3 and Figure 2.4)

Figure 2.1 Ratio of Construction Investment to GDP (Japan)



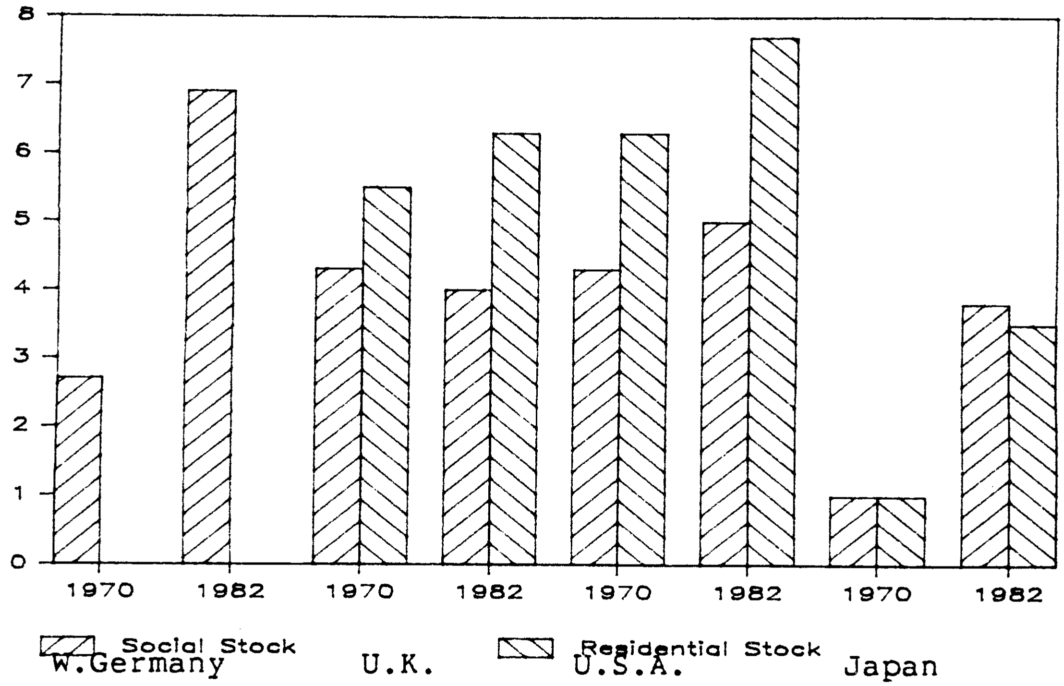
Source: Kensetsu Toukei Youran 1985, 1975

Figure 2.2 Ratio of Construction Investment to GNP (U.S.A.)



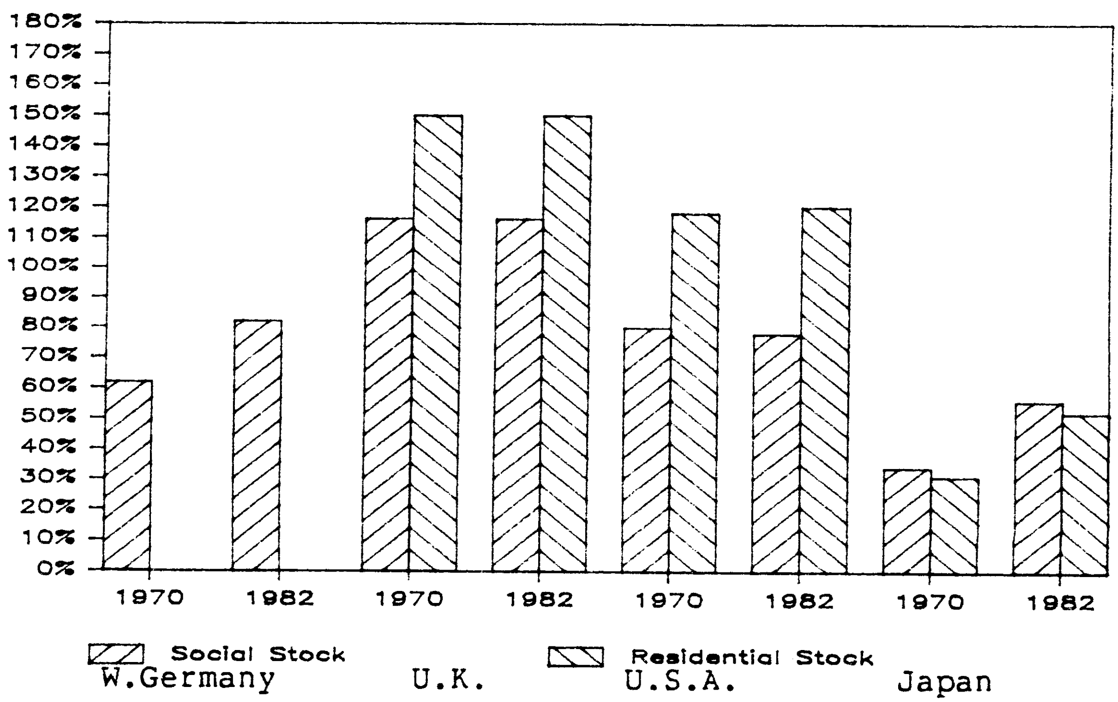
Source: Economic Report of the President, 1986

Figure 2.3 Social and Residential Stock per Capita
(1000 dollar)



Source: Kensetsu Hakusho, 1984

Figure 2.4 Social and Residential Stock as Percentage of GNP



Source: Kensetsu Hakusho, 1984

Although the proportion of construction investment to GDP appears almost constant except for 1972 and 1973 when the proportion grew exceptionally high due to the active investment stimulated by the economic peak, their proportion in 1980 constant yen, however, shows that the magnitude of construction investment has gradually decreased from 21.66 percent in 1965 to 17.81 percent in 1983 while it is 17.8 percent in 1965 and 17.1 percent in 1983 in nominal terms. (Figure 2.1)

2.2.2 Construction Industry in the United States

In the United States, Private Domestic Investment (PDI) has been around 15 percent of GNP. New construction put in place by the private sector accounts for about 45 percent of PDI or 7 to 8 percent of GNP. In addition, the construction put in place by the public sector is almost 2 percent of GNP. Therefore, construction put in place both by private and public sectors is about 10 percent of GNP during the last twenty years in current dollar. (Figure 2.2)

The ratio of construction investment to GNP seems to have decreased gradually with some cyclical fluctuations during the last two decades.

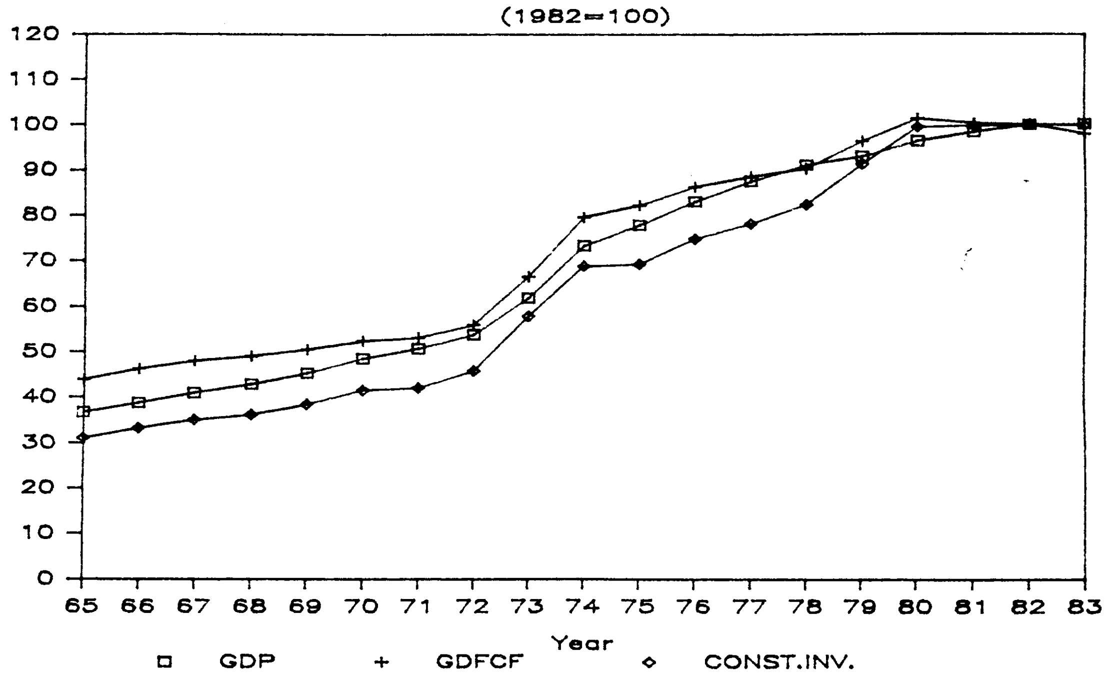
2.3 Cost Escalation of Construction in Japan

Figures 2.5 and 2.6 show deflators of GDP, GNP, Fixed Capital Formation (FCF), and construction investment for both Japan and the United States. It shows that these deflators are very close to one another in the United States while those of Japan indicate that cost escalation of construction investment is much faster than the others. Particularly, it is faster than FCF, showing that the cost escalation of the construction is much more serious than those of products of the manufacturing industry, which account the rest 30 percent of FCF. This fast cost escalation makes shrinking magnitude of the construction industry less significant in Japan.

2.3.1 Cost Escalation of Labor

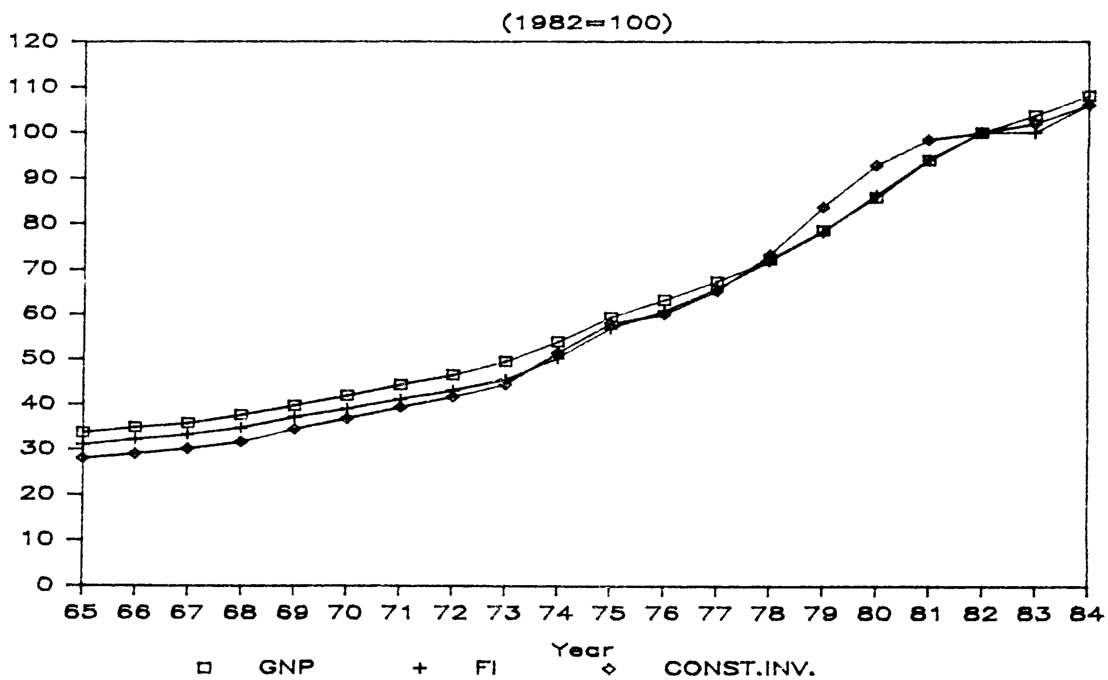
This serious cost escalation of construction investment in Japan is due to two factors: labor cost and intermediate input cost. The wages of construction workers has increased significantly during the last twenty years especially for the non-regular workers. They had suffered considerable low wage levels before the "High Growth Era" compared with other industries. However, economic growth in the 60's and the early 70's have changed the supply and demand balance and increased their wages. For instance, the wages of non-regular workers has increased 45.5 percent in 1973. The wages of regular workers also has increased since 1955. The average wage of construction workers was 14,609 yen per month and that of the manufacturing industry was 16,717 yen in 1955 while the former has increased to 71,727 and the latter to 71,447 by 1973. Thus, by the early 70's, construction wages reached the manufacturing industry average and, indeed, had exceed it.

Figure 2.5 Deflators (Japan)



Source: Annual Report of National Account, 1965 - 1985

Figure 2.6 Deflators (U.S.A.)



Source: Economic Report of the President, 1986

This cost escalation of wages by the early 70's is depicted in figure 3.3 in chapter three. It shows that before the first oil crisis, the cost index of wages had increased much faster than that of construction materials.

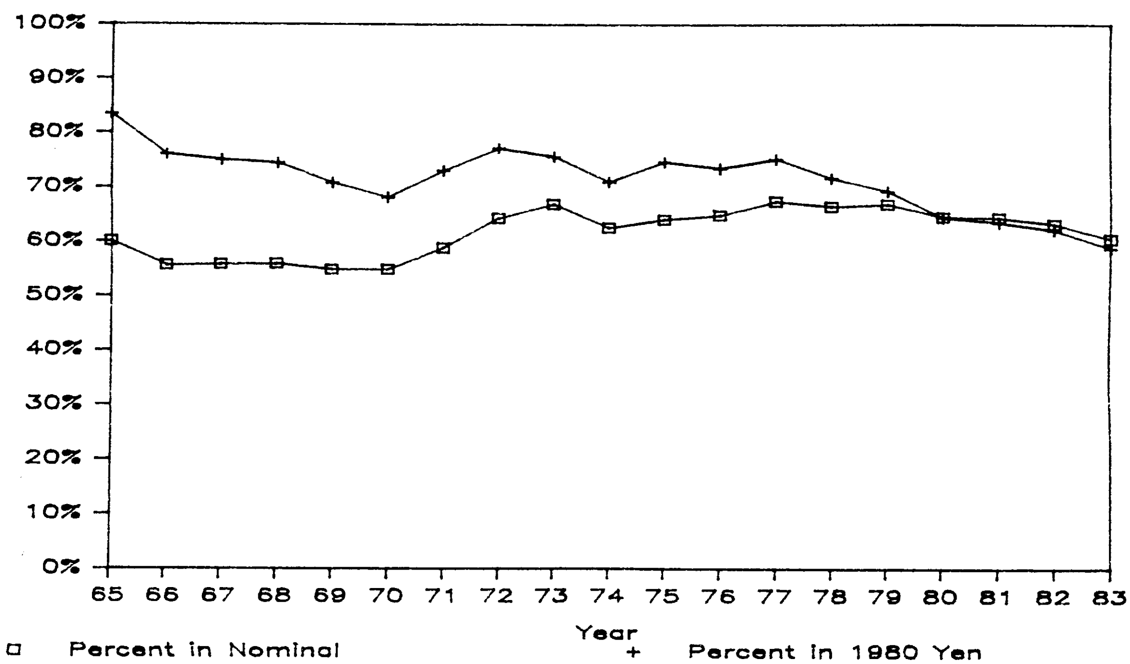
2.3.2 Cost Escalation of Construction Materials

The cost of construction materials also had escalated especially during the oil crisis as the construction industry depends much on the imported material. The cost of construction material has escalated 27.2 percent in 1974. Foreign exchange rate also affects the cost escalation. When Japanese currency is depreciated, the cost escalates very quickly while yen is appreciated, it is stable.

2.4 Magnitude of Construction Industry

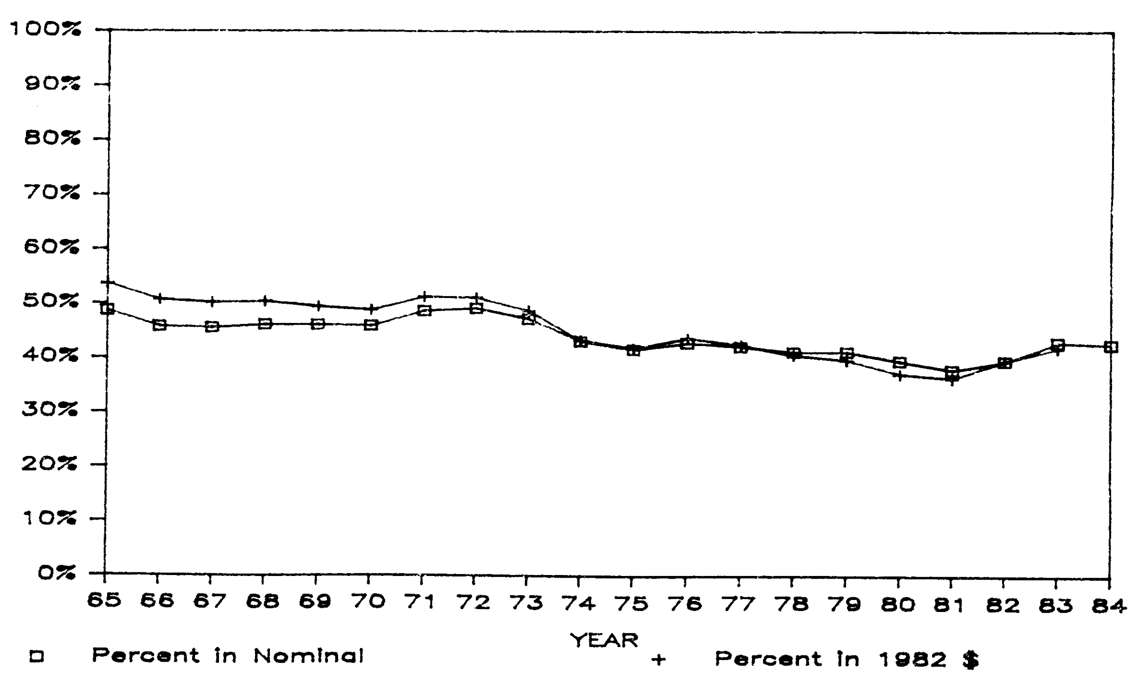
As a result of this cost escalation of construction, construction investment has lost its magnitude as a part of Gross Domestic Fixed Capital Formation (GDFCF) besides this decline of construction investment in real numbers. Figures 2.7 and 2.8 show the ratio of construction investment to GDFCF in Japan and that of private construction investment to PDFI in the U.S.. Although it stays almost constant about 60 percent in nominal terms, it has decreased from 83.4 percent in 1965 to 58.8 percent in 1983 in real terms. It shows that manufacturing industry had somehow, most probably by increasing productivity, minimized it's cost escalation while the construction industry could not increase productivity that much.

Figure 2.7 Ratio of Construction Investment to GDFCF (Japan)



Source: Annual Report of National Accounts, 1965 - 1985

Figure 2.8 Ratio of Construction Investment to PDFI (U.S.A.)



Source: Economic Report of the President, 1986

Thus, although the cost escalation of construction inflated the construction investment in nominal terms, the importance of the construction industry seems to have decreased in the national economy especially in the fixed capital formation during the past two decades in Japan. This trend is most easily observed since the late 70's when the manufacturing industry began to focus on so called the "high-tech" products.

This trend is also observed in the United States, although it is less significant. The proportion of construction investment to GNP has decreased from 12.6 percent in 1965 to 8.5 percent in 1984 in 1982 constant dollar while it has decreased only from 10.5 percent in 1965 to 8.3 percent in 1984 in nominal terms. (Figure 2.2)

2.5 Market Structure

During the last two decades, the market structure of the construction industry also has changed. In this section, these changes in the construction market together with the similarities and differences between the construction markets of the two countries are discussed.

2.5.1 Public vs. Private

New construction put in place by the public and the private sectors is shown in figure 2.9 for Japan and figure 2.10 for the U.S.. Back in 1965, public construction counted about 30 percent of total new construction both in the U.S. and in Japan. Until 1970, it used to be more than 30 percent in the U.S. which is slightly higher than that of

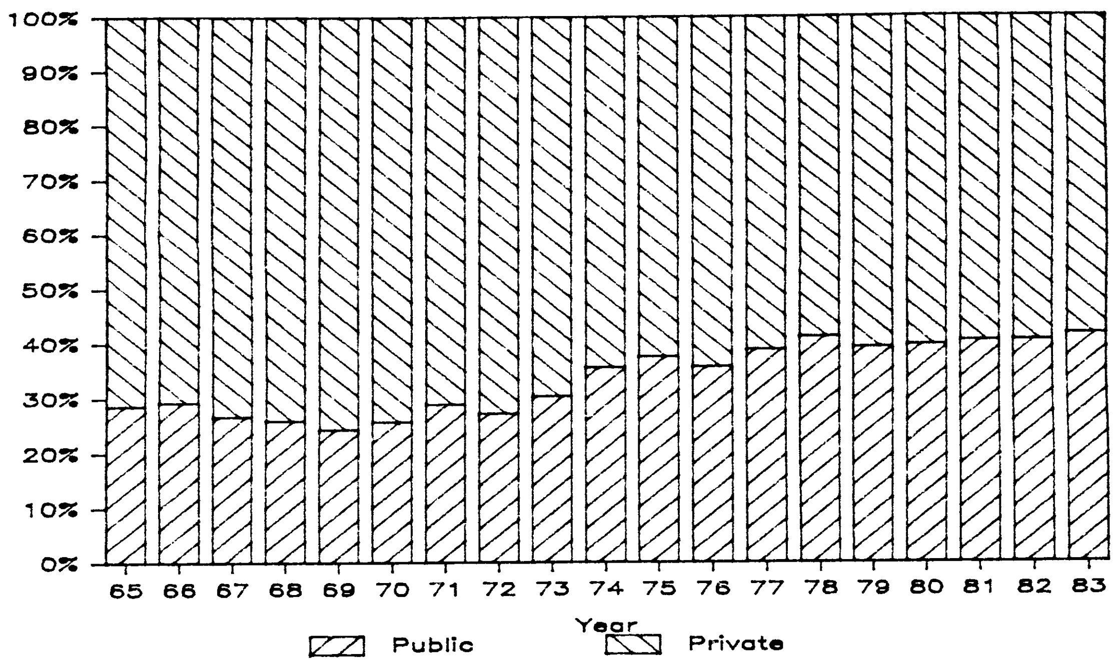
Japan which was between 25 percent and 30 percent. Nevertheless, in Japan, this segment had risen from 29 percent in 1971 to 41 percent in 1978 and has stayed relatively constant while in the U.S., it has decreased gradually from 30 percent in 1975 to 18 percent in 1984. As a result, Japan's public construction is almost twice as much as that of the U.S. percentagewise recently. This difference seems to come from the disparity of government policies. In the U.S., the rate of public construction investment to government expenditure has decreased from 12.6 percent in 1965 to 7.5 percent in 1982 while that of Japan stays over 30 percent until 1980. Nevertheless, there is a tendency to decrease public construction also in Japan and it has decreased slightly since 1977. As Japanese government seems to continue this policy to reduce the size of government, this high rate of Japanese public construction is expected to decrease in the near future.

2.5.2 Type of Construction

New construction put in place by the type of construction is shown in figure 2.11 for Japan and figure 2.12 for the U.S.. The major characteristic of the Japanese construction market is that the proportion of heavy construction is considerably high, almost 40 percent, all through the last twenty years. In particular, heavy construction by the public sector has increased from 19.6 percent in 1965 to 31.5 percent in 1985, showing the government's emphasis on the social capital formation. On the contrary, heavy construction by the private sector has decreased from 17.9 percent to 8.1 percent during the same period, indicating that the social and economic environment make it difficult for the private sector to invest in social assets. However, aforementioned Japanese policy to decrease public construction, at the same time, encourages private sector's investment in social assets and provides incentives for it. In other words, Japanese government has encouraged privatization in the last few years. Therefore, the proportion of private heavy construction is expected to increase and to offset the decrease in public construction to some extent in the future.

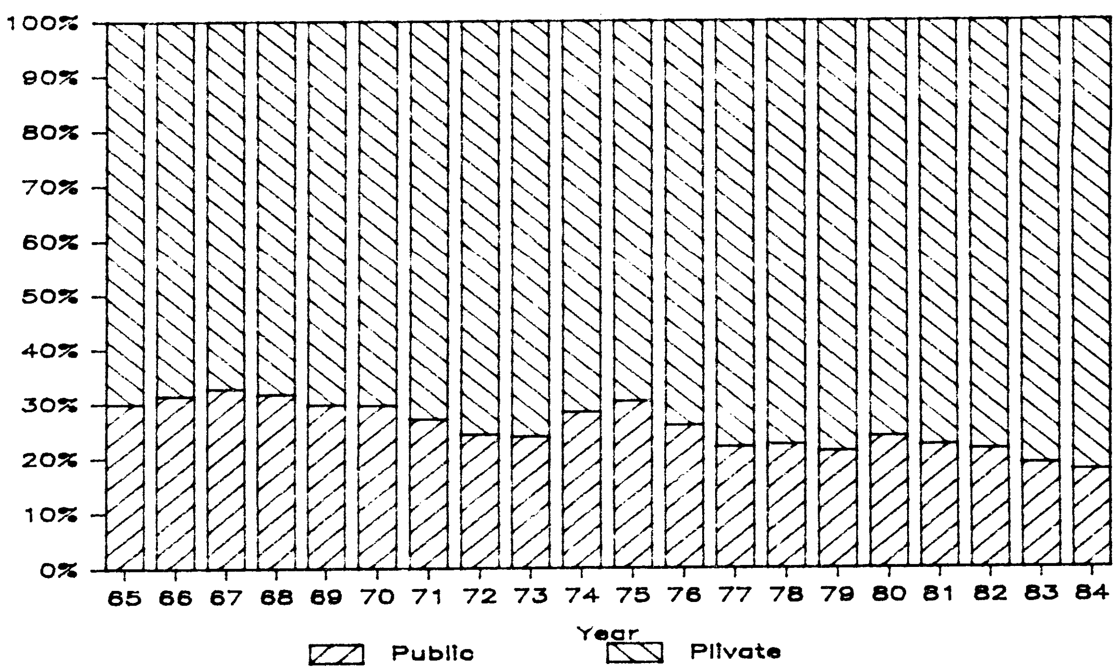
In the U.S., the proportion of construction investment by type of construction appears to fluctuate significantly. Residential investment, in particular, fluctuate heavily. For instance, it has decreased 23.3 percent in one year from 1972 to 1973 and increased 46.3 percent in one year from 1983 to 1984. This significant fluctuation affects the whole construction industry considerably because the residential construction accounts for almost 40 percent of total construction on average in the U.S., whereas it is about 30 percent in Japan. This relative importance and heavy fluctuation of residential construction deform the structure of the construction market and caused other types of construction segments to fluctuate. However, in terms of real construction volume, non residential and heavy construction are more stable in the United States.

Figure 2.9 Private vs. Public Construction (Japan)



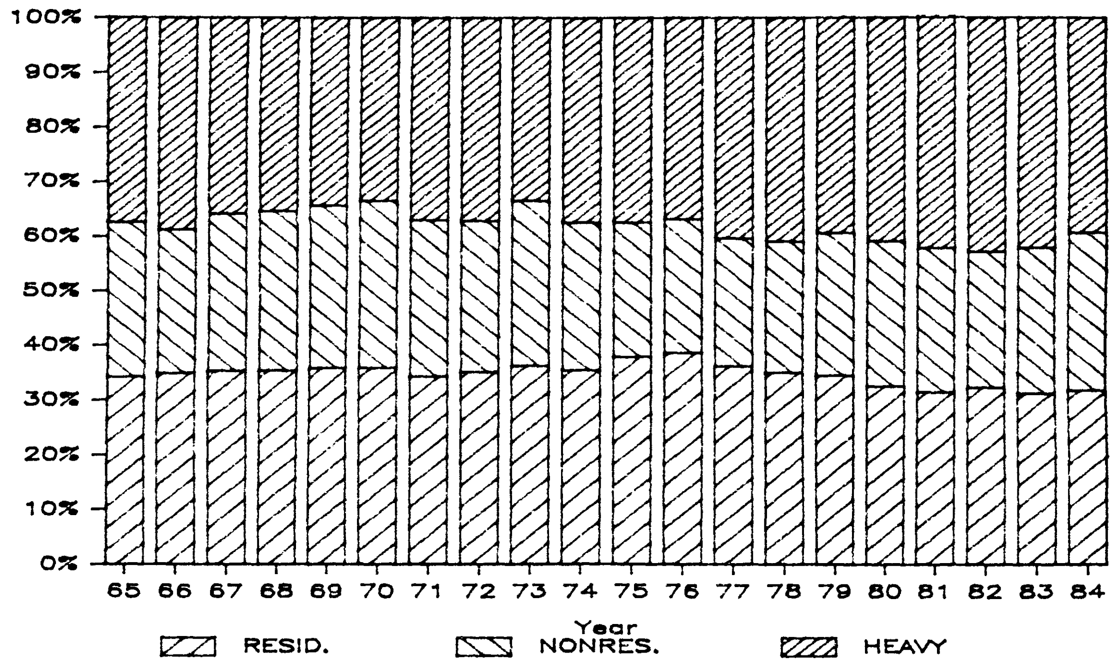
Source: Kensetsu Toukei Youran, 1985, 1975

Figure 2.10 Private vs. Public Construction (U.S.A.)



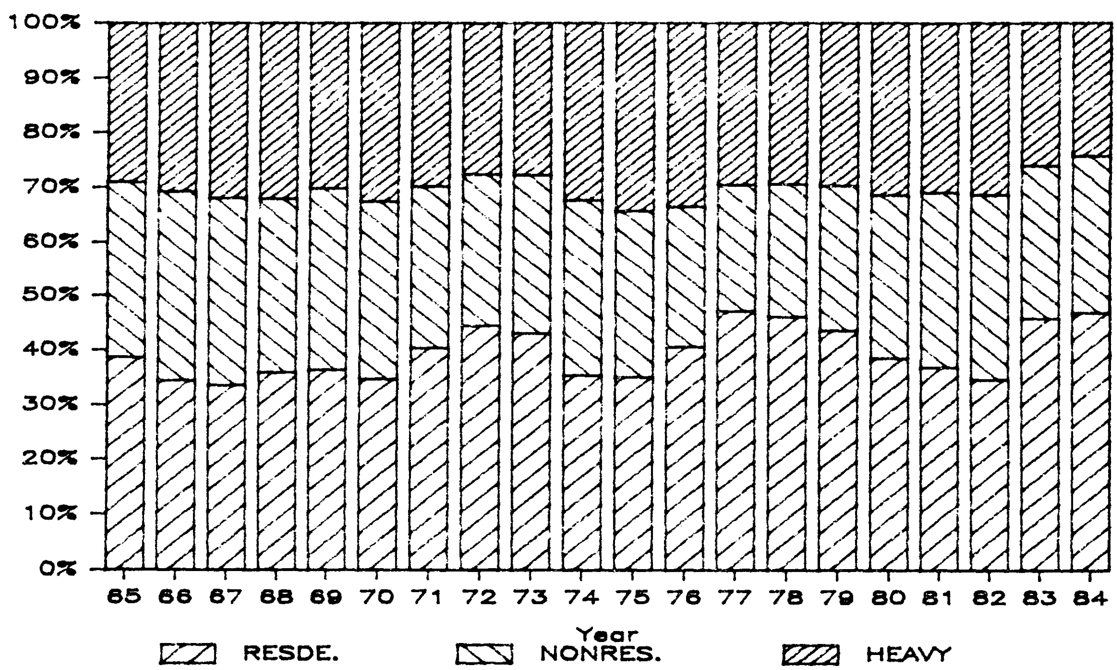
Source: Economic Report of the President, 1986

Figure 2.11 Type of Construction (Japan)



Source: Kensetsu Toukei Youran, 1985, 1975

Figure 2.12 Type of Construction (U.S.A.)



Source: Economic Report of the President, 1986

Table 2.2 shows average and standard deviation of percent increase of each construction investment in real terms. It shows that for residential construction Japan has the least standard deviation while the U.S. has the greatest standard deviation. Other construction activities, non residential building and heavy construction, show less standard deviation in the United States.

Table 2.2 Average and Standard Deviation of Percent Increase by Kind of Construction

(from 1966 to 1983 for Japan)
(from 1966 to 1984 for U.S.A.)

	Japan		The United States	
	Average	S.D.	Average	S.D.
Public	4.86%	10.77	-1.98%	4.48
Private	6.50%	10.53	2.59%	9.51
Heavy Construct.	5.20%	10.68	-0.10%	4.79
BLDG. Construct.	6.23%	9.97	1.37%	9.77
Residential	6.08%	9.36	2.92%	17.26
Non Residential	6.95%	12.35	0.29%	7.04

Note: Percent increase from previous year in real terms.

Source: Kensetsu Toukei Youran, 1985, 1975
Construction Review, 1965 - 1985
Compiled by the author

2.6 Summary of Chapter Two

1) The ratio of construction investment to GDP is almost 20 percent in Japan which is the highest among developed countries and almost twice as much as that of the U.S..
2) Cost escalation of construction industry is relatively higher in Japan.
3) The ratio of construction investment to GDP in real terms has decreased both in Japan and in the United States. It is less significant in the U.S..
4) The ratio of construction investment to GDFCF has decreased significantly in Japan especially in the late 70's.
5) The proportion of public construction used to be about 30 percent of total construction in both countries. Now, however, it has increased in Japan to 40 percent and decreased in the United States to 20 percent.
6) Heavy construction's share is higher in Japan and housing construction's share is higher in the U.S..
7) Except for residential construction, construction investment is more stable in the United States than in Japan.

APPENDIX 1 SNA and NIPA's

System of National Account (SNA) is a system of macroeconomic statistics which record the whole economic activity of the country prepared by Japanese Economic Planning Agency since 1970. SNA is almost the same account system as the National Income and Product Accounts (NIPA's) which is provided by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) for the United States since 1972.

Figures 2.13 and 2.14 show schematic designs of the SNA and NIPA's respectively. In the upper left square of these systems is the use matrix, a matrix that shows commodity input to a kind of economic activity (industry). Every cell in this matrix represents yen (or dollar in the United States) amount of intermediate input of the commodity at the left of the row to the industry at the top of the column. Therefore, the column sum of the matrix is the total intermediate inputs of the industry and the row sum of the matrix shows total intermediate output of the commodity.

In the row of construction commodity, all intermediate output is maintenance and repair construction (M&R) such as rehabilitation and remodeling because the new construction is capitalized as fixed assets which belongs to the final demand sector. In Japan all maintenance and repair construction is classified as intermediate output while in the United States, about 20 percent of the maintenance and repair construction is capitalized and included in Private Domestic Investment in final demand sector.

This use matrix is very similar to the Input-Output table (I-O table), which will be explained later in the third chapter, but not the same because of the difference of the definition of a sector, an industry and a commodity. In a I-O table both columns and rows represent industrial sectors while, in the use matrix, columns and rows represent industries and commodities respectively. An industry category is defined by Miller and Blair as a cluster of establishments as classified by Standard Industrial Classification (SIC) code according to their primary or characteristic products. A commodity is defined as a characteristic product of SIC code whether the product is produced as primary or secondary goods or services. [Miller and Blair, 1985] According to Tiebout, sectors and industries are defined as follows; "industries refer to aggregates of firms producing similar product. Sectors refer to kind of market industries serve" [Tiebout, 1962]. Thus the concept of a sector is that every sector produces only a primary product, and therefore there is no difference between an industry and a commodity. Although the use matrix is theoretically less pure than the I-O table, and, therefore, cannot be used in Input-Output analysis directly, it has several advantages over the I-O table as follows:

1) It require less effort and time to construct.
2) It has greater compatibility with other statistics that are usually provided by the industry.
3) It is useful when analyzing a real industry.
4) Deflators are often provided and therefore numbers can be changed into real terms.

The rectangle below the use matrix shows the value added sector. As SNA employs domestic concept rather than national concept, this shows the structure of Gross Domestic Product of Japan. Value added sector, or GDP, consists mainly of four components: 1) Employees' Compensation, 2) Operation Surplus, 3) Capital Assets Depreciation and 4) Indirect Tax. In the United States, this sector is called "charges against Gross National Product" and operation surplus and capital assets depreciation are combined into profit type income. The column sum of the value added sector of an industry shows the GDP by the industry (or GNP by the industry in the U.S.).

To the right of the use matrix is the final demand sector. It shows the Yen (or $) amount of the commodity purchased by households and government, Capital Formation and Net Export. The total amount of the final demand is the Gross Domestic Expenditure (GDE), or Gross National Product (GNP) in the United States. GDE consists of: 1) Private Final Consumption Expenditure, 2) Government Final Consumption Expenditure (which does not include Public

Capital Formation), 3) Gross Domestic Capital Formation, which includes all construction investment, and 4) Export net of Import. In NIPA's, final demand sector consists of 1) Private Consumption Expenditure, 2) Government Purchase (which does include Public Capital Formation), 3) Gross Private Domestic Investment (which does not include Public Capital Formation) and 4) Export net of import. The row sum of the final demand sector of a commodity is Gross Domestic Expenditure (GDE) by the commodity. The cell at the intersection of the row of construction and the column of Gross Domestic Fixed Capital Formation, which is Gross Domestic Capital Formation net of inventory increase, shows the (domestic) construction investment. GDE is equal to GDP but GDE by the industry is not equal to GDP by the industry (or commodity).

The difference between domestic concept, which is used in Japan, and national concept, which is used in the United States is that the latter includes the net receipt of factor income from the rest of the world. This difference is less than 1 percent both in the United states and in Japan; therefore, in this analysis of the construction industry the difference is negligible.

Figure 2.13 Schematic design of Systems of National Account (SNA)

USE MATRIX — FINAL DEMAND — TOTAL OUTPUT

	INDUSTRY (1)(2)(3)(4)(5)(6)	SUB TOTAL	FINAL DEMAND (E)(F)(G)(H)	SUB TOTAL	TOTAL OUTPUT
(7)					
(8)					
(9)		[b]	0 0 [e] 0	[f]	[h]
(10)					
(11)					
(12)					
SUB TOTAL	[a]		[g]	GDE	

VALUE ADDED

(A)		
(B)		
(C)		
(D)		
SUB TOTAL	[c]	GDP

TOTAL OUTLAY

	[d]	

(1)-(6): Industry
Assume (3) as the Construction Industry
(7)-(12): Commodity
Assume (9) as Construction
(A): Employees' Compensation
(B): Operation Surplus
(C): Capital Consumption
(D): Indirect Tax
(E): Household Final Consumption
(F): Government Final Consumption
(G): Capital Formation
(H): Net Export

[a]: Total Intermediate Input to the Construction Industry
[b]: Total Intermediate Output of Construction
[c]: Value Added by the Construction Industry
=GDP by the Construction Industry
[d]: Total Outlay of Construction Industry
= [a]+[c]
[e]: =Capital Formation of Construction
=Fixed Capital Formation of Construction
=Construction Investment
=Final Demand of Construction
= [f]
[g]: Total Capital Formation
=Fixed Capital Formation + Inventory Change
[h]: Total Output of Construction
= [b]+[e] = [b]+[f]

Figure 2.14 Schematic Design of National Income and Products Accounts (NIPA's)

USE MATRIX / FINAL DEMAND / TOTAL OUTPUT

	INDUSTRY (1)(2)(3)(4)(5)(6)	SUB TOTAL	FINAL DEMAND (E)(F)(G)(H)	SUB TOTAL	TOTAL OUTPUT
(7) (8) (9) (10) (11) (12)		[b]	0 [e][f] 0	[g]	[h]
SUB TOTAL	[a]			GNP	

VALUE ADDED

(A) (B) (C)		
SUB TOTAL	[c]	(D)

TOTAL OUTLAY

	[d]	

(1)-(6): Industry
  Assume (3) as the Construction Industry
(7)-(12): Commodity
  Assume (9) as Construction
(A): Employees' Compensation
(B): Profit type Income
(C): Indirect Tax
(D): Charges Against GNP
(E): Personal Consumption Expenditure
(F): Government Purchase
(G): Capital Formation
(H): Net Export

[a]: Total Intermediate Input to the Construction Industry
[b]: Total Intermediate Output of Construction
  = approximately 80% of M&R Construction
[c]: Value Added by the Construction Industry
  = GNP by the Construction Industry
[d]: Total Outlay of Construction Industry
  = [a]+[c]
[e]: Construction by Public Sector
[f]: Construction by Private Sector
[g]: Total Construction Investment
  = Fixed Capital Formation + Inventory Change
  = [e]+[f]
[h]: Total Output of the Construction Industry
  = [b]+[g] = [b]+[e]+[f]

CHAPTER 3 INPUT-OUTPUT ANALYSIS

3.1 Introduction

In this chapter, the construction industry is analyzed using the framework of Input-Output analysis to find the structural similarities and differences between the construction industries of the United States and Japan and to identify their changes from the point of time horizons.

Fundamentals of the Input-Output analysis and definitions of terms used in this chapter are provided in appendix two at the end of this chapter.

3.2 Input Pattern of Construction Industry

Direct input requirement of the United States and Japanese construction industry are shown in table 3.1 and table 3.2 respectively. In general, the input pattern of the Japanese construction industry has changed significantly during the twenty years from 1960 to 1980 whereas that of the United States appears stable during the thirty years from 1947 to 1977.

In Japan, on the one hand, direct input from manufacturing industry has significantly decreased. While on the other hand, direct input from other industry have generally increased. Particularly, direct input from the value added sector, the service industry, financial services and the trade and transportation has increased significantly.

Table 3.1 Direct-Input Requirements of Construction Industry

(Japan)

Sector \ Year	1960	1965	1970	1975	1980
Agriculture	0.0081	0.0024	0.0015	0.0011	0.0015
Mining	0.0160	0.0316	0.0216	0.0193	0.0201
Manufacturing	0.5203	0.4220	0.4479	0.3634	0.3760
Construction	0.0010	0.0009	0.0014	0.0002	0.0011
Utility	0.0023	0.0056	0.0048	0.0068	0.0091
Finance	0.0576	0.0745	0.0744	0.0783	0.0801
Transportation	0.0415	0.0426	0.0338	0.0503	0.0418
Service	0.0061	0.0077	0.0190	0.0223	0.0339
N.A.D. (1)	0.0311	0.0132	0.0178	0.0232	0.0074
SUB TOTAL	0.6842	0.6278	0.6221	0.5650	0.5775
Value Added	0.3158	0.3722	0.3779	0.4350	0.4225
TOTAL	1	1	1	1	1

N.B.: (1) Not adequately distributed.

Source: Minami, 1986.

Table 3.2 Direct-Input Requirements of Construction Industry (U.S.A.)

Sector \ Year	1947	1958	1963	1967	1972	1977
Agriculture	0.0031	0.0034	0.0038	0.0025	0.0028	0.0035
Mining	0.0094	0.0109	0.0086	0.0090	0.0090	0.0091
Construction	0.0002	0.0001	0.0003	0.0003	0.0003	0.0011
Manufacturing	0.3795	0.3831	0.3703	0.3637	0.3521	0.3720
T & T (1)	0.1324	0.1219	0.1147	0.1049	0.1014	0.1096
Service	0.0634	0.0615	0.0671	0.0765	0.0731	0.0792
Other	0.0011	0.0014	0.0012	0.0008	0.0028	0.0032
SUB TOTAL	0.5893	0.5823	0.5661	0.5577	0.5415	0.5778
Value Added	0.4107	0.4177	0.4339	0.4423	0.4585	0.4222
TOTAL INPUT	1	1	1	1	1	1

N.B.: (1) Trade and Transportation.

Source: Miller and Blair, 1985.

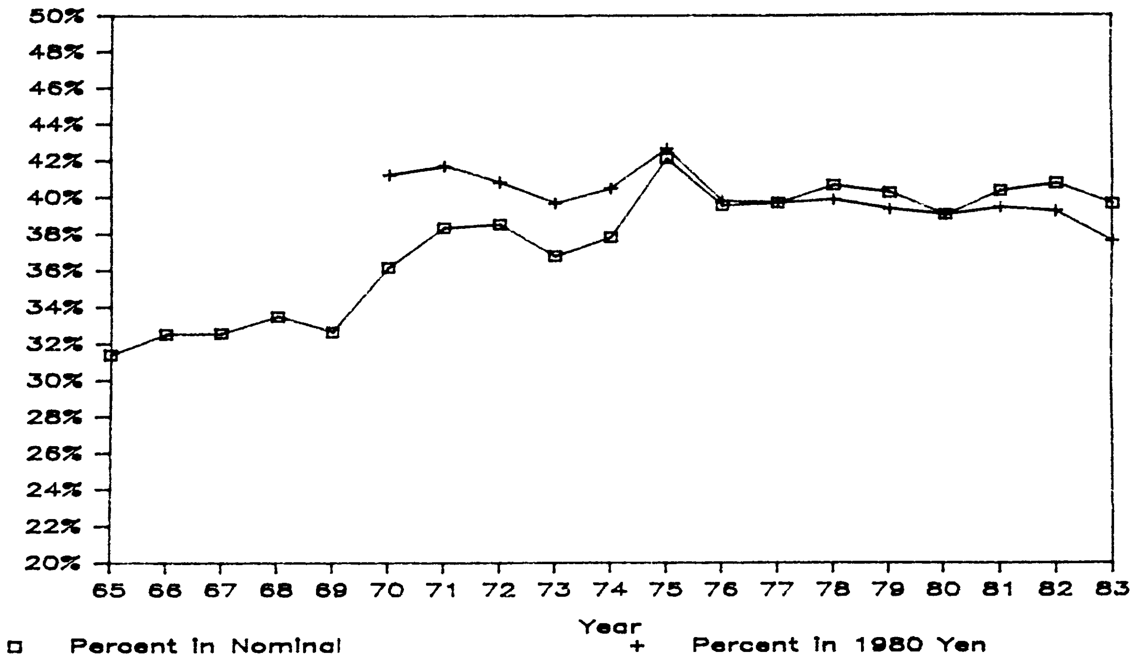
The input from manufacturing industry has decreased from 52.03 percent in 1960 to 36,34 percent in 1975 and has slightly increased to 37.60 percent in 1980. This decrease is almost offset by the increasing input from value added sector. It has increased from 31.58 percent in 1960 to 43.50 percent in 1975 and slightly decreased to 42.25 percent in 1980.

These two changes in the input structure seem to be inconsistent with the industrialization of construction industry such as prefabrication that might have increased the input from the manufacturing industry and decreased the labor at site, i.e., input from the value added sector.

However, as direct input requirement is counted by nominal Yen amount, it is hard to say whether these changes came from technical changes or from changes in relative price of products and wages. In order to identify it, numbers should be changed into real terms.

In figure 3.1 total intermediate input and value added are expressed in 1980 constant yen by using the deflators provided by Japanese Economic Planning Agency since 1970. It indicates that the proportion of value added has decreased from 41.2 percent in 1970 to 37.5 percent in 1983 despite it's increase in nominal terms.

Figure 3.1 Proportion of Value Added Sector to Total Output



Source: Annual Report of National Accounts, 1975,1985
Compiled by the author

This decrease in real terms accords with the active industrialization and increasing productivity in Japanese construction industry. Thus, the difference in deflators between intermediate input and value added, especially the cost escalation of wages which is described in chapter two is so great that deforms the input structure, in the next two section, value added sector and intermediate input from other sectors are discussed independently.

3.3 Components of Value Added Sector

As mentioned in appendix one at the end of chapter two, value added sector can be disaggregated into a few components. In Japan, they are employees' compensation, operation surplus, capital consumption and indirect tax. By analyzing these numbers, labor intensity or capital intensity of a sector can be observed.

The components of value added are shown in table 3.3. In this table, as earnings of self employed workers are included in the operation surplus and they constitute a considerable part of the total construction workers, which will be discussed in chapter four, it is hard to find total employees' compensation. However, the obvious increase of capital consumption is observed both in building, including maintenance and repair construction, and heavy construction. In building construction, it has increased from 3.96 percent in 1960 to 7.66 percent in 1980. In the heavy construction, it has increased from 6.83 percent in 1960 to 15.6 percent in 1970 and decreased slightly afterwards reflecting the downward economy after the oil crisis. This increased capital consumption indicates active investment in construction machinery by Japanese construction firms especially in the so-called "High Growth Era" before the oil crisis. Unfortunately, these data are not available for the United States.

Table 3.3 Component of Value Added in Percent (Japan)

Building construction (including M&R construction)

Component of V.A. \ Year	60	65	70	75	80
Exp. outside Household	4.23%	9.64%	7.59%	6.54%	6.07%
Compensation to Emp.	45.14%	52.81%	42.99%	46.95%	51.34%
Operation Surplus	45.83%	30.71%	39.28%	36.36%	32.17%
Capital Consumption	3.96%	4.17%	7.60%	7.42%	7.62%
Indirect Taxes	0.78%	2.66%	2.54%	2.74%	2.80%
Subsidy	0.00%	0.00%	0.00%	0.00%	0.00%
Value Added Total	100.00%	100.00%	100.00%	100.00%	100.00%

Heavy Construction

Component of V.A. \ Year	60	65	70	75	80
Exp. outside Household	3.69%	8.30%	5.71%	5.57%	4.67%
Compensation to Emp.	45.42%	68.29%	56.05%	57.78%	65.69%
Operation Surplus	43.39%	13.40%	21.18%	20.91%	15.97%
Capital Consumption	6.83%	8.43%	15.61%	15.12%	12.26%
Indirect Taxes	0.65%	1.57%	1.64%	1.58%	2.02%
Subsidy	0.00%	0.00%	-0.06%	-0.96%	-0.62%
Value Added Total	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Annual Report on National Accounts, 1963 - 1985

Compiled by the author

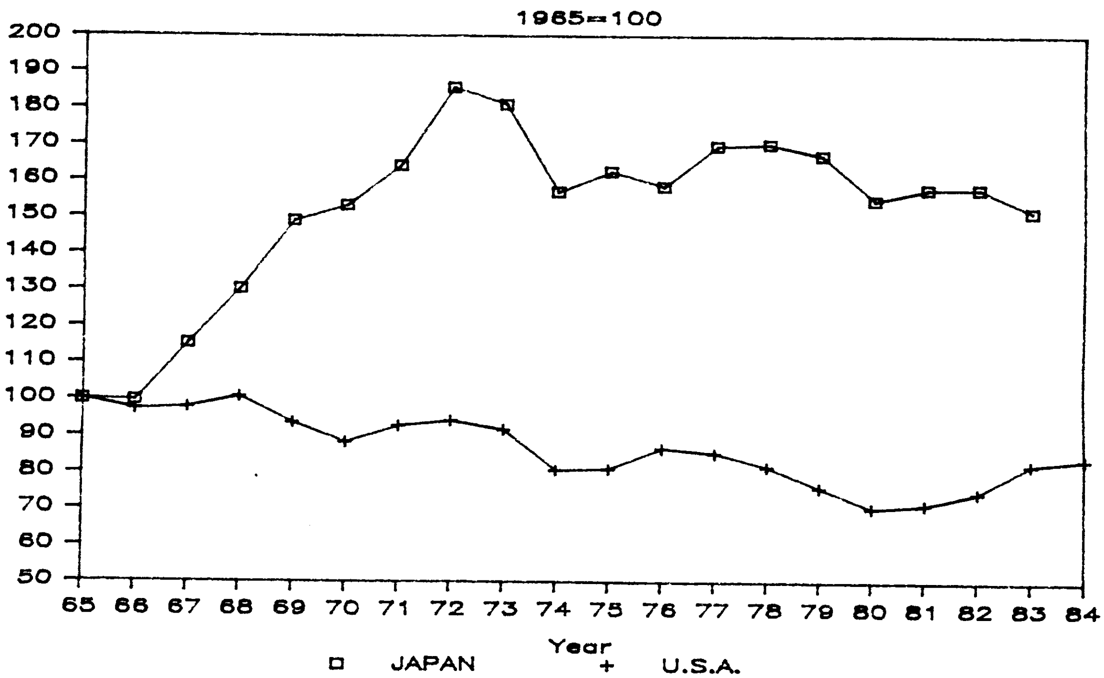
3.4 Construction Investment per Worker

Simultaneously with this capital investment by the Japanese construction industry, the productivity of worker, which is defined as construction investment per worker in real terms, has sharply increased. It has almost doubled from 5,483,000 yen per worker in 1965 to 10,482,000 yen per worker in 1972 in 1980 constant yen. In the U.S., however, productivity does not show such increase during the last 20 years. Rather, it has declined slightly with some cyclical fluctuations. Figure 3.2 shows workers productivity assuming that of 1965 is 100. It trace almost the same line as capital consumption by the Japanese construction industry. Capital intensity of construction establishments is discussed further in chapter four.

3.5 Changes in Intermediate Input

As described earlier in this chapter, the increasing unit cost of labor deforms the direct input requirements of Japanese construction industry and makes it difficult to find changes in intermediate input structure. In order to make them clearer, more detailed share of intermediate input to the total intermediate input are prepared by tables in appendix three at the end of this chapter. These tables are constructed from 72 sector tables of Japan and 82 sector tables of the United States. The major changes observed in the two countries are summarized in table 3.4.

Figure 3.2 Construction Investment per Worker



Source: Kensetsu Toukei Youran, 1975, 1985
Construction Review, 1965 - 1985

Compiled by the author

Table 3.4 Changes in Intermediate Input Structure

TREND	JAPAN	U.S.A.
INCREASE	Metal product Misc.ind.product Trade & transportation Service Utility (electricity) Finance & Insurance	Lumber & Wood Electric machinery Service
DECREASE	Wood Steel & Iron Electric machinery Other	Furniture Paint Stone & clay product Metal product Steel and Iron Transportation Other

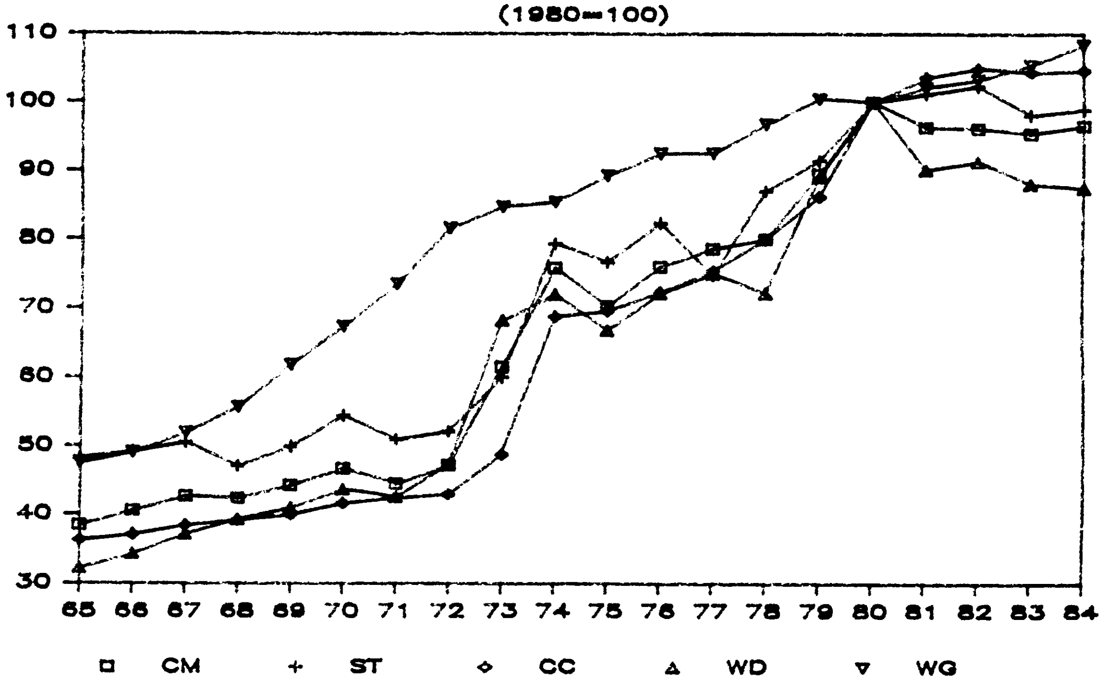
Source : Economic Statistics Annual
Survey of Current Business
Compiled by the author

Although these changes are less significant in the United States, they make a clear contrast. Only input from the service sector has increased both in Japan and in the U. S.. In Japan, it has increased from 0.8 percent in 1960 to 5.0 percent in 1980, and in the U.S. it has increased from 6.7 percent in 1947 to 9.9 percent in 1977. To be more concrete, input from service sector consists of architectural design, engineering, construction management and testing laboratories.

The increasing input from the service sector represents the better quality required for construction in recent years. Although this trend is more significant in Japan where it has quadrupled in twenty years, it is still about one half of that of the U.S..

Only input from steel and iron primary product is decreasing both in Japan and in the U.S.. In Japan, it has decreased from 11.5 percent in 1960 to 5.4 percent in 1980. This decrease is almost replaced by the increase of metal product which has increased from 11.65 percent in 1960 to 19.2 percent in 1980. It has lost its share from 6.6 percent in 1947 to 3.9 percent in 1977 in the U.S.. In general, the use of primary steel products is greater in Japan reflecting the heavy construction oriented market structure and the structural requirement by the earthquakes. Nevertheless, this trend of decreasing input of primary steel product is mainly contributed by its low cost escalation rate because the input of cement and ready mixed concrete, which is the other material to form reinforced concrete structure and belongs to the non-metal mineral sector in Japan and the stone and clay product in the United States, stays almost constant in both countries. In fact, as shown in figure 3.3, the escalation of steel and iron price index is less than that of the total construction material.

FIGURE 3.3 Wholesale Price Index of Construction Material and Wage Index in Japan



CM: Construction Material ST: Steel and Iron
CC: Cement and Ceramics WD: Wood and Lumber
WG: Wage of Construction Worker

Source: Economic Statistics Annual

Compiled by the author

However, in Japanese non residential building the use of concrete also is declining and the use of metal products, of which fabricated steel structure constitutes almost 70 percent, have increased by 170 percent during the period. It indicates that the steel structure is replacing rein forced concrete structure in non-residential buildings.

Intermediate input from wood and lumber sector shows an interesting contrast between the two countries. It has increased from 9.7 percent in 1947 to 13.8 percent in 1977 in the U.S. while that of Japan has decreased from 22.1 percent in 1960 to 13.2 percent in 1980. In the United States, both in 1977 and 1972, the economy enjoyed its peak and housing construction increased dramatically. This active housing construction obviously affected the increased inputs from the wood and lumber sector. In Japan, although most homes are traditionally made of wood and the use of wood showed high proportion in the construction industry, almost 60 percent of total wood is imported from foreign countries, of which 50 percent comes from the U.S.. It is by far the greatest imported product used in the construction industry. However, the relative expensive price of wood discourages its use of wood even in housing construction. Moreover, the increasing proportion of prefabricated houses, which was 15 percent in 1975 and 25 percent in 1984 has also accelerated this trend. As a result, the ratio of total floor area of wooden structure to the total floor area constructed has decreased from 41.6 percent in 1982 to 36.2 percent in 1984. [Kensetsu Hakusho, 1985]

To find more general changes of the input pattern of the construction industry, aggregated tables are provided in appendix three at the end of this chapter. In these tables intermediate tangible input are classified by the degree of processing rather than the kind of material. Aggregated eight sectors of these tables are;

1) Material and less processed product
2) Processed product
3) Machinery
4) Utility (Electric power supply)
5) Trade and transportation
6) Finance and Insurance
7) Service
8) Other

In the United States, almost no significant change except for the increased input from service sector is observed while considerable changes can be observed in Japan especially in building construction.

First of all, on the one hand, input of material and less processed product have decreased from 47.4 percent in 1960 to 37.0 percent in 1980 in total construction or from 52.6 percent in 1960 to 34.3 percent in 1980 for building construction which includes maintenance and repair construction. On the other hand, input of processed products has increased from 15.3 percent to 20.6 percent in total construction or from 16.1 percent to 26.8 percent in building construction during the same period. As a result, the rate of processed products to material and less processed product has increased from about 30 percent in 1960 to 55 percent in 1980 in total construction and from 30 percent to 80 percent in building construction. In the United States this rate stays constant at about 50 percent for total construction and 80 percent in the building construction. This increase of processed product shows rapid industrialization of construction industry in Japan. As a result, the input structure of the construction industry became very similar in these two countries throughout the late 70's.

3.6 Total requirement and Output Multiplier

"Total requirement (direct and indirect input requirement) shows how much the total dollar production is required from the industry at the top for each dollar of delivery to final demand sector by the industry at the left." [Miernyk, 1965]. The column sum of this matrix, which is called output multiplier, shows total production required to increase the sectors output by a unit. In general, labor intensive industries such as service, mining and agriculture in Japan show low output multipliers. Tables 3.5 and 3.6 show output multipliers of Japan and the U.S.. Japanese construction industry used to have relatively high output multiplier. It was 2.701 in 1960 and was second only to the manufacturing industry whose output multiplier was 2.704. This high output multiplier has decreased to about 2.4 by 1965 and has remained almost constant up until 1980.

Table 3.5 Output Multipliers (Japan)

YEAR	AGR	MIN	MANU	CONST	UTIL	FINC	TANS	SERV	N.A.D.
60	1.701	1.725	2.704	2.701	1.769	1.470	1.759	1.522	2.558
65	1.734	1.741	2.535	2.359	1.665	1.410	1.651	1.494	2.374
70	1.779	1.760	2.550	2.427	1.719	1.447	1.619	1.752	2.080
75	1.880	2.056	2.654	2.362	2.131	1.491	2.347	1.775	2.862
80	2.119	2.126	2.779	2.427	2.252	1.520	2.464	1.886	3.268

Source: Economic Statistics Annual

Table 3.6 Output Multipliers (U.S.A.)

YEAR	AGR	MIN	CONST	MANU	T&T	SERV	OTHR	AVE.
47	2.113	1.565	2.220	2.319	1.524	1.804	1.898	1.920
58	2.143	1.624	2.204	2.286	1.562	1.782	2.066	1.952
63	2.216	1.677	2.156	2.272	1.523	1.697	1.927	1.924
67	2.239	1.687	2.127	2.238	1.538	1.684	1.832	1.907
72	2.295	1.680	2.085	2.254	1.464	1.608	1.108	1.785
77	2.338	1.675	2.208	2.354	1.573	1.648	1.144	1.848

Source: Survey of Current Business

Compiled by the author

Table 3.7 Influencing Power Coefficients (Japan)

YEAR	AGR	MIN	MANU	CONST	UTIL	FINC	TANS	SERV	N.A.D.
60	0.855	0.867	1.359	1.358	0.889	0.739	0.884	0.765	1.286
65	0.920	0.924	1.345	1.252	0.883	0.748	0.876	0.793	1.260
70	0.934	0.924	1.340	1.275	0.903	0.760	0.851	0.920	1.093
75	0.865	0.946	1.221	1.087	0.980	0.686	1.080	0.817	1.317
80	0.915	0.918	1.200	1.048	0.973	0.656	1.064	0.814	1.411

Source: Economic Statistics Annual

Compiled by the author

Table 3.8 Influencing Power Coefficients (U.S.A.)

YEAR	AGR	MIN	CONST	MANU	T&T	SERV	OTHR	AVE.
47	1.100	0.815	1.156	1.208	0.793	0.939	0.988	1.000
58	1.098	0.832	1.129	1.171	0.800	0.913	1.058	1.000
63	1.152	0.872	1.121	1.181	0.792	0.882	1.002	1.000
67	1.174	0.885	1.116	1.174	0.807	0.883	0.961	1.000
72	1.286	0.941	1.168	1.263	0.820	0.901	0.621	1.000
77	1.265	0.906	1.195	1.273	0.851	0.891	0.619	1.000

Source: Survey of Current Business

Compiled by the author

During this period, however, other sectors such as agriculture, mining, utility. and trade, have increased their output multiplier almost by 25 percent. As a result, the relative importance of the construction industry has declined during the last two decades.

Miyazawa defines the influencing power coefficient as the output multiplier divided by mathematical average of output multiplier of all industries [Miyazawa ed., 1975]. In this coefficient, the size of the sector is ignored and, therefore, it is not adequate for comparing two countries. However, it might be useful to find changes in a country.

Tables 3.7 and 3.8 show influencing power coefficient of Japan and the U.S.. The influencing power coefficient of Japanese construction industry shows sharp decline from 1.36 to 1.20 while that of the U.S. has increased slightly from 1.16 to 1.19 during the last three decades. Despite this sharp declining influencing power coefficient, the output multiplier does not show such decline mainly due to increasing output multiplier of other sectors especially that of the manufacturing industry which has increased from 2.55 in 1970 to 2.78 in 1980.

The relative high output multiplier is one distinguishing feature of Japanese sectors in general. The average output multiplier of Japanese sectors is 2.32 whereas that of the United States is 1.85. It might be related to the dual structure which is frequently pointed out as characteristic of Japanese industry especially in

Manufacturing industry. Dual structure refers to the subcontracting system which is employed to give stiff organization characterized by lifetime employment system and seniority system flexibility by subcontracting a considerable proportion of production. It, therefore, appears in the cell of total requirement from manufacturing industry to manufacturing industry. In the most recent tables it is 2.04 in Japan and 1.73 in the U.S..

3.7 Summary of Chapter Three

1) Inter-industry structure is more stable in the United States than in Japan.
2) Value added in construction industry has increased due to cost escalation of labor cost in Japan.
3) Intermediate input structure indicate the active industrialization of Japanese construction industry.
4) In the most recent I-O tables, the U.S. and Japanese construction industries shows similar structure.
5) The proportion of less processed product and processed product in intermediate input shows that degree of industrialization in Japan exceeds that of the U.S..
6) Output multiplier shows declining effect of construction industry to the total industry.

APPENDIX 2 INPUT-OUTPUT ANALYSIS

Input-Output analysis was first developed by Wassily Leontief in 1936. The structure of Input-Output tables (I-O tables), which forms the basis of this analysis, is almost the same as SNA and NIPA's which are explained earlier in chapter one. The difference is that I-O tables use the concept of sector rather than concept of industry and commodity so that the row sum (output of a sector) is always equal to the column sum (outlay of a sector). It makes the I-O tables a powerful tool for analyzing industries by construction matrices such as A matrix and (I-A) inverse matrix.

Input-output tables show flows of commodity and services in monetary terms. A column of a I-O table shows input to the sector at the top of the column from sectors of the row at the left. Input to a sector consists mainly of two kinds of input; One is intermediate input from processing sector and the other is input from value added sector such as compensation to employees.

A row in a I-O table shows out put of a sector at the left of the row to the sector at the top of the column. Output of a sector also consists mainly of two kinds of output; One is intermediate output to processing sectors and the other is output to final demand sectors such as private consumption expenditure.

Direct-input coefficient matrices is constructed from a I-O table by dividing intermediate input and value added by the total outlay of a sector (or by column normalizing the I-O tables). Direct-input coefficient is denoted by a_{ij} and the direct-input coefficient matrix is denoted by $A=[a_{ij}]$. It shows the input structure or price structure of a sector. Each cell in the A matrix shows intermediate inputs per unit production of a sector at the top of the column. The column sum of the direct-input coefficient of intermediate input is called "Backward Linkage", showing the proportion of intermediate input to the total output of a sector.

Inverse matrices of direct-input coefficient matrices show direct and indirect impact by increasing the total output of a sector by a unit while the aforementioned direct-input coefficient matrices only show direct impact of increasing the total output by unit. Secondary and tertiary effect of increasing output can be expressed by the power series of $I+A^1+A^2+A^3$ .... which is mathematically given by (I-A) inverse matrix, where I is the identity matrix. This matrix is also known by the name of Leontief's Inverse. The column sum of this matrix shows direct and indirect intermediate input generated by increasing the output of the sector by a unit and is thus called the Output Multiplier.

Direct-output coefficient matrices are given by dividing intermediate output of sectors by the total output of the sectors (or by row normalizing the I-O tables). Direct-output coefficient is denoted by b_{ij} and the direct-output coefficient matrix is denoted by $B=[b_{ij}]$. This matrices show the output structure of sectors. The row sum of the matrix is called "Forward Linkage" of the sector, showing the proportion of intermediate output to the total output of the sector. In the construction sector, intermediate output consists of maintenance and repair construction.

Table 3.9 Intermediate Input Structure (Japan)

Building Construction (including M&R Construction)

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Other mining	23.4	75.8	99.9	162.7	192.0
	1.7%	2.7%	1.4%	1.3%	1.0%
(M)Miscellaneous fabric	30.0	53.5	78.3	207.5	323.9
	2.2%	1.9%	1.1%	1.6%	1.6%
(M)Wood milling	302.3	534.0	1209.1	1785.2	2658.6
	22.1%	18.8%	17.1%	13.9%	13.2%
(P)Furniture	36.8	103.2	253.1	583.1	879.9
	2.7%	3.6%	3.6%	4.5%	4.4%
(M)Chemicals	15.2	25.7	50.6	110.7	181.0
	1.1%	0.9%	0.7%	0.9%	0.9%
(M)Petrol. product	11.0	24.5	96.9	33.4	85.7
	0.8%	0.9%	1.4%	0.3%	0.4%
(M)Nonmetal-mineral	187.8	403.9	1022.5	1612.0	2369.2
	13.7%	14.3%	14.5%	12.5%	11.8%
(M)Steel	147.1	198.4	432.0	707.7	838.2
	10.7%	7.0%	6.1%	5.5%	4.2%
(P)Non-ferrous product	5.4	7.8	7.4	125.0	239.1
	0.4%	0.3%	0.1%	1.0%	1.2%
(P)Metal product	158.2	418.9	1232.3	2320.0	3872.0
	11.6%	14.8%	17.5%	18.0%	19.3%
Machinery	59.5	99.8	197.6	257.7	470.1
	4.3%	3.5%	2.8%	2.0%	2.3%
Eclectic machinery	56.1	123.4	289.4	685.5	618.9
	4.1%	4.4%	4.1%	5.3%	3.1%
Transp. machinery	13.0	13.1	45.3	4.6	200.0
	0.9%	0.5%	0.6%	.0%	1.0%
(P)Misc.indust.product	25.5	56.6	173.4	349.3	634.4
	1.9%	2.0%	2.5%	2.7%	3.2%
Electric powersuply	2.0	11.9	27.4	94.9	171.8
	0.1%	0.4%	0.4%	0.7%	0.9%
Trade	103.3	301.2	732.0	1479.8	2433.2
	7.5%	10.6%	10.4%	11.5%	12.1%
Finance&Insurance	16.5	48.1	113.6	299.6	370.3
	1.2%	1.7%	1.6%	2.3%	1.8%
Real estate rent			25.2	88.7	214.5
	0.0%	0.0%	0.4%	0.7%	1.1%
Transportation	63.8	146.9	297.6	983.4	1295.4
	4.7%	5.2%	4.2%	7.6%	6.4%
Community service	0.9	11.7	11.4	32.4	135.8
	0.1%	0.4%	0.2%	0.3%	0.7%
Service	10.7	19.1	216.6	460.3	904.5
	0.8%	0.7%	3.1%	3.6%	4.5%
Other sectors	100.2	156.9	447.3	482.4	997.9
	7.3%	5.5%	6.3%	3.7%	5.0%
TOTAL INTEMED. INPUT	1368.6	2834.4	7058.7	12865.9	20086.4
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Economic Statistics Annual, Compiled by the author

Table 3.9 Intermediate Input Structure (Japan, Cont'd)

Heavy Construction

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Other mining	27.6	134.2	250.6	496.3	920.6
	3.4%	10.1%	8.2%	7.8%	7.8%
(M)Miscellaneous fabric	1.2	0.6	3.9	23.1	11.8
	0.1%	.0%	0.1%	0.4%	0.1%
(M)Wood milling	40.2	50.0	50.2	110.6	200.0
	5.0%	3.7%	1.6%	1.7%	1.7%
(P)Furniture	0.8	2.8	0.0	32.9	54.2
	0.1%	0.2%	0.0%	0.5%	0.5%
(M)Chemicals	0.7	2.5	10.1	34.8	60.3
	0.1%	0.2%	0.3%	0.5%	0.5%
(M)Petrol. product	28.7	45.9	95.0	23.0	232.7
	3.6%	3.4%	3.1%	0.4%	2.0%
(M)Nonmetal-mineral	105.5	191.4	537.0	1301.0	2397.8
	13.1%	14.3%	17.6%	20.4%	20.3%
(M)Steel	104.0	138.3	310.9	622.9	890.5
	12.9%	10.4%	10.2%	9.8%	7.5%
(P)Non-ferrous product	2.1	1.9	1.0	283.5	429.4
	0.3%	0.1%	.0%	4.4%	3.6%
(P)Metal product	106.8	146.3	341.4	597.4	987.7
	13.2%	11.0%	11.2%	9.4%	8.4%
Machinery	17.4	55.2	177.7	322.7	816.5
	2.2%	4.1%	5.8%	5.1%	6.9%
Eclectic machinery	110.5	163.7	291.3	55.3	166.1
	13.7%	12.3%	9.5%	0.9%	1.4%
Transp. machinery	31.9	20.8	57.2	7.2	816.5
	4.0%	1.6%	1.9%	0.1%	6.9%
(P)Misc.indust.product	4.1	7.0	13.7	55.8	132.6
	0.5%	0.5%	0.4%	0.9%	1.1%
Electric powersuply	2.8	11.5	20.8	80.6	165.9
	0.3%	0.9%	0.7%	1.3%	1.4%
Trade	51.6	113.6	273.3	529.8	1041.6
	6.4%	8.5%	8.9%	8.3%	8.8%
Finance&Insurance	10.8	30.1	67.7	181.3	254.6
	1.3%	2.3%	2.2%	2.8%	2.2%
Real estate rent			29.4	80.6	107.6
	0.0%	0.0%	1.0%	1.3%	0.9%
Transportation	49.2	92.6	166.1	613.0	813.7
	6.1%	6.9%	5.4%	9.6%	6.9%
Community service	0.6	8.5	5.6	13.0	85.5
	0.1%	0.6%	0.2%	0.2%	0.7%
Service	7.4	11.6	75.0	218.7	701.1
	0.9%	0.9%	2.5%	3.4%	5.9%
Other sectors	104.0	105.5	277.9	701.7	535.3
	12.9%	7.9%	9.1%	11.0%	4.5%
TOTAL INTEMED. INPUT	808.0	1334.0	3055.8	6385.2	11822.2
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Economic Statistics Annual, Compiled by the author

Table 3.9 Intermediate Input Structure (Japan, Cont'd)

Total Construction

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Other mining	51.0	210.0	350.5	659.0	1112.6
	2.3%	5.0%	3.5%	3.4%	3.5%
(M)Miscellaneous fabric	31.2	54.1	82.2	230.7	335.7
	1.4%	1.3%	0.8%	1.2%	1.1%
(M)Wood milling	342.5	584.0	1259.3	1895.9	2858.6
	15.7%	14.0%	12.5%	9.8%	9.0%
(P)Furniture	37.6	106.1	253.1	616.0	934.1
	1.7%	2.5%	2.5%	3.2%	2.9%
(M)Chemicals	15.9	28.2	60.7	145.5	241.4
	0.7%	0.7%	0.6%	0.8%	0.8%
(M)Petrol. product	39.8	70.4	191.9	56.4	318.5
	1.8%	1.7%	1.9%	0.3%	1.0%
(M)Nonmetal-mineral	293.4	595.3	1559.4	2913.1	4767.0
	13.5%	14.3%	15.4%	15.1%	14.9%
(M)Steel	251.1	336.7	742.8	1330.6	1728.7
	11.5%	8.1%	7.3%	6.9%	5.4%
(P)Non-ferrous product	7.4	9.8	8.4	408.5	668.5
	0.3%	0.2%	0.1%	2.1%	2.1%
(P)Metal product	265.0	565.2	1573.7	2917.3	4859.6
	12.2%	13.6%	15.6%	15.2%	15.2%
Machinery	76.9	155.0	375.3	580.3	1286.6
	3.5%	3.7%	3.7%	3.0%	4.0%
Eclectic machinery	166.6	287.0	580.7	740.8	785.0
	7.7%	6.9%	5.7%	3.8%	2.5%
Transp. machinery	44.9	33.8	102.5	11.7	1016.6
	2.1%	0.8%	1.0%	0.1%	3.2%
(P)Misc.indust.product	29.6	63.5	187.1	405.0	767.0
	1.4%	1.5%	1.8%	2.1%	2.4%
Electric powersuply	4.8	23.4	48.2	175.5	337.8
	0.2%	0.6%	0.5%	0.9%	1.1%
Trade	154.9	414.9	1005.3	2009.6	3474.9
	7.1%	10.0%	9.9%	10.4%	10.9%
Finance&Insurance	27.3	78.2	181.3	480.9	624.8
	1.3%	1.9%	1.8%	2.5%	2.0%
Real estate rent	0.0	0.0	54.6	169.3	322.1
	0.0%	0.0%	0.5%	0.9%	1.0%
Transportation	113.0	239.6	463.7	1596.3	2109.2
	5.2%	5.7%	4.6%	8.3%	6.6%
Community service	1.5	20.2	17.0	45.5	221.3
	0.1%	0.5%	0.2%	0.2%	0.7%
Service	18.1	30.6	291.5	679.1	1605.6
	0.8%	0.7%	2.9%	3.5%	5.0%
Other sectors	204.3	262.5	725.2	1184.1	1533.2
	9.4%	6.3%	7.2%	6.2%	4.8%
TOTAL INTEMED. INPUT	2176.6	4168.4	10114.4	19251.1	31908.6
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Economic Statistics Annual, Compiled by the author

able 3.10 Intermediate Input Structure (U.S.A.)

New Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Stone & Clay Mine		478	670	1030	1074
	1.8%	1.2%	1.4%	1.4%	0.9%
(M)Lumber & Wood		3553	4550	8896	16086
	9.7%	9.0%	9.5%	11.9%	13.8%
(P)Furniture		526	565	641	906
	1.5%	1.3%	1.2%	0.9%	0.8%
(M)Chemicals		201	136	328	399
	1.1%	0.5%	0.3%	0.4%	0.3%
(M)Paints		308	456	563	1573
	0.6%	0.8%	0.9%	0.8%	1.3%
(M)Petrol. product		1119	1400	1995	4771
	2.9%	2.8%	2.9%	2.7%	4.1%
(M)Stone & Clay product		5813	6177	9313	12630
	12.1%	14.7%	12.9%	12.5%	10.8%
(M)Steel		2125	1456	2469	4569
	6.6%	5.4%	3.0%	3.3%	3.9%
(M)Non-ferrous Metals		1244	2155	2516	2782
	2.6%	3.1%	4.5%	3.4%	2.4%
(P)Metal product		7246	9378	14041	17443
	15.4%	18.3%	19.5%	18.8%	14.9%
Machinery		952	1233	1623	2346
	4.5%	2.4%	2.6%	2.2%	2.0%
Eclectic machinery		2177	2541	4321	7417
	4.4%	5.5%	5.3%	5.8%	6.3%
(P)Misc.indust. product		89	111	174	390
	0.2%	0.2%	0.2%	0.2%	0.3%
Utility		205	64	154	603
	0.4%	0.5%	0.1%	0.2%	0.5%
Trade		5453	6503	10065	17064
	14.7%	13.8%	13.5%	13.5%	14.6%
Finance & Insurance		401	572	748	1843
	1.3%	1.0%	1.2%	1.0%	1.6%
Real estate rent		307	599	709	451
	0.6%	0.8%	1.2%	1.0%	0.4%
Transportation		2143	2135	3322	4377
	5.3%	5.4%	4.4%	4.5%	3.7%
Service		2959	4382	7669	14161
	7.6%	7.5%	9.1%	10.3%	12.1%
Other sectors		2330	2950	4036	5939
	6.8%	5.9%	6.1%	5.4%	5.1%
TOTAL INTERMED. INPUT		39629	48033	74613	116824
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Survey of Current Business
Compiled by the Author

Table 3.10 Intermediate Input Structure (U.S.A., Cont'd)

Maintenance and Repair Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Stone & Clay Mine		259	261	377	969
	2.0%	3.0%	2.7%	2.5%	2.7%
(M)Lumber & Wood		723	396	824	2245
	6.4%	8.3%	4.1%	5.4%	6.3%
(P)Furniture		4	17	121	370
	0.3%	.0%	0.2%	0.8%	1.0%
(M)Chemicals		54	18	116	261
	1.1%	0.6%	0.2%	0.8%	0.7%
(M)Paints		859	868	1061	1251
	13.4%	9.9%	9.0%	6.9%	3.5%
(M)Petrol. product		540	624	1137	2447
	5.7%	6.2%	6.5%	7.4%	6.8%
(M)Stone & Clay Product		410	697	1474	3480
	8.4%	4.7%	7.2%	9.6%	9.7%
(M)Steel		317	296	285	1081
	4.2%	3.7%	3.1%	1.9%	3.0%
(M)Non-ferrous Metals		209	209	128	770
	4.3%	2.4%	2.2%	0.8%	2.1%
(P)Metal product		838	1697	1469	6538
	13.5%	9.7%	17.5%	9.6%	18.2%
Machinery		281	216	499	655
	1.1%	3.2%	2.2%	3.3%	1.8%
Eclectic machinery		489	764	1814	2925
	4.4%	5.6%	7.9%	11.9%	8.1%
(P)Misc.indust. product		77	91	138	129
	0.7%	0.9%	0.9%	0.9%	0.4%
Utility		90	9	65	230
	0.4%	1.0%	0.1%	0.4%	0.6%
Trade		1720	1723	2732	6290
	21.1%	19.9%	17.8%	17.9%	17.5%
Finance & Insurance		161	86	293	467
	0.8%	1.9%	0.9%	1.9%	1.3%
Real estate rent		134	101	306	176
	0.5%	1.5%	1.0%	2.0%	0.5%
Transportation		490	478	934	1507
	4.6%	5.7%	4.9%	6.1%	4.2%
Service		281	529	606	1030
	0.9%	3.2%	5.5%	4.0%	2.9%
Other sectors		727	592	899	3074
	6.3%	8.4%	6.1%	5.9%	8.6%
TOTAL INTERMED. INPUT		8663	9672	15278	35895
	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Survey of Current Business
Compiled by the Author

Table 3.10 Intermediate Input Structure (U.S.A., Cont'd)

Total Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Stone & Clay Mine		737	931	1407	2043
		1.5%	1.6%	1.6%	1.3%
(M)Lumber & Wood		4276	4946	9720	18331
		8.9%	8.6%	10.8%	12.0%
(P)Furniture		530	582	762	1276
		1.1%	1.0%	0.8%	0.8%
(M)Chemicals		255	154	444	660
		0.5%	0.3%	0.5%	0.4%
(M)Paints		1167	1324	1624	2824
		2.4%	2.3%	1.8%	1.8%
(M)Petrol. product		1659	2024	3132	7218
		3.4%	3.5%	3.5%	4.7%
(M)Stone & Clay Product		6223	6874	10787	16110
		12.9%	11.9%	12.0%	10.5%
(M)Steel		2442	1752	2754	5650
		5.1%	3.0%	3.1%	3.7%
(M)Non-ferrous Metals		1453	2364	2644	3552
		3.0%	4.1%	2.9%	2.3%
(P)Metal product		8084	11075	15510	23981
		16.7%	19.2%	17.3%	15.7%
Machinery		1233	1449	2122	3001
		2.6%	2.5%	2.4%	2.0%
Eclectic machinery		2666	3305	6135	10342
		5.5%	5.7%	6.8%	6.8%
(P)Misc.indust. product		166	202	312	519
		0.3%	0.4%	0.3%	0.3%
Utility		295	73	219	833
		0.6%	0.1%	0.2%	0.5%
Trade		7173	8226	12797	23354
		14.9%	14.3%	14.2%	15.3%
Finance & Insurance		562	658	1041	2310
		1.2%	1.1%	1.2%	1.5%
Real estate rent		441	700	1015	627
		0.9%	1.2%	1.1%	0.4%
Transportation		2633	2613	4256	5884
		5.5%	4.5%	4.7%	3.9%
Service		3240	4911	8275	15191
		6.7%	8.5%	9.2%	9.9%
Other sectors		3057	3542	4935	9013
		6.3%	6.1%	5.5%	5.9%
TOTAL INTERMED. INPUT		48292	57705	89891	152719
		100.0%	100.0%	100.0%	100.0%

Source: Survey of Current Business
Compiled by the Author

Table 3.11 Aggregated Intermediate Input Structure (Japan)

Building Construction (including M&R Construction)

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Material	722.2	1323.6	2996.7	4744.2	6887.7
	52.8%	46.7%	42.5%	36.9%	34.3%
(P)Product	220.5	578.7	1658.7	3252.3	5386.3
	16.1%	20.4%	23.5%	25.3%	26.8%
Machinery	128.6	236.2	532.3	947.8	1289.0
	9.4%	8.3%	7.5%	7.4%	6.4%
Electric power supply	2.0	11.9	27.4	94.9	171.8
	0.1%	0.4%	0.4%	0.7%	0.9%
Trade&Transportation	167.1	448.2	1029.6	2463.2	3728.7
	12.2%	15.8%	14.6%	19.1%	18.6%
Finance & Insurance	16.5	48.1	113.6	299.6	370.3
	1.2%	1.7%	1.6%	2.3%	1.8%
Service	11.6	30.8	227.9	492.8	1040.3
	0.8%	1.1%	3.2%	3.8%	5.2%
Other	100.2	156.9	472.4	571.1	1212.4
	7.3%	5.5%	6.7%	4.4%	6.0%
TOTAL INTERMED. INPUT	1368.6	2834.4	7058.7	12865.9	20086.4
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in Table 3.9
Product is the sum of the items with (P) in Table 3.9

Source: Economic Statistics Annual
Compiled by the author

Table 3.11 Aggregated Intermediate Input Structure

(Japan Cont'd)

Heavy Construction

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Material	310.1	564.9	1258.7	2895.3	5143.3
	38.4%	42.3%	41.2%	45.3%	43.5%
(P)Product	111.7	156.1	355.1	686.1	1174.4
	13.8%	11.7%	11.6%	10.7%	9.9%
Machinery	159.9	239.7	526.2	385.1	1799.2
	19.8%	18.0%	17.2%	6.0%	15.2%
Electric power supply	2.8	11.5	20.8	80.6	165.9
	0.3%	0.9%	0.7%	1.3%	1.4%
Trade&Transportation	100.8	206.2	439.3	1142.8	1855.4
	12.5%	15.5%	14.4%	17.9%	15.7%
Finance & Insurance	10.8	30.1	67.7	181.3	254.6
	1.3%	2.3%	2.2%	2.8%	2.2%
Service	7.9	20.0	80.6	231.8	786.6
	1.0%	1.5%	2.6%	3.6%	6.7%
Other	104.0	105.5	307.3	782.4	642.9
	12.9%	7.9%	10.1%	12.3%	5.4%
TOTAL INTERM. INPUT	808.0	1334.0	3055.8	6385.2	11822.2
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in Table 3.9
Product is the sum of the items with (P) in Table 3.9

Source: Economic Statistics Annual
Compiled by the author

Table 3.11 Aggregated Intermediate Input Structure

(Japan Cont'd)

Total Construction

SECTOR \ YEAR	1960	1965	1970	1975	1980
(M)Material	1032.2	1888.5	4255.3	7639.5	12031.0
	47.4%	45.3%	42.1%	39.7%	37.7%
(P)Product	332.2	734.8	2013.8	3938.4	6560.7
	15.3%	17.6%	19.9%	20.5%	20.6%
Machinery	288.4	475.9	1058.5	1332.8	3088.2
	13.3%	11.4%	10.5%	6.9%	9.7%
Electric power supply	4.8	23.4	48.2	175.5	337.8
	0.2%	0.6%	0.5%	0.9%	1.1%
Trade & Transp.	267.9	654.4	1469.0	3606.0	5584.0
	12.3%	15.7%	14.5%	18.7%	17.5%
Finance & Insurance	27.3	78.2	181.3	480.9	624.8
	1.3%	1.9%	1.8%	2.5%	2.0%
Service	19.6	50.8	308.5	724.5	1826.9
	0.9%	1.2%	3.1%	3.8%	5.7%
Other	204.3	262.5	779.8	1353.5	1855.2
	9.4%	6.3%	7.7%	7.0%	5.8%
TOTAL INTERMED. INPUT	2176.6	4168.4	10114.4	19251.1	31908.6
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in Table 3.10
Product is the sum of the items with (P) in Table 3.10

Source: economic Statistics Annual
Compiled by the author

Table 3.12 Aggregated Intermediate Input Structure (U.S.A.)

New Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Material		14841	17000	27110	43884
	37.4%	37.4%	35.4%	36.3%	37.6%
(P)Product		7861	10054	14856	18739
	17.1%	19.8%	20.9%	19.9%	16.0%
Machinery		3129	3774	5944	9763
	8.8%	7.9%	7.9%	8.0%	8.4%
Utilities		205	64	154	603
	0.4%	0.5%	0.1%	0.2%	0.5%
Trade & Transportation		7596	8638	13387	21441
	20.0%	19.2%	18.0%	17.9%	18.4%
Finance & Insurance		401	572	748	1843
	1.3%	1.0%	1.2%	1.0%	1.6%
Service		2959	4382	7669	14161
	7.6%	7.5%	9.1%	10.3%	12.1%
Other		2637	3549	4745	6390
	6.8%	6.7%	7.4%	6.4%	5.5%
TOTAL INTERMED. INPUT		39629	48033	74613	116824
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in table 3.10.
Product is the sum of the items with (P) in table 3.10.

Source: Survey of Current Business
Compiled by the author

Table 3.12 Aggregated Intermediate Input Structure

(U.S.A. Cont'd)

Maintenance & Repair Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Material		3371	3369	5402	12504
	45.6%	38.9%	34.8%	35.4%	34.8%
(P)Product		919	1805	1728	7037
	14.5%	10.6%	18.7%	11.3%	19.6%
Machinery		770	980	2313	3580
	5.5%	8.9%	10.1%	15.1%	10.0%
Utilities		90	9	65	230
	0.4%	1.0%	0.1%	0.4%	0.6%
Trade & Transportation		2210	2201	3666	7797
	25.6%	25.5%	22.8%	24.0%	21.7%
Finance & Insurance		161	86	293	467
	0.8%	1.9%	0.9%	1.9%	1.3%
Service		281	529	606	1030
	0.9%	3.2%	5.5%	4.0%	2.9%
Other		861	693	1205	3250
	6.3%	9.9%	7.2%	7.9%	9.1%
TOTAL INTERMED. INPUT		8663	9672	15278	35895
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in table 3.10.
Product is the sum of the items with (P) in table 3.10.

Source: Survey of Current Business
Compiled by the author

Table 3.12 Aggregated Intermediate Input Structure

(U.S.A. Cont'd)

Total Construction

SECTOR \ YEAR	1958	1963	1967	1972	1977
(M)Material		18212	20369	32512	56388
	39.0%	37.7%	35.3%	36.2%	36.9%
(P)Product		8780	11859	16584	25776
	16.6%	18.2%	20.6%	18.4%	16.9%
Machinery		3899	4754	8257	13343
	8.2%	8.1%	8.2%	9.2%	8.7%
Elec. pow. supply		295	73	219	833
	0.4%	0.6%	0.1%	0.2%	0.5%
Trade & Transportation		9806	10839	17053	29238
	21.1%	20.3%	18.8%	19.0%	19.1%
Finance & Insurance		562	658	1041	2310
	1.2%	1.2%	1.1%	1.2%	1.5%
Service		3240	4911	8275	15191
	6.2%	6.7%	8.5%	9.2%	9.9%
Other		3498	4242	5950	9640
	6.7%	7.2%	7.4%	6.6%	6.3%
TOTAL INTERED. INPUT		48292	57705	89891	152719
	100.0%	100.0%	100.0%	100.0%	100.0%

N.B.
Material is the sum of the items with (M) in table 3.10.
Product is the sum of the items with (P) in table 3.10.

Source: Survey of Current Business
Compiled by the author

CHAPTER 4 STRUCTURE OF CONSTRUCTION INDUSTRY

4.1 Introduction.

The next two chapters discuss the structure of the construction industry and the large size general contractors in particular. As it focuses each construction establishment, numbers given in these chapters may be inconsistent with the numbers given in the former two chapters due to double counting of subcontracting, exclusion of force account, inclusion of M&R construction and inclusion of service which is classified as service sector in the former two chapters.

Chapter four discusses construction establishments in general, while chapter five focuses large size construction establishments and leading contractors in Japan.

4.2.1 Construction Establishment in Japan.

In Japan, the number of registered construction firms including proprietorship counted a record high of 516,000 in 1984 of which 440,329 are primarily in the construction industry. The rest are such companies as trading companies and ship builders whose primary business are outside construction industry. The number of firms has increased constantly since 1970 when it was 163,000. [Construction White paper, 1985] The number of workers employed in the construction industry has increased from 3,940,000 to 5,410,000 during this period. Their percentage share in the total non-agricultural work forces has also increased from 8.9 percent in 1965 to 11.0 percent in 1980 and has stayed relatively constant thereafter.

As the number of construction firms increases, the average number of workers per establishment has decreased from 24 in 1970 to 10 in 1980. Among the 5,410,000 workers, by type of employment 70 percent are regular workers, 13 percent are proprietorship and the rest are temporarily workers. By type of firms, 70 percent of total workers work for corporations and 30 percent work for proprietorships. [Kensetsu Toukei Youran, 1985]

4.2.2 Construction Establishment in the U.S.

In the U.S., the number of establishments is 1,389,000 including proprietorship in 1982. The number of construction workers has increased from 3,230,000 in 1965 to 4,661,000 in 1985. However, their percentage in total nonagricultural work forces has fluctuated between 4.4 percent and 5.3 percent during the last two decades. The average number of workers of an establishment is 3.1, which is still smaller than that of Japan. The dominance of small size firms in the U.S. construction industry is mainly due to residential oriented U.S. construction market structure and small size of special trading contractors. According to Mathieu and Rubinstein, "Three-quarters of all employees for single home contractors worked for establishment with 1 to 4 employees. Over three-fourth of the non employee firms were special trading contractors, i.e. those engaged in activities such as plumbing, heating, air-conditioning and electrical work." The greater volume of the M&R construction, which accounts for almost 20 percent of total construction, also contributes this relative small size of establishments. According to 1982 census, almost 30 percent of construction performed by special trade contractors, which accounts more than three-quarters of proprietorship, is M&R construction. [1982 Census of Construction Industries, 1984]

4.3 Size of Construction Establishments

The top 113 Japanese construction firms in Japan whose capital is over 1 billion yen, which is 0.025 percent of total establishments, employ 274,000 employees and their value of completion is 11,800,000 million yen of original contracts. The number of employees is about 5.1 percent of total construction workers and their value of completion is more than 25 percent of total original construct. The second largest 842 Japanese construction firms whose capital is between 0.1 and 1 billion yen, which is 0.19 percent in numbers, employ 225,000 workers and their value of completion is 5,288 million yen. Their employees' number is 4.2 percent of total construction workers and the value of completion is 11.2 percent of the total.

In the U.S., the size of establishment is categorized by the number of employees rather than the size of capital. The largest 121 construction firms, accounting for 0.009 percent of total establishment, employ 6.7 percent of total workers and receive 8 percent of total business receipts. The second largest 234 construction firms account for 0.017 percent of total establishments and employ 2.9 percent of total workers and receive 4.6 percent of total business receipts. Establishments without employees account for 67 percent of total establishment and 17 percent of total workers, while receiving 11 percent of total business receipts.

Both in Japan and in the U.S., small establishments seem to dominate the construction industry. The construction establishments of the smallest category account for almost 60 percent in both countries. In the U.S., these establishments are businesses without employees, while in Japanese establishments have 5.6 employees on average. Therefore, dominance of the small establishments is more clearly observed in the U.S.. In addition to the differences in market structure, there seems to be two more reasons for it. The first reason is the preference of independence in the U.S. According to Mathieu and Rubinstein, "..the viability of the small construction firms may be a strong desire for the independence on the part of skilled construction workers." [Construction Review, Sept/Oct 1985]. The other reason is the legal requirement for Japanese construction establishments. Since 1972, construction firms in Japan have been required to have permission from the Minister of Construction or local governors depending on their size of operation by

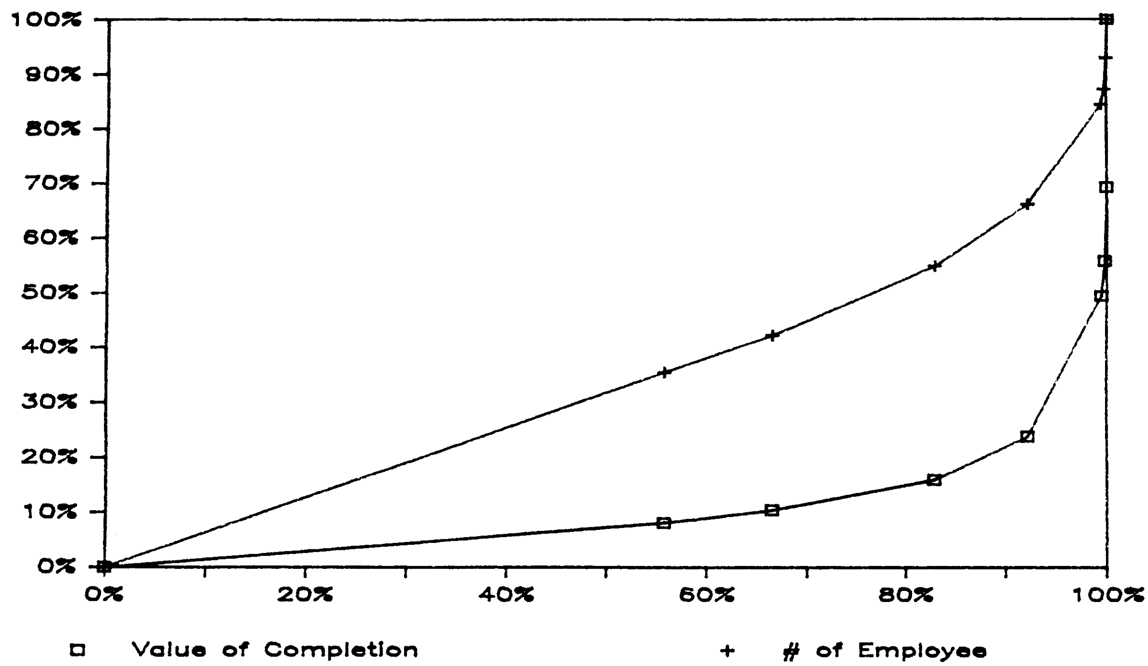
"Kensetsugyo-ho" (Construction Contractors Low). In order to protect owners from troubles associated with unreliable contractors (i.e., bankruptcy). It even requires proprietors to meet certain requirement such as experience, financial status and capability of management to bid jobs. As a result, such proprietors as typically found in the United States hardly can find their way in the construction industry in Japan.

4.4 Economies of Scale

Figures 4.1 and 4.2 show cumulative percentages of construction workers and business receipts added from the smaller establishments. In these figures, the X axis shows the cumulative percentage of establishment and the Y axis shows the cumulative percentages of both employment and business receipt. Figures 4.3 and 4.4 show the upper three percent of these figures to give clearer views of large size establishments. If all establishments have the same employment and the same business receipts, a diagonal linear line represents both employment and receipts.

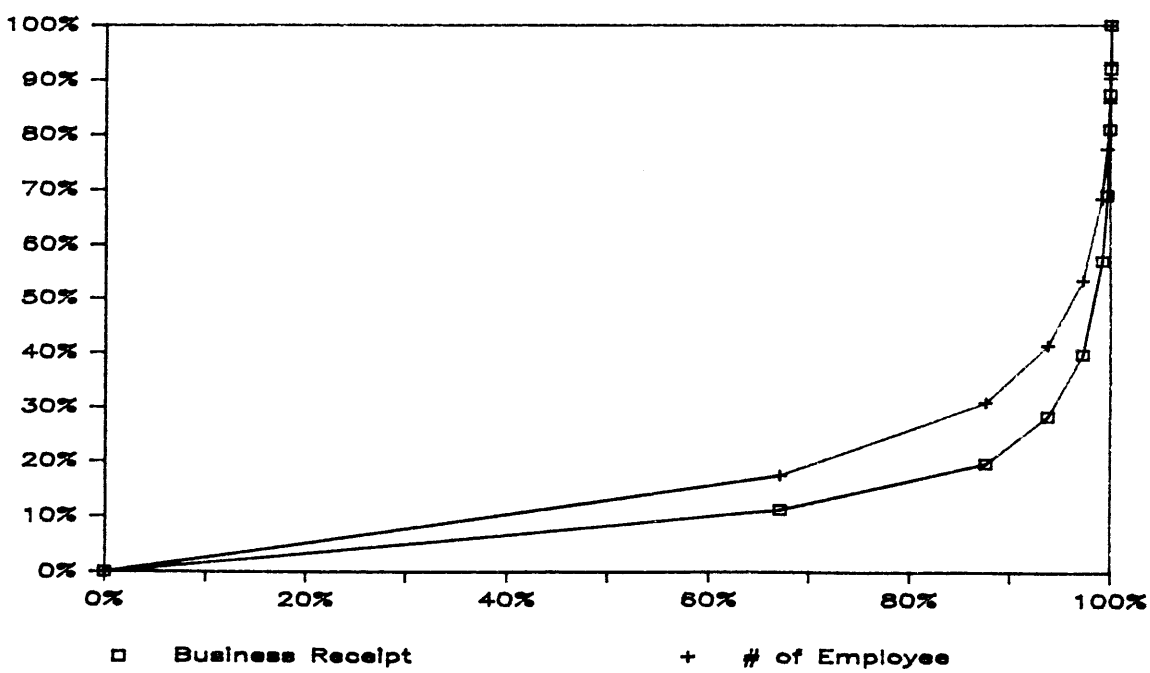
In the U.S., employment shows an exponential line while it is more linear in Japan. These line shows that size of establishment ranges more widely in the U.S..

Figure 4.1 Cumulative Employment and Value of Completion (Japan, 1981)



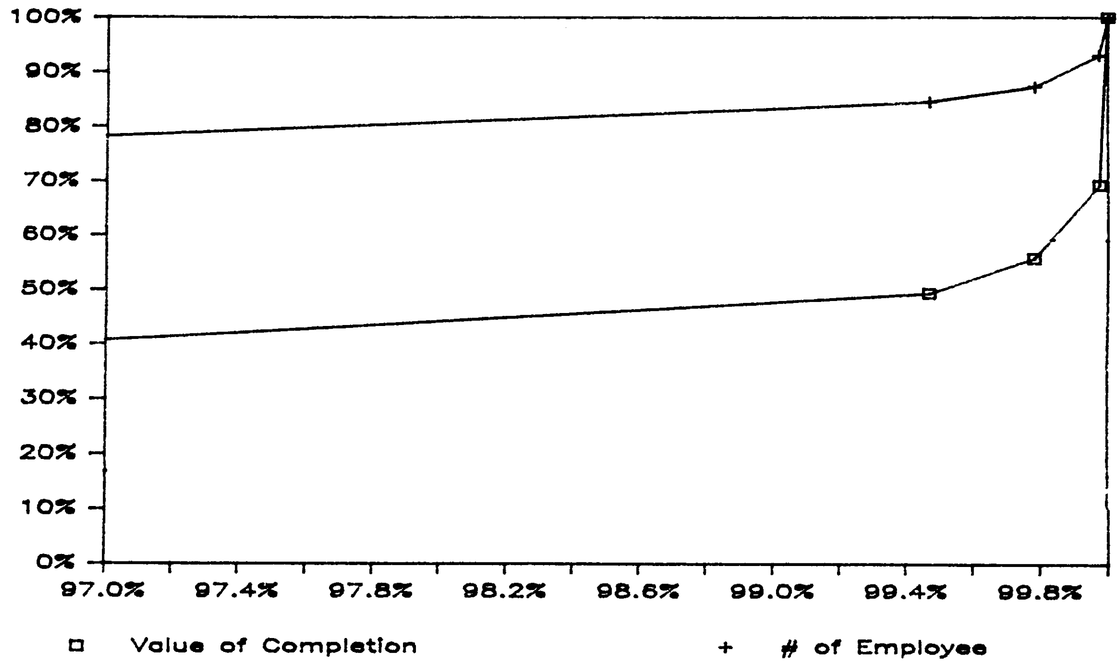
Source: Kensetsu Toukei Youran, 1985

Figure 4.2 Cumulative Employment and Value of Completion (U.S.A., 1982)



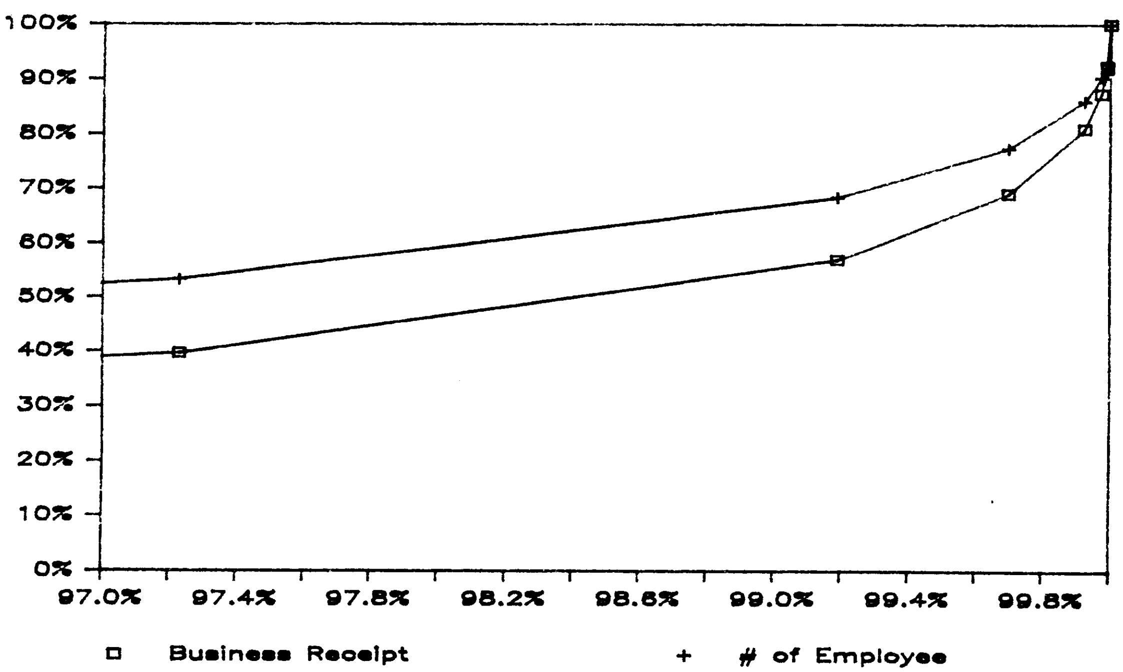
Source: 1982 Census of Construction Industries, 1984

Figure 4.3 Cumulative Employment and Value of Completion (Japan, Detail of Upper 3%, 1981)



Source: Kensetsu Toukei Youran, 1985

Figure 4.4 Cumulative Employment and Value of Completion (U.S.A., Detail of Upper 3%, 1982)



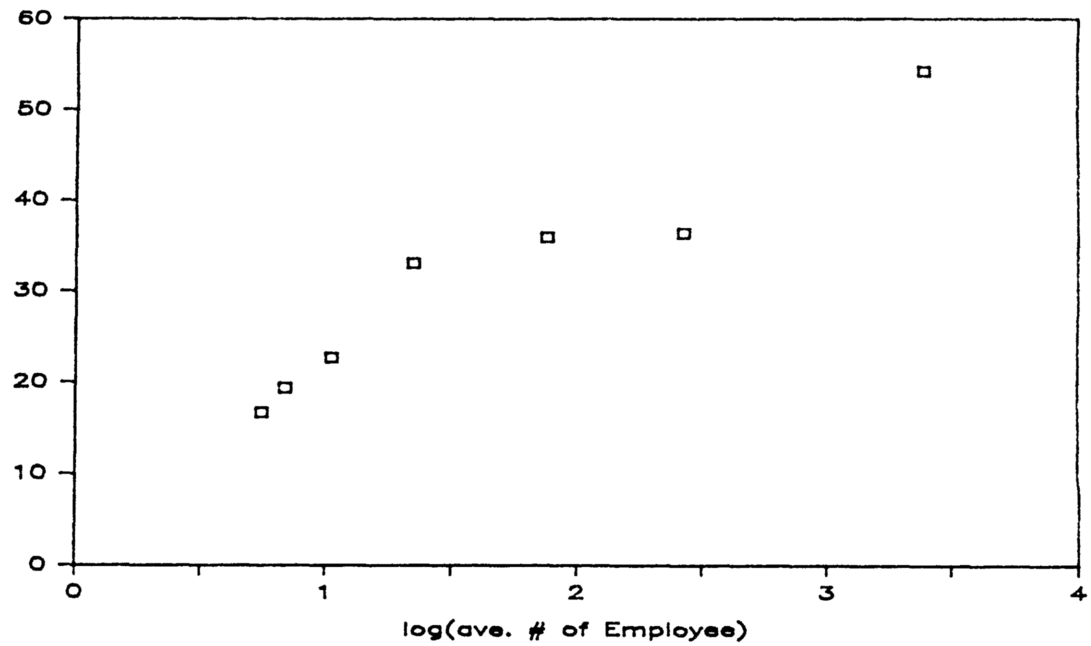
Source: 1982 Census of Construction Industries, 1984

The lines of values of completion make similar exponential lines in both of the two countries. However, in Japan this line lies far below the employment line while it is very close to the line of employment in the U.S..

These lines show that, in the U.S., the size of construction establishments, in terms of business receipt, is proportional to the number of workers. In Japan, however, value of completion is not proportional to the number of workers; i.e. establishments with greater number of employee have greater value of completion per worker. In other words, the productivity of worker is relatively constant in the U.S. while, in Japan, a larger establishment has a greater productivity. Particularly, as shown in figures 4.3 and 4.4, construction firms of the largest category in Japan have an exceptionally high value of completion compared with their employment.

Figures 4.5 and 4.6 show the volume of completion or business receipts per worker. In these figures, the X axis represents the common logarithm of the number of worker. It makes a steep, continuous increasing line in Japan whereas it is relatively flat and more importantly, decreases at the largest size in the U.S.. This high productivity of large size firms in Japan is attained by their capital intensity as well as peculiar labor subcontracting systems which are discussed later.

Figure 4.5 Value of Completion per Worker (Japan, 1981)
(Million yen)



Source: Kensetsu Toukei Youran, 1985

Figure 4.6 Value of Completion per Worker (U.S.A., 1982)
(Thousand dollar)

Source: 1982 Census of Construction Industries, 1984

4.5 Construction Establishment with Payroll

Tables 4.1 to 4.4 in appendix three at the end of this chapter give more detailed statistics for construction establishments with payrolls in the U.S. and construction corporations in Japan. Net business receipts, which are the total business receipts or values of completion net payment to subcontractors, shows the same tendency as total business receipts. (row H) The row below the net business receipt per employee (row H) shows the index of worker productivity, assuming that net receipt per employee for the second smallest category is 100. Establishments of these categories are chosen as the criteria because they have similar average employee numbers of 6.9 and 6.5 in the U.S. and Japan respectively.

It shows that the largest construction firms have the highest worker productivity of 214.2 in Japan, while that of the United states is only 123.0, which is smaller than that of construction establishment with 20 to 49 employee.

It is difficult to compare these numbers between the two countries on the same scale because of fluctuating exchange rates and different structures of the industry. Assuming a foreign exchange rate of 200 yen to the dollar, the worker productivity is higher for every class of construction firms in Japan. Moreover, that of the largest construction firms is almost three times as much as that of the U.S..

The rows (I) through (M) in these tables show the cost structure of construction establishments. One characteristic about Japanese construction industry is that it include labor as a separate cost item. The characteristics are as follows:

1) These laborers come from other firms or proprietors.
2) Laborers are paid by working hours or days rather than the tasks they perform.
4) Laborers are usually directly controlled by the original contractors.

From the point of organization, this labor can be considered as a form of subcontracting, because they are hired only when needed. However, from the point of their tasks, they are very close to the lower level employees of the original contractor because they are controlled by their managers or superintendents, and they are paid not by the specific tasks of the project. This system may come from the Japanese tradition of using temporary construction workers who were primarily involved in agriculture and did not form organized work forces. Regardless of the history, it makes original contractors flexible to the business fluctuations by cutting the cost of keeping unnecessary payrolls during economic through.

The sum of the cost of labor and other expenses at the site, which mainly consist of the payrolls of the employees at site, gives almost the compatible number to the cost of payroll in the United States. It might have inflated the aforementioned productivity of the Japanese construction worker by understating the number of employees.

Payment to subcontractors on the whole is higher for Japanese construction firms (row J in tables 4.1 to 4.4). It accounts for almost 40 percent for establishments in Japan and 25 percent for the U.S. firms. Besides, as Japanese construction firms pay an additional 10 percent for the aforementioned labor cost, they pay out almost 50 percent of value of completion back to the construction industry. This fact reflects a strong intra-industry dependency. The largest establishments in Japan pay 55.5 percent into construction industry, whereas the largest establishments in the United States pay only 23.3 percent back into construction industry.

This high degree of intra-industry dependency of the construction industry in Japan promotes construction firms to form hierarchical structures. In this hierarchical structure, it is not unusual that a part of the original contract is subcontracted several times, from the original contractor to the primary subcontractor and from the primary subcontractor to the secondary subcontractor and so on, until it is actually performed. According to Terasawa, such cases are typically observed in the labor intensive subcontracts such as carpentry [Terasawa, 1985, pp.41].

This relationship between contractors is not an ad-hoc one. Large size contractors usually have a group of subcontractors and keep a continuous relationship. The number of this group is reported to be 4839 in 1984, while the number of member companies of large size contractors is usually 300 to 700. [Nakamura, 1985]

By organizing such groups, large size original contractors can maintain the quality of tasks performed by subcontractors and the subcontractors can receive certain amounts of contract regardless of business fluctuations. Also subcontractors have other benefits, such as training programs offered by original contractors. However, there is also a strong counter argument against this system; large contractors force smaller subcontractors to accept unfavorable contract condition such as late payment. [Terasawa, 1980]

4.6 Capital Intensity of Construction Firms

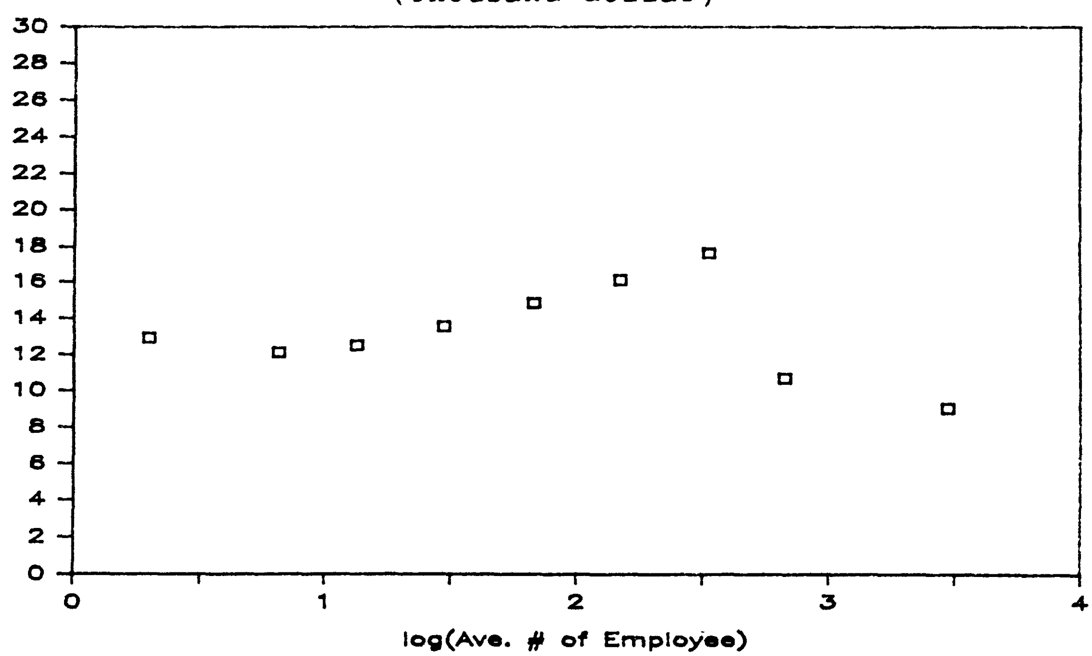
As discussed in chapter three, capital intensity is a index showing the degree of industrialization. Row (P) of tables 4.1 and 4.2 shows depreciable assets of construction firms which include buildings, construction machinery and equipment.

Figures 4.7 and 4.8 show depreciable assets per employee in the same way as figures 4.5 and 4.6. As the number of employees increases, depreciable assets per employee also increases in Japan, whereas in the U.S., it peaks at the middle. Assuming the exchange rate of 200 yen to one dollar, the firms in the largest category has more than twice as much assets in Japan as they do in the U.S..

Table 4.7 Depreciable Assets per Employee (Japan, 1981)
(Million yen)

Source: Kensetsu Toukei Youran, 1985

Table 4.8 Depreciable Assets per Employee (U.S.A., 1982)
(Thousand dollar)



Source: 1982 Census of Construction Industries, 1985

Besides their capital intensity, Japanese construction firms have a greater capital utilization rate or productivity of capital, which is given by net value of completion divided by depreciable assets, regardless of the size of the firms (row R in tables 4.1 to 4.4). It is almost six for the majority of firms in Japan. In the U.S., although it is almost six for large size firms, it is three to four for small size firms. This indicates these capital assets are not effectively utilized in the smaller firms.

Thus, productivity of capital is relatively high and constant in Japan, whereas their U.S. counterparts (particularly in small size firms), have low productivity of capital. High and constant productivity of capital in Japan might be achieved through the hierarchical structure of construction industry by eliminating redundant investment and utilizing capital assets more efficiently through coordination among various size of firms.

4.7 Summary of Chapter Four

1. The size of construction firms ranges more widely in the U.S.
2. Productivity of worker (value of completion divided by number of worker) does not vary much depending on the size of construction firms in the U.S. compared with that in Japan.
3. Productivity of worker increases as the size of the firm increases in Japan.
4. Construction firms in the largest category have exceptionally high productivity of workers in Japan.
5. Labor subcontracting system in Japan might affect this high productivity of worker.
6. Construction firms in Japan subcontract a greater amount of original contracts that result in higher intra-industry dependency.
7. Firms in the largest category have the greatest capital intensity in Japan and least capital intensity in the U.S..
8. Construction firms in Japan have a relatively constant capital utilization rate (or productivity of capital) compared with the U.S..
9. Construction firms in the smaller category have low productivity of capital in the U.S..

Table 4.1 Construction Establishment by Size of Capital (Japan, 1981)

Size of Capital	(Million yen) 0-1.99	2-4.99	5-9.99	10-49
(A) Number of Establishment	47210	74667	41459	32085
	23.870%	37.753%	20.963%	16.223%
(B) Number of Employee	264376	515202	439465	715496
(A)*(C)	10.4%	20.3%	17.3%	28.2%
(C) Employee/Establishment	5.6	6.9	10.6	22.3
(D) Val. of Completion	4418526	9994701	9978933	23676388
(M.YEN)	5.9%	13.3%	13.3%	31.6%
(E) Val.Compltn./Emply	16713	19400	22707	33091
(F) Net Val of Compltn	2976118	6831881	6381038	14166875
(E)-(J) (M.YEN)	6.7%	15.4%	14.4%	31.9%
(G) Net/Total Val. Com (F)/(D)	67.4%	68.4%	63.9%	59.8%
(H) Net Recpt/Employee	11257	13261	14520	19800
13262=100	84.9	100.0	109.5	149.3
Cost per establishment (% of Value of Completion)				
(I) Material&Component	25091	35771	65173	176260
	26.8%	26.7%	27.1%	23.9%
(J) Pymt to Subcontract	30553	42359	86782	296385
	32.6%	31.6%	36.1%	40.2%
(K) Labor	10446	15062	24360	72911
	11.2%	11.3%	10.1%	9.9%
(L) Other Exp. at Site	8458	15653	23210	84241
	9.0%	11.7%	9.6%	11.4%
(N) COST SUB TOTAL	74548	108845	199525	629797
	79.7%	81.3%	82.9%	85.3%
(X) Other Expenses	17327	21748	32015	75079
	18.5%	16.2%	13.3%	10.2%
(O) Operation Surplus	1718	3264	9154	33051
(D)/(A)-(N)-(X)				
	1.8%	2.4%	3.8%	4.5%
(P) Depreciable Assets	10687	15001	24341	72936
(Q) D.A./Employee	1908	2174	2296	3271
(R) Productivity of D.A. {(F)/(A)}/(P)	5.88	6.10	6.33	6.06

Source: Kensetsu Toukei Youran. 1985
Compiled by the Author

Note: Unit in 1000 yen except for rows (D) and (F)

Table 4.1 Construction Establishment by Size of Capital (Japan, 1981, Cont'd)

Size of Capital	(Million yen) 50-99	100-999	1000-
(A) Number of Establishment	1400	842	113
	0.708%	0.426%	0.057%
(B) Number of Employee	106120	224898	274409
(A)*(C)	4.2%	8.9%	10.8%
(C) Employee/Establishment	75.8	267.1	2428.4
(D) Val. of Completion	3813111	8191378	14874021
(M.YEN)	5.1%	10.9%	19.8%
(E) Val.Compltn./Emply	35932	36423	54204
(F) Net Val of Compltn	1979520	4328409	7795884
(E)-(J) (M.YEN)	4.5%	9.7%	17.5%
(G) Net/Total Val. Com (F)/(D)	51.9%	52.8%	52.4%
(H) Net Recpt/Employee	18654	19246	28410
13262=100	140.7	145.1	214.2
Cost per establishment (% of Value of Completion)			
(I) Material&Component	547226	1793333	24556593
	20.1%	18.4%	18.7%
(J) Pymt to Subcontract	1309708	4587850	62638384
	48.1%	47.2%	47.6%
(K) Labor	195422	608296	10339942
	7.2%	6.3%	7.9%
(L) Other Exp. at Site	284710	1180131	16407430
	10.5%	12.1%	12.5%
(N) COST SUB TOTAL	2337066	8169610	113942349
	85.8%	84.0%	86.6%
(X) Other Expenses	224999	731963	8749535
	8.3%	7.5%	6.6%
(O) Operation Surplus (D)/(A)-(N)-(X)	161586	826905	8936621
	5.9%	8.5%	6.8%
(P) Depreciable Assets	208417	738505	11221561
(Q) D.A./Employee	2750	2765	4621
(R) Productivity of D.A. {(F)/(A)}/(P)	6.80	6.94	6.13

Source: Kensetsu Toukei Youran. 1985
Compiled by the Author
Note: Unit in 1000 yen except for rows (D) and (F)

Table 4.2 Construction Establishment by Size of Employment (U.S.A., 1982)

Number of Employee	1-4	5-9	10-19	20-49	50-99
(A) Number of	284825	85449	47954	27207	7090
Establishment	62.366%	18.710%	10.500%	5.957%	1.552%
(B) Number of	566895	559039	641525	810300	482731
All Employee	13.3%	13.1%	15.0%	19.0%	11.3%
(C) Employee/Estblsmt. (A)/(B)	1.99	6.54	13.38	29.78	68.09
(D) All Busns. Receipt	30713	31655	41608	63174	44255
	9.5%	9.8%	12.8%	19.5%	13.6%
(E) Busns.Rcpt/Employee (D)/(B)	54.2	56.6	64.9	78.0	91.7
(F) Net Recpt	24397	25058	31899	45734	30776
(E)-(J)	10.5%	10.7%	13.7%	19.6%	13.2%
(G) Net/Bsnes Recpt (F)/(D)	79.4%	79.2%	76.7%	72.4%	69.5%
(H) Net Recpt/Employee	43.0	44.8	49.7	56.4	63.8
44.8=100	96.0	100.0	110.9	125.9	142.2
Cost of Total Receipt (% of total Receipt)					
(I) Material&Component	10871	10783	13357	19053	12409
(I)/(E)	35.4%	34.1%	32.1%	30.2%	28.0%
(J) Pymt. to Subcon.	5330	5532	8360	15337	11941
(J)/(E)	17.4%	17.5%	20.1%	24.3%	27.0%
(K) Rent (Machinery)	329	429	590	910	700
(K)/(E)	1.1%	1.4%	1.4%	1.4%	1.6%
(L) CapitalExpenditure	559	596	730	1041	762
(L)/(E)	1.8%	1.9%	1.8%	1.6%	1.7%
(M) Payroll	5906	7598	10427	15339	10376
(M)/(E)	19.2%	24.0%	25.1%	24.3%	23.4%
(N) COST SUB TOTAL	22996	24939	33464	51679	36188
	74.9%	78.8%	80.4%	81.8%	81.8%
(O) Operation Surplus	7718	6716	8145	11495	8067
(D)-(N)	25.1%	21.2%	19.6%	18.2%	18.2%
(P) Depreciable Assets	7325	6779	8003	10980	7159
(Q) D.A./Employee	12.9	12.1	12.5	13.6	14.8
(R) Productivity of D.A. {(F)/(A)}/(P)	3.33	3.69	3.98	4.17	4.29

Source: 1982 Census of Construction Industries, 1984
Compiled by the Author

N.B. <---- Data are included in the left column

Unit: million dollar except for per employee data which are expressed in 1000 $

Table 4.2 Construction Establishment by Size of Employment (U.S.A., 1982, Cont'd)

Number of Employee	100-249	250-499	500-999	1000-
(A) Number of	3126	694	234	121
Establishment	0.684%	0.152%	0.051%	0.026%
(B) Number of	462999	232220	157945	361415
All Employee	10.8%	5.4%	3.7%	8.5%
(C) Employee/Estblsmt.	148.11	334.61	674.98	2986.90
(A)/(B)				
(D) All Busns. Receipt	43526	2E+07	2E+07	3E+07
	13.4%	7.3%	5.2%	9.0%
(E) Busns.Rcpt/Employee	94.0	101.4	107.1	80.6
(D)/(B)				
(F) Net Recpt	29265	15318	10893	19928
(E)-(J)	12.5%	6.6%	4.7%	8.5%
(G) Net/Bsnes Recpt	67.2%	65.1%	64.4%	68.4%
(F)/(D)				
(H) Net Recpt/Employee	63.2	66.0	69.0	55.1
44.8=100	141.0	147.2	153.9	123.0
Cost of Total Receipt (% of total Receipt)				
(I) Material&Component	11886	10505	<-----	7492
(I)/(E)	27.3%	26.0%	<-----	25.7%
(J) Pymt. to Subcon.	12839	7261	5402	6909
(J)/(E)	29.5%	30.8%	31.9%	23.7%
(K) Rent (Machinery)	701	338	189	324
(K)/(E)	1.6%	1.4%	1.1%	1.1%
(L) CapitalExpenditure	761	390	157	227
(L)/(E)	1.7%	1.7%	0.9%	0.8%
(M) Payroll	10376	5374	3744	9526
(M)/(E)	23.8%	22.8%	22.1%	32.7%
(N) COST SUB TOTAL	36563	33359	<-----	24479
	84.0%	0.1%	<-----	0.1%
(O) Operation Surplus	6963	7091	<-----	4651
(D)-(N)	16.0%	17.5%	<-----	16.0%
(P) Depreciable Assets	7449	4096	1687	3265
(Q) D.A./Employee	16.1	17.6	10.7	9.0
(R) Productivity of D.A.	3.92	3.75	6.45	6.10
{(F)/(A)}/(P)				

Source: 1982 Census of Construction Industries, 1984
Compiled by the Author
N.B. <---- Data are included in the left column
Unit: million dollar except for per employee data which are expressed in 1000 dollar

Table 4.3 Construction Establishment by Type of Activity (Japan, 1981)

Type of Activity	GENERAL	BUILDING	HEAVY
(A) Number of Estab.	15485	129120	67975
	2.8%	23.4%	12.3%
(B) All Employee	564755	1009813	1262194
	11.4%	20.3%	25.4%

Data below are based on sample of 2603 establishment and may have some inconsistency with numbers shown other part in this thesis. Numbers below are average of sample firms in the category.

(C) Employee/Establish	14.5	10.6	15.5
(D) Ttl Const. Receipt	749189	460883	473458
(E) Const.Rcpt/Employee (D)/(C)	51668	43480	30546
(F) Net Recpt (E)-(J)	401052	218806	307922
(G) Net/Total Const.Re (F)/(D)	53.5%	47.5%	65.0%
(H) Net Recpt/Employee (F)/(C)	27659	20642	19866
Cost of Construction (% of Total Cost)			
(I) Material&Component	168726	79435	106531
	22.5%	17.2%	22.5%
(J) Pymt to Subcontract	348137	242077	165536
	46.5%	52.5%	35.0%
(K) Labor	56279	42777	50818
	7.5%	9.3%	10.7%
(L) Other Exp. at Site	78819	30169	84008
	10.5%	6.5%	17.7%
(M) Cost Sub Total	651961	394458	406893
	87.0%	85.6%	85.9%
(X) Other Expenses	59794	42146	45178
	8.0%	9.1%	9.5%
(O) Op. Surplus (F)/(A)-(N)-(X)	37434	24279	21387
	5.0%	5.3%	4.5%
(P) Depreciable Assets	54359	28311	79390
(Q) D.A./Employee	3749	2671	5122
(R) Productivity of D.A. (F)/(P)	7.38	7.73	3.88

Source: Kensetsu Toukei Youran, 1985
Compiled by the Author

Note: Unit 1000 yen.

Table 4.3 Construction Establishment by Type of Activity (Japan, 1981, Cont'd)

Type of Activity	P.A.E.	OTHER	TOTAL
(A) Number of Estab.	105218	233000	550798
	19.1%	42.3%	100.0%
(B) All Employee	1032203	1100198	4969163
	20.8%	22.1%	100.0%

Data below are based on sample of 2603 establishment and may have some inconsistency with numbers shown other part in this thesis. Numbers below are average of sample firms in the category.

(C) Employee/Establish	16.0	12.0	14.50
(D) Ttl Const. Receipt	320888	299379	454160
(E) Const.Rcpt/Employee (D)/(C)	20056	24948	31321
(F) Net Recpt (E)-(J)	207658	208571	265720
(G) Net/Total Const.Re (F)/(D)	64.7%	69.7%	58.5%
(H) Net Recpt/Employee (F)/(C)	12979	17381	18326
Cost of Construction (% of Total Cost)			
(I) Material&Component	86866	88150	102819
	27.1%	29.4%	22.6%
(J) Pymt to Subcontract	113230	90808	188440
	35.3%	30.3%	41.5%
(K) Labor	25029	28342	41296
	7.8%	9.5%	9.1%
(L) Other Exp. at Site	39395	28589	51690
	12.3%	9.5%	11.4%
(N) Cost Sub Total	264520	235889	384245
	82.4%	78.8%	84.6%
(X) Other Expenses	42335	44428	46718
	13.2%	14.8%	10.3%
(O) Op. Surplus	14033	19062	23197
(F)/(A)-(N)-(X)	4.4%	6.4%	5.1%
(P) Depreciable Assets	26728	31076	42775
(Q) D.A./Employee	1671	2590	2950
(R) Productivity of D.A. (F)/(P)	7.77	6.71	6.21

Source: Kensetsu Toukei Youran, 1985
Compiled by the Author

Note: Unit 1000 yen
P.A.E.: Plumbing, Air conditioning and Electric
OTHER: Other trade contractors

Table 4.4 Construction Establishment by Kind of Activity (U.S.A., 1982)

Kind of Activity	BUILDING	HEAVY	SP.TRADE	TOTAL
(A) Number of Establishment	123180	28187	299408	450775
	27.3%	6.3%	66.4%	100.0%
(B) Number of Employee	993629	852065	2389193	4234887
	23.5%	20.1%	56.4%	100.0%
(C) Employee/Establish (A)/(B)	8.07	30.23	7.98	9.39
(D) Ttl Const. Recpt.	113239222	67271540	129657840	310168602
	36.5%	21.7%	41.8%	100.0%
New Const.	106416462	55093913	92753723	254264098
	93.97%	81.90%	71.54%	81.98%
M & R Const.	6822760	12177627	36904117	55904504
	6.03%	18.10%	28.46%	18.02%
(E) Const.Rcpt/Employee (E)/(B)	114.0	79.0	54.3	73.2
(F) Net Recpt	57367100	54653951	119983838	232004889
	24.7%	23.6%	51.7%	100.0%
(G) Net/Total Const.Re (F)/(D)	50.7%	81.2%	92.5%	74.8%
(H) Net Recpt/Employee (F)/(B)	57.7	64.1	50.2	54.8
Cost of Construction (% of Total Cost)				
(I) Material&Component	25590334	22345976	47991940	95928250
	22.6%	33.2%	37.0%	30.9%
(J) Pymt to Subcont.	55872122	12617589	9674001	78163712
	49.3%	18.8%	7.5%	25.2%
(K) Rent (Machinery)	864386	1728453	1901484	4494323
	0.8%	2.6%	1.5%	1.4%
(L) CapitalExpenditure	1258359	1645372	2247879	5151610
	1.1%	2.4%	1.7%	1.7%
(M) Payroll	17048609	19443725	41604663	78096997
	15.1%	28.9%	32.1%	25.2%
(N) Cost Subtotal	100633810	57781115	103419967	261834892
	88.9%	85.9%	79.8%	84.4%
(O) Op. Surplus (D)-(N)	12605412	9490425	26237873	48333710
	11.1%	14.1%	20.2%	15.6%
(P) Depreciable Assets	12122106	20028868	23377673	55528648
(Q) D.A./Employee	12.200	23.506	9.785	13.112
(R) Productivity of D.A. (F)/(P)	4.74	2.73	5.13	4.18

Source: 1982 Census of Construction Industries, 1984
Compiled by the Author

Note: Unit: Million dollar except for per employee data which is expressed in 1000 dollar.

CHAPTER 5 BIG FIVE GENERAL CONTRACTORS IN JAPAN

5.1 Introduction

As described in chapter four, large size construction establishments in Japan are not only big in size but also have many characteristics, such as capital intensity and hierarchical subcontracting structure in the industry. These large size general contractors, the big five contractors in particular, play essential roles in Japanese construction industry. In this chapter, these big five general contractors are discussed.

The first part of this chapter discusses their role in the industry and inter-industry. The second part of this chapter discusses some of the characteristics of these contractors, which are as follow: 1) Design capabilities, 2) Safety control, 3) Research and development capabilities, and 4) Quality control programs.

5.2 Historical Backgrounds

The big five general contractors have always lead the construction industry in Japan even prior to World War II. According to Nakamura [1985], the top five construction firms in 1944 in order of size were Shimizu-gumi, Ohbayashi-Gumi, Takenaka-koumuten, Okura-doboku (currently known as Taisei-kensetsu) and Kajima-gumi. All these firms still remain as the big five contractors today. It is interesting to note that all the top 10 construction firms at that time still remain in the construction industry and have kept their same prestigious positions. Thus, the big general contractors have established stable positions in the industry. This stability of the big general contractors indicates high entrance and exit barriers of the industry. It contrasts clearly with small size construction establishments, which typically have low entrance and exit barriers.

The one exceptional movement in Japanese construction industry is Kumagai-gumi, which has increased its share with a relatively aggressive policy and has caught up to the big five contractors. However, it should be recognized that Kumagai-gumi used to be one of the top ten contractors in 1944. Also it must be noted that it increased its share mainly through overseas construction projects, indicating the difficulty of increasing share in the domestic market.

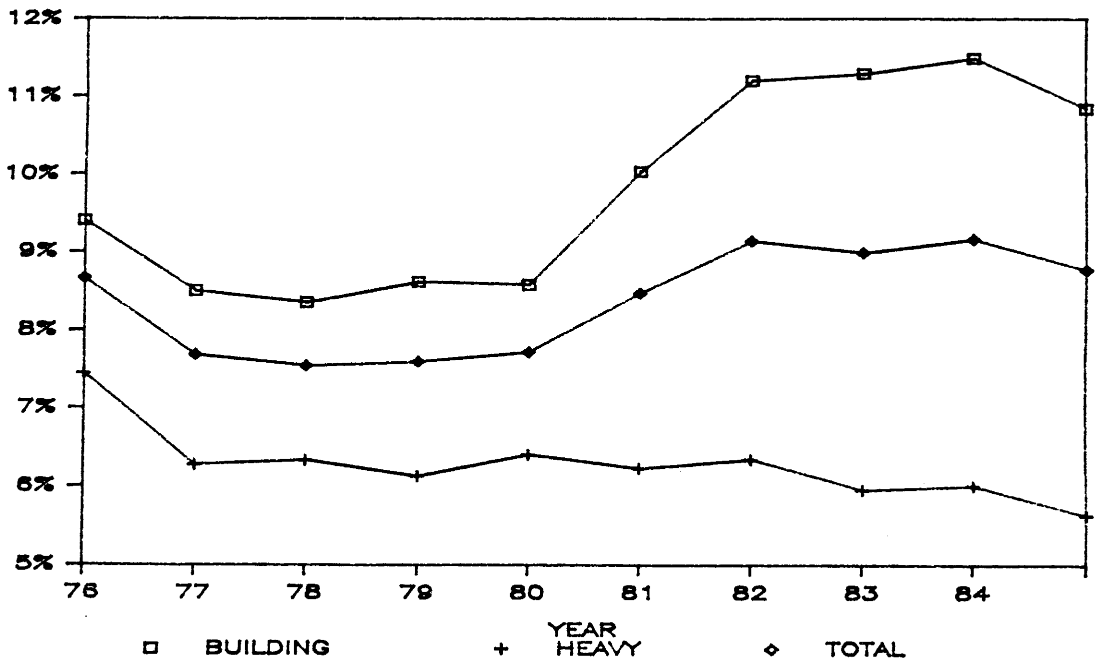
5.3 Share in the Domestic Market

Their share in the total domestic construction market is shown in figure 5.1. The total share of the big five (Kajima-kensetsu, Taisei-kensetsu, Shimizu-kensetsu Ohbayashi-gumi and Takenaka-koumuten) plus one (Kumagai gumi) contractors has fluctuated between 7.55 percent and 9.17 percent during the last ten years. This fluctuation of their share in the construction market seems to come from the phase difference of construction investment due to the magnitude of the project they are involved. Figure 5.2 shows the percent increase of the value of construction from previous years of the big five plus one general contractors and total construction investment, indicating a topological difference.

By type of construction, they construct both buildings and heavy construction except for Takenaka-koumuten which specializes in building construction and has a subsidiary specializes heavy construction. The other big five contractors' market consists roughly of 70 percent of building construction and 30 percent of heavy construction.

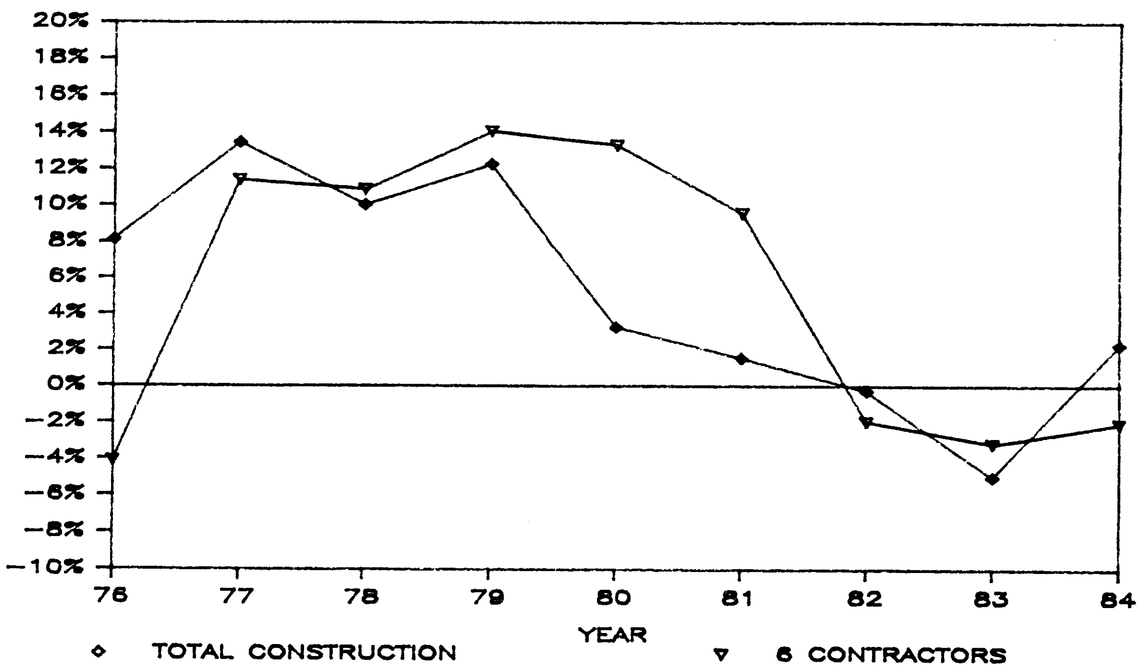
Big five plus one contractors' share in the total building construction has increased from about 9 percent in the late 70's to almost 11 percent in the 80's. In the heavy construction, on the contrary, it has decreased from 7.45 percent in 1975 to 5.64 percent in 1984 reflecting the aforementioned government and local governments policy to give priority to the local contractors over nation-wide contractors in public construction. This policy is more clearly depicted in the statistics for top 43 contractors. Their share in public construction has continuously decreased from 30.0 percent in 1965 to 16.5 percent in 1983.

Figure 5.1 Domestic Market Share of Top Six Contractors



Source: Annual Reports of General Contractors

Figure 5.2 Percent Increase of Construction Volume



Source: Annual Reports of General Contractors

5.4 Similarity Among the Big Five Contractors

The summary of the big five contractors is given in table 5.1. As shown, many similarities can be observed among them. Their number of employees is between 9,000 and 13,000. Their sales are between 70 billion and 100 billion yen. Their field of operation is limited to building construction and heavy construction. They do not have a lot of business in the field of industrial construction such as petroleum refining, petrochemical plant and nuclear power plant. They all have in-house design capability and their own research institutes Except for Taisei-kensetsu, owners have strong influence in their management. Their market consists of almost 70 percent of building construction and 30 percent of heavy construction except for Takenaka Koumuten. The percentage of foreign construction is between 5 and 10 percent, which is considerably low for the size of operation compared with their counterpart in the U.S. and European countries. They receive almost 80 percent of their business from the private sector. This is accomplished through negotiation -- not through the bidding process.

Table 5.1 Big Five General Contractors in Japan (1984)

	Kajima	Taisei	Shimizu	Ohbayashi	Takenaka
Founded in	1930	1917	1937	1936	1937
Employee	13042	12236	10181	9988	8983
Sales(B.Yen)	932062	968332	923544	766318	686476
Building	62%	70%	79%	64%	94%
Heavy	33%	27%	19%	32%	2%
Other	5%	3%	2%	4%	4%
Foreign const.	6%	7%	9%	5%	4%
Head Office	Tokyo	Tokyo	Tokyo	Tokyo	Osaka
President	Owner		(Owner)	Owner	Owner
R & D	Yes	Yes	Yes	Yes	Yes
Design Cap.	Yes	Yes	Yes	Yes	Yes

Source: Nakamura, 1985

5.5 Industrial Groups

Some of the similarities among these general contractors can be explained by their involvement in the industrial groups. There are mainly two types of industrial groups in Japan. The fast and most dominant industrial groups are so called "Zaibatsu Group", based on pre-war zaibatsu cliques, and the second is based on large companies that have grown up after World War II such as Toyota Motor Corp., Hitachi Ltd., Matsushita Electric Industrial Co..

The six industrial groups of the first category are called "Big Six", which are listed in table 5.2.

Table 5.2 "Zaibatsu-Groups" of Japanese Industry

Name of the group	Main bank	(1)	Member construction firm
Nimoku-kai	Mitsui Bank	24	Mitsui kensetsu
Kinyo-kai	Mitsubishi Bk.	28	Mitsubishi kensetsu
Hakusui-kai	Sumitomo Bkank	21	Sumitomo kensetsu
Fuyo-kai	Fuji Bkank	29	Taisei kensetsu
Sansui-kai	Sanwa Bank	42	Ohbayashi gumi
Sankin-kai	D.K.B. (2)	45	Shimizu kensetsu

Note (1) : Number of member companies.

(2) : Daiich-Kangyo Bank.

Source : Japan Economic Almanacs, 1985

Table 5.3 Example of Industrial Groups

Fuyo Group (1984)

Member Companies	Capital	Business	Sales
Fuji Bank	111375	Bank	19511375
Yasuda Trust Bank	30000	Trust Bank	8825909
Yasuda Life Insur.	N.A.	Life Insur.	N.A.
Yasuda Fire and Marine	40500	Fire Insur.	711443
Marubeni	46693	Trading	13563875
Taisei	38869	Construction	968322
Tokyo Tatemono	5703	Real Estate	24996
Nisssin Flour	9854	Milling	314904
Sapporo Breweries	14175	Brewery	379928
Nichirei	11412	Food	276370
Nisshinbo	11377	Textile	210153
Toho Rayon	3000	Textile	85376
Sanyo kokusaku pulp	14245	Pulp	276404
Showa Denko	43730	Chemical	411660
Kureha Chemical Ind.	9944	Chemical	121766
Nippon Oil	11004	Chemical	117883
Nihhon cement	10836	Cement	157013
Toa nenryo	24490	Petro.ref	1086191
Nippon Kokan	156850	Steel	1500780
Kubota	67420	Agr.Machine	589209
Nippon seiko	24741	Bearing	237836
Nissan Motor	112473	Car	3618076
Hitachi	140154	Electric	2648207
Oki Electric	28414	Elec.appr	361866
Yokogawa Hokushin	12276	Electric	139782
Canon	27891	Bsns.Machine	485024
Tobu railway	30149	Railway	150047
Keihin railway	17279	Railway	104276
Showa line	7715	Transportation	150303

Source: Nikkan Kogyo Shinbun 11.7.85.

Three of the big five contractors are official member companies of such industrial groups which include: Shimizu-kensetsu, Taisei-kensetsu and Ohbayashi-gumi belong to Sankin-kai (D.K.B. group), Fuyo-kai (Fuji group) and Sansui-kai (Sanwa group) respectively. In addition, Kajima-kensetsu has close relations with Mitsui and Sumitomo groups. Table 5.4 shows major stock holders and their share in the big five plus one contractor. The bank heading the industrial group usually has the greatest share of the construction firms except for the owners. However, it is not unusual that two or more banks finance one general contractor. For example, Sumitomo Bank and Mitsui Bank owns 4.94 percent and 3.45 percent of Kajima's stocks respectively. Beside their share in equity, through long term and short term loan, theses large banks finance their member companies intensively. Table 5.5 shows the balance sheets of Ohbayashi Corp. and Turner Corp.. In this table, the difference in accounting convention for construction in progress are adjusted so as to make them compatible. It shows that debt to equity ratio of Ohbayashi is 3.52 and that of Turner is 1.84.

Also it is common that a corporation to belong to an industrial group that finances construction firms outside its group. For instance, Nippon Life Insurance finances five of the six major contractors. Such cases are often observed for member companies with intensive construction investment such as life insurance companies.

Table 5.4 Stock Holders of Big Five plus One Contractors

Share holders\Const.firms	(1)	(2)	(3)	(4)	(5)	(6)
Mitsui group						
Mitsui Bk.	3.45		1.51			
Mitsui Trust Bk.	2.14					
Mitsubishi group						
Mitsubishi Bk.					3.06	
Mitsubishi Trust Bk		2.96				
Mitsubishi R.E.				1.86		
Sumitomo group						
Sumitomo Bk.	4.94					3.82
Sumitomo Trust Bk.	1.84					1.56
Sumitomo Life Ins.			1.14			
Fuji group						
Fuji Bk.				5.14		
Yasuda Trust Bk.				2.52		
Sanwa group						
Sanwa Bk.			4.10			
Toyo Trust Bk.			0.85			
Nippon Life Ins.	2.24	1.83	6.48	2.35		2.20
D.K.B. group						
D.K.B.		7.19				
Fukoku Life Ins.		1.48				
Owner	5.47	2.21	12.35		3.38	9.74
Employee group	2.63	5.34	3.82	5.81	0.82	4.79

Note (1) Kajima-kensetsu.
(2) Shimizu-kensetsu.
(3) Ohbayashi-gumi.
(4) Taisei-kensetsu.
(5) Takenaka-koumuten.
(6) Kumagai-gumi.

Source: Nakamura, 1985.

Table 5.5 Adjusted Balance Sheet of Ohbayashi and Turner

(Dec 31, 1984)	OHBAYASHI (M.YEN)	(M.$)	(%)	TURNER (M.$)	(%)
		ASSETS			
CURRENT ASSETS					
Cash	69,662	348.3	12.5%	22.7	13.5%
Mark.Sec.	45,233	226.2	8.1%		
Act.Receivable	148,325	741.6	26.7%	16.2	9.7%
Inventory	152,270	761.4	27.4%	13.8	8.3%
Other	16,873	84.4	3.0%	25.8	15.4%
Total	432,363	2,161.8	77.9%	78.5	46.9%
INVESTMENT					
Security	16,109	80.5	2.9%		
Subsidiary	9,573	47.9	1.7%		
Other	47,173	235.9	8.5%	66.1	39.5%
Total	72,855	364.3	13.1%	66.1	39.5%
PROP.PLANT.EQUIPMENT					
Land	26,456	132.3	4.8%	0.8	0.5%
Buildings	18,094	90.5	3.3%	2.7	1.6%
Machin. & Equipmt.	43,289	216.4	7.8%	9.9	5.9%
Const. in progress	1,872	9.4	0.3%	19.3	11.5%
(Acm.Depreciation)	(39,662)	(198.3)	-7.1%	(16.7)	-10.0%
Total	50,049	250.2	9.0%	16.0	9.6%
OTHER ASSETS				6.7	4.0%
TOTAL ASSETS	555,267	2,776.3	100.0%	167.3	100.0%
		LIABILITIES			
CURRENT LIABILITIES					
Bank loan	123,365	616.8	22.2%	25.8	15.4%
Acct. payable	192,589	962.9	34.7%		
Accrd.expenses	9,032	45.2	1.6%	19.1	11.4%
Other	30,958	154.8	5.6%	43.9	26.2%
Total	355,944	1,779.7	64.1%	88.8	53.1%
LONG-TERM LIABILITIES					
Total	76,376	381.9	13.8%	19.6	11.7%
SHAREHOLDERS' EQUITY					
Stocks	26,936	134.7	4.9%	4.5	2.7%
Paid in captl.	6,470	32.4	1.2%	2.0	1.2%
R.earnings	82,770	413.9	14.9%	60.8	36.3%
Other	6,771	33.9	1.2%	(8.4)	-5.0%
Total	122,947	614.7	22.1%	58.9	35.2%
TOTAL LIABILITIES	555,267	2,776.3	100.0%	167.3	100.0%

Sources: Annual Reports 1984 of Ohbayashi and Turner

5.6 Intra-industrial Group Vertical Integration

Although the structure of industrial groups is not a simple one (by being involved in one or a few industrial groups), general contractors can receive relatively constant orders from member companies or from companies who have the same main bank. Also as a members of such groups, they have the advantages to cooperate with other members of the groups. Such corporations are well illustrated in the process of developing construction robots which is described in the next chapter. Thus, as often pointed out, [e.g. Sasaki, 1981] this intra-industry group vertical integration also works for the construction industry.

However, involvement in industrial groups also has negative effects. For instance, the tight control within an industrial groups is so strong that often makes it difficult for members to effectively diversify into other fields. For instance, even if a contractors wants to expand their business toward development, it will be very difficult to compete with real estate companies or private railway companies who have much more experience in such field. Also, such restrictive policy may deprive the contractors of the advantage and privileges of the membership they enjoy now.

Being a member of an industrial group, general contractors are expected to have the same technology because in an industrial group, technical disadvantage of a member construction firm is disadvantageous to the whole industrial group. Even if it be difficult to maintain such high technological capabilities, these firms benefit from the protection of the group by being given first preference. For example, Mitsubishi Motor Co. has produced "Debonair", an mid-size car, for almost 20 years without major model changes at the rate of less than 50 car a month. As it is not an attractive car, no one except member companies willing to buy it. If Mitsubishi group companies buy similar cars from Toyota Motors or Nissan, member companies could have enjoyed better performance, comfort and service and Mitsubishi Motors also could have increased it's profit by cutting off such less profitable model.

In the construction industry, such pressure for member contractors promotes the technology transfer very quickly. For instance, slurry walls were first introduced to Japan in early 1960's from ICOS of Italy and took no more than five years for all big general contractors to acquire this technology. As Paulson pointed out, rigid social and physical conditions in Japan require such techniques to utilize limited land especially in the crowded area of Tokyo and Osaka area. [Paulson, 1980a] For the Japanese contractor technical disadvantages may be fatal even if these advantages do not last long. Such business environment inevitably gives general contractor similar character.

5.7 Intra-industry Coordination

Intra-industry coordination is another factor that gives the general contractors a similar character. The center of such intra-industry coordination is the Ministry of Construction. For example, in early 60's, it committed the Association of General Contractors (AGC) to study high-rise structures. As a result, all the big general contractors share the basic skill required for the high rise building including design, construction and management of the project. [Miura, "Nihon no Kensetsu Seisan", 1977, pp 114.] Also, the Ministry of Construction encourages general contractors to form joint ventures to improve construction industry financially and technically. ["Kensetsu-sho (Ministry of construction)", 1979, pp 120.]

The private sector, as well as the public sector, have strong incentives for the intra-industry coordination mainly in order to stabilize their business fluctuations. Just like other major Japanese companies, Japanese general contractors adhere to the life employment system, which makes organizations less flexible to business fluctuations. Also their capital intensive nature compared to their U.S. counterparts forces the contractors to stabilize their size of operation to utilize their depreciable assets effectively. Thus, these characteristics make contractors prefer the size of the operation to profitabilities. As general contractors cannot share the market by types of construction or geographical area, because of the similarity of their character, they cooperate to share the market through negotiation to avoid severe price competition. However, such preference of big contractors has decreased their profit margin continuously since the oil crisis. (Table 5.6)

Table 5.6 Operational Profit Margin of Contractors (%)

SIZE \ YEAR	70	72	74	76	78	80	82	84
LARGE	7.0	5.4	5.6	5.6	3.1	4.2	4.3	3.1
MEDIUM (BLDG)	4.0	3.9	4.5	5.1	2.2	2.5	3.0	1.9
MEDIUM (HVY)	5.9	5.0	4.9	5.8	4.3	3.9	3.8	3.4
SMALL (BLDG)	3.6	3.5	3.6	5.2	1.6	2.7	3.7	2.7

Source: Nakamura, 1985, pp38.

Such efforts to stabilize business fluctuations also appears in the form of joint ventures. Although joint venture was first introduced to manage risks and to solve technical problems, it has been used as a method to share the market in Japan. For example, seven out of eight skyscrapers at Shinjuku, new center of Tokyo, were completed by such joint venture. The rest one is owned by Taisei Corporation. Such joint venture s are commonly used even in small projects such as condominiums of 30,000 sf..

Thus, through intra-industry group vertical integration and through intra-industry coordination, the Japanese Big general contractors have shared domestic construction market, and as a result attained their similar character.

5.8 Design Capability

Table 5.7 and table 5.8 show comparisons between top five design and engineering firms and design divisions of big five general contractors. Table 5.7 shows the number of engineers and architects of those firms. For the general contractors, these numbers include only those who work for design divisions, while they include all engineers and architect for the design and engineering firms. The total number of those in five design and engineering firms is 2413, while those working for five construction firms is 4344 in 1984. Average size of general contractors' design division is almost the same as the largest design and engineering firm, Nikken sekkei, which has 1004 engineers and architects. Furthermore, as this number for the design firms is not limited to those working for design division but also includes those working for construction management and quantity surveying and so forth, the actual number working for design and engineering division is almost 600. Therefore, design divisions of the big five general contractors are the top five design establishment in terms of their size.

Table 5.7 Number of Engineers and Designers

Year	79	80	81	82	83	84
[Top Five Design and Engineering Firms]						
Nikken Sekkei	951	951	966	987	1003	1004
Mitsubishi Jisho	398	420	434	428	431	418
Yamashita Sekkei	277	286	289	292	298	305
Kume Arch.	328	340	357	365	357	371
Nihon Sekkei	286	292	297	296	297	315
TOTAL TOP 5	2240	2289	2343	2368	2386	2413
[Top Five General Contractors]						
Takenaka	954	1005	1131	1177	1158	1167
Taisei	723	718	690	678	619	631
Kajima	889	887	900	919	889	875
Ohbayashi	693	731	749	814	824	835
Shimizu	660	679	719	768	812	836
TOTAL TOP 5	3919	4020	4189	4356	4302	4344

Source: Nikkei-Architecture, 1980-1985
Compiled by the author

Table 5.8 Type of Building Design

BUILDING TYPE	COM	CONDO	FAC	GYM	EDCT	HOSP
[Top Five Design and Engineering Firms]						
Nikken Sekkei	27%		12%	9%		
Mitsubishi Jisho	63%					
Yamashita Sekkei						
Kume Arch.	16%				22%	12%
Nihon Sekkei	30%					10%
[Top Five General Contractors]						
Takenaka	25%	14%	10%			
Taisei	25%	N.A.	20%			
Kajima	22%	11%	37%			
Ohbayashi	30%	15%	18%			
Shimizu	31%	17%	25%			

N.B.
COM: Commercial building CONDO: Condominium
FAC: Factory GYM: Gymnasium
EDCT: Educational bldg. HOSP: Hospital

Source: Nikkei-Architecture, 1980-1985
Compiled by the author

5.8.1 Design-Build Contract

The term design-build contract in the U.S. refers to a system in which design firms, engineering firms and builders cooperate with one another from the programming stage of a project in order to perform fast track construction and cost effectiveness of the project. In Japan, however, it refers to a special contract between a general contractor and an owner that the general contractor will do everything from planning to the completion of the construction without employing outside design and engineering firms. This peculiar design build contract comes from the fact that architectural design is not yet established as an independent profession in Japan. In fact, even two of the five top design firms, Nikken-Sekkei and Mitsubishi-Jisho, used to be in-house architects for the "Zaibatsu" cliques. Coincidently, they belongs to the groups, Sumitomo group and Mitsubishi group, that do not have one of big five contractors as their members.

Table 5.9 shows the amount of such design-build contracts for building construction and total building construction contract. It accounts for about 40 percent of total building construction in all the five contractors. Particularly, Takenaka-koumuten, which specializes in building construction, has a high percentage (about 50 percent) of design-build contract. As the market share of those contractors in building construction is about 10%, they design almost 4 % of the total building in Japan.

Table 5.9 Design-Build Contract by the General Contractors

Year	79	80	81	82	83	84
DESIGN BUILD CONTRACT (Billion Yen)						
Takenaka	247	336	332	346	332	297
Taisei	190	176	130	215	248	247
Kajima	190	178	234	233	200	253
Ohbayashi	155	194	207	191	189	194
Shimizu	248	250	262	325	306	288
TOTAL TOP 5	1029	1134	1164	1310	1275	1279
BUILDING CONSTRUCTION CONTRACT (Billion Yen)						
Takenaka	520	589	648	685	660	666
Taisei	505	547	685	659	642	649
Kajima	392	528	612	613	553	554
Ohbayashi	378	456	482	468	512	485
Shimizu	605	632	727	816	758	722
TOTAL TOP 5	2401	2752	3154	3242	3125	3076
PERCENTAGE OF DESIGN BUILD CONTRACT TO TOTAL BLDG. CONTRACT						
Takenaka	48%	57%	51%	50%	50%	45%
Taisei	38%	32%	19%	33%	39%	38%
Kajima	48%	34%	38%	38%	36%	46%
Ohbayashi	41%	43%	43%	41%	37%	40%
Shimizu	41%	40%	36%	40%	40%	40%
TOTAL TOP 5	43%	41%	37%	40%	41%	42%

Source: Nikkei-Architecture, 1980-1985
Compiled by the author

Nevertheless, design division of general contractors used to be an unimportant part of their business until the so called "High Growth Era" ended in the early 70's by the oil crisis. During this era, general contractors could easily obtain contracts sufficient to keep themselves busy and offered design services only upon owners request. Recently, however, design divisions of the general contractors have been considered to be an essential part of the business and one of the major strategies to increase market share.

According to the survey conducted by "Nikkei architecture" [July 15, 1985], the major types of structures, applying design-build contract are commercial buildings, condominiums and factories, which account for 25-30 percent, 10-17 percent and 14-22 percent of the total design build contracts respectively. These percentages does not vary so much within the top general contractors, whereas, as shown in table 5.7, top design firms seem to have their own specialties.

Although general contractors can design buildings that require aesthetic design or special design skills such as museums, auditoriums, hospitals and colleges and it is not unusual that they win design competitions, their majority of work is such buildings where they can demonstrate their organizational and size advantage. Thus, similarities among big five contractors can be observed also in their design divisions.

5.8.2 Strength of Design-Build Contract

The strength of this design-build contract is that they can fully utilize the organizational advantages to cut the project schedule, to find optimum balance of quality and cost and to construct failure free buildings.

From the planning phase of the project, many divisions such as construction engineering, structural design, legal consultation and marketing participate in the project to facilitate the process in the most effective manner; engineering divisions propose the most effective construction methods, structural design divisions proposes the best suited structural systems, marketing divisions study alternative uses of the lot and so on.

Thus, design-build contracts by general contractors in Japan provide very convenient systems for the owners.

5.8.3 CAD Application

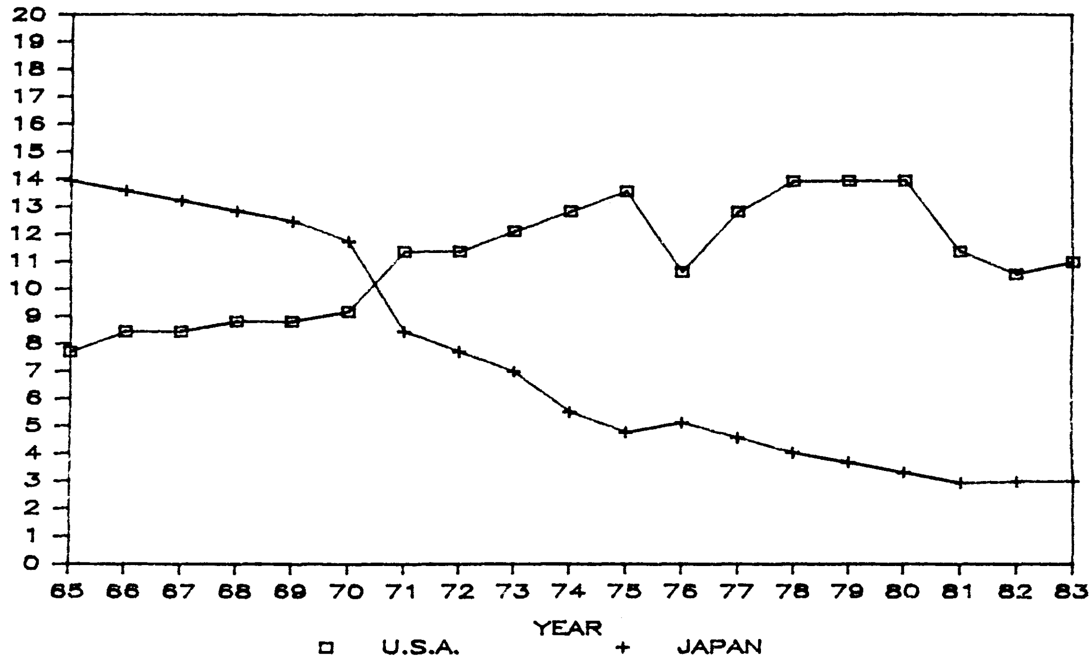
During these design-build processes, computers are fully utilized for structural analysis and computer aided design. Although the basic technology of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) came from the United States, it's application to the construction industry is most effectively developed and used most extensively by general contractors in Japan. All the five general contractors have developed their own CAD system, which is not only used for drafting and presentation purposes but also for sharing data with various activities, such as structural design, engineering design, quantity surveying in order to eliminate redundancy, to review alternatives from various areas and to speed up the design process. [Takase, 1985]

For example, Ohbayashi-gumi has developed a Totalized Architectural Design and Drafting System (TADD), which incorporates with CADAM, enables extensive use of CAD by architectural, structural and engineering designers. Furthermore, part of this system is sold through CADAM.

5.9 Safety Control

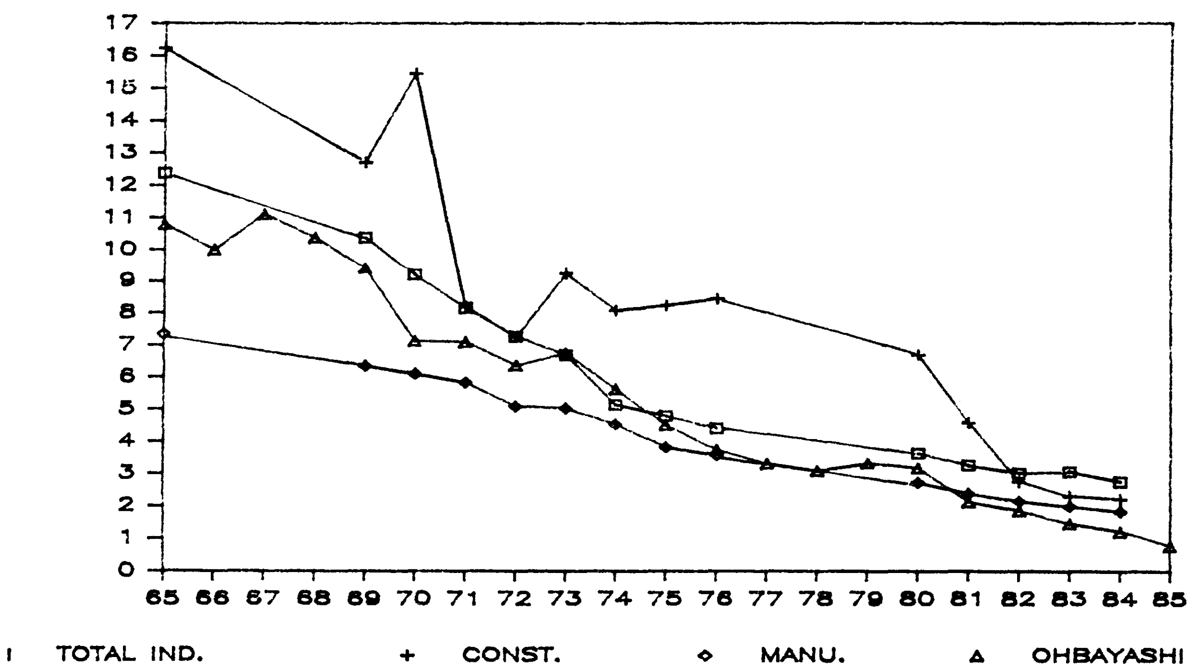
Safety control is one major issue that must be solved in the construction industry. In Japan , those who are injured and killed account for 29.2 percent and 41.1 percent on the total industry in 1984 respectively [Ministry of Labor, 1985]. However, occupational injury in Japan has decreased during the last two decades. As shown in figure 5.3, frequency rate, which is given by the number of injury per one million working hour, has decreased in Japan while it has gradually increased from 1961 in the U.S.. Furthermore, the frequency rate for the construction industry has decreased more significantly from 12.7, which is higher than that of total industry, in 1965 to 2.2 in 1984, which is substantially lower than that of total industry. In the U.S., however, it is 11.0 for the total industry and 19.4 for the construction industry, which is still among the highest in total industry.

Figure 5.3 Accident Frequency Rate of Japan and the U.S.



Source: Ministory of Labor, 1985

Figure 5.4 Accident Frequency Rate of Industries in Japan



Source: Ministory of Labor, 1985.

The big construction firms have still better records. Figure 5.4 shows frequency rates of total industry, the construction industry, the manufacturing industry and Ohbayashi-gumi for the last twenty years. It has decreased to less than one tenth during the last twenty years and now it is lower than that of manufacturing industry since 1981. This significant decrease of occupational injury in Japan is performed by the policy of Ministry of Labor to put responsibility of safety control on the employer. In the construction industry, the project manager of general contractors is responsible for the safety control at the site. If there is a violation of safety codes or negligence that results in accidents, the project manager is prosecuted. For instance, in December 1984, sixteen construction workers were injured or killed in a project of old bridge demolition. Recently, not only the project manager but also engineers at the head office of the general contractor were prosecuted [The Asahi, March 26, 1986]. Furthermore, such accidents will disqualify contractors to bid public works.

Thus, the cost of accidents is very expensive for contractors both directly and indirectly, and is the major motivation for general contractors to decrease occupational injury at construction sites. To decrease accidents, special division are set up to regularly make visits to construction sites and check safety conditions. Also, they sometimes make safety training programs for subcontractors.

5.10 Research and Development

One of the characteristics of general contractors in Japan is their research and development (R&D) capabilities. As Paulson wrote, Japanese general contractors have successfully adopted the organized pattern of R&D. [Paulson, 1980a] In 1983, R&D expenditure by construction industry in Japan was 101.3 billion yes (about 500 million dollar). It was 2.2 percent of total R&D expenditures by industries in Japan. The big five general contractors spend 29.0 billion yen which was 28.6 percent of total R&D expenditure by the construction industry. 1612 employees work for their R&D institutes which account for 3 percent of total employees. The ratio of their R&D expenditures to the total sales and operational profit were 0.79 percent and 19.6 percent in 1983 respectively. [Report on the Survey of Research and Development, 1984]

According to Paulson, their incentives for the general contractors to put much emphasis on the R&D activities are as follows:

1) Strict building codes.
2) Japan's rigid physical and social constraints.
3) Safety requirement.
4) Prequalification documentation needed bid on major public works.
5) Tax incentives.
6) Competitive technical edge given to company by patenting and licensing technologies for more

productive, economic effective construction design and procedures.

Thus, the political social and business environment make the general contractors to put much emphasis on the R&D activities.

The construction industry's internal expenditure on R&D by type of activity is shown in table 5.10.

Table 5.10 R&D Expenditures by Type of Activity. (1983)

Type of Activity	Expenditure (Million Yen)	Percentage
Basic Research	5,714	5.6%
Applied Research	24,489	24.2%
Development	71,136	70.2%

Source: Report on the Survey of Research and Development, 1984

This percentage distribution is almost the same with total industry. The tendency to put much importance on development rather than basic research is commonly found in Japanese industries. There are two reasons for it. The first reason is that R&D by industries, institutes and universities share the total R&D by type of activity. Table 5.11 shows the type of R&D activity by kind of organization.

Table 5.11 Type of R&D Activity by Kind of Organization

Organization	Industries	Institutes	University
Basic Research	5.7%	12.6%	56.4%
Applied Research	22.0%	30.8%	35.7%
Development	72.3%	56.6%	7.9%

Source: Report on the Survey of Research and Development 1985

As a result of this sharing, R&D in industries can concentrate on the development.

The second reason is the aforementioned industrial groups. Many companies in different fields can cooperate with another to make the most of their R&D capability as a group and avoid redundant basic research. Table 5.12 shows the R&D by other industries in the field of construction. Not only the construction industry but also other industries make research areas in the field of construction. Among them, industries that produce construction material such as chemical industry, ceramic and clay product industry and steel and iron industry have almost a 5 percent share of R&D in construction.

Table 5.12 Construction R&D by All Industry

Industry	Expenditure (Million Yen)	Percentage
All Industries	88,980	100.00%
Agriculture	37	0.04%
Construction	63,132	70.95%
Mining	109	0.12%
Chemicals	4,741	5.33%
Ceramics & Clay	3,876	4.36%
Iron & Steel	4,251	4.78%
Fabricated metal products	1,322	1.49%
General Machinery	1,202	1.35%
Transportation, Communication & public Utilities	4,332	4.87%

Source: Report on the Survey of Research and Development 1984

On the contrary, R&D by construction industries is limited in the field of construction indicating the nature of construction industry that has limited intermediate output and secondary products and their reluctance to diversify into other fields of operation, such as petroleum refinery.

The organization and research conducted by Taisei corporation are shown in figure 5.5. It does not vary much within the big five general contractors.

Figure 5.5 Organization and Research Conducted by Taisei Corporation

```
                ---Planning Department
                |     |
                |     |--Planning division
                |     |--Data division
                |      --Building System Division
                |
                |---Building Construction Department
                |     |
                |     |--Finishing Material Laboratory
                |     |--Other Material Laboratory
                |     |--Air Conditioning and Sanitary Laboratory
                |     |--Acoustic Engineering Laboratory
                |     |--Structural engineering Laboratory
                |     |--Steel Structure Laboratory
                |     |--Soil and Foundation Laboratory
                |      --Vibration Laboratory
                |
Director---------Heavy Construction Department
                |     |
                |     |--Heavy Construction Structural
                |     |--engineering Laboratory
                |     |--Material Laboratory
                |     |--Soil Engineering Laboratory
                |      --Hydraulic Engineering Laboratory
                |
                |---Experiment Department
                |     |
                |     |--Structural Experiment Laboratory
                |      --Other Experiment Laboratory
                |
                 ---Project teams
                      |
                       --Water Jet Project Team
```

Source: Technical Research Institute Taisei Corporation, 1985.

5.11 Quality Control

Total Quality Control (TQC) has been the most controversial issue among the big general contractors in Japan during the last ten years. The principles of total quality control by Feigenbaum, who first introduced the concept of total quality control in 1961, is excerpted in appendix four at the end of this chapter. TQC was fist introduced by Takenaka-koumuten in 1976. Takenaka was awarded the "Deming prize" in 1979, which is given to a few firms with excellent quality-control program, as the first construction firm in Japan. Two more general contractors of the big five, Kajima and Shimizu, announced introduction of TQC in the late 70's and also were awarded the same prize in the early 80's. As like many other technologies, TQC has transferred very quickly in the construction industry. Now, all of the top general contractors have introduced quality-control programs in varying degree.

The concept of Quality Control (QC) was first introduced by Dr. Deming to Japan immediately after WW II. It was widely applied by many manufacturing firms during the 50's and 60's. In the construction industry, however, it was not introduced until the "High Growth Era" ended by the first oil crisis, because of the supply side market due to "hot" domestic construction. According to Araki, the major motivation to introduce TQC by construction firms was a strategy to increase their market share facing the shrinking domestic market after the first oil crisis [Araki, 1980].

The application of TQC in the construction industry, however, have many problems. For instance, construction workers are less conscious about the quality of the work they perform. They have difficulty in understanding some fundamentals necessary for the Statistical Quality Control (SQC) such as standard deviation. The production process is less repetitive and no project has exactly the same condition as another project. Many participants from different organizations, such as designers, engineers, general contractors and subcontractors, are involved in a project and their relationship is only temporary. Their responsibilities to the final product is not clear. For example, if a roof reaks, it is often difficult to identify whether it is due to the careless detail design by the architect or negligence of the general contractor's supervision and inspection or defective workmanship by the subcontractors. Also it is very difficult to measure the performance of a project. Evaluation of a building is quite subjective and differs by the point of view from which it is evaluated.

The big general contractors in Japan certainly have advantages to introduce TQC to their counterparts in the U.S. from these points of view. As shown earlier in this chapter, they are extensively involved in both service oriented areas of construction such as design, programming, engineering and R&D and actual production processes at the site. Their relationship with the owner is not a temporary one, but a perpetual one through industrial groups. Also they have a stable relationship with their hierarchical subcontractors and, therefore, they have incentives to invest and educate subcontractors fundamentals of TQC. TQC is also practiced in their sales, engineering and design divisions.

In addition, the construction industry itself has some features that make the application of TQC more attractive. Unlike the products of the manufacturing industry, the products of the construction industry are well defined in some sense because the requirement of the owner is usually identified before production in contrast, progress of the manufacturing industry are difficult to identify. Subsequently, marketing is the one of the essential parts of TQC. Moreover, as almost no effort was made in the construction industry to apply TQC, the effect of it must be greater than that in the other industries.

The actual process of introducing TQC took at least three years and required many human resources to establish the program and to educate members including those of subcontractors. The introduction of TQC, however, also created stress in the traditional and stable "Japanese" organization. Those who are involved in the TQC often complain. Also, there have been a lot of counter arguments to TQC and many books against TQC were published [e.g. Kamada, 1985]. However, these counter arguments discusses only the side effect of the introduction and not address the and concerning TQC's potential for reducing effectiveness of the introduction and not essential arguments no essential argument was made to decrease the effectiveness of TQC.

As Feigenbaum wrote, TQC is a customer-oriented program and the owners surely benefit from it in terms of the cost effectiveness of their investment. Therefore, it must be an effective strategy to penetrate in the construction market. It was quite reasonable that Takenaka-Koumuten introduced TQC because the construction market was not actively utilizing their surplus human resources. The process of introducing TQC by construction firms is similar to the way Japanese other industry have increased their competitiveness.from recessions or hostile environment.

5.12 Summary of Chapter Five

1) Big five general contractors in Japan have dominated the domestic construction market since before the World War II and have kept their position.

2) They have a lot of similarity.

3) Their similarity is attained by intra-industry coordination and intra- industry coordination.

4) Their design divisions have largest design and engineering organization in Japan.

5) Their design-build contract is a customer oriented system, utilizing their scale merit such as Computer Aided Design,

6) Their accident frequency rate is lower than that of the manufacturing industry and that of the U.S. construction industry by far.

7) Business, social, physical and political environment in Japan encourages R&D activity in the construction industry.

8) They introduced TQC after the first oil crisis in order to provide most cost-effective products and services for customers.

APPENDIX FIVE TOTAL QUALITY CONTROL

Excerpt from Feigenbaum, A.V., TOTAL QUALITY CONTROL third edition, 1983, pp.823-829

The principles of Total Quality Control: A Summary

A series of "principles" continues to simmer out of industry's experience with the management of quality and total quality control.

An interpretation of these principles is presented below. It is offered as a summary of the "total quality management" approach which regards the quality of products and services as primary business strategy and fundamental determinant for business health, growth, and economic viability.

1. Total quality control may be defined as

   An effective system for integrating the quality development, quality-maintenance, and quality improvement efforts of various groups in an organization so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction.

2. In the phase "quality control," the word "quality does not have the popular meaning of "best" in any absolute sense. It means "best for certain customer requirements." These requirements are the (a) actual use and (b) selling price of the product.

3. In the phrase "quality control," the word "control" represents a management tool with four steps:
   a. Setting quality standards
   b. Appraising conformance to these standards
   c. Acting when the standards are exceeded
   d. Planning for improvements in the standards

4. Several quality-control methods have carried on in industry for many years. What is new in the modern approach to quality control is (a) the integration if these often unconnected activities and an engineered, operating systems framework which places the responsibility for customer-oriented quality efforts across all the main-line activities of an enterprise, giving quality organizationwide impact, and (b) the addition to the time-tested methods used of the new quality-control technologies which have been found useful in dealing with and thinking about the increased emphasis upon reliability in product design and precision in

parts manufacture.

5. As a major new business strategic area, quality is explicitly structured to contribute to business profitability and positive cash flow. Total-quality-control programs are highly cost-effective because of their results in improved levels of customer satisfaction, reduced operating costs, reduced operating losses and field service costs, and improved utilization of resources.

6. The need for such programs is underscored by changing buyer-producer relationships and major market place demands for quality. These are reflected in mounting product and service liability trends and consumer pressures which impact strongly upon products. In addition, there are new social and economic demands for more effective materials use and production processes to turn out increasingly technologically based products, new working patterns in factories and offices, and a growing trend toward inter nationalization of market.

7. The factors affecting product quality can be divided into two major groupings: (a) the technological, that is , machines, materials, and processes; (b) the human, that is, operators, foremen, and other company personnel. Of these two factors, the human is of greater importance by far.

8. Total quality control is an important aid to the good engineering designs, good manufacturing methods, and conscientious product service activity that have always been required for the delivery of high-quality articles.

9. The fundamentals of quality control are basic to any manufacturing process, whether the product is a nuclear reactor, a space vehicle, a consumer durable, or bakery, drug, brewery products. They are equally basic to so-called service industries, where the product may be an intangible, such as medical care, hotel accomodations, or telephone communications.

Although the approach is somewhat different if the production is job shop rather than large quantity or small components rather than large apparatus, the same fundamentals still obtain. This difference in approach can be readily summarized: In mass-production manufacturing, quality-control activities center on the product, whereas in job-lot manufacturing, they are a matter of controlling the process.

10. Quality control enters into all phases of the industrial production process, starting with the costomer's specification and sale to the customer through design engineering and assembly to shipment of the product and installation and field service for a customer who remains satisfied with the product.

11. Effective control over the factors affecting quality demands controls at all important stages of the production and service processes. These controls can be termed the <u>job of quality control</u>, and they fall into four natural classifications:

a. New-design control
b. Incoming-material control
c. Product control
d. Special process studies

12. New-design control involves the establishment and specification of the desirable cost-quality, performance-quality, safety-quality, and reliability-quality standards for the product, including the elimination of location of possible source of quality troubles before the start of formal production.

13. Incoming-material control involves the receiving and stocking, at the most economical levels of quality, of only those parts, materials, and components whose quality conforms to the specification requirements.

14. Product control involves the control of products at the source of production and through field service so that departures from the quality specification can be corrected before defective products are manufactured and proper product service can be maintained in the field.

15. Special process studies involves investigation and tests to locate the causes of defective products so as to improve quality characteristics and implement permanent corrective action.

16. A total quality system may be defined as

> The agreed companywide and plantwide operating work structure, documented in effective, integrated technical and managerial procedures, for guiding the coordinated actions of the people, the machines, and the information of the company and plant in the best and most practical ways to assure customer quality satisfaction and economical costs and quality.

The quality system provides integrated and continuous control to all key activities, making it truly organizationwide in scope.

17. The details for each quality-control program must be tailored to fit the needs of individual plants, but certain basic areas of attention are common to most programs for total quality control.

18. The target of the quality program attention is to

control product quality throughout the process of design, manufacturing,shipment, and service so as to prevent the occurance of unsatisfactory quality.

19. Benefits often resulting from total quality programs are improvements in product quality and design, reduction of production-line bottlenecks. By-product benefits are improved inspection and test methods, sounder setting of time standards for labor, definite schedules for preventive maintenance, the availability of powerful data for use in company advertising, and furnishing of factual basis for cost accounting standards for scrap, rework, and inspection.

20. Quality cost are a means for measuring and optimizing total-quality-control activities.

21. Operating quality costs are divided into four different classifications:
a. Preventive costs, which include quality planning and other costs associated with preventive nonconformance and defects.
b. Appraisal costs, or the costs of incurred in evaluating product quality to maintain established quality levels.
c. Internal failure costs, caused by defective and nonconforming materials and products that do not meet company quality specifications. These include scrap, rework, and spoilage.
d. External failure costs, caused by defective and nonconforming products reaching the customer. They include complaints and in-warranty product service costs, costs of product recall, court costs, and liability penalties.

22. Cost reductions - particularly reduction in operating quality costs - result from total quality control for two reasons:
a. Industry has often lacked effective, customer oriented quality standards. It has, therefore, often unrealistically tilted the scale in the balance between the cost of quality in product and the service that the product is to render.
b. An expenditure in the area of prevention can have a severalfold advantage in reducing costs in the area of internal failure and external failure. A saving of many dollars for each dollar spent in prevention is often experienced.

23. Organizationwise, total quality control is management's tool for delegating authority and responsibility for product quality, thus relieving itself of unnecessary detail while retaining the means of assuring that quality results will be satisfactory. There are two basic concepts important in organizing for quality control.

The first is that <u>quality is everybody's job</u>. Every component has quality-related responsibility, e.g., Marketing for determining customers' quality preferences, engineering for specifying product quality specifications, and Shop Supervision for building quality into the product.

The second concept is that <u>because quality is everybody's job, it may become nobody's job</u>. Management must recognize that many individual responsibilities for quality will be exercised most effectively when they are buttressed and served by a well-organized, full-time, genuinely modern management function whose only area of operation is in the quality-control jobs.

24. While the general manager must, in principle, become the chief designer of the quality program, the general manager and the other major company functions are assisted by an effective, modern, quality-control function.

25. This quality-control organizational component has twin objectives: (a) to provide quality assurance for the company's product, i.e., simply to be sure that the products shipped are right, and (b) to assists in assuring optimum quality costs for those products. It fulfills these objectives through its three subfunction: <u>quality engineering</u>, <u>process-control engineering</u>, and <u>quality information equipment engineering</u>. These quality control subfunctions provide basic engineering technologies that are applicable to any product for assuring its right quality at optimum quality cost.

26. <u>Quality engineering</u> contributes to the quality planning which is fundamental to the entire quality-control program for the company.

27. <u>Process-control engineering</u> monitors the application of this quality-control program on the production floor and thus gradually supplants the older policing inspection activity.

28. <u>Quality information equipment engineering</u> designs and develops the inspection and testing equipment for obtaining the necessary quality measurements and controls. Where justified, this equipment is combined with production to provide automatic feedback or results for control of the process. All pertinent results are then analyzed as basis for adjustment and corrective action on the process.

29. From the human relations point of view, quality-control organization is both a

a. <u>Channel of communication</u> for product-quality information among all concerned employees and groups.

b. <u>Means of participation</u> in the over all quality-control program by these employees and groups.

Quality-control organization is a means of breaking down the attitude sometimes held by factory operators and functional specialist that "our quality responsibility is so small a part of the whole that we're really not a part of the plant quality-control program nor are we important to it."

30. Total-quality-control programs should be developed carefully within a given company. It is often wise to select one or two quality areas, to achieve successful results in attacking them, and to let the program grow step by step in this fashion.

31. Necessary to the success of the quality program in a plant is the very intangible but extremely important spirit of quality-mindedness, extending from top management right to the men and women at the bench.

32. Whatever may be new about the total-quality-control program for a plant must be closely coupled throughout the entire plant organization so as to obtain willing acceptance and cooperation.

33. A quality-control program must have the complete support of the top management. With lukewarm management support, no amount of selling to the rest of the organization can be genuinely effective.

34. Management must recognize at the outset of its total-qulity-control program that this program is not a temporary quality improvement or quality cost reduction project. Only when the major problems represented by the internal quality improvements and cost reductions are out of the way can be the quality-control program take over its long-range role of the management control over quality.

35. Statistics are used in an overall quality-control program whenever and wherever they may be useful, but statistics are only one part of the total-quality-control pattern; they are not the pattern itself. The five statistical tools that have come to be used in quality control activities are

a. Frequency distributions
b. Control charts
c. Sampling tables
d. Special methods
e. Product reliability

The point of view represented by these statistical methods has, however, had profound effect upon the entire area of total quality control.

36. The statistical point of view in total quality resolves essentially in to this: Variation in product quality must be constantly studied - within batches of product, on

processing equipments, between different lots of the same article, on critical quality characteristics and standards. This variation may best be studied by the analysis of samples selected from the lots of product or from units produced by the same processing equipments. The development of advanced electronic and mechanical test equipment has provided basic improvement in the approach to this task.

37. The demands of total quality control are increased by automation of the manufacturing process. With automatic equipment, higher quality levels for parts sometimes are necessary for trouble-free operation. In fact, until higher quality levels are attained, excessive down time may make operation of the automated process uneconomic. Rapid detection of out-of-control conditions, feedback for process adjustment, and quick response of the process to correction are essential to low defect and noneconomic rates.

38. An important feature of total quality program is that it controls quality at the source. An example is its positive effect in stimulating and building up operator responsibility for, and interest in, product quality through measurements taken by the operator at the station.

39. Product reliability is, in effect, "product function over the product life expectancy(time)." It is a part of the balanced total product-quality requirement - just as are appearance, maintenability, serviceability, supportability, and so on - and hence cannot be treated separately from total quality control.

40. The total quality program provides the discipline, methodology, and techniques to assure consistently high product quality in the four basic job of

a. New-design control
b. Incoming-material control
c. Product control
d. Special process studies

It coordinates the effort of the people, the machines, and the information which are basic to total quality control to provide high customer quality satisfaction which brings competitive advantage to the company.

Quality is, in its essence, a way of managing. And total quality control's organizationwide impact involves the managerial and technical implementation of customer-oriented quality activities as a prime responsibility of general management and of the mainline operations of marketing, engineering, production, industrial relations, finance, and service as well as of the quality-control function itself at the most economical levels which provide full customer satisfaction.

CHAPTER 6 ROBOTS DEVELOPED BY GENERAL CONTRACTORS IN JAPAN

6.1 Introduction

The term "Robot" was first used by Czeck writer Karel Capek after Czeck word "Robota", which means compulsory, in 1923. Robots became very popular through cartoons and science fiction. However, it was not until the early 1960's that the first industrial robot was produced in the U.S.. The first industrial robot introduced in Japan, a simple playback robot, was imported from the U.S. in 1967.

In the early 70's they were introduced mainly into the automotive industry which suffered labor shortage due to rapid increasing exports. During the 70's, many firms in the manufacturing industry introduced robots into their production lines. By the end of 70's, they had outgrown their novelty in secondary industry .

Finally, in the 80's it extended out of manufacturing industry to other industries. The "Japanese Economic Journal" describes the current situation of robots introduction in Japan as follows:

> A recent noteworthy trend is that demand for industrial robots has began to shift from its traditional strong hold in manufacturing industry to construction, commerce, and primary sector areas such as farming, forestry fishing. [Japan Economic Journal, 1985]

The purpose of this chapter is to make a study of the application of industrial robots in the construction industry, and to make a brief survey of construction robots developed by general contractors in Japan in particular. Also, several strategies to develop construction robots are proposed.

6.2 Definition and Industrial Robots in Manufacturing Industry

The definition of an industrial robot by Robot Institute of America is as follows:

> A robot is a reprogramable multifunctional manipulator designed to move parts, tools or specified devices through revisable programed motion.

It is distinguished from conventional automation by its multifunctional and reprogramable functions. Therefore, while conventional automation is usually for mass-production of single product, industrial robots are introduced for even small production of various products.

The Japanese Industrial Robot Association classifies industrial robots into six types according to their complexity as follows from lower degree to higher degree of automation.

1) Manual manipulator
2) Fixed sequence robot
3) Variable sequence robot
4) Playback robot
5) Numerical control robot
6) Intelligent robot

The number of industrial robots by country is shown in table 6.1. It shows that robots are most widely introduced by Japanese industries.

Table 6.1 Number of Industrial Robot by Country (1982)

Country \ Type of Robot	(3)	(4) (5) (6)
Japan	14,000	3,000
U.S.A.	3,000	2,200
W. Germany	850	450

Source: Japanese Industrial Robot Association, 1984.

Note: (3) Variable sequence robot. (4) Playback robot.
(5) Numerical control robot. (6) Intelligent robot.

Almost all of these robots have been introduced by the manufacturing industry. In the manufacturing industry, the following reasons have accelerated the introduction of robots:

1) High utilization rate allows low capital consumption per unit production. (Economies of Scale)

2) Increased demand variation in the recent years.

3) Sharp wage increase especially for skilled worker.

4) A reduction in the cost of computing equipment that controls the robots.

5) Technical and system development have made many tasks feasible for robots.

6) Through mass-production, manufacturing industry is familiar with mechanization and have achieved high

degree of industrialization.

According to Kunimoto [1984], the active introduction of industrial robots in Japan is due to the following facts in addition:

1) Active R&D in industries promotes application of advanced technology.

2) Participation of small- and mid-size firms accelerated the development of various type of robots.

3) Development of advanced technology, control devices in particular, made the robots economically feasible.

4) Workers' consciousness of quality and productivity made themselves accept introduction of robots to the production line without serious objection.

5) Incentives provided by government such as tax deduction encouraged establishments to introduce them.

However, most of the industrial robots introduced in Japan are rather lower level robots compared with the U.S.. The reason for this is that they are not introduced individually but introduced so that they work as a part of systems. These systems which consist of many robots, are called Flexible Manufacturing System (FMS). FMS is a system that can produce many kinds of products on one production line and can easily correspond to design change of products. For example, in the factory of Toyota Motor Co., cars of several different types are produced in one production line.

The features of FMS are that it can utilize the capability of each robot more effectively than introducing them individually. It increases the utilization rate of robot by producing several kinds of products on one production lines, and make the factory compact. The last feature, in particular, may be one reason why construction investment has not shown significant increase, regardless of the peak of national economy until after the first oil crisis. According to Hasegawa [1984], FMS has been introduced since early 70's in Japan, and has spread much faster than any other countries. The number of such system is almost twice as much as those in the U.S. in 1982 [Hasegawa, 1984].

Thus, successful introduction of industrial robots not only depends on the performance and technology of each individual robot, but also on the coordination among robots in order to make the system truly effective. It makes the introduction of robots economically feasible.

Nevertheless, there are some drawbacks to this FMS. The first draw back is: as the systems become more complex, it becomes more difficult to control them, and, particularly in the case of system failure, it is difficult to resume regular operation quickly. The second draw back is: as technology involved in FMS is developing very rapidly, it may become obsolete soon before these systems are fully depreciated.

6.3 Robot Application in the Construction Industry

In the construction industry, robotics application is still on the testing phase and does not have many precedences. However it is expected to be used more extensively in the future for the following reasons and therefore quite prospective field.

The first reason is that there is necessity to increase productivity in the construction industry. The productivity of the construction industry has not increased significantly as the manufacturing industry has in the last few decades, and the use of construction robots is expected to increase productivity. The major factor that had increased the productivity of the manufacturing industry was mass production until the end of 60's. However the technology of mass production did not work in the production process of construction. Therefore, as shown in chapter three, the cost escalation of the construction industry is much faster than that of the manufacturing industry. The construction robot will be the first automated industrialization in the construction industry.

Secondly, as shown in chapter five, construction industry is still among the most hazardous industries. In fact, the number of those who lost life in the construction industry account more than 40 percent of total industry. The introduction of robots is expected to improve such hazardous working conditions.

Finally, the third objective of construction robots is to control the quality of construction, especially in the quality as defined in the Total Quality Control TQC. As the construction industry depends so much on labor, the quality of products vary much depending on the skill of workers. It is very difficult to decrease such deviation of quality of the product. However, there is an obvious fact that owners require better quality for the cost they pay for. Construction robots are expected to contribute in the quality control programs.

6.4 Problems of Construction Robot

Nevertheless, there are many problems that prevent the application of robotics in the construction industry. They can be categorized into three major problems; 1) Technical problems, 2) Economical problems, and 3) organizational problems.

6.4.1 Technical Problems

Although the construction industry has some similarities with the manufacturing industry, such as assembling components, it has a lot of characteristics that have prevented the industrialization commonly found in the manufacturing industry.

In a typical manufacturing industry, products go through the production line while in the construction industry products usually (the structure) remain in a permanent location forcing each crew to go to that specific point to perform their tasks. Therefore, if the construction robots are to replace labor, they must have mobility. However, mobility of robots, mobile robot without tracking rail in particular, still remains as a problem.

Another technical problem is handling capacity of industrial robots. Components used in the construction industry are usually heavier than those of the manufacturing industry. Typical handling weight of industrial robots ranges from 50 to 200 lb. [Warszawski, 1984, 15] while some components used in construction range in tons.

Tasks involved in the construction themselves also have several problems. Unlike the tasks particularly found in the manufacturing industry those in the construction industry are ill-structured and difficult to teach robots them. Tasks involved in construction use all function of human labor such as sensing, walking, handling and thinking. Furthermore, they are less repetitive, and, therefore, it is difficult to use lower level industrial robots such as variable sequence robots.

Although the introduction of industrial robots are not for mass-production of single product but, for such rather ill-structured tasks, those in construction are far more complex and ill-structured than those in the manufacturing industry.

This problem is due in part due to the building system which was originally developed for human workers and conventional construction machinery. Usually, building components are designed for either workers or conventional construction machinery such as cranes. For example, gypsum boards and concrete blocks are designed for human labor and precast concrete and steel structures are designed for construction machinery. Neither of them are best suitable size and shape for robots.

6.4.2 Economical Problems

With all these technical problems, what makes construction robots remain at the test phase is economics. Although few of the construction robots disclose their prices, the cost of construction robots including development cost and cost saving at construction site have never published. This fact indicates implicitly their economical infeasibility so far.

Low utilization rate of construction machinery and equipment in particular makes construction firms reluctant to invest in such capital assets. This low utilization rate stem from the facts that construction products are usually assembled at site and machinery must be transported from site to site. Furthermore, there is no guarantee that this machinery can be used continuously. Also, the volume of a task per site is limited and it will require further investment to use a robot for various tasks.

6.4.3 Organizational problems

In addition to technical and economical problems, there are still organizational problems. Unlike the manufacturing industry the construction industry is highly fragmented and no single firm can take the initiative in the project. In other words, few construction firm have tried to coordinate the construction industry and to take the risk of developing construction robots.

This fragmented structure of construction industry also makes it difficult to make systems of construction robots that have been very effective in manufacturing industry. Unlike the manufacturing industry, tasks are too independent to be organized into a standard system.

The development of construction robots requires various kinds of technology and experience in the real construction. Therefore, it is difficult for a construction firm or manufacturer to develop them without cooperating with many establishment outside their own industry.

6.5 Construction Robots Developed by General Contractors in Japan

General contractors in Japan, however, have had some advantages in solving some of these problems listed above. Actually, almost all of the construction robots were developed by general contractors in Japan as of 1985.

First of all, as described in chapter five, they are deeply involved in actual construction and own much construction machinery. As shown in table 5.5, the leading contractor in Japan has more than twenty times construction machinery and equipment as that in the U.S.. Their capital intensive nature shows that the mechanization of construction industry accounts them to invest further in construction robots. Actually, some of the robots have been developed for the use on conventional machinery. The fact that these firms owns so much machinery enhances the development of robots.

Secondly, they have taken the initiative in the construction industry to organize and lead hierarchical subcontracting groups. They have always acted as a risk taker in the construction industry, introducing new technology such as slurry wall since 1960's.

Thirdly, as a member of industrial groups, they can relatively easily cooperate with other manufacturing firms. Actually, many of the construction robots have been developed by joint research between general contractors and manufacturing firms. For example, the concrete distributor developed by Ohbayashi-gumi was made possible by joint research between Ohbayashi-gumi and Mitsubishi-jyukogyo.

Fourthly, as Japan has limited land and, moreover, (the construction investment in Japan is concentrated in Metropolitan Tokyo area), the utilization rate of machinery is higher than that in the U.S..

Finally, as described in chapter five, intra-industry coordination works in the development of construction robots. The Ministry of Construction funds 400 million yen for the special research project of construction robotics. Eleven general contractors, of which five are the big five contractors, participate in the project and share the results.

Thus, the construction industry in Japan has fully utilized their advantages described in chapter five to develop construction robots.

Table 6.2 show the construction robots developed by the general contractors in Japan during the last five years. Beside these listed above, there are many more construction machinery with types of automatic control system such as automatic sliding form system and control system of several cranes. Although many of the construction robots are low level ones, they, at least, contribute to the industrialization of the construction.

These robots can be roughly categorized into three types. The first is automatic control of construction machinery currently exists. Such effort was made since the late 60's. For example, the self-leveling excavator was developed in late 60's. These robots are economically very prospective because the marginal investment to the machinery is relatively small compared with other types of construction robots. The bodies of such equipment are usually developed before, and, therefore, their effort can be concentrated on the control devices. Furthermore, they can catch up with technical development relatively easily because the added control system can be replaced by more advanced control system at small additional costs.

Table 6.2 Construction Robots by General Contractors

Year	Activity of Construction Robot
1980	Concrete spraying machine for tunneling
1980	Concrete conveyor
1981	Re-bar processor
1982	Tower crane control system
1982	Automatic Excavator for slurry wall
1982	Exterior wall and window cleaning
1982	Concrete distributor
1982	Concrete conveyor
1982	Exterior inspector
1983	Automatic tunneling machine
1983	Automatic pebble compactor
1983	Rock wool sprayer
1983	Retention assembling robot
1983	Floor cleaning robot
1983	Remote control excavator
1983	Concrete distributor with crane function
1984	Automatic wire release for steel erection
1984	Re-bar placer
1984	Automatic sealed excavator
1985	Concrete finisher

Source: Kunimoto, 1984

The second type of construction robots are those used to handle fluid material such as concrete and rock wool. As these materials are easy to feed and handle, and usually the tolerance required for these tasks is larger than other finishing material, they are technically easier to develop compared with robots for handling concrete blocks, panels etc.. Also their tasks are relatively well-structured. The primary problem with these robots is their utilization rate. In building construction, in particular, the amount of such tasks are limited in a project and it is difficult to utilize them at economically feasible levels.

The third type of construction robots are those that trace and cover planner surface. These include: exterior wall washing robots, exterior wall inspecting robots, floor finishing robots and floor cleaning robots. They perform simple tasks while they move along the surface. These robots Have been developed because of the relatively well-structured tasks and programmability of the movement.

6.6 Future Strategy to Develop Construction Robot

6.6.1 Productivity of Construction Investment

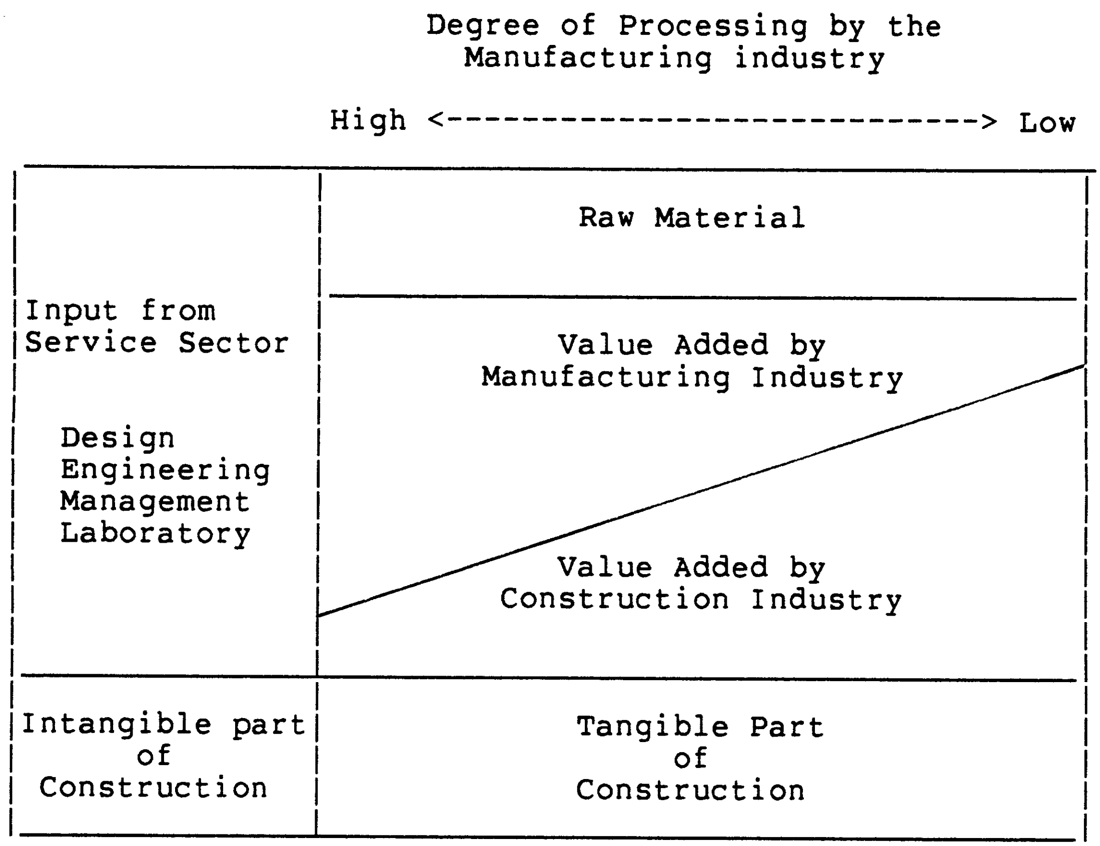
One of the primary objectives of introducing robots is to increase productivity. So far, the productivity of construction focuses usually on the productivity at construction site or productivity of the construction industry. However, to increase the productivity of construction investment, the productivity at site manufacturing industries and service sectors must be taken into consideration.

Figure 6.1 shows the schematic design of construction. It shows that construction can be divided into two major categories: tangible parts and intangible parts. Intangible parts consist input from the service sector, such as design, engineering and management services. Tangible parts consist of raw materials and value added by the manufacturing industry and the construction industry. Raw materials are first processed by manufacturing industry and then assembled by the construction industry. As the degree of processing becomes higher, the value added by manufacturing industry increases. Alternatively, as the degree of processing becomes lower, value added by the construction industry increases.

As the amount of raw materials used in construction do not vary much depending on the technology involved in it, to increase the productivity is to decrease the input other than raw material. Input other than such material are introduced from service sectors, value added by the manufacturing industry and value added by the construction industry.

Therefore, to increase the productivity of construction is to make the most effective production system of design, engineering, and management activity, value added by the manufacturing industry and value added by the construction industry.

Figure 6.1 Schematic Design of Construction



Source: Compiled by the author.

In the 60's most of the efforts to increase the productivity were focused on productivity at construction site by prefabrication of components. However, with all the sophisticated prefabrication design, only few such systems are still used now. It is most probably because the prefabrication systems invented in 60's were not the most effective, especially in terms of cost and production procedure. It shows that to achieve industrialization of the building by using robots, we must be careful about not only what is feasible with in the given framework, but also what is the most effective production system including design prefabrication, and construction at site.

To increase the productivity of construction investment is to decrease the three areas in figure 6.1: input from service sector, value added by the manufacturing industry and value added by the construction industry. So far, efforts to increase productivity have been made almost independently of these sectors.

For example, by factory automation, manufacturing industry has increased their productivity to produce material and components used in construction industry. As shown in chapter three, cost escalation of steel has been far smaller than those of other input due to increased their productivity. Also decreased input from manufacturing industry in monetary terms in the input-output tables shows their increased productivity compared with those of construction industry.

Input from service sectors, however, is very difficult to decrease due to the increased required quality for the construction and the nature of service industry that depend mainly on the human resources. Nevertheless, even in this field, the use of computers has increased their productivity at least in terms of quantity.

6.6.2 Strategies to Introduce Construction Robot

The first step to introduce construction robots is thus to introduce them within the framework of construction industry. To increase the productivity of value added by construction industry, labor and capital goods must be used in the most economical way.

In that sense, capital intensity is the key to the successful introduction of construction robots. If the business, social and political environment do not allow intensive investment in construction machinery, it will not be economically feasible to invest in construction robots. To attain the capital intensity, construction machinery must be fully utilized to decrease the cost of capital goods per production. Thus, capital intensity can only be attained by the high utilization of construction machinery.

In Japan, as shown in chapters three and four, upward economy during the 50's and 60's accelerated the capital intensity of construction industry, especially in the large size construction firms, and now they are prepared to introduce robots.

In fact, many of construction robots are based on conventional construction machinery. Movable construction machinery is relatively easy for addition of control devices. For example, excavators used for tunneling can move on a track and therefore it is relatively easy to control them by micro processor and increase their productivity. Also sliding forms with automatic control system is reported to have increased their productivity and enabled to cut product duration [Ohbayashi Technical Report, February, 1986].

6.6.3 Cooperation Among Sectors

The second step of introducing robots in the construction industry is attained by cooperation between two or more sectors. By cooperation of two or more sectors, construction robots can generate additional benefits rather than limiting their activity in one sector: There are four possible combination of sectors; 1) Construction industry and service sector, 2) Construction industry and manufacturing industry 3) manufacturing industry and service sectors and 4) Construction industry, manufacturing industry and service sectors. The third case, combination of manufacturing industry and service sectors has achieved increased productivity by using Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) especially in the production of prefabricated houses. However, it is beyond the framework of this thesis and only the rest three cases are focused hereafter.

Case A Construction industry and service industry.

As shown in chapter three, increased importance of input from the service industry indicates increased concern to the quality of the project by owners. From the nature of creative work by designers, engineers and managers, this tendency cannot be avoided. Nevertheless, by cooperating with the construction industry, both can increase their productivity further. For example, as mentioned in chapter five, quality control is an emerging field that has increased importance in recent years. The task of quality control, which is more of service industry than of construction industry, can be more effectively performed by adding a measuring instrument to construction machinery. Also Management Information System (MIS) could be more effectively incorporated with such measuring instruments. Another type of robots that belongs to this type is a robot that processes rather raw material at the construction site according to the construction documents. For example, there are a few robots processing and placing re-bars at construction site. If equipped with the compatibility of Computer Aided Design (CAD), they can process and place re-bars without going through the process of working drawing just like some advanced steel fabricaters use numerical control processor and eliminate this process. Also, it may not be difficult to output the record of tasks for quality control.

Thus, by providing robots with interface capability with service sector, additional benefits can be generated, and, therefore, it can be more profitable.

Case B Construction Industry and Manufacturing Industry

As mentioned earlier, the building system was established at the specific point of time and at the specific levels of production technology of both construction industry and manufacturing industry. However, once established, these systems work as open systems and are difficult to change because many participants are involved in it, and require established coordination among them.

One possibility to introduce robots in this framework is to set a temporary assembly factory in a construction site. Usually, the limitation of prefabrication is from the size of the units. Bulky units are difficult to transport physically and economically. The reason that volumetric units for construction are not widely used stems from this reason. Assembly yards at construction sites solve this problem, and also enable the use of ready made industrial robots because they only have to move in the limited area. Also, to provide these robots with tracking systems may not be very difficult and expensive because of the limited working area.

For example, slab units can be fabricated by this method. Steel beams and deck plates are assembled and then electric conduit, ducting and other components attached to slabs are assembled at this automated assembly yard. Succeedingly, they are lifted by conventional crane to the exact location. Another example is a robot that assembles thick re-bars, which are commonly used in slurry wall and power plants.

The advantages of such kind of robotics applications are as follows:

1) Limited area of robot operation.

2) Easy and intensive control.

3) Safer operation.

4) Relatively easy application of conventional industrial robots.

Case C Construction, Manufacturing Industries and Service Sectors

As mentioned earlier, cooperation of sectors enables to save transaction of various information. If the construction robots mentioned in case B have the compatibility with the CAD/CAM system, it is more easier to program them, to control them, and collect data for feed back from them.

Thus, construction robots can be more effective if they can cooperate with other sectors. For the further development of construction robots, we must not limit ourselves in the conventional framework of construction industry. Only by cooperating with other sectors both in the development phase and actual construction phase, the most effective system can be attained.

6.7 Summary of Chapter Six

1) Industrial robots have been actively introduced mainly in manufacturing industry since early 70's.

2) The number of robots in Japan is greatest in the developed countries.

3) Japanese industry, however, uses relatively lower level robots effectively in Flexible Manufacturing Systems.

4) Construction Robots are still in the test phase.

5) Almost all construction robots are developed by general contractors in Japan.

6) They use their advantages described in chapter five fully to develop construction robots.

7) To develop construction robots, not only the construction industry, but also other sectors, such as material manufacturers, and design and engineering sectors should be involved.

8) CAD/CAM and MIS work an essential role to make robots effective.

CHAPTER 7 JAPANESE CONTRACTORS IN OVERSEAS CONSTRUCTION

7.1 Introduction

In this chapter, the activities of Japanese contractors in the overseas market are described. Topics include their motivation, their market structure and the activity of large size general contractors in particular.

7.2 Declining Domestic Market

As described in chapter two, the construction industry in Japan faces decreasing domestic market. Nevertheless, both residential and social stocked assets are far below the average of developed countries. Therefore, there are obvious needs for further construction. Thus, how can such needs not be translated into construction demand? Unlike many developing countries, both corporations and individuals retain considerable amount of monetary assets. In fact, many Japanese investors now look for investment opportunities in the foreign countries.

There are two possible reasons for this decreasing construction investment despite the need for construction. The first reason is the structural changes in the industries. Since the early 70's, simultaneously with the gravity of industry shifting from heavy industry to so-called "high-tech" industries, construction investment as a part of fixed capital formation has decreased significantly as shown in chapter two. To produce such products as IC tips requires investment in machinery rather than investment in factories.

Furthermore, as the Japanese industry in the overseas market becomes more and more competitive, trade imbalances are increasing. It has caused serious economic, political and business problems, both in the importing countries and exporting countries. As a result, Japanese manufacturing industries came to the point that they export production facilities and technical know-how rather than their product.

According to the Ministry of Finance, foreign direct investment by the Japanese manufacturing industry has increased from 819 million dollar in 1974 to 2,278 million dollar in 1981. Among it, the proportion of investment in developed country to the total investment also has increased from 25.1 percent in 1974 to 54.9 percent in 1981. Thus, the Japanese manufacturing industry began to invest not in Japan but in the foreign country in order to ease trade frictions.

Secondly, the limited supply of land for construction seriously has affected the domestic construction investment especially in the metropolitan Tokyo area. In fact, supply of land for housing has decreased from 23,400 ha in 1972 to 9,800 ha in 1983 as shown in figure 7.1. Land supply by the private sector in particular has decreased from 18,300 ha in 1973 to 6,700 ha in 1983. This limited supply of land has attrcted many speculative investors, which has escalated the land acquisition cost incredibly. In the suburbs of

Tokyo, the cost of land acquisition is four to five times as much as the construction cost. Such cost escalation undoubtedly discouraged investing in residential construction.

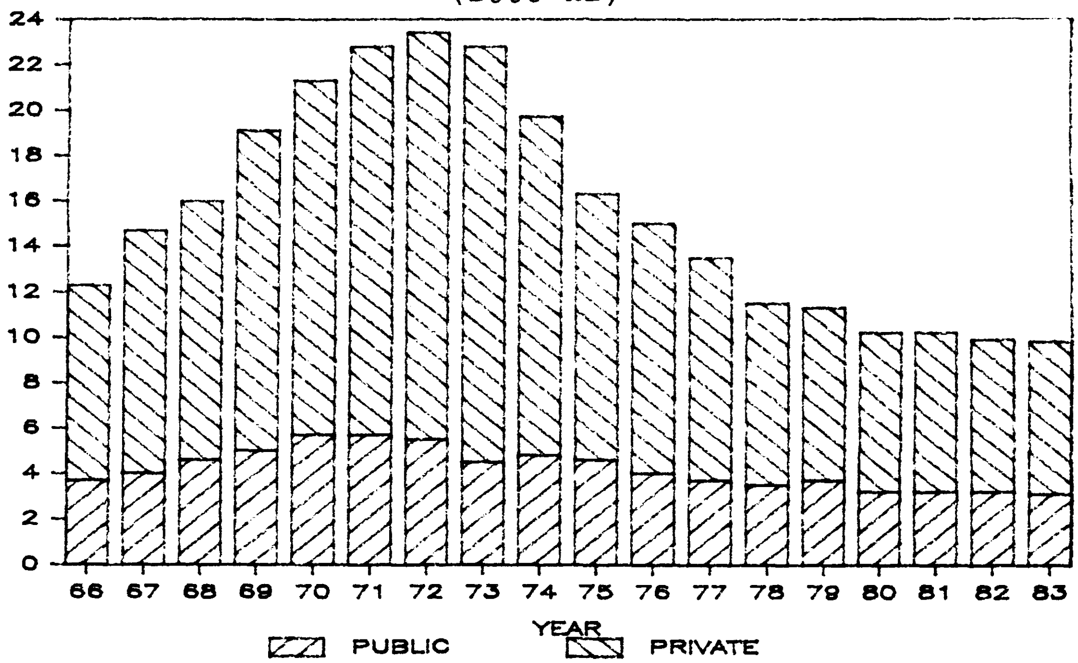
This sharp escaltion of land cost is observed in the commercial area also, particularly in downtown Tokyo. It impedes sound development of the urban functions. In fact, the most expensive land in the world is Ginza district of Tokyo as of 1985 [The Nihonkeizai Shinbun, April 1, 1986]. According to The Nihonkeizai Shinbun, the increasing land acquisition cost is due to active demand of office space by foreign enterprises and speculative investment in land.

The land acquisition cost of commercial areas in downtown Tokyo has increased 54 percent and 31 percent in 1985 and 1984 respectively [The Asahi, April 1 1986]. Therefore, It has more than doubled during the last two years.

Furthermore, the data for these land costs is published by government agencies for taxing purposes, and, therefore, it actually understates the actual transaction cost. The actual cost escalation is said to have more than doubled in one year [The Asahi, April 1, 1986]. This serious cost escalation becomes more significant compared with the relatively stable consumer price index in Japan.

Figure 7.1 Land Supply for Residential in Japan

(1000 ha)



Source: Suzuki, 1985

These extraordinary cost escalations indicate poor policy by the government. The Asahi accuses such political environment as follows:

> The reasons for this unusual cost escalation is: 1) politicians make money from such cost escalation by brokerage of land, and 2) the policy to stabilize land cost is not very helpful in election. Furthermore, they stimulate such escalation by selling government owned land which was $160 per sf. ten years ago at $4500 this year [The Asahi, April 1, 1986].

Thus, poor political environment has disturbed the sound development of both residential and commercial area in the metropolitan Tokyo district and, consequently, the need for construction does not generate proportional construction investment. In this sense, Japanese construction industry is not "mature" in comparison to the U.S. construction industry. Nevertheless, there is not much possibility that domestic construction investment can become active again because of the very stable political conditions.

The motivation for general contractors to enter into the overseas construction market is to make up for the decreasing domestic market and to utilize their surplus resources including human resources and capital goods. According to Hasegawa [1985] all the top general contractor utilize only 60 to 70 percent of their capacities recent years.

7.3 Overseas Construction after the Oil Crisis

After the first oil crisis, Japanese contractors had successfully increased there work in the overseas construction market. Figure 7.2 shows the amount of contracts awarded to Japanese contractors in the foreign countries since 1965. As shown, it had increased significantly from 170 billion yen in 1973 to 1014 billion yen during the period between 1973 and 1983 in nominal terms.

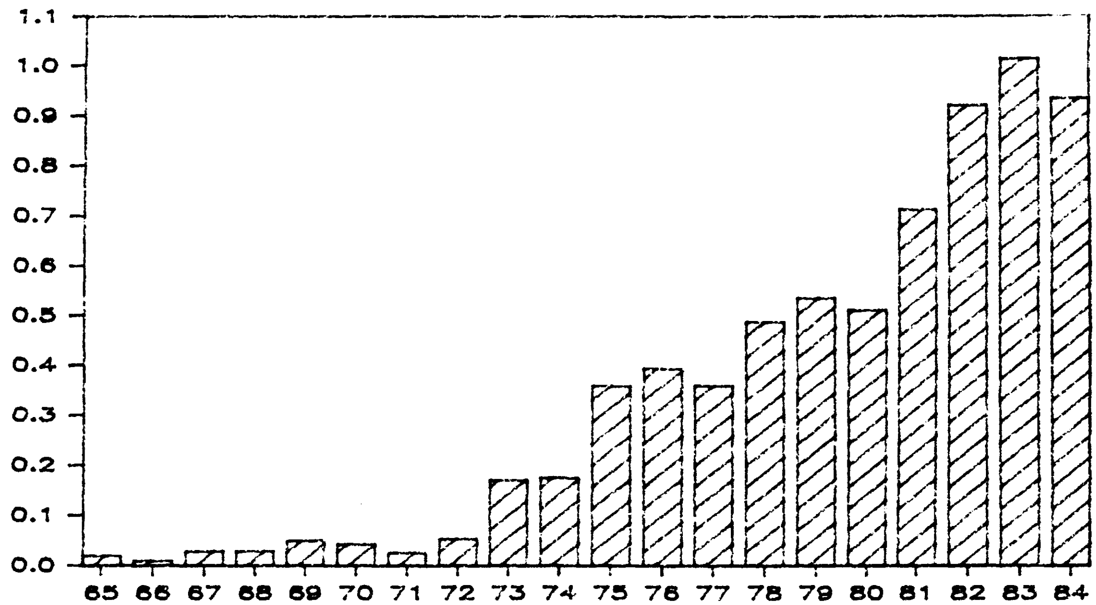
The area of their operation is shown in figure 7.2 as percentage of total. During the 70's, the share of both Middle East and Asia accounted for about 40 percent of the total. Contracts awarded in the Middle East, in particular, seemed to dominate the Japanese overseas construction market in the late 70's. However, since 1979, the share of Asia countries has increased gradually to more than 70 percent in 1982. The most recent and remarkable trend is the increasing share of the U.S.. In 1984, the U.S. share had grown to more than 20 percent of the total Japanese overseas contract for the first time.

Although the amount of overseas construction appears to have increased continuously, The amount of contracts by area has fluctuated considerably reflecting unstable political, economical and social environment and the changing world economy.

The amount of contracts by country shows even more significant fluctuations, indicating difficulty in establishing a stable market in the foreign countries. Table 7.1 shows the top three countries for Japanese overseas construction since 1972.

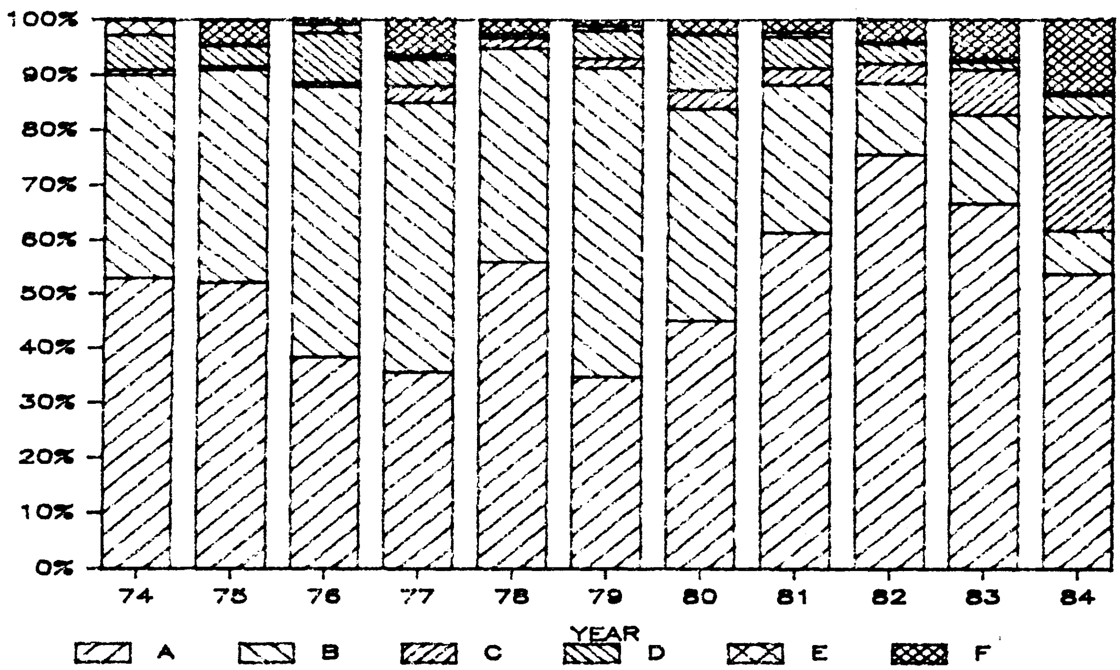
Figure 7.4 shows the type of projects performed by Japanese contractors in the overseas market. Although it fluctuates like any other data for overseas construction, an increasing trend in building construction can be observed. During the 60's the proportion of building construction was about 15 percent, whereas in the 80's, it has grown almost 40 percent. On the contrary, heavy construction, particularly large project such as dams and reclamation works, has gradually decreased.

Figure 7.2 Overseas Construction by Japanese Contractors
(Trillion yen)



Source: Overseas Construction Association of Japan, 1985.

Figure 7.3 Share of Overseas Contract by Area



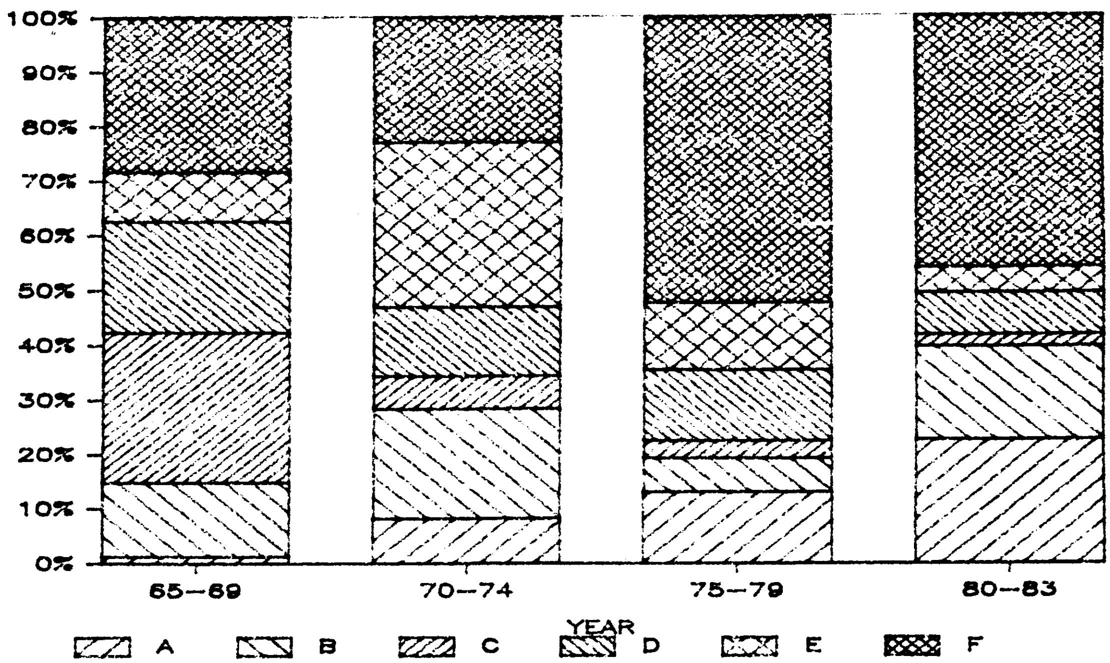
A: Asia B: Middle East C: U.S.A.
D: Other America E: Africa F: Other
Source: Overseas Construction Association of Japan, 1985.

Table 7.1 Overseas Construction by Country (The amount of contract and its Proportion)

YEAR	Total Contract (Billion yen)	1	2	3
1972	53.3	Indonesia 11.2 21%	Singapore 10.0 19%	Malaysia 8.1 15%
1973	170.7	Brazil 65.7 38%	Malaysia 29.4 17%	Taiwan 20.7 12%
1974	175.7	Iraq 29.1 17%	Hong Kong 27.1 15%	Indonesia 21.1 12%
1975	359.2	Hong Kong 60.3 17%	Iraq 55.3 15%	Singapore 51.4 14%
1976	393.6	Singapore 47.8 12%	U.A.E. 46.2 12%	Kuwait 39.8 10%
1977	359.9	Iran 44.8 12%	Iraq 38.4 11%	Saudi Arabia 36.0 10%
1978	488.3	Indonesia 84.6 17%	Iraq 81.9 17%	Hong Kong 78.8 16%
1979	536.5	Iran 242.0 45%	Hong Kong 60.7 11%	Indonesia 32.6 6%
1980	511.0	Iraq 117.5 23%	Singapore 58.7 11%	Hong Kong 43.2 8%
1981	712.7	Malaysia 157.8 22%	Iraq 130.8 18%	Hong Kong 43.2 6%
1982	921.5	Hong Kong 246.1 27%	Malaysia 163.6 18%	Singapore 141.1 15%
1983	1014.0	Singapore 260.6 26%	Malaysia 155.4 15%	Indonesia 108.5 11%

Source: Overseas Construction Association of Japan, 1985.

Figure 7.4 Overseas Construction by Type of Project

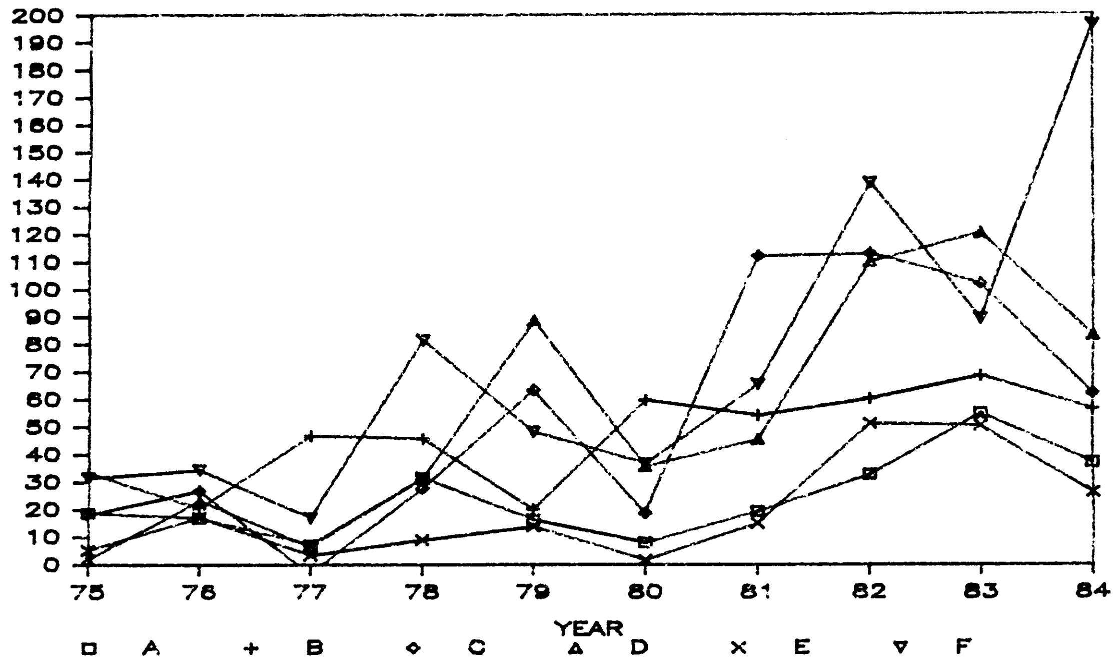


A: Private Building B: Public Building
C: Reclamation D: Dam
E: Harbor Facilities F: Other Heavy Construction

Source: Overseas Construction Association of Japan, 1985.

Simultaneously with the expansion of their operation, Japanese contractors have established foreign subsidiaries all over the world. As of 1983, the number of such subsidiaries was 120 of which 29 were located in the U.S. and 22 were settled in Malaysia. Almost 400 employees from parent companies are working in these subsidiary employing almost 3000 staffs. In addition, 600 employees are working at their branch offices and 3300 employees are directly involved in construction. Therefore, almost 4300 Japanese employees are working in the foreign countries.

Figure 7.5 Overseas Construction by the Big Five plus One
(Billion yen)



A: Ohbayashi B: Kajima C: Shimizu
D: Taisei E: Takenaka F: Kumagai

Source: Annual reports, compiled by Ohbayashi-gumi, 1985.

The number of subsidiaries in the U.S. is unproportionally greater than those in other countries. It shows that Japanese contractors consider the U.S. market one of the most prospective markets. Actually, overseas construction by Japanese contractors in the U.S. has gradually and steadily increased during the last five years.

7.4 Big Five in the Overseas Market

In the overseas construction market, the big five general contractors do not dominate in the Japanese share like they do in the domestic market. Figure 7.5 shows the amount of foreign contracts by them. Although obvious increasing trends can be observed, considerable fluctuations are also observed in many firms.

Table 7.2 shows the amount of contract awarded to Japanese firms by country and each general contractor's share in it.

It shows that general contractors share the overseas construction market for most countries. In many countries, only a few contractors domonate the market. For example, 95 percent of contracts awarded to Japanese firms in Kuwait were won by Shimizu-kensets and only Kumagai-gumi receives contracts in Australia. There is no country where all the big five contractors equally share contracts like they do in the domestic market.

There are several reason for it. First of all, the international market is so large that it is difficult for a contractor to know everything about it. Therefore, through preliminary studies, they focus on a few target countries that have potential markets. They try to concentrate their efforts on those specific countries rather than spreading their efforts over the world.

Table 7.2 Contractors Share by Country (1983)

Country	(1)	Contractor	Contract	(%)
Singapore	263.9	Goyo-kensetsu	82.4	31.2%
		*Takenaka-koumuten	38.6	14.6%
		*Ohbayashi-gumi	38.4	14.6%
Malaysia	164.6	Hazama-gumi	29.6	18.0%
		*Kajima-kensetsu	17.6	10.7%
		Fudou-kensetsu	16.8	10.2%
		*Shimizu-kensetsu	16.6	10.1%
		*Takenaka-koumuten	15.9	9.7%
Indonesia	114.3	Kumagai-gumi	48.9	42.8%
		*Taisei-kensetsu	38.1	33.3%
		*Ohbayashi-gumi	5.8	5.1%
U.S.A.	83.2	Aoki-kensetsu	24.9	29.9%
		*Ohbayashi-gumi	20.2	24.3%
		*Taisei-kensetsu	19.7	23.7%
Hong Kong	78.7	Nishimatsu-kensetsu	16.1	20.4%
		Fudou-kensetsu	15.9	20.2%
		Kumagai-gumi	14.8	18.8%
		Aoki-kensetsu	11.0	14.0%
Kuwait	68.2	*Shimizu-kensetsu	65.0	95.4%
Australia	54.2	Kumagai-gumi	54.2	100.0%
Saudi Arabia	54.0	Sato-kogyo	27.3	50.6%
		Goyo-kensetsu	9.3	17.2%
		*Taisei-kensetsu	6.8	12.6%
Thailand	21.7	*Takenaka-koumuten	4.3	19.9%
		*Ohbayashi-gumi	4.2	19.4%
		Tokyu-kensetsu	4.1	18.9%
Algeria	18.7	Hazama-gumi	14.6	78.2%
Sri Lanka	17.5	*Taisei-kensetsu	9.8	56.1%
		Hazama-gumi	2.7	15.5%
		Toda-kensetsu	2.4	13.7%
Egypt	16.6	*Kajima-kensetsu	13.0	78.3%

Source: Ohbayashi Co., 1984
Note : Unit in billion yen
* One of the big five contractors

The second reason is the magnitude of the project. As the small project will not generate enough profit to cover overhead costs, the size of international project is usually larger than those in the domestic market. Therefore, the fluctuations of projects are more significant and result in unstable market share.

Third, as they usually have ad-hoc relationships with the owners, they cannot receive orders continuously as in the domestic market.

Finally, their type of project is a demand-push type construction rather than a supply-pull type construction. During the 70's they had made little effort to generate demand in the foreign countries. What they have done was to target those countries with "hot" construction markets.

Thus, although Japanese contractors have expanded their operations in the overseas market as a whole, each contractor had not penetrated the marked intensively enough to establishe a stable market.

These facts suggest the theory of "a perfect market", where everyone shares information equally. In such market, only risk takers can expect higher returns. However, this type of market hardly exists in the international construction market. The chief reason for the inperfect condition is the sheer geographical limitation which hinders effective communication.

Such mal-distributiond of information discourages Japanese contractors to form joint venture in the international construction. In fact, it seems very strange that general contractors in Japan, that frequently form joint venture in the domestic market even in a small projects, rarely form joint venture in the international projects that have greater volumes of construction and higher risks.

General contractors have established a special organization, the Overseas Construction Association of Japan, Inc., in order to collect information from all over the world and coordinate general contractors toward the international projects. Nevertheless, it also does not appear to function properly.

Thus, although they share the domestic market through intra-industry coordination, they have not established ways to share the international market. Therefore, the amount of contracts fluctuate significantly as compared with that of domestic market.

7.5 Summary of Chapter Seven

1) Japanese contractors launched into overseas market after the first oil crisis.

2) They have expanded their operation in the foreign countries during the 70's and the early 80's.

3) The area where they have received contracts shifted from The Middle East in 70's to Asia in the early 80's.

4) Although the amount of contracts are still limited, contract in the developed countries has steadily increased since the beginning of the 80's.

5) The type of project also has shifted from heavy construction to building construction.

6) Contract volume of each country has fluctuated significantly.

7) A few Japanese contractors share markets in a overseas countries.

CHAPTER 8 CONCLUSION AND FUTURE RESEARCH

8.1 Conclusions

Throughout this thesis, the construction industries in the U.S. and Japan are analyzed from various points of view. There are many findings. Findings about the construction industry in the national economy and the construction establishments are summarized in table 8.1 and table 8.2 respectively.

From the result of the study, the economies of scale appears to work for the construction industry in Japan; Worker productivity increases as the size of establishment increases in Japan because of the high capital intensity and hierarchical subcontracting structure. The big five contractors at the top of this hierarchical structure have many characteristics which are categorized into three major factors.

They are:

1) Customer oriented services

2) Technical advantages

3) Integrated services in the construction industry

Table 8.1 Findings about Construction Industry

	Japan	U.S.A.
Market Size	20% of GNP	10% of GNP
Market Structure	Private 60% Public 40%	Private 80% Public 20%
	Residential 30% Other Bldg. 30% Heavy 40%	Residential 40% Other Bldg. 30% Heavy 20%

Source: Compiled by the author

Table 8.2 Findings about Construction Establishments

	Japan	U.S.A.
Size	Ranges wide	Ranges very wide
Productivity of worker	Increases as the size of the firm increases	Same trend as Japan but less significant
Capital intensity	Increases as the size of the firm increases	Peaks at the mid-size firms
Productivity of Capital	About 6 for the majority	Small size: 3 - 4 Large size: 6
Proportion of Subcontract	40%	25%

Compiled by the author

1) Customer Oriented Services

Japanese large size contractors offer extensive services for the owners such as design service and quality control programs. They free the owners from the trouble associated with the fragmented nature of the construction industry such as coordination among the designers and contractors. Their design service incorporated with other divisions, CAD system, and quality control programs assure the owners of having the best quality for the cost.

2) Technical Advantages

Due to the legal, physical, and social constraints, Japanese general contractors are familiar with advanced technologies such as up-down construction. The upward economy before the oil crisis and less fluctuating construction volumes for contractors allow them to invest in construction machinery for advanced technologies. They have acquired much know-how from such technology, which is sometimes as important as the technology itself. This technology development is supported by their engineering divisions and R&D institutes.

3) Integrated Service in the Construction Industry

On one hand, their services extend far into service oriented field, while on the other hand they are deeply involved in the actual construction process through organizing subcontractors. Such involvement appears in their comparatively low accident frequency rate.

Although some of these characteristics, such as subcontracting groups, do not work in the overseas construction, most of these properties are strong tools for penetrating overseas markets.

So far, Japanese contractors have received orders mainly from developing countries with intensive capital investment. However, such demand-push markets do not last very long as in the case of OPEC countries. They have obvious needs to stabilize their overseas activity. One way to stabilize fluctuations is to focus on the developed countries where construction is more of supply-pull market. In such markets, Japanese contractors will be able to fully utilize their advantages.

In recent years, Japanese enterprises have searched for investment opportunities more in the foreign countries. Foreign direct investment by them has increased significantly during the last decade, including those by the manufacturing industry. It appears the best opportunity to demonstrate their properties and to get accustomed to the local problems of the construction such as building codes, subcontractors, unions and public authority.

8.2 Future Researches

All through this thesis, the increased importance of the role of service sectors in construction is observed. these service sectors include: design, engineering , management, testing laboratories and financial. Actually, the properties of the Japanese contractors are not limited in the conventional construction industry, but the combination of the construction industry and the service sectors. In the U.S., such services are more fragmented and independent and are classified as a service sector.

In this thesis, these construction related service sectors have not been discussed deeply. However, as this trend will continue in the construction industry, each of the sectors is worth further research.

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