POTENTIAL OF STRATEGIC INFORMATION SYSTEMS FOR JAPANESE CONSTRUCTION FIRMS

by

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ABSTRACT

The potential of strategic information systems (SIS) for Japanese construction firms was analyzed. First, SIS in Japan's construction industry was defined using the analogy of SIS in other industries.

Then, characteristics of Japan's construction industry were discussed with special regard to Japanese general contractors which are playing an important role in the industry. They are offering vertically integrated services but their management is still based on manual systems.

From this discussion, it is apparent that the integration of information in construction has a great potential for improvement of productivity. Opportunities for SIS will increase as the complexity and diversity of construction processes increase.

Japanese construction firms are not yet using information systems and technology (IS/IT) strategically. Some strategies for SIS which Japanese construction firms should take are suggested.

Thesis Supervisor: Dr. Fred Moavenzadeh

Title: Professor of Civil Engineering

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Hisashi Inagawa

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Chapter 1

Introduction

1.1 Purpose and Scope

A new kind of information system and technology (IS/IT) has been having a significant influence on competitiveness in different kinds of industries: airline, air freight forwarder, insurance service, financial service, and so forth. Such IS/IT, used to gain competitive advantage, is called a strategic information system (SIS). SIS is recognized as completely different from conventional IS/IT, which has been used primarily to improve the productivity and efficiency of individual tasks. However, construction industry firms, especially in Japan, do not use SIS well enough to differentiate themselves from their competitors.

In the 1980s, computerization proceeded rapidly in large Japanese construction firms. They introduced computers, which brought many benefits such as office automation, computer-aided design (CAD), and speedy transaction work.

However, it cannot be said that they are making full use of the advances in computers or information system and technology. Almost all construction management processes are still manual. Computer applications have not yet made dramatic improvements in productivity in construction. Nor has any Japanese construction firm used SIS to enhance its competitiveness so far.

Hamano (1980) pointed to the reasons why Japanese construction firms have been reluctant to use computers for management control purposes. These are as follows:

Reason 1: Main market had been domestic, not international.

Reason 2: Traditional management system without computers has been preferred.

Reason 3: Difficulty of standardizing work because each project is unique.

These conditions may no longer apply. Japan's construction industry is changing. Currently, Japanese construction firms are actively seeking new markets overseas in order to continue to grow. Competitive construction management ability is now indispensable for huge and complicated construction projects. In Japan, the concepts of CIM (computer integrated manufacturing), transferred to the construction industry, have become known as CIC (computer integrated construction). CIC requires standardization and integration of design and construction processes. Japanese construction firms cannot do without computers as management control tools anymore. However, they are a long way from being able to create competitive advantage by strategic use of IS/IT.

Sophisticated computer hardware and software is available for many construction industry fields. Recent developments in database management technology enable companies to integrate information which is scattered through their organizations. Increased use of construction robotics and automation and industrialization of construction, which require integrated control systems, is urgent because of an aging labor force and predicted future shortages. Standardization of soft- and hardware for CAD is being developed. There now exists a growing potential for Japanese construction firms to use these computer technologies as strategic tools.

Referring to Cherneff (1991), the opportunities for strategic development of IS/IT are especially great in industries, like the AEC (architecture-engineering-construction) industry, which involve an information-intensive community process such as the design, construction, and management of facilities. Such an industry is fragmented due to diversified specialties and the complicated interaction of players. The fragmentation creates inefficiencies in many aspects of the industry. Therefore, successful applications of SIS can have a great influence on competition in many ways.

Given the fragmentation of Japan's construction industry, there are great opportunities for the strategic development of IS/IT. Information technology can no longer be just a system for reducing the cost of obtaining, processing, and transmitting information. It is essential that Japanese construction firms recognize IS/IT as a tool for competitive advantage.

IS/IT will have a great impact on competition in the construction industry. This thesis describes how Japanese construction firms should use IS/IT as a competitive advantage now and in the future. The thesis also suggests some appropriate strategies for the major Japanese general contractors (GCs) which are playing a important role in Japan's construction industry.

1.2 Thesis Overview

Chapter 2 shows how SIS is different from conventional IS/IT. Ways in which SIS creates competitiveness are discussed. The importance of integration by IS/IT in the highly fragmented Japan's construction industry is discussed.

Chapter 3 describes the characteristics of a Japan's construction industry, the number of firms, value of construction investment, scheduling and quality control, and so forth. Fragmentation of the industry is analyzed. The chapter gives special attention to Japanese GCs who have become multi-disciplinary, as customer needs have become diversified. Other contemporary trends in the demand and supply sides are described. On the basis of the above discussion, the future of the industry is projected.

In chapter 4, the potential of SIS for Japanese construction firms is discussed. On the basis of the evolution of IS/IT in Japanese GCs, which has enhanced functional isolation of computer systems, requirements for implementation of SIS are revealed. Opportunities for SIS are analyzed showing possible positive impacts and benefits of SIS and integration of players in Japan's construction industry. Potential advantages for Japanese GCs are summarized. Some strategies for SIS which Japanese GCs can take are suggested.

In chapter 5, the findings and conclusions are summarized.

Chapter 2

Definition of Strategic Information Systems in Japan's Construction Industry

2.1 Definition of Strategic Information Systems

In 1982, regulations were issued which prohibited continuation of the biased display method used in American Airlines' computerized reservation system (CRS), Sabre. American Airlines enabled travel agents to reserve and ticket automatically by leasing Sabre terminals, which displayed information which was biased in favor of American Airlines. The company was thus able to gain shares of 40 percent in the computerized travel agency market. As stated in the regulation, the system was "no longer employed merely as a neutral scheduling mechanism to automate the seat reservation process" (Wiseman, 1985). The Sabre reservation system brought absolute competitiveness to American Airlines. This was the first example that showed the strategic effects of information systems and information technology (IS/IT) in the U.S.

In Japan, in 1985, Itoyokado, one of the major Japanese retail shops introduced an IS/IT called POS (point of sales). Itoyokado was able to control all retail goods sold by POS. The company remarkably reduced inventory time of retail goods by linking them to its procurement system and achieved "just-in-time" delivery service for its customers. Itoyokado could respond to diversifying customer needs in a timely manner. The company achieved net operating income of 6 percent while other retail shops were obtaining only 2 percent to 3 percent.

2.1.1 Strategic Significance of SIS

Why did these IS/IT draw so much attention? What difference is there between SISs and the IS/IT which have been used so far? The case of American Airlines shows how effectively IS/IT improves customer (travel agents) service. The system had much larger impact on the competition than conventional IS/IT had ever before. Further, it became apparent that strategic use of IS/IT had a large effect on the way of a customer's doing business. Travel agents could offer other travel information and travel planning services besides airline ticketing. American Airlines could enhance a linkage with travel agents by providing further information. Their latest IS/IT was advanced enough to support the linkage.

The case of Itoyokado shows how successfully and promptly IS/IT could respond to diversification of customer needs. The company could be differentiated from rivals by its POS in customer services. It is also important to know that implementation of POS and organizational changes effected each other. Organizational changes enabled the firm to introduce POS. Then POS changed the firm's organizational structure.

In 1985, Professor Charles Wiseman, author of Strategy and Computers (1985), dubbed information systems used for strategic purposes *strategic information systems* (SIS). As a result of extensive analysis of information systems, he realized that implementation of SIS could be accounted for not by the conventional perspective, but by a new strategic perspective on information systems.

The conventional perspective identifies the significance of two varieties of systems: management information systems (MIS) and management support system (MSS). According to Wiseman's definition, "the former is used to automate basic business processes and the latter to satisfy the information needs of decision makers." Organizations can have an analytical framework in search of advantage by using the strategic perspective. By supporting the organization's strategic perspective, SIS support or shape its competitive strategy.

The difference between SIS and the traditional or conventional IS/IT identified by Wiseman is that while SIS is intended to handle information strategically, traditional IS/IT emphasizes its capacity for transaction of information. Successful implementation of SIS always requires the strategical perspective.

2.1.2 Evolution of Information Systems and Technology

In the late 1960s, development of Electronic Data Processing System (EDPS) emphasized improvement of efficiency and productivity within a single transaction or departmental task. Information system departments (ISD) were established in companies and they took the initiative in computerization of their companies. Their missions were achieved successfully in accordance with the rapid growth of computer technology.

In the 1970s, companies began to pay attention to MIS and MSS. Naturally, ISDs were engaged in developing the systems. It might be easily imagined that ISD could understand information systems were useful support tools for management activities, especially if systems which were operating independently could be integrated to control and manage accumulated information systematically. However, top management was hardly involved in planning of MIS and MSS. Further, top management could not understand the effects of the systems. As Rockart and Crescenzi (1984) noticed, top management was almost never involved in the development of EDPS and MIS and MSS. "Information systems were considered primarily paperwork-processing systems with little impact on organizational success or failure."

In the 1980s, successful cases of SIS applications came out in accordance with advanced IS/IT. Strategic use of IT was made possible by the digitalization of telecommunications networks which "gradually dissolved boundaries among the data-processing, office systems, and communications markets. (Calder, 1989)" Use of personal computers and workstations became popular, and structuring information networks became easier and less expensive.

2.1.3 Examples of Strategic Use of IS/IT

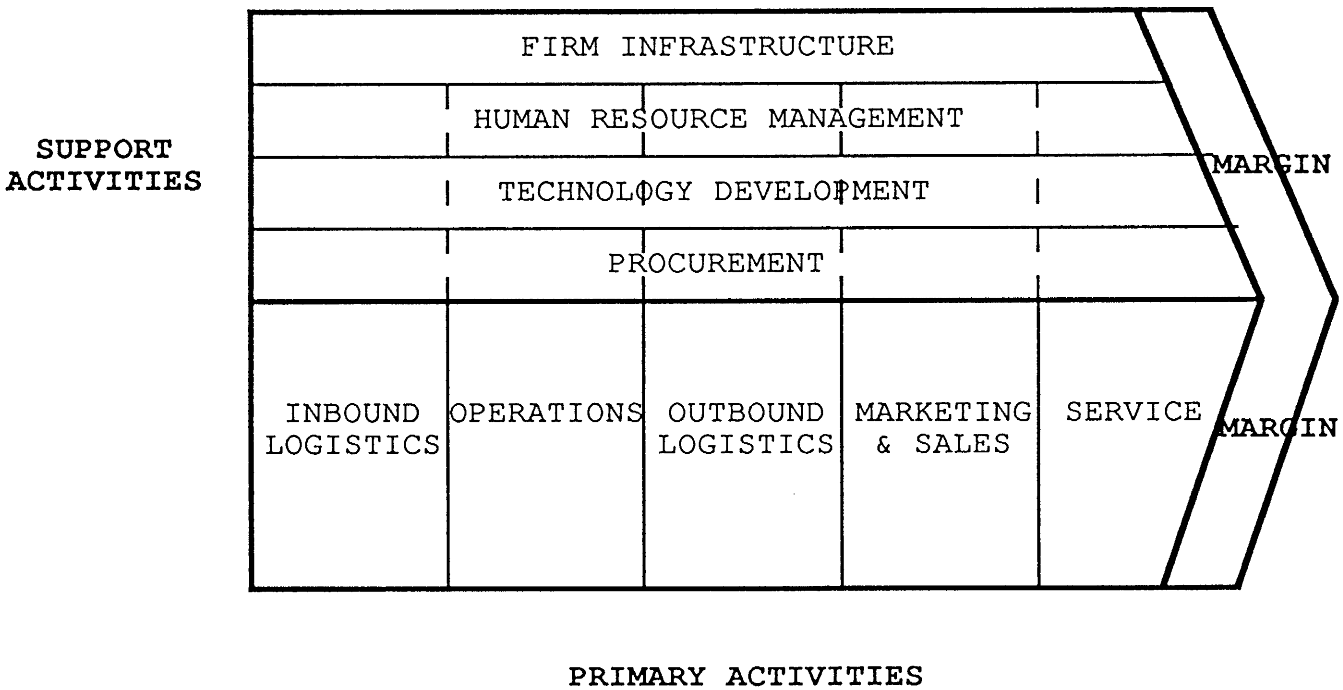
USAA (United Service Automobile Association) and Emery Worldwide are doing business in information-intensive industries. In such a business, which services information itself, quickness and accuracy are a priority. Successful application of SIS in this business brings much a greater competitive advantage than in other industries.

USAA (according to Harvard Business School case study)

USAA is a good example of the importance of IS/IT within a firm's "value chain" (Porter, 1985). Porter's concept divides a firm's activities into "value activities" (see Figure 2.1.1). Porter says that a firm can gain competitive advantage over its rivals by performing these activities at a lower cost.

USAA, a financial services company, was formerly a property and casualty insurance company for military officers. The company enjoyed a special relationship with its members until it suffered from downturns in the economy. In order to survive, the company needed to respond quickly to their members' changing needs. USAA's information systems played an important role in their efforts to diversify and expand into new products and services.

Figure 2.1.1 The Generic Value Chain



(source: Porter, M., 1985)

The company's primary objective is service to the customer. Its evolution of information systems began with the expression "paperless environment," which was intended to improve service quality by reducing paper-processing work. A number of systems were installed in the 1970s and policy and claims processing were automated.

As customer services became diversified, emphasis on information systems transformed from productivity of paper-processing work to sharing information. An integrated system, Automated Insurance Environment (AIE), was developed to upgrade the operational lines, and all system activities and resources were centralized under an Information Services Division. AIE contributed to establishing a single USAA image for the company's customers which was a priority for USAA's top management. A single image meant highly integrated customer services which differentiated USAA from its rivals. USAA's IS evolution clearly shows the transformation of its perspective on information system from a conventional to a strategic one.

USAA improved its productivity markedly by the use of integrated information systems. Further, its IS/IT could offer such highly integrated customer services that USAA could perform customer services in a way that led to differentiation and a premium price.

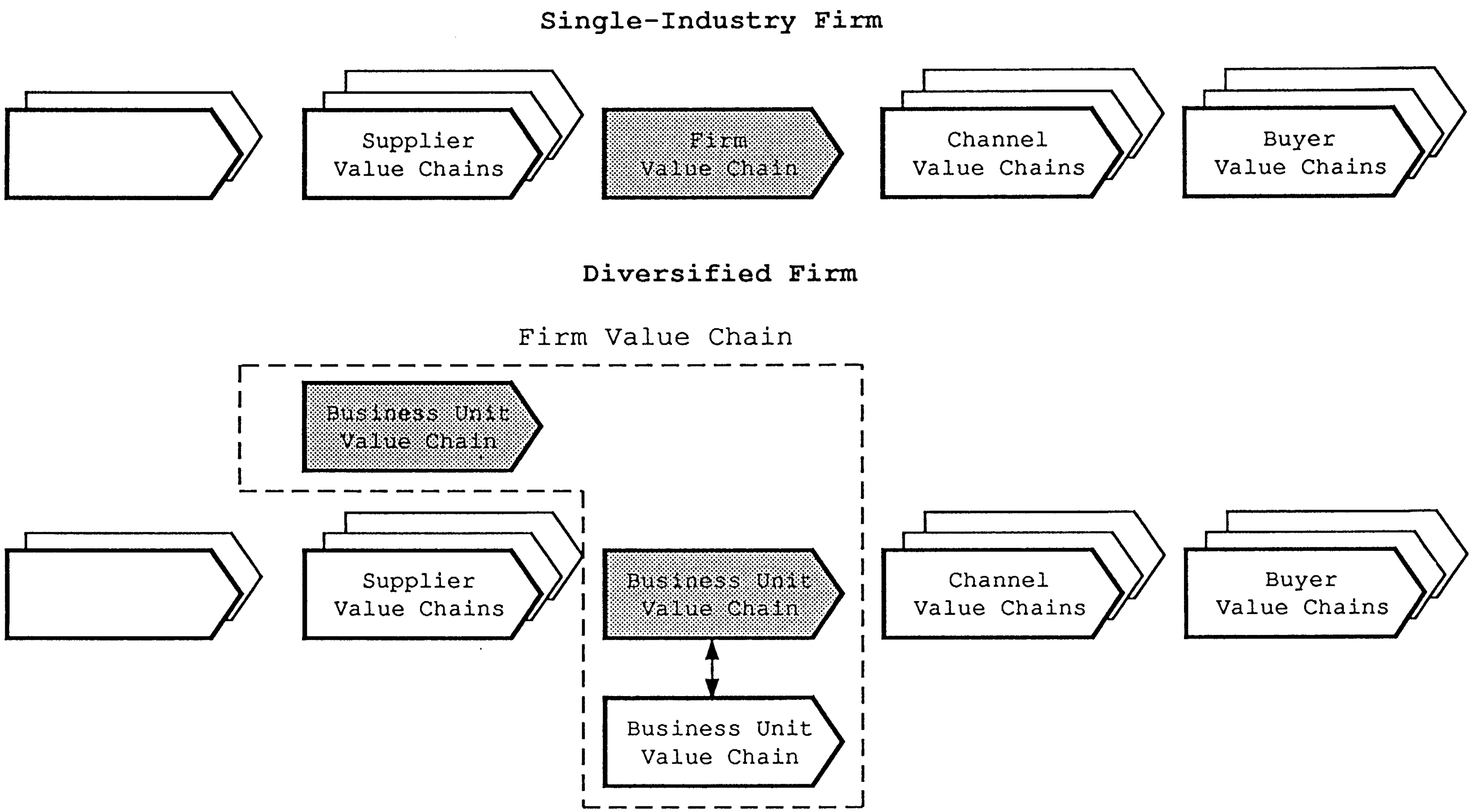
It is also noteworthy that the company had the organizational flexibility to accept the new integrating IS/IT. Implementation of SIS usually requires organizational changes due to its strategic impact. To create a single customer image, USAA centralized all systems which previously had been dispersed through divisions. It was necessary to remove barriers among divisions in order to integrate information. Top-down approach in implementing SIS was one of the important key factors.

Emery Worldwide (according to Harvard Business School case study)

Emery is an example of a firm that successfully linked its value chain to the customer's value chain by IS/IT. Porter (1985) showed that the value chain for a firm is embedded in the "value system" (see Figure 2.1.2). A firm's value chain and that of the outsider's are interdependent in the value system. A firm can create competitive advantage by optimizing not only links within its value chain, but also links to the outside.

Emery Worldwide, which was founded in 1946, was a pioneer of the air freight forwarder business, offering overnight service within the U.S. The company also extended priority delivery overseas. From 1967 to 1969, it developed an information system, EMCON. EMCON functioned as an interactive tracing, tracking, rating, invoicing, and reporting system. The new information system's capability of tracking both cost and location enabled the manufacturing customer to hold less inventory. Then, the customer's link to EMCON offered the possibility not only of entering

Figure 2.1.2 The Value System



(source: Porter, 1985)

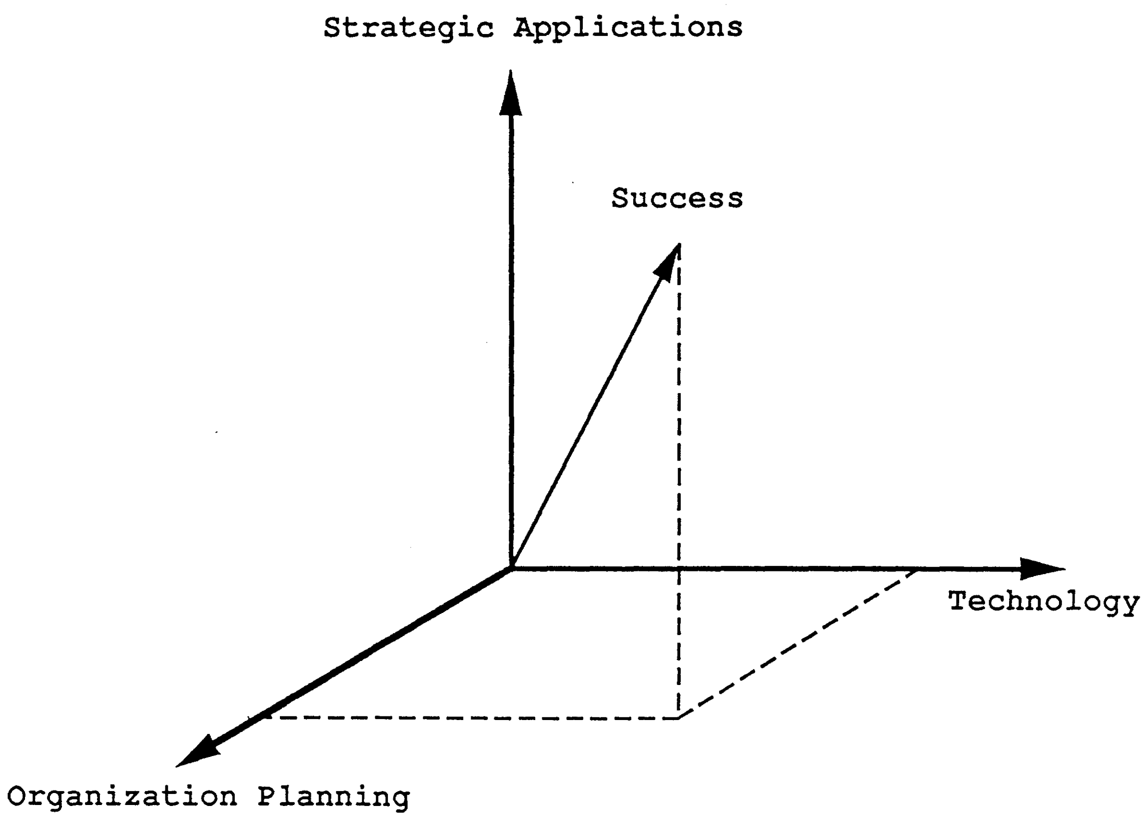
information, but also of lowering the customer's costs. For example, each shipment would be rated by the customer's system and the customer would dispense with auditing transportation invoices. The company often modified its business practice in accordance with changes in the customer's requests in order to fulfill the company's primary strategy - "any size, any weight, any value shipment." In order to retain the strategy, its backbone information system, EMCON had been modified continually and had always been the company's information support system. Since 1982, Emery has been developing a new system architecture for EMCON. The objective of this development is to make EMCON more flexible.

Emery continues to be competitive in the air freight industry by affecting the customer's values chain continuously. Emery's information system, EMCON, has acquired strategic significance by optimizing the link to the customer.

Summary

Madnick (1987) illustrates the important factors which bear on implementing IS/IT (see Figure 2.1.3). Understanding strategic applications and IS/IT are essential of course. A third critical dimension, the importance of planning organizational change, should not be overlooked for successful SIS. In the cases of USAA and Emery Worldwide, the combination of their clear strategic applications, advanced

Figure 2.1.3 Factors Critical to Success

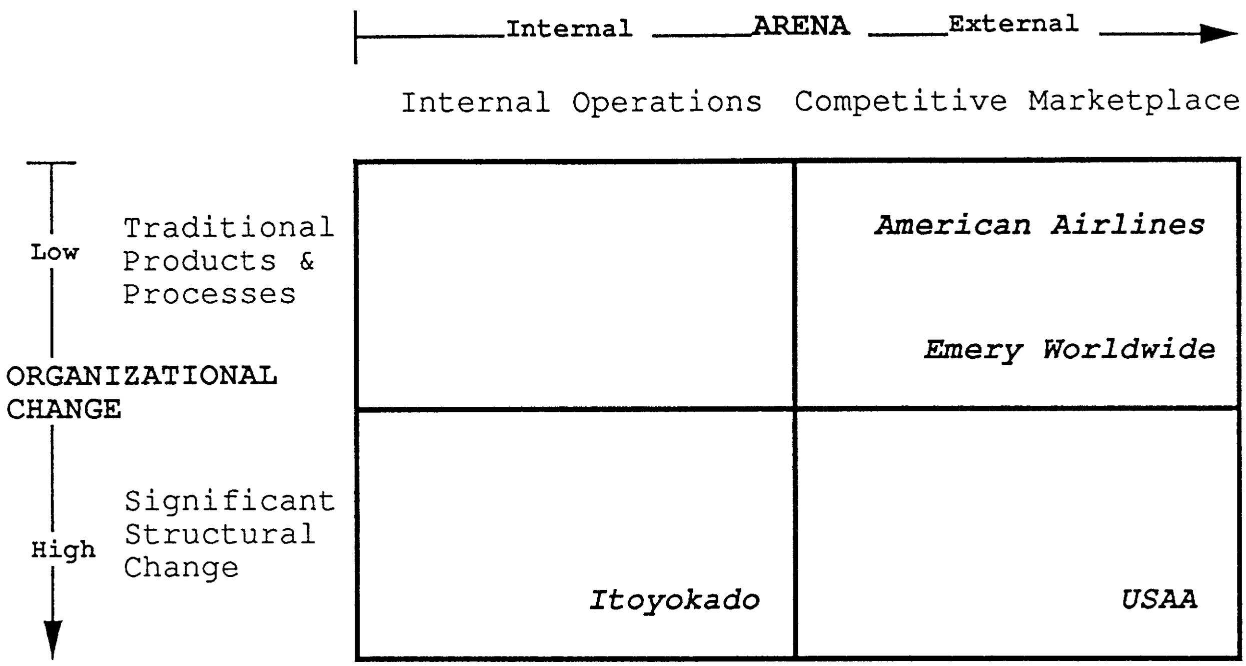


(source: Madnick, 1987)

IS/IT, and organizational flexibility produced their own SIS. Figure 2.1.3 shows that the success of SIS requires achievements along all three dimensions.

Madnick also provides a way of thinking about the strategic use of IS/IT by the Strategic Opportunities Matrix (see Figure 2.1.4). USAA used SIS to develop new products and processes and to make organizational changes which resulted in improved competitiveness in the insurance market. Its SIS development can be placed in the lower right quadrant. Emery's SIS can be placed in upper right quadrant, because the company has focused its IS/IT on improving customer's accessibility to its traditional services, and on improving these services as well.

Figure 2.1.4 Strategic Opportunities Matrix



(source: Madnick, 1987)

2.2 Definition of Strategic Information Systems in Construction Industry

Computer technologies have also permeated the construction industry. Computer applications are found in various processes of design and construction: cost estimation, computer-aided design (CAD), structural design, construction management, automation, and so forth. Although individual applications are highly sophisticated and advanced, strategic use of IS/IT, which has become possible through continuing advancement of computer technologies, is not yet fully developed in the construction industry.

Major challenges facing the industry are to gain efficiency in the design process for increasingly complicated projects and to improve the productivity of construction work, especially since the industry faces a prospective shortage of labor. In order to remain competitive in this industry, it is very important to integrate accumulated data and information by the strategic use of IS/IT.

2.2.1 Integration of Information

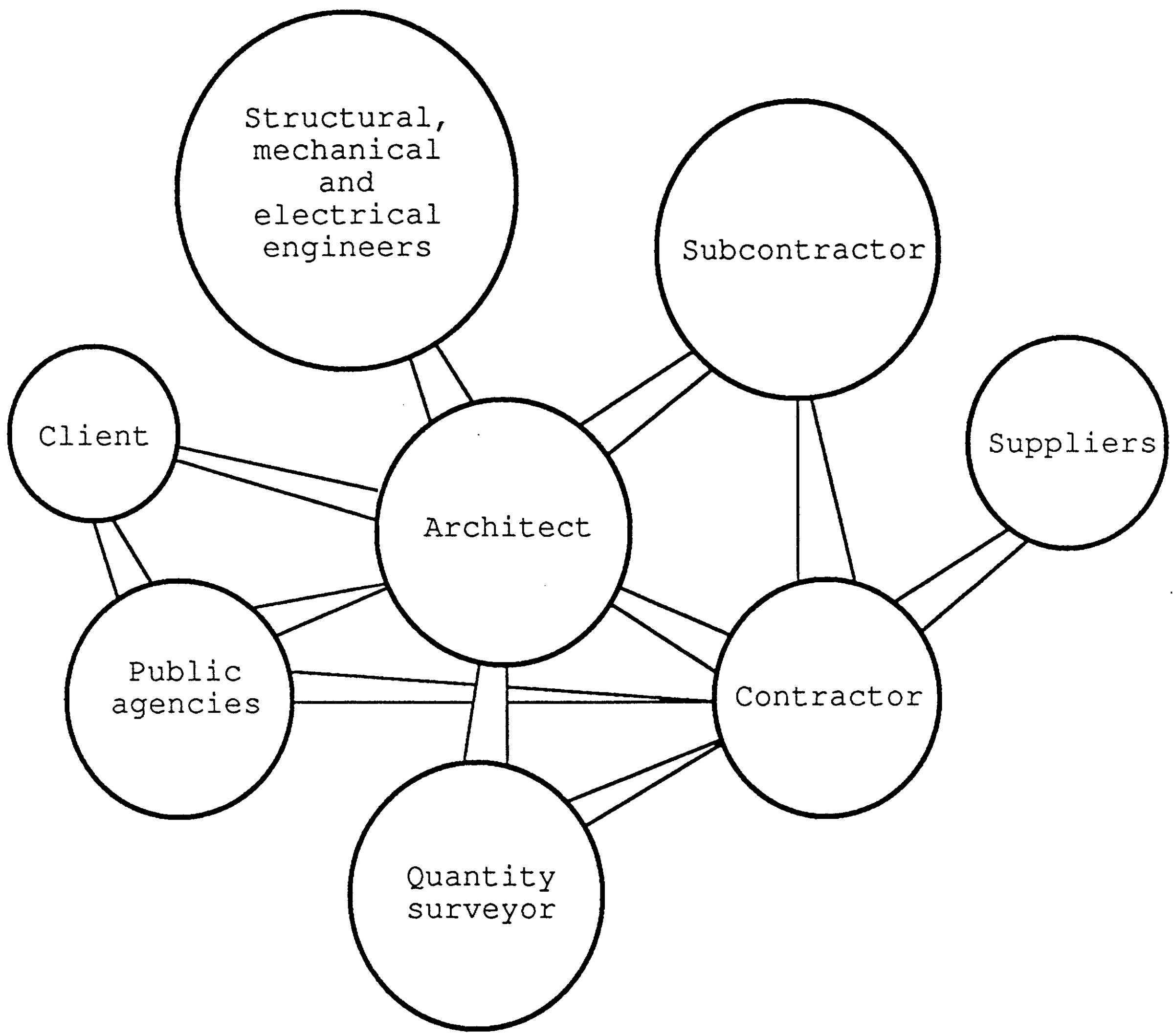
Because of the nature of construction products, achieving a competitive advantage by means of IS/IT in construction industry is relatively difficult compared with other industries, such as manufacturing and the information service industry. First, the design and construction processes are unique for each construction project. Each product is one-of-a-kind and the design process itself is very people-intensive. Therefore, production costs cannot be lowered by the mass production techniques which are used in manufacturing.

Second, the design and construction process involves many kinds of expertise, such as that of the developer, architect, engineers, suppliers, general contractor, sub-contractors, financial institutions, and owner. Betts, et al. (1989) refers to eight different categories of stakeholders in IS/IT (see Figure 2.2.1). And he observed that the complexity of stakeholders restricts the extent of SIS use.

Howard et al. (1989) notes that fragmentation in the architecture/engineering/construction (AEC) industry in the U.S. lowers productivity. A very large number of establishments, fragmentation of the designers by specialty, and fragmentation of the buyers constitute vertical fragmentation (between planning, design, and construction) and horizontal fragmentation (between specialists) in the U.S. AEC industry. Integration of information among the planners, designers, lenders, builders, and operators can "mitigate this existing organizational fragmentation" that fosters inefficiencies in project phases. Howard et al. also points out that computer-integrated design and construction offers opportunities to improve competitiveness in the U.S. AEC industry.

Fragmentation in the construction industry leads to low

Figure 2.2.1 Construction IT Stakeholders



(source: Betts, M, et al., 1991)

productivity and inefficiency. Computer applications for individual tasks cannot simply improve productivity in construction and will not lead to competitive advantage. Such use of IS/IT is almost the same as the traditional one, even if the IS/IT is supported by highly advanced computer technology. Strategic use of IS/IT can only have a great influence on competition in construction in terms of information integration.

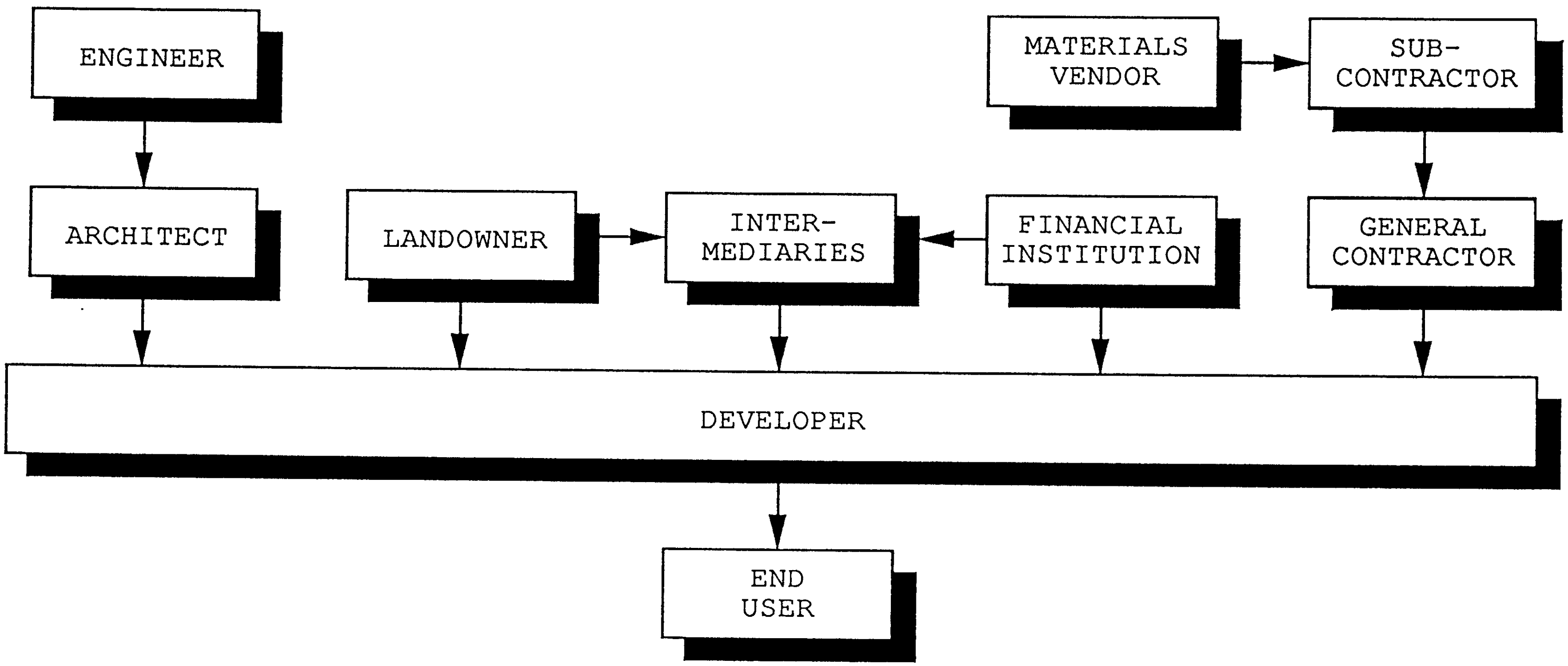
2.2.2 Examples of Integration of Information in Construction

Real property development

Macomber, in an article in Urban Land (1989), points to the importance of IS/IT for the real property developer. He describes four principle types of IS/IT: shared databases, integrated systems, knowledge-based systems, and representational technologies. As he mentioned, opportunities for integrated IS/IT are great in the real property value chain because of fragmentation in real property development (see Figure 2.2.2).

He noticed that while relatively "substantial savings in communications and productivity" have been gained in the architect/engineer/contractor/facilities manager relationship by successful computer applications, the developer is not doing business efficiently in the development process, because direct exchange of information is not allowed by

Figure 2.2.2 The Real Property Value Chain



(source: Urban Land, Aug., 1989)

"the middleman who is paid for service and information".

Information varies in its meaning according to the player. Each player tries to extract necessary data from the same information. As information is passed from one player to another player, more data is added and its cost increases. It appears that effective integration of information among the players' value chains can lead to lower-cost solutions for property development. Linkage to other players also leads to differentiation of developer business. It is important for the developer to select other players' value chains to be linked by this integration. Under a certain strategy which can maximize the value of information shared between the value chains, the developer can operate IS/IT in its business as a strategic information system (SIS).

Dyer/Brown & Associates (according to Harvard Business School case study)

Dyer/Brown & Associates achieved great improvements of productivity in drawings and specific design elements with CAD. CAD eliminated a substantial amount of trial and error, and shortened the updating process. By using CAD the company was able to provide developers with expanded services, such as calculations. Further, they enhanced a relationship with a specific developer by developing CAD capability in interior space planning. This CAD capability had a large effect on the developer's critical concern; the timing issues, that is, the ability to produce things quickly was very important for the developer.

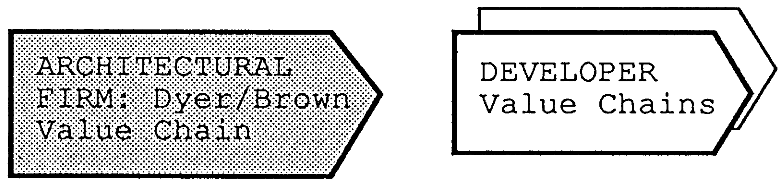
Dyer/Brown was always trying to develop strategic use of CAD in the value system (see Figure 2.2.3). First, their purpose in using CAD was to expand and enhance customer services by improving productivity and efficiency in their design processes. Speed and accuracy obtained by CAD made major contributions to their client's development activities. Next, Dyer/Brown concentrated on a specific capability of CAD, space interior planning, to enhance a relationship with a particular developer. Thus CAD was indispensable for Dyer/Brown to enter into a close strategic alliance with the developer. This CAD capability allowed them to rapidly respond to the developer's aggressive marketing by providing quick turnaround of design alternatives.

It is obvious that Dyer/Brown's definite strategic perspective on CAD was to expand customer services. Further, intense development of CAD capacity in the interior space planning area reached to the end users (tenants)' value chains. Tenants preferred Dyer/Brown's interior design to their own architects', because Dyer/Brown could offer interior design at lower cost through its excellent CAD. Dyer/Brown's next target was the larger tenants who were interested in more customized design services.

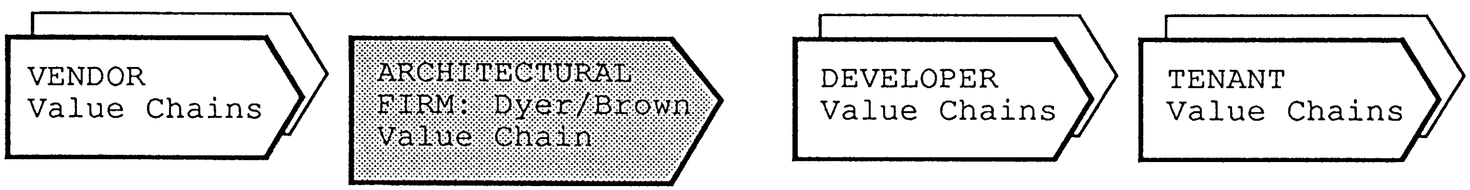
Development of CAD as a design tool will also affect the suppliers' (software vendors') value chain, because it leads to standardization issues for CAD applications. Standardization will bring flexibility into Dyer/Brown's CAD

Figure 2.2.3 The Value System: Dyer/Brown case

Relationships with Developer



The Whole Value System



design capability. That is, they will be able to use CAD not only as a production tool, but also as a design tool. As a result, their strategic use of CAD will effect the whole value system (see Figure 2.2.3), and aggressively differentiate Dyer/Brown from other design firm.

Information technology at Bechtel

Howard and Okazaki, in a article in Construction Business Review (1991), describe the use of integrated information technology at Bechtel.

There is an important trend in organization from centralization to decentralization. Bechtel's organizational structure is highly decentralized, and "the resources are divided and there are rigid boundaries between functions." Each discipline - engineering, construction, procurement, information services - has its own computer system, language, and protocol. On the other hand, new information technology has advanced enough not only to support the organizational trend, but also to share resources among divisions.

Recently, in order to take advantage of the new technologies, they are trying to share resources among divisions through an integrated information system. They are constructing a different organizational structure by breaking down the boundaries between divisions.

Automation of project process by department is limited. It is necessary to train people project by project due to different information system. They need to take a team approach by the integration system in order to maximize efficiency and effectiveness of work processes. By doing so, the company's new information system will enable them to consolidate development and minimize training.

Summary

Integration of information and exchange of information has great significance in the construction industry. Among which players or disciplines information should be integrated depends on the players. The firm can define and plan its own strategy in this context.

2.3 Definition of Strategic Information Systems in Japan's Construction Industry

Japan's construction industry is fragmented like the U.S. industry not only in terms of number of establishments, but also in terms of specialties and of owners. Japan's general contractors (GCs), especially the larger ones, have a special position in this industry. They have very large numbers of employees, ranging from a few thousand to ten thousand. Engineers are from a wide range of specialties. They have R&D capabilities which have effected improvement in the productivity of the industry. Issues about productivity in design and construction processes and about international markets are very important concerns for them to survive in the industry.

2.3.1 Overview of Japan's Construction Industry

Japan's construction industry will be described in detail in chapter 3. This section provides a brief overview of the industry.

Land fever in Japan, which began in 1971, accelerated R&D activities in the construction industry. Maximizing utilization of land had priority, especially in urban-area construction. New requirements in the design and construction process, for example, legal issues, building codes, public issues, and so forth added much complexity to urban construction projects. Time-consuming trial and error procedures during conceptual planning added to this complexity.

Excellent R&D capabilities in Japan's construction industry, particularly in the so-called 14 major GCs, have resulted in various new construction technologies and techniques. This includes the active installation of many computer systems and their application in offices, research institutes, and construction sites of the large GCs. However, full use of IS/IT is still developing.

One characteristic of Japan's construction industry is that "a larger establishment has a greater productivity being supported by capital intensity as well as peculiar labor subcontracting systems" (Hasegawa, 1986). Thus it seems that the relatively large GCs should be able to take great advantage of strategic use of IS/IT, because concentration and integration of a variety of information provides great opportunities for improvement of efficiency. In addition to intense R&D on construction technology and techniques, improvement of productivity by SIS is another significant way to help insure survival in the industry.

R&D capability is also essential for major GCs to keep up with their rivals. Large general contractors have a variety of human resources. It is more important for a GC to cover a wide range of different R&D fields than to focus on a specific field. Their researchers' specialties range so widely that research directions are likely to be dependent on their bottom-up suggestions.

The firm's potential ability for problem solving is high because there are, within the organization, people from many different fields of speciality. Currently, an individual researcher's or engineer's knowledge is stored on his or her own personal computer. Therefore, much of their knowledge and information in a firm is held on highly decentralized basis. Middle managers currently lack the tools to act strategically by identifying fellow workers who might help solve specific problems.

The management information systems (MIS) in Japan's construction industry have not been developed to the level which exists in the U.S. AEC industry. Almost all Japanese construction firms' management processes still remain manual. Levy (1990) found the following differences between the organizational traits of employees of Japanese and U.S. corporations:

Organizational Trait	**Japanese**	**American**
Interaction with Managers	Open office mentality On daily basis	Private office mentality On "as needed" basis
Corporate profit goals	Market share Long term	Short term

In Japan, the open office environment doesn't make managers feel that computerized MIS are necessary. When a manager needs some information from fellow workers, he can always call someone and get the information directly from the person who has it. Long-term corporate profit goals also effect managers' decision-making process. It is unusual for them to make a decision quickly. Industry managers usually discuss issues as a group before making a decision, and they share responsibility for it. This contributes to Japanese managers' lack of interest in MIS.

Strategic use of IS/IT must therefore follow a top-down approach because it always requires managerial strategies and organizational changes. However, implementation of SIS is not easily accepted by many top executives of Japanese GCs, who insist on traditional management ways. On the other hand, now that new generations of company managers are accustomed to the use of computers, new applications of IS/IT are becoming more feasible.

For almost all Japanese GCs, quality of products has been given top priority for a long time. They believe that quality control is the single most important element to retain relationships with clients. Therefore, the concept of TQC (Total Quality Control) was readily acceptable to them. Many of major GCs were making efforts to win the Deming Prize in the 1980s. TQC activities extended to every division or section throughout company from headquarter office to branch offices, jobsites, and technical research institute. However, it is not clear whether or not companies have gained competitive advantage by TQC activities.

The basic approach to TQC has been as follows. Several people form a so-called "TQC group" which helps to identify the problem areas in their office. They set up a specific objective to eliminate the problem; and they initiate a series of trial and error approaches towards achieving the objective. When they accomplish the objective, they reorganize the way of doing things and prepare a standardized format. Although the format is to be renewed periodically by re-evaluation, it is not uncommon that it remains unchanged and becomes useless because of later changes in working procedures. Therefore, TQC activities have not been proven to be an effective tool in Japan's construction industry.

2.3.2 Importance of SIS in Japan's Construction Industry

It is obvious that involvement of top management is indispensable for the development of SIS. That is, development of SIS requires top-down planning. So far, Japanese construction firms have adopted computer systems without organizational changes. Implementation of IS/IT has been conducted by bottom-up planning, mostly by IS divisions. Even if it becomes known that organizational change would lead to a more efficient use of IS/IT, it is difficult, if not impossible, to change the organization by bottom-up planning.

In order to lower production costs and differentiate themselves from rivals, Japanese GCs have concentrated on using computers to improve productivity in individual divisions. This approach did not produce enough improvement to have much favorable impact on the firm's overall competitiveness. Some top executives, however, are beginning to recognize that strategic use of IS/IT, which enables a firm to share information among its divisions, is becoming of critical importance to the future survival in the industry. Recently, each major GC has recognized the need to restructure IS/IT as one of the most important elements of its long range plan.

Hattori and Kita (1991) defined the role of GCs as networking multi-business organizations and handling information for planning and management of design and construction. Therefore, it is advantageous for GCs to integrate and exchange information systematically.

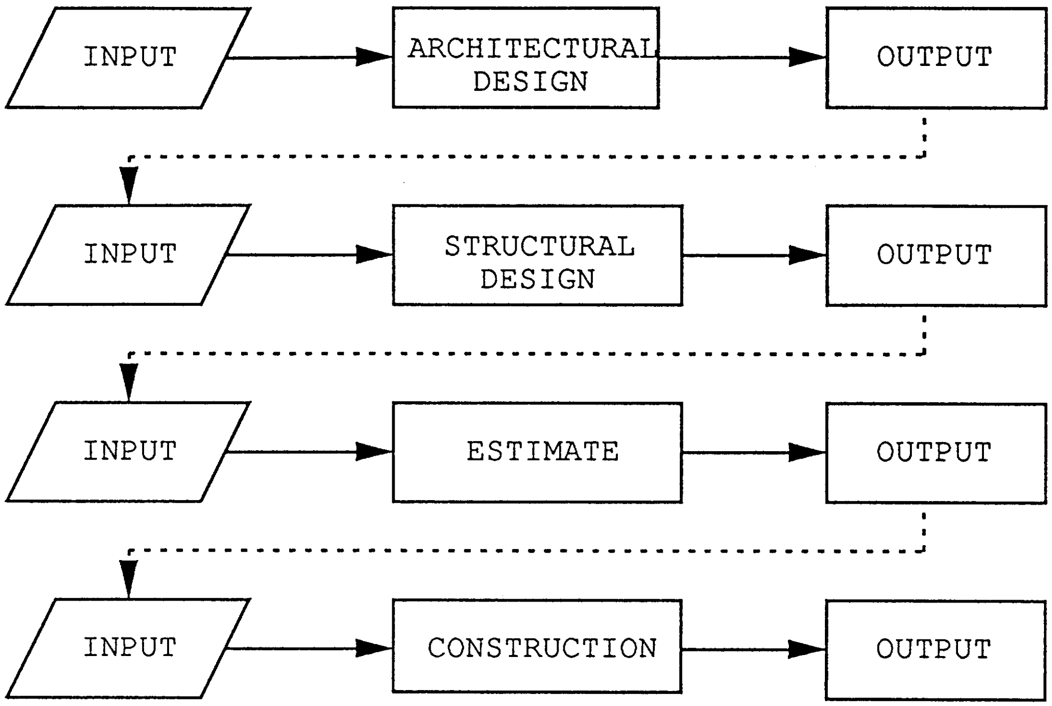
For example, in several design and construction activities, it will be essential to integrate and exchange information. Construction robotics or automation will need systematic management of information to control many different types of construction robots and complete a whole building. Exchanging information between construction and manufacturing industries is needed to develop and operate such systems. "In addition, as the concept of facility management (FM) services becomes popular, clients' request for building data or information will be increasing." (Japan IBM, 1991). Structuring the system between the client and contractor will be needed. Continuing development of intelligent or integrated CAD is beginning to enable the effective management of information for every design and construction process. Traditionally, each process has required its own format of input and output because of the different points of view which exist toward the same information among the players involved in the design and construction process (see Figure 2.3.1).

One source of Japanese GCs' competitiveness is a highly sophisticated ability in structural analysis. "Design of complicated and huge structures requires structural engineers to develop their own programs.(Nakai, 1989)" However, the future integration of existing structural analysis techniques could lead to significant improvement in reliability and productivity.

Karstila et al.(1991) observed that since standardization of exchange data between different areas is too difficult to solve, standardization within a firm is a better way. Japanese GCs, whose activities extend from design to construction, have a relatively large advantage on this point (see Figure 2.3.2). Recently one of Big Six, Taisei Corporation, developed a integrated CAD system which was named LORAN-T (Long Range Architectural Networking in Taisei). The development of LORAN-T shows not only Japanese GCs' motivation to integrate internal information using CAD as the core, but also points to the existing inefficiency in Japanese GCs.

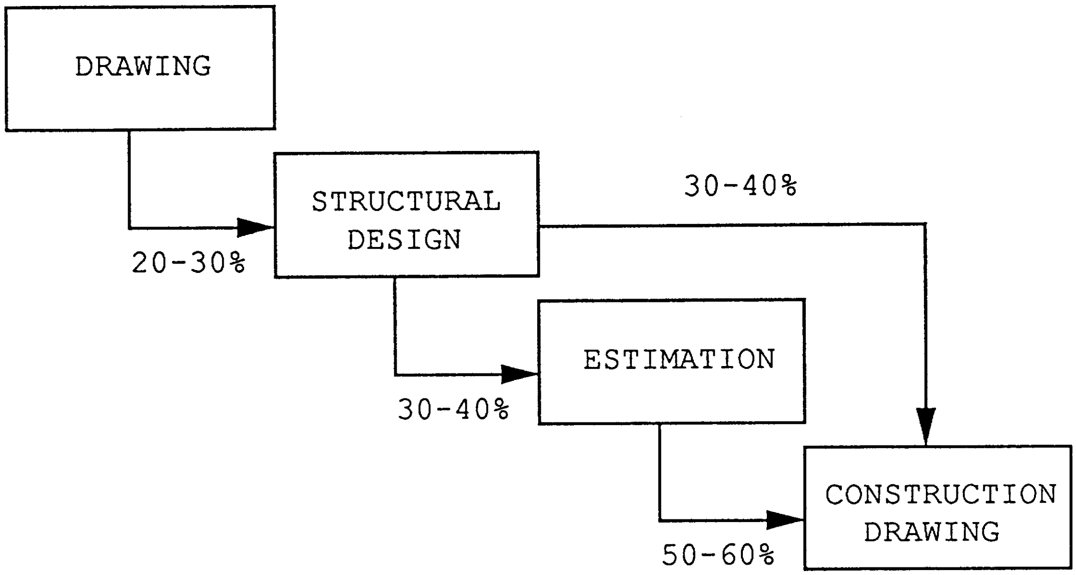
LORAN-T was developed to overcome the difficulty of information exchange among three types of CAD: drawing,

Figure 2.3.1 Data Exchange



(source: Morimoto, O. et al., 1990)

Figure 2.3.2 Percentage of Data Sharing



(source: Morimoto et al., 1990)

checking building codes, and presenting computer graphics. Re-entry of data is needed to exchange information from one type of CAD to the other. This always takes some time and opens the door for mistakes. The objective of the development of LORAN-T was to improve the quality of design by improving the accuracy of data exchange among the CAD systems. For the system, an integrated 3-D architectural semantic model database was developed. It is noteworthy that the in-house database was developed in cooperation with a developer and an electronic company. As a result, accurate and quick data transfer to construction is expected to shorten construction time and improve quality of construction work. (Kato et al., 1990)

It is apparent that sharing information is effective for improvement of productivity and quality and bears a lot of merits for GCs. One of the reasons why the development is slow and difficult is the large investment of money and time which is needed. Top executives must develop an understanding of the importance of IS/IT from a long term stand in order for its full potential and benefits to be realized in the future.

Chapter 3

Japan's Construction Industry

Although Japan's construction industry has given priority to improvement of productivity, its productivity is still low compared with that of manufacturing industries. But the Japanese construction industry's strengths are quality control and maintaining project schedules. Human efforts, overtime work, and trial-and-error on the use of innovative methods and technology on the work site have largely contributed to those characteristics.

In general, over the last several years, Japanese investment in the U.S. has decreased after the "bubble economy" ended in Japan. The "bubble economy" is a term used to describe the temporary prosperity that arose when Japanese investors obtained huge profits by reselling expensive land in urban areas and they invested in property overseas as well as in domestic propery. The center of the international market for Japanese construction firms is transfering to the Pacific Rim and Asian countries. This situation is urging them to change their strategy in the international market.

3.1 Characteristics of Japan's Construction Industry

3.1.1 General Trends

<u>Establishment</u>

Japan's construction industry consisted of 515,440 registered construction firms in 1991. The number of construction firms has been decreasing slightly since 1985, but it tended to increase in 1991 (see Figure 3.1.1). According to the analysis of change in the number of construction firms by prefecture in 1991, there are increases in the number of small and medium-sized construction firms in the regions of major cities of Tokyo, Kanagawa, Osaka, Hyogo, and Fukuoka, due to aggressive urban development.

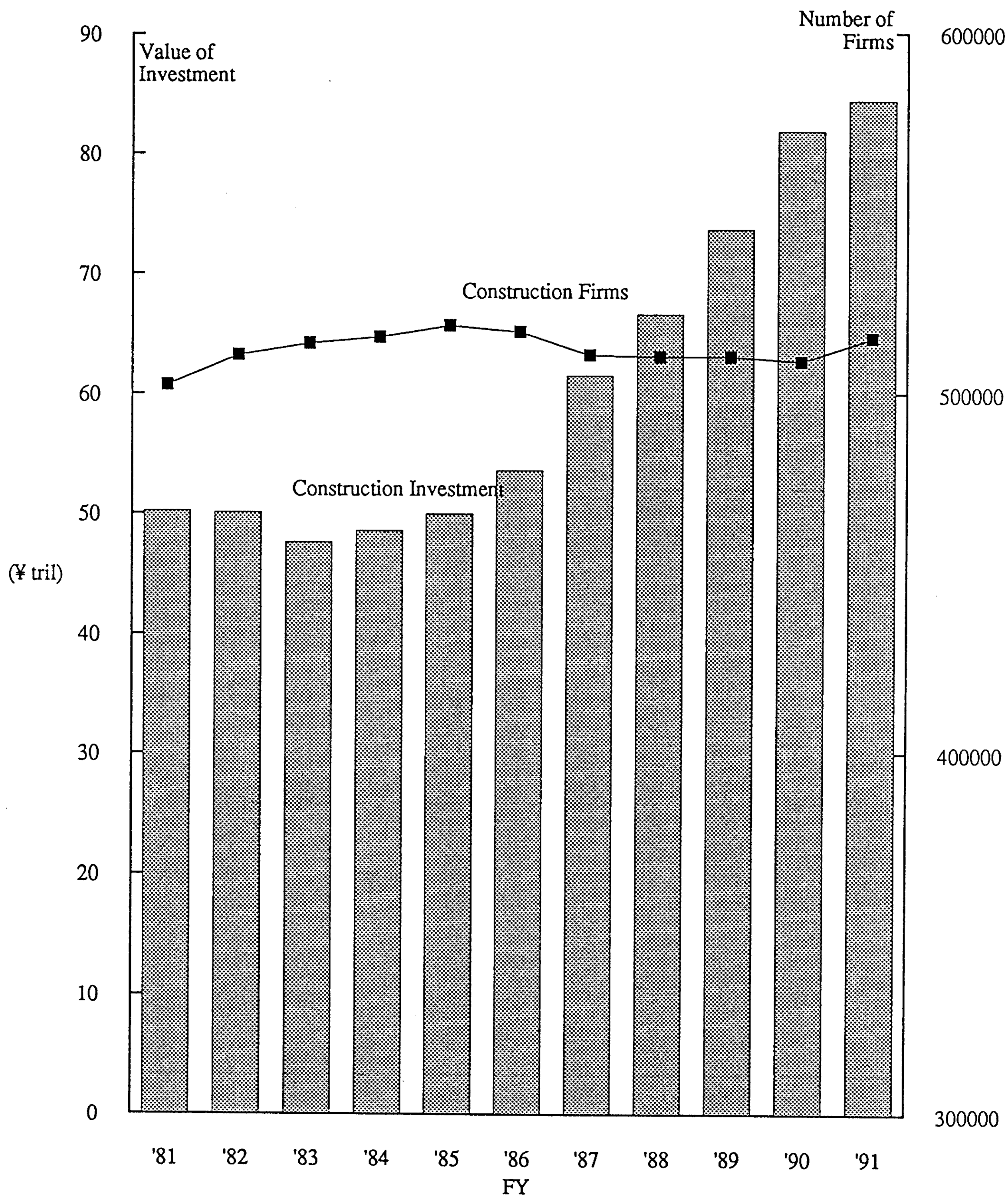
It can be said that Japan's construction industry is fragmented in terms of the number of small establishments. They account for about 98 percent of the total number of construction firms. In terms of the size of capital, small and medium-sized firms, which are capitalized less than ¥ 50 million, dominate the industry (see Table 3.1.1).

On the other hand, large firms, which are capitalized more than ¥ 100 million, dominate the industry in terms of value of construction completed (see Table 3.1.2). Of the large firms, 50 firms have contracted 32.77 percent of total construction investment in 1990 (see Table 3.1.3).

<u>Civil construction and architectural construction investment</u>

Construction investment was decreasing until 1985. Construction investment as a percentage of GNP fell to 15.5 percent in 1985. During that recession, there was a gradual scaling down of civil construction investment. Since 1985

Figure 3.1.1 Value of Construction Investment and the Number of Construction Firms



(source: Ministry of Construction, 1991)

Table 3.1.1 Change in Construction Establishments by Scale of Firms

(percentage)

FY	I	II	III	IV	V	VI	VII
1982	63.31	16.42	9.80	9.19	0.62	0.52	0.14
1983	61.49	16.84	10.46	9.85	0.68	0.54	0.14
1984	59.97	17.23	11.02	10.35	0.73	0.56	0.14
1986	57.33	17.74	11.64	11.76	0.81	0.58	0.14
1987	55.82	17.98	12.08	12.54	0.85	0.58	0.16
1988	54.11	18.18	12.69	13.34	0.92	0.59	0.17
1989	51.75	18.20	13.66	14.61	0.98	0.62	0.18
1990	48.93	18.36	15.05	15.77	1.04	0.65	0.20

Note: Capital sizes in Yen value are as below

I	below	¥ 2 mil
II	¥ 2 mil	- ¥ 5 mil
III	¥ 5 mil	- ¥ 10 mil
IV	¥ 10 mil	- ¥ 50 mil
V	¥ 50 mil	- ¥ 100 mil
VI	¥ 100 mil	- ¥ 1 bil
VII	above	¥ 1 bil

(source: Ministry of Construction, 1991)

Table 3.1.2 Values of Construction Completed by Specialized Construction Firms (1989)

	A	B	C	D	E	F
Number of Firms	20,751	47,842	42,087	47,209	2,406	1,144
(%)	12.85	29.63	26.07	29.24	1.49	0.71
Const. Completed (%)	2.26	10.46	9.36	30.31	8.26	39.34

Total Number of Firms	161,439
Total Construction Completed	¥ 86,198,411 mil

Note: Capital sizes in Yen value are as below

A	below		¥ 2 mil
B	¥ 2 mil	-	¥ 5 mil
C	¥ 5 mil	-	¥ 10 mil
D	¥ 10 mil	-	¥ 50 mil
E	¥ 50 mil	-	¥ 100 mil
F	above		¥ 100 mil

(source: Ministry of Construction, 1990)

Table 3.1.3 Change in Value of Contracts by GCs

(¥ trillion)

FY	1983	1984	1985	1986	1987	1988	1989	1990
A	9.55	9.61	12.16	12.75	14.80	18.00	21.82	26.82
(%)	20.06	19.80	24.33	23.80	24.06	27.00	29.63	32.77
B	1.67	1.70	1.82	1.98	2.25	2.48	2.77	2.94
(%)	3.51	3.51	3.64	3.69	3.65	3.71	3.76	3.59
A+B (%)	23.57	23.31	27.97	27.49	27.71	30.71	33.39	36.36

Note: Statistic are based on the contractors picked up by Ministry of Construction.
Classifications of firm are as below.

A Capital size above ¥ 100 million
1982 - 1984 43 firms
1985 - 1990 50 firms

B Capital size below ¥ 100 million
465 firms

(source: Ministry of Construction, 1991)

construction investment has increased (see Figure 3.1.2), but civil construction investment is growing slowly compared with architectural (building) construction investment (see Figure 3.1.3). Civil investment as a percentage of construction investment was 41.1 percent and 36.2 percent respectively in 1985 and 1990.

On the other hand, the proportion of architectural investment in construction investment is increasing. Especially, private architectural investment has been expanding. The rate of increase in private architectural investment has constantly been over 10 percent in nominal terms (over 8 percent in real terms) since 1987.

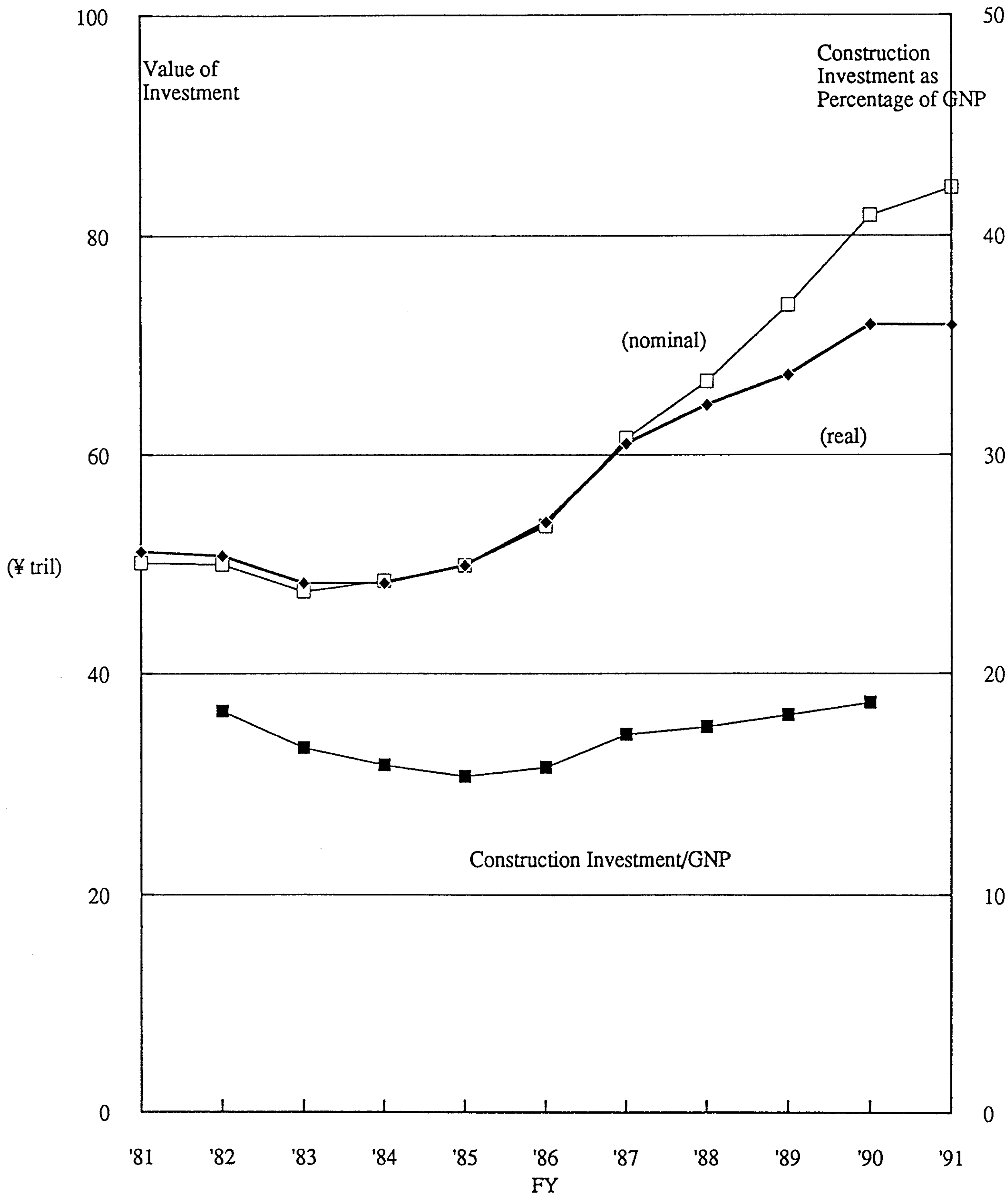
However, in 1991 construction investment decreased because of the cessation of the bubble economy, the rate of increase in private investment fell to 2.3 percent in nominal terms (-0.9 percent in real terms).

3.1.2 Schedule and Quality Control

This section refers to scheduling and quality control in Japan's construction industry. The ability to maintain construction schedules and quality control are major strengths of Japan's construction industry. Also, these two strengths are considered to be important for retaining good relationships with clients.

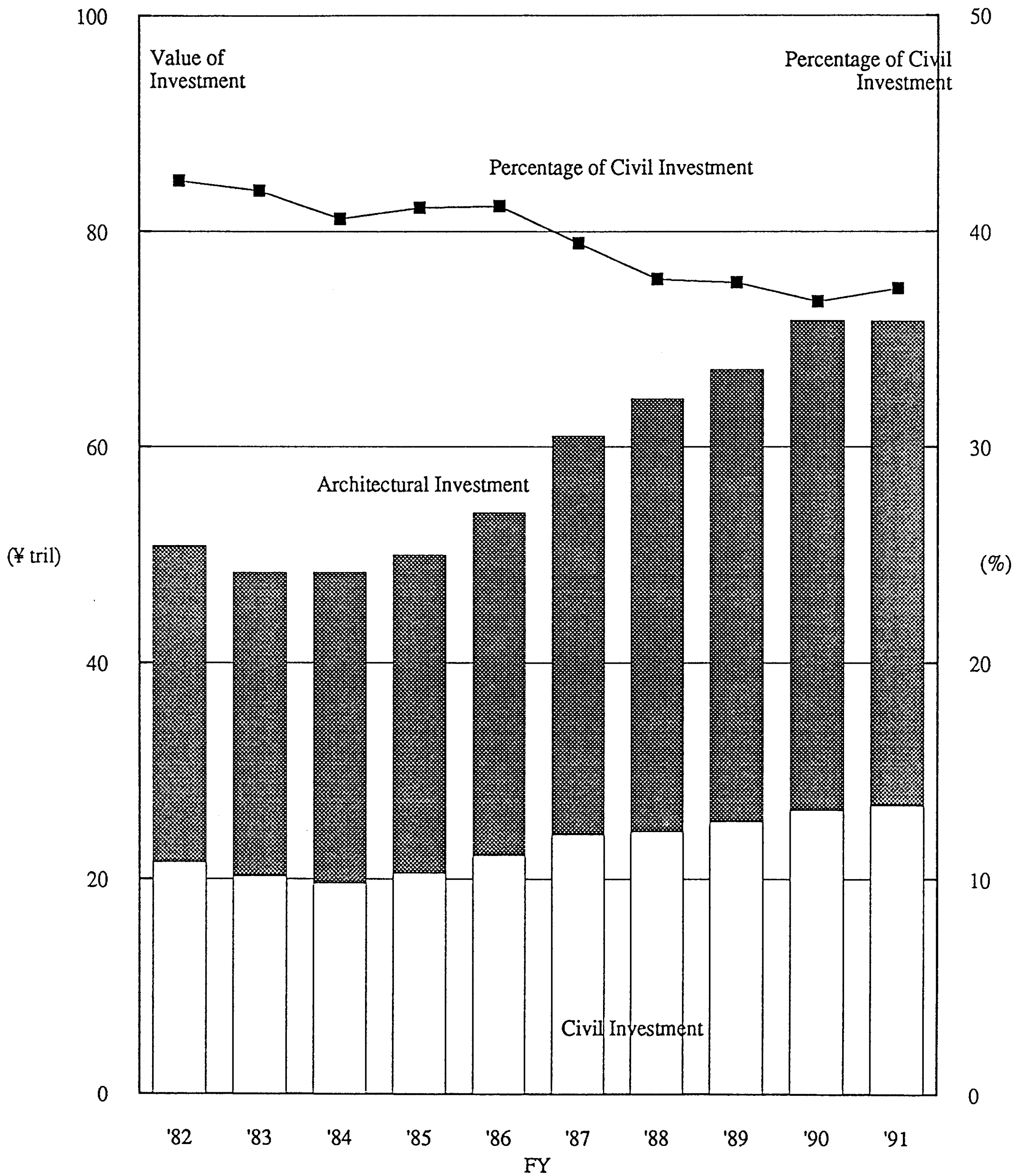
Construction workers' working time, including overtime, has greatly contributed to these prime objectives. The

Figure 3.1.2 Value of Construction Investment as Percentage of GNP



(source: Ministry of Construction, 1991)

Figure 3.1.3 Changes in Civil and Architectural Investment



(source: Ministry of Construction, 1991)

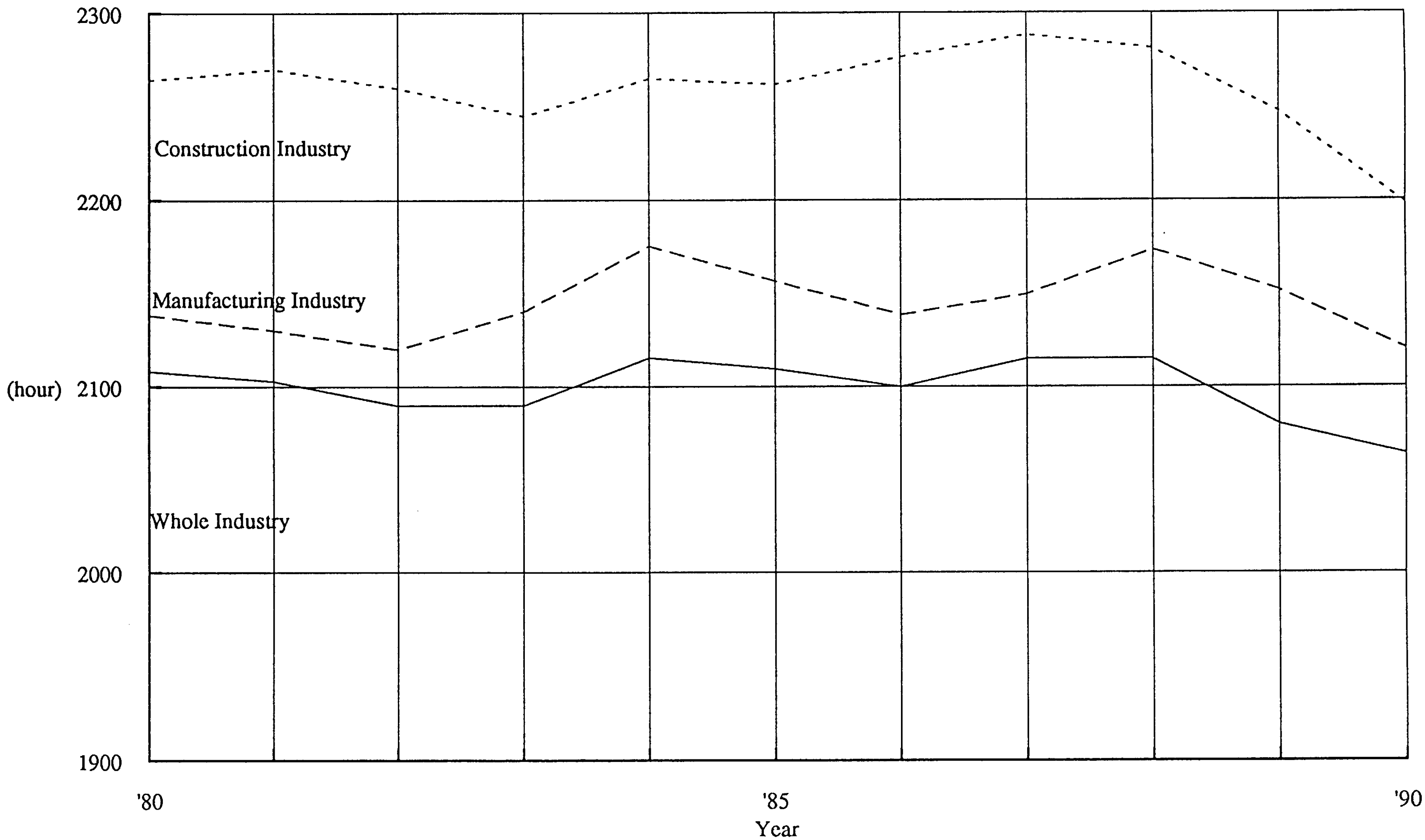
average number of hours worked annually per worker in construction industry is decreasing, mainly because many construction firms started a 5 working-day system, but the difference between hours worked in the construction industry and other Japanese industries is still large (see Figure 3.1.4).

Scheduling

Undoubtedly, "maintaining a project schedule is of prime importance" (Levy, 1990) for Japanese construction firms. Since the bidding system in Japan depends on negotiation, ability to maintain schedules greatly improves the chances of getting more jobs in the future from the client. Japanese construction firms also emphasize this objective in order to maintain a good reputation.

Almost all Japanese construction workers make every effort to maintain a schedule. However, it is not common to manage construction phases on the jobsites using computerized CPM (critical path method) programs. Good organization and personal management account for maintaining schedules. Everyday meetings by all heads of professions coordinate the sequence of construction tasks. Each construction superintendent manages several professions and every profession is coordinated by meetings of superintendents. On-time delivery of products is manually managed for the most part.

Figure 3.1.4 Annual Working Time by Construction and Manufacturing Industry



(source: Japan Construction Association,1991)

Quality control

Quality control here is defined as the management activity to obtain the desired level of quality of product. Takase (1989) mentions that well-managed project delivery systems and quality control on the construction sites have resulted in the delivery of high quality products on time. This is an area of great difference with the project delivery systems in the U.S. and Europe, where design specifications and drawings must be completed at the time of contracting. In Japan, material choice and detailed drawings are made by the contractor's construction engineers and managers on-site.

Construction jobsites are often used for trial application of new construction materials and methods. For instance, when new high-strength concrete is first used, the firm's technical research institute maintains quality control and educates workers on the jobsite.

However, the latest survey by Nikkei Architecture (1990) revealed that the recent construction boom strained quality control capabilities in the industry. Architectural design firms, especially large firms, claimed lowered quality in design processes. GCs also claimed quality control problems in construction. It is apparent that dependency on the placement of orders outside caused the quality problems because of outside firms' low productivity and low management ability. Management of quality control largely depends on human efforts.

3.1.3 Japanese GCs

Japanese GCs have played an important role in the construction industry. Many have long histories: some of them have been in business for over 100 years. They are working on a large portion of Japan's construction business; specially the so-called major GCs, which refers to the top 14 GCs, are playing a role in every part of the construction business: real estate development, architectural design, engineering consulting, structural analysis, R&D on construction technology and materials, and construction. These functions are integrated vertically and these integrated functions are very convenient for the customer. This vertically integrated service, not only construction, but also real estate, design, consulting, R&D, and so forth, is characteristic of Japanese major GCs.

Similarity

Hasegawa (1986) points to similarities in Japanese GCs. Their fields of operation are limited to building and heavy construction. Because differences between GCs are slight, it is difficult to distinguish them by market share of types of construction or by geographical area.

There are similarities in Japanese GCs' overseas activity, except for one major GC, Kumagai-Gumi. Overseas activity averages 10 to 15 percent of the major GCs total contract value. Large GCs have been working overseas to compensate for ups and downs in domestic construction investment (see Figure 3.1.5). While the overseas contracts of large GCs was around 8 percent until 1985, the percentage has declined to around 4 percent since 1985.

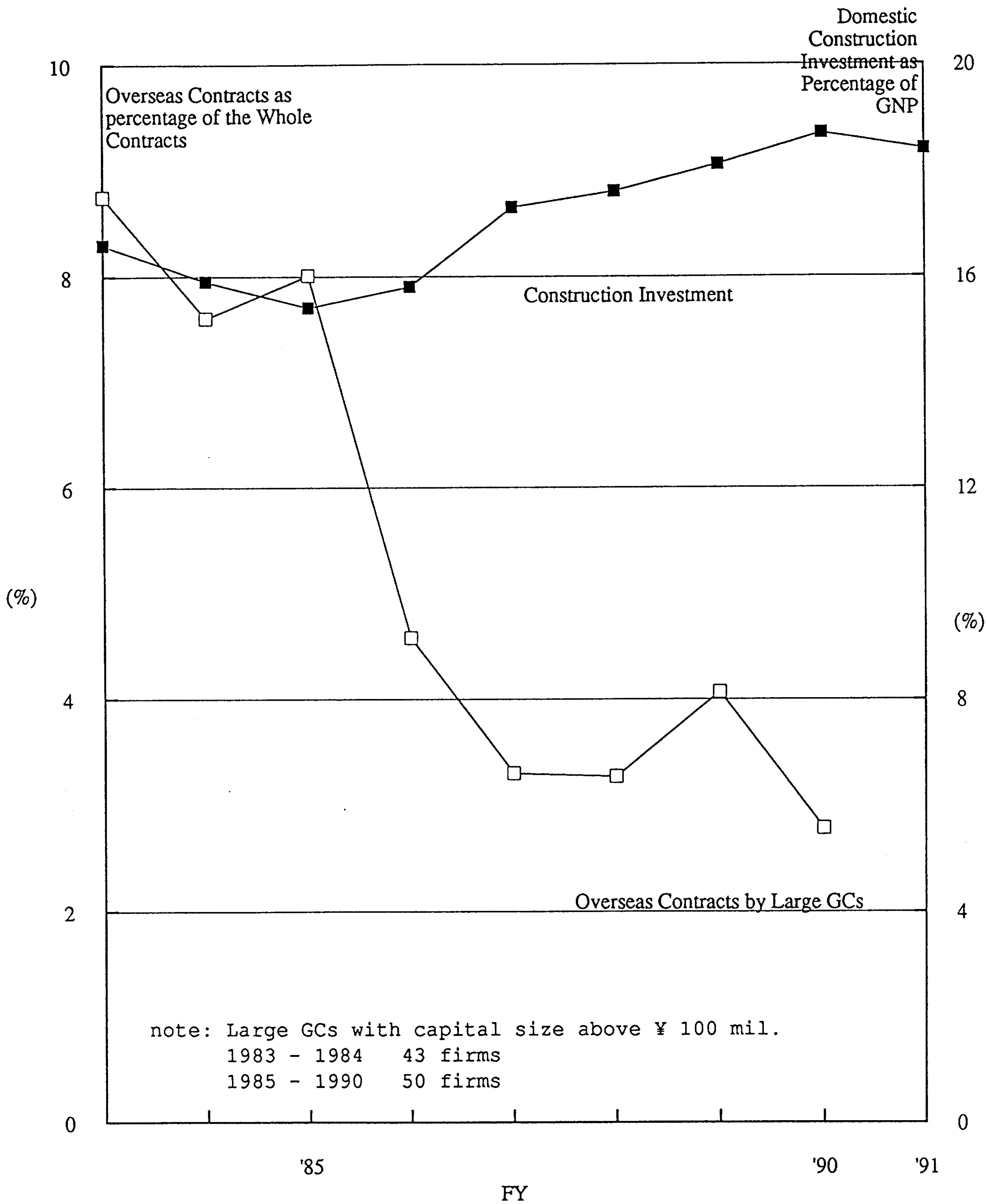
The stable domestic market share of GCs also contributes to the similarities. GCs must seek jobs overseas during the recession because of the difficulty of expanding domestic market share. Moreover, since a firm's annual turnover is a major determinant of contracting a domestic job, GCs must contract overseas in order to maintain their annual turnover during the recession. As Bennet mentioned (1987), overseas activity helps maintain a firm's market share of domestic activity.

However, of the Japanese major GCs, the so-called "big 6" which contracted over ¥ 1 trillion - Shimizu, Kajima, Obayashi, Takenaka-komuten, Taisei, and Kumagai-gumi - are differentiating from each other to a certain extent. For instance, Takenaka-komuten is focusing on architectural construction capability, Kajima, Co. has strength in design of nuclear power plants, and Kumagai-gumi is concentrating on overseas activity as a developer. On the other hand, other major GCs can hardly differentiate themselves from others by means of specific areas.

Importance of design division

Japanese major GCs emphasize their own design divisions. First, because design capability is essential for offering

Figure 3.1.5 Value of Overseas Contracts by Large GCs



(source: KENSETSU KATSUDO (Construction Activity), 1991) vertically integrated services when they are doing business as a developer. Second, public works like dams and nuclear power plants require design capability.

It is apparent that the importance of design divisions of GCs is due to the popularity of design-build contracts. Almost all Japanese GCs have their own design division. Design-build contracts account for 30 to 50 percent of the value of all contracts in major GCs (see Table 3.1.4). The proportion of design-build contract is easily affected by the ups and downs of the economy (see Figure 3.1.6). Since 1985, as construction investment increased, the value of design-build contracts by the 9 major GCs also increased.

Human resources

Major GCs have great a variety of human resources because of the diversified social needs they serve. Their specialties cover a wide field: biotechnology, nuclear engineering, mechanical and electrical engineering, mathematics, social science, agricultural engineering, and so forth. They have highly advanced technical institutes, which offer opportunities for high-grade research to new graduates.

Time and cost of training new comers are substantial. Many GCs spend a few years training new employees. For example, they circulate new employees through construction sites or divisions periodically, and make every employee attend training programs at regular intervals in order to educate them according to their level of management

Table 3.1.4 Value of Design-Build Contracts by Major GCs

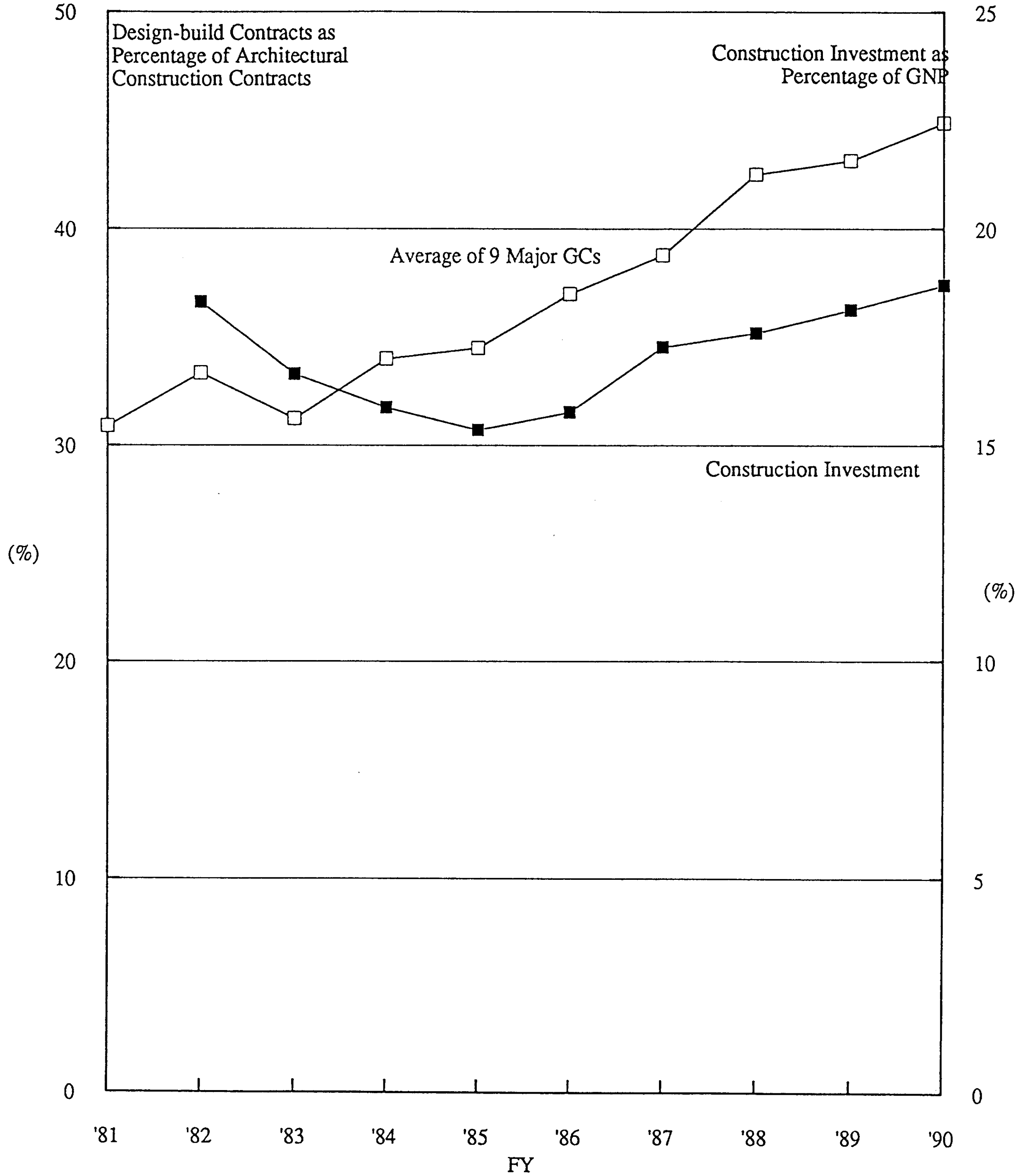
(¥ million)

FY	1986	1987	1988	1989	1990
TK	412,753	880,945	1,283,763	1,170,107	1,892,114
(%)	53.8	58.8	54.0	55.6	55.9
KJ	294,324	757,308	1,136,998	1,417,217	1,700,229
(%)	45.9	36.4	52.9	52.4	55.2
SM	300,150	921,290	1,283,763	1,605,359	1,977,963
(%)	38.6	46.0	50.0	45.8	47.3
TS	265,200	785,700	1,000,167	1,346,647	1,695,200
(%)	39.1	40.3	43.2	47.4	47.7
OB	211,800	703,717	862,111	1,171,236	1,521,375
(%)	36.9	41.6	42.8	36.5	36.9
FJ	113,700	314,200	376,560	491,432	612,902
(%)	37.1	41.8	51.5	48.0	45.0
TD	83,970	319,722	253,015	534,346	675,900
(%)	30.9	27.8	41.2	40.4	47.0
KM	125,720	496,900	594,800	-	856,534
(%)	22.3	23.8	31.5	-	35.4
HM	78,930	292,040	310,410	314,650	411,220
(%)	28.3	17.0	21.9	29.5	33.6

Note: Percentages show proprtion of D-B contracts
in Architectural construction

(source: Nikkei Architecture, 1987 - 1991)

Figure 3.1.6 Value of Design-Build Contracts by 9 Major GCs



(source: Nikkei Architecture, 1982 - 1991) capability.

Research and development

R&D expenditures as a percentage of net income in Japan's construction industry was 0.47 percent in 1989. On the other hand, R&D expenditures in the manufacturing industries were 3.21 percent, and there is still large difference between them. However, R&D expense in the Big 6 has reached 1 percent of net income, about ¥ 10 billion. R&D activity is one of their major strategies.

As Levy (1990) mentioned, "long term relationships between contractor and client are very valuable to the contractor who has such a relationship, but must be very frustrating to the competition. One method of wooing a client away from a long standing relationship is to come up with a design so innovative that it cannot be dismissed by the property owner." Japanese GCs are always doing R&D on the latest subjects by two kind of approaches.

First, Japanese GCs are doing R&D in co-operation with government agencies. There are a number of standard specifications and building codes in Japan, which GCs have made great contributions to establishing. It is very important for them to participate in this early stage in order to keep up with the latest technical trends.

Second, Japanese GCs are also studying with many universities. Their close relationships with universities give them good opportunities to capture newly graduated students. Moreover, a new employee who was studying in a particular research area retains a long relationship with his university, and the firm can take the initiative in the research area.

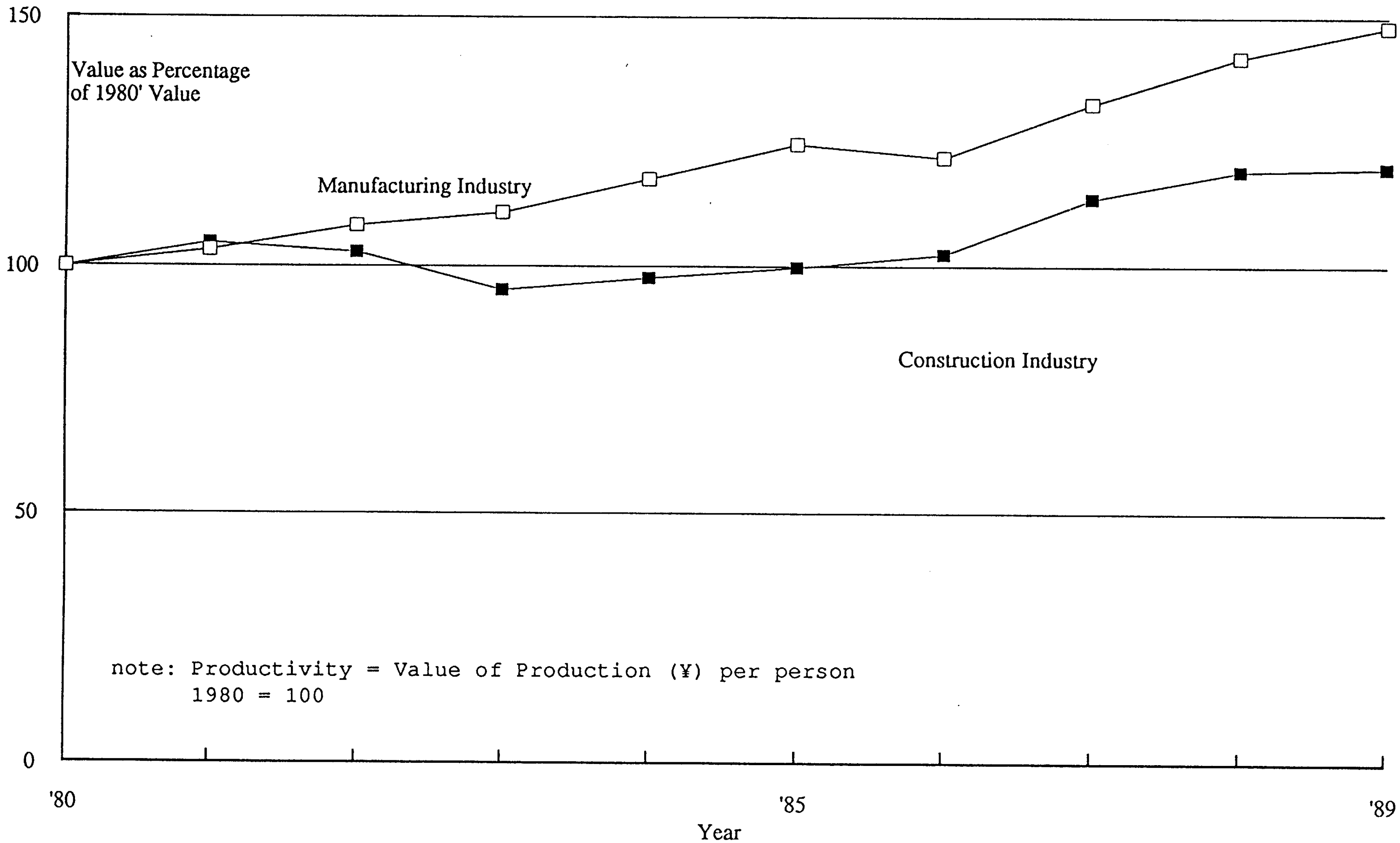
3.1.4 Productivity

Levy (1990) mentioned that "Japanese builders are constantly searching for new ways to increase their rates of productivity." However, industry productivity has not necessarily improved for several years. Compared with the manufacturing sector, the difference in productivity between them is increasing year by year (see Figure 3.1.7).

Major GCs doubled the value of contracts, and tripled net operating income for the last 5 years, but on the other hand, the number of employees has not doubled. The amount of value created per employee increased. It can be said that their employees' efforts has largely contributed to this increase.

Innovation of construction technology and materials itself hardly can offset lowered productivity by small firms and an aging and shrinking labor force. Up until now, efforts in major GCs have improved productivity of the whole construction industry. In the future, in order to improve the productivity, it will be necessary to involve small and medium-sized firms in activity for improvement of productivity.

Figure 3.1.7 Productivity by Construction and Manufacturing Industries



(source : Economic Planning Agency, 1991)

3.2 The Latest Trend in Construction Technology and Methods

There are important trends in Japan's construction industry on the demand side and the supply side. On the demand side, development of intelligent buildings became popular in Japan. Almost every building needs to be intelligent to some extent. And high quality and reliability required for construction products is making the development of new construction materials vital. Further, application of new materials enables the construction of large-scale and high-rise structures.

Significant supply side trends occur in both design and construction. In the design process, major GCs are engaged in the development of integrated CAD. The construction industry faces a serious shortage and aging of the labor force, and construction automation or industrialization of construction is an important concern to improve productivity in construction processes.

IS/IT is indispensable for integrating the increasing number of specialties engaged in the development of intelligent buildings and large-scale and high-rise structures. IS/IT is helpful for sharing data among different divisions and for changing the nature of the construction industry, which is largely depending on a human workforce.

3.2.1 Demand Side 1: Intelligent Building

Nobody doubts that nowadays business in Japan is largely dependent on an information-intensive society. As a result, office and commercial buildings are required to function as a vehicle for internal and external information.

An intelligent building is defined as a building that necessarily has building automation, office automation, telecommunication, and comfortable working space. There are two kinds of approaches to creating intelligent buildings. One approach is to add multi-functions to a building, such as networking systems, monitoring systems for office environment, etc. Another is to make a building itself high-tech, for instance, equipping them with a seismic isolation system.

The new Tokyo capital buildings which were completed in 1991 were intended to be intelligent, including intelligent fire protection systems, independent HVAC systems, AI-controled elevator systems, maintenance systems, and so forth.

In the future, as the building rehabilitation market expands, conventional buildings will be converted to intelligent buildings and intelligent buildings will be required to have further intelligent functions. Construction experience with intelligent buildings will be necessary to enter this market.

3.2.2 Demand Side 2: New Materials

As a concept of life cycle cost for buildings and structures becomes popular, high quality and performance for construction materials are required. And taking into account high-utilization of expensive land, increases in materials cost can be acceptable.

Concrete which is simply mixed with water, cement, and aggregates has been used for a long time because of very low-cost materials. With the addition of carbon fiber for high durability, ultra-fine particles for high strength, and specially designed chemical admixtures for high performance (no compaction needed), new kinds of concrete will have improved qualities. And instead of the conventional steel, which is used as reinforcement for concrete and structural members, fiber reinforced plastics and FR (fire resistant) steel are considered as new structural materials.

Even if use of new materials leads to increased construction costs, high quality and reliability resulting from high quality materials is desirable.

Moreover, application of new materials brings benefits in construction of large-scale, long-span, high-rise structures, on the ground, underground, in the ocean, and in space.

3.2.3 Supply Side 1: Integration of Design and Construction by CAD

CIC (Computer Integrated Construction) in the construction industry has become popular in Japan like CIM (Computer Integrated Manufacturing) in the manufacturing industry. According to Shimodaira (1991), "CIC is intended to smooth information flow among design, construction, maintenance, and FM (facility management) stages and to automate design and construction procedures by means of computer". It can be said that the concept of CIC is based on the development of standardization and database (DB) technology in CAD. Exchanging and sharing CAD data will be needed to realize CIC.

The traditional CAD systems had been developed for specific kind of design: architectural, structural, or mechanical design. CAD technology appeared with a problem of compatibility of data among systems. In 1980, IGES (Initial Graphics Exchange Specification) was the first standardization of CAD in the U.S. Although DXF (Data Exchange File Format) began to be used as a standard between personal computer CAD systems in Japan, the standardization issue is still difficult to solve. Along with development of DB (database) technology, CAD which enables the exchange and sharing of data between design and construction processes is being developed by major GCs and major architectural design firms.

Now that almost every construction firm, no matter what size, has a CAD system, development of CAD is conducted in different ways. First, small architectural design firms started networking among themselves by CAD. Networking among different types of small design firms - architectural, mechanical, interior design and so forth - can compensate for the disadvantages of small-sized firm. Also small firms are going to offer FM-oriented services for the owner by using integrated design data.

The second example is unification of CAD systems between a major GC and cooperative design firms. In this case, both firms benefit. For a GC, it helps to improve speed and accuracy in the design process. For a design firm, it helps to learn design know-how.

Third, major architectural design firms which have architectural, structural, and mechanical design divisions are trying to strengthen integrated design capability by data exchange among divisions.

Forth, major suppliers of construction-related products are transfering their own product catalogues to electronic CAD-data. This will effect sales of new products. Designers will be assured of having the latest information of products.

Finally, GCs are trying to integrate design and construction processes (e.g., integrated CAD). As mentioned in chapter 2 by refering to Taisei's LORAN-T, development of integrated CAD is one of the latest issue for Japanese GCs. The number of papers at the Information System Symposium of Architectural Institute of Japan is increasing year by year.

Sharing data or information is the biggest issue. Here, CAD has an important role. That is, CAD cannot be simply a drafting tool, but must be at the core of the integration of the design process.

3.2.4 Supply Side 2: Industrialization of Construction

Japan's construction industry is facing a serious shortage of skilled workers and an aging labor force. Industrialization of construction, that is, minimizing the manufacturing process by humans at the jobsite, is recognized as one solution to the labor-force problem.

In order to industrialize the construction process, there are two different approaches. One is to automate the construction process at the jobsite by using robots. Another is to prefabricate building components and parts off site. There is some report that although the prefabrication method is one solution to the productivity problems of the construction industry, its effect on productivity is uncertain. That is, in spite of time and cost savings, its products have had quality and technical problems.

Construction automation is needed not only to improve productivity, but also to secure employment of young, high-quality workers. Young workers tend to enter industries other than construction industry (see Table 3.2.1) due to the "3K" (KITSUI: hard, KITANAI: dirty, KIKEN: dangerous) image of the industry. Construction automation must help to overcome the 3K image. This section will focus on construction robots.

<u>Construction robot</u>

Table 3.2.1 Change of Workeforce Composition

	1980	1983	1986	1990
Construction Industry	(%)	(%)	(%)	(%)
below age of 29	22.1	19.2	16.7	16.8
between age of 30 - 49	54.5	54.0	54.5	50.7
above age of 50	23.4	26.8	28.8	32.5
Manufacturing Industry	(%)	(%)	(%)	(%)
below age of 29	22.3	20.8	21.1	22.5
between age of 30 - 49	56.5	56.4	54.3	49.4
above age of 50	21.2	22.8	24.6	28.1
All Industries	(%)	(%)	(%)	(%)
below age of 29	23.8	22.3	21.8	22.8
between age of 30 - 49	50.2	50.1	49.3	46.7
above age of 50	26.0	27.6	28.9	30.5

(source: General Affairs Agency, Rodoryoku Chosa
(Survey of Workforce),1992)

Although construction robots have just begun to work, many Japanese construction companies are already using construction robots to perform different kinds of tasks. As Bennett, et al. (1987) pointed out, "there is strategic difference in development of robot between Japan and the West. Japan is based on small-scale prefabrication. The West is based on large-scale prefabrication." Robots are substituted for individual construction tasks in Japan (see Table 3.2.2). The development of construction robots can be divided into the following types of tasks.

1) Hard work, or work in bad conditions
2) Skilled work
3) Work needing a multiple human workforce
3) Work in dangerous settings

Almost every robot is required to move by itself, because these robots are developed to do individual tasks instead of workers. It is necessary to program work procedures, and at the same time, to program the route of movement. In contrast to stationary manufacturing robots, construction robots are required to move and avoid obstacles. Mobility is a critical issue for the development of construction robots. For use of either a single robot or multiple robots, coordination with other tasks is essential.

A forecast of demand for robots in non-manufacturing industries (Japan Industrial Robot Association, 1989) reveals that demand in the construction industry is the highest of

Table 3.2.2 Construction Robots

Field		Type of Work	Developer A	B	C	D
Archi-tecture	Land	Heap-up Stones	1			
	Frame-work	Place Steel Bars	8			
		Weld Steel Bars	1			
		Spray Fireproofing to Structural Steel	1			
		Weld Shear Studs	1			
		Distribute Concrete	1			
		Finish Concret Slabs	7			
		Install Exterior Walls	1			
	Fin-ishing	Finish Ceilings	3			
		Install Exterior Handrails	1			
		Spray Paint Exterior Walls	4			1
	Testing	Test Integrity of Exterior Tile and Masonry Walls	4			
		Inspect Clean Rooms	6		1	
		Inspect Ducts		1		1
	Clean-up	Clean Ducts				1
		Clean Slabs				2
		Wipe Windows				1

Note: Types of Developer are as below.

A Contractor
B Plant builder
C Construction equipment maker
D Other

(source: Journal of Robot Institute of Japan, 1990)

Table 3.2.2 Construction Robots (cont'd)

Field		Type of Work	Developer A	B	C	D
Civil	Ocean	Ocean Survey			1	
		Undersea Work			1	
	Dum	Form Concrete Panels	1			
		Distribute Concrete	1			
		Convey Concrete	2			
	Tunnel	Spray Shot-crete	5			1
		Assemble Segments	3		1	
		Crash Rock	1			2
		Measure Sections	1			
		Reform Linings	1			
	Road	Aotomation of Road Construction			1	
	Bridge	Hoist Concrete Corms	1			
		Paint Bridges			1	
	Test	Test Soil Compaction	2			

Note: Types of Developer are as below.

A Contractor
B Plant builder
C Construction equipment maker
D Other

(source: Journal of Robot Institute of Japan, 1990) all industries (see Table 3.2.3). Statistical survey of construction robots currently at work cannot be found because of the short period of time they have been in use. However, Japanese GCs are researching and developing aggressively in cooperation with manufacturing and heavy construction equipment makers. As Table 3.2.2 (Construction Robots) shows, it is important to note that main players are not universities or public institutes, but GCs.

Hasegawa (1990) noticed that there are 8 steps during development of construction robots.

1) Search for needs
2) Investigation of general conditions
3) Development of elementary technology
4) Design of prototype
5) Examination of trial operation
6) Partial practical use
7) Systematic operation of multiple robots
8) Commercialization of hardware and software

According to Hasegawa, "Most of Japan's construction robots have reached the 5th step and a few have reached the 6th step". He emphasized that "the 7th step is necessary to achieve major improvement of productivity". This means that not only is individual advanced robot technology important, but also integrated control systems are necessary to take advantage of construction robotics.

Table 3.2.3 Expectation of Robot Development

Ranking	Field	Number of application areas
1	Civil & Architecture	163
2	Health & Welfare	74
3	Agriculture & Livestock	73
4	Service	72
5	Fisheries & Ocean Development	70
6	Prevention of Disasters	62
7	Forestry	56
8	Nuclear	47
9	Transportation & Warehouse	45
10	Waste Disposal	45
11	R&D	43
12	Space Development	37
13	Electricity	36
14	Educational	23
15	Mining	21
16	Telecommunication	21
17	Gas	15
18	Water & Sewage	8
19	Commercial & Distribution	5
	Total	918

(source: Japan Industrial Robot Association, 1989)

3.3 The Future of Japan's Construction Industry

This section describes the future of Japan's construction industry. As mentioned in chapter 2, it is necessary for a firm to have a long-term perspective of business environment for planning of SIS. The section is divided into four parts. The first part describes the fragmentation of the construction industry. The second part concerns the domestic market. The third part covers the international market.

3.3.1 Increasing Fragmentation

Fragmentation of demand-side

Buyers in the construction industry consist of real estate developers, home buyers, entrepreneurs, and local agencies. As the number of large construction projects increases, the number of multi-owner or multi-developer will also increase. Their product needs tend to be high-grade, that is, high-tech clean rooms, intelligent building, and century-lasting houses. The up-grade of construction products is proceeding. For non-residential buildings, the rate of increase of unit cost is bigger than the rate of increase of construction cost. Since the difference between construction cost and unit cost of buildings can be considered as an increase of up-grade, this indicates greater willingness on the part of buyers to pay more for high-grade facilities and high-quality materials (see Figure 3.3.1).

Fragmentation of supply-side

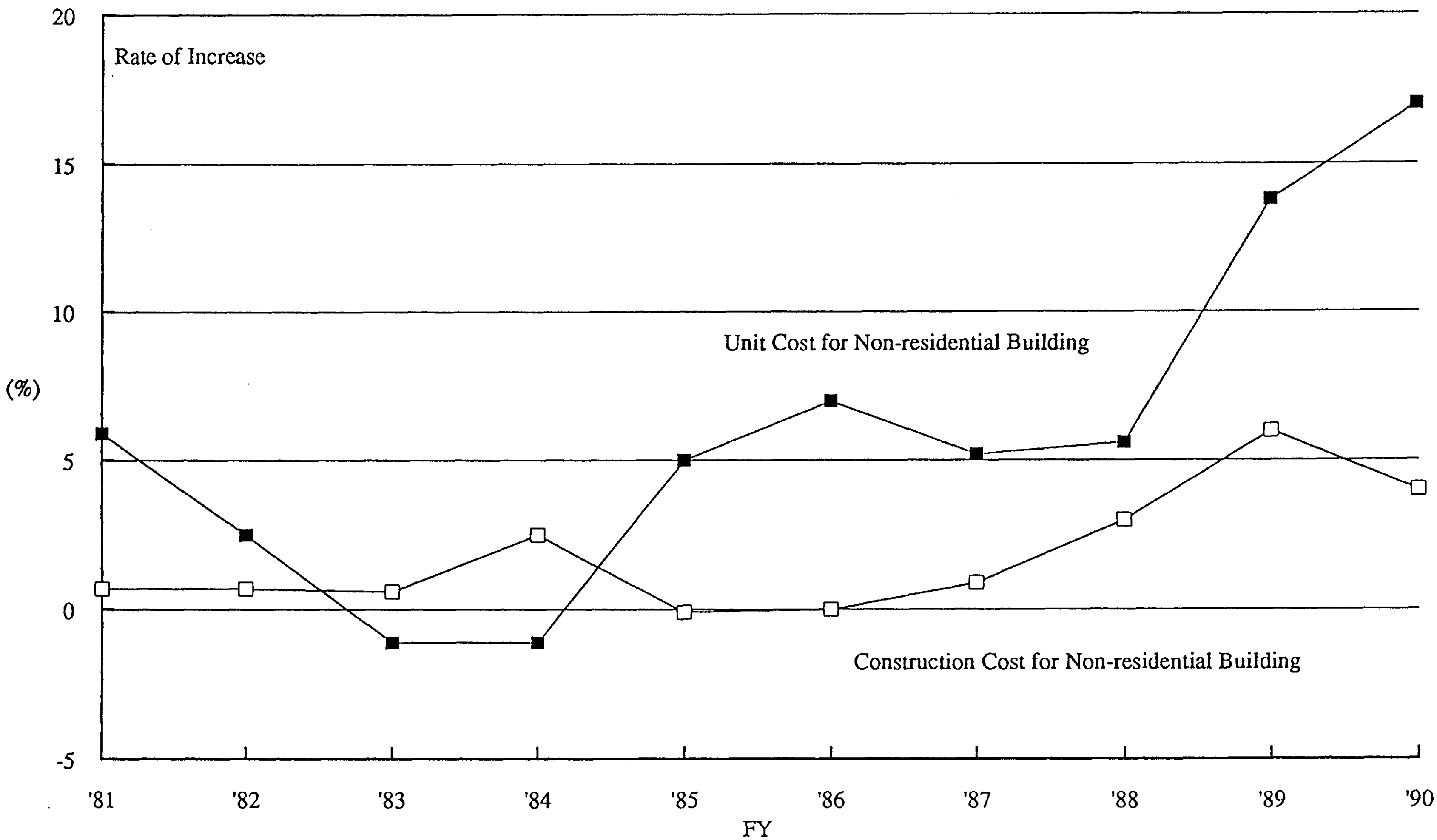
The number of construction firms decreased slightly since 1985. It tended to increase a little bit in 1991. What should be noticed is the change in composition of establishments. The proportion of small (¥ 2 M - 10 M) and medium (¥ 10 M - 100 M) establishments will continue to increase (see Figure 3.3.2).

Construction demand in urban areas has been high. However, major business firms have already constructed their labs and offices in local areas. They also are dispersing. As local construction demand increases, the number of small and medium construction firms on regional basis also will increase.

The designers of constructed facilities are fragmented. Although major design firms or design divisions of GCs are engaged in mechanical and electrical design singly, the number of design functions will be increased in the construction of high-rise buildings and intelligent buildings.

Recently, a number of new materials were commercialized, and many of them are expected to be utilized as construction materials. Application of new material affects construction processes. For instance, application of admixtures for high-strength or high-quality concrete changes the processes of different construction stages: concrete delivery, testing,

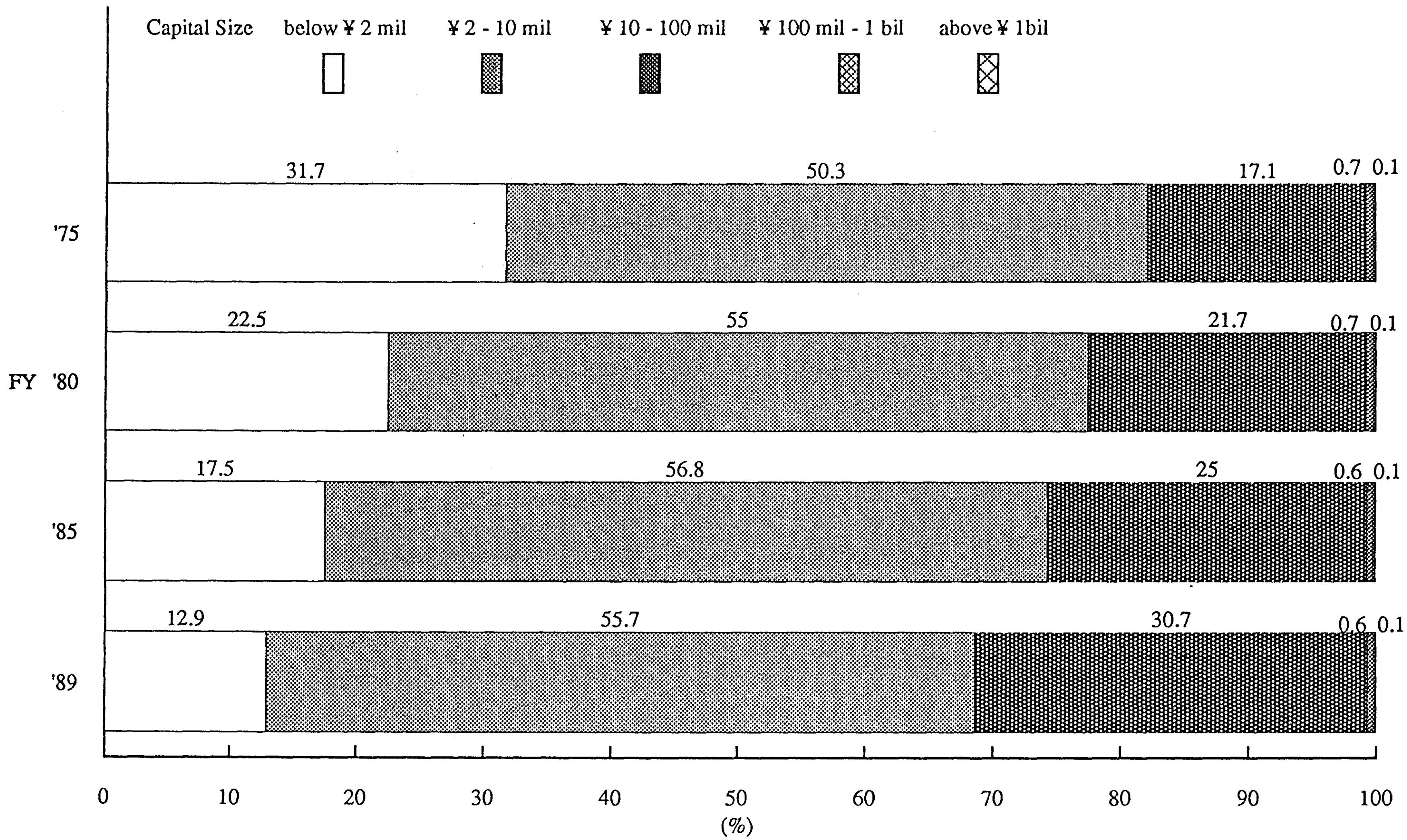
Figure 3.3.1 Rate of Increase of Unit Cost and Construction Cost



(source: Ministry of Construction, 1991)

note: Unit cost = construction cost per square meter

Figure 3.3.2 Change in Composition of Construction Firms by Scale of Firm



(source: Ministry of Construction, 1991)

quality control, curing concrete, and so forth. Unless new expertise in innovative technology and materials is integrated within a firm, greater fragmentation could result.

Japanese GCs

In response to diversification of buyers' needs, Japanese GCs have absorbed a great variety of human resources. (see Table 3.3.1) GCs are working in many R&D areas. As Hasegawa mentioned (1988), "the research and development activities of Japanese general contractors cover not only construction technologies, but also electronics, biotechnology, urban redevelopment, space development, and new frontier market development. Their employees boast a wide range of specialized knowledge in both natural and social sciences." Major Japanese GCs are trying to become total engineering firms to cover a wide territory of business activity. Activities of engineering consultation are increasing in fields related to global environmental issues, industrial waste and hazardous waste management, and energy conservation issues. As a result, GCs will interact with firms in other industries more and more often.

Japanese general contractors will be required to have broader knowledge and more technologies than ever. Their multi-disciplinary organizations will be expanding further. Consequently, difficulty in management within firms will be increased. Moreover, the market place will select larger construction firms, that have acquired different kinds of

Table 3.3.1 Specialties of Newcomers in a typical Major GC

Specialty		1983	1987	1989	1991
Civil	Civil Engineering	24	20	23	38
	Agricultural Eng.	2	1	1	3
	Biology				1
	Environmental Eng.				1
	Fisheriology				1
	Industrial Chemistry			1	1
	Math/Physics/Geology	1	1	1	1
	Nuclear Physics				1
	Social Development Eng.			1	
	Shipbuilding				
	Resource Eng.	1		2	
	Information Eng.			1	
	Sanitary Eng.		1		
Architecture	Arch. Eng.	26	23	50	89
	Social Eng.		2		2
	Environmental Eng.	1		1	
	Nuclear Physics	1			
Mechanical /Electronics	Electrical Eng.	2		1	5
	Information Eng.				1
	Mechanical Eng.	1	1	4	5
Total		59	48	86	149

(source: HAZAMA Co., 1991)

professions or the industry would be further fragmented as the number and kind of professions increase.

3.3.2 Domestic market

Construction investment in Japan since 1985 has been increasing favorably. However, the rate of increase of construction investment fell from 11.1 percent in FY 1990 to 3.1 percent in FY 1991. At the same time the bubble economy burst, the rate of increase in private construction investment fell to 2.3 percent in FY 1991, compared with 12.8 percent in FY 1990. The rate of increase of private architectural construction investment did not grow, remained flat in FY 1991, largely due to a decrease in private residential construction.

One of the redirections in the domestic market is localization. Dispersion of city functions has begun. Many growing firms which have headquarters in major cities began to locate their offices and labs in local regions. There is no reason that these facilities must be in urban areas because of highly developed telecommunication and transportation systems.

Refering to the construction cost of reinforced concrete office buildings, it is still cost-effective to construct buildings in local districts rather than in major cities such as Tokyo, Osaka, Nagoya, etc. Extreme increases in land prices in urban areas due to the bubble economy is one of the factors that will continue to drive dispersion from major urban cities to local cities. It is reasonable to invest in higher quality and function of facilities rather than in expensive land.

3.3.3 International market

Why overseas? What motivation?

As described in the previous section, it is difficult for Japanese construction firms to gain share in the domestic market. Therefore, they have contracted overseas in accordance with the ups and downs in domestic construction investment (see again Figure 3.1.5).

Bennett, et al. (1987) points out two reasons that Japanese GCs seek overseas market.

REASON 1: In order to mitigate unemployment, it has been necessary for the major contractors to diversify and seek work overseas.

Overseas works lead to the substantial indirect employment created in Japan, for design, engineering and management, and component suppliers.

REASON 2: Japanese contractors are categorized by Classes - A, B, C etc. Amount of work is determined by this classification, which is mainly derived from the contractor's annual turnover.

When it doesn't have enough domestic construction, a firm can help maintain domestic market share by extension of overseas activity.

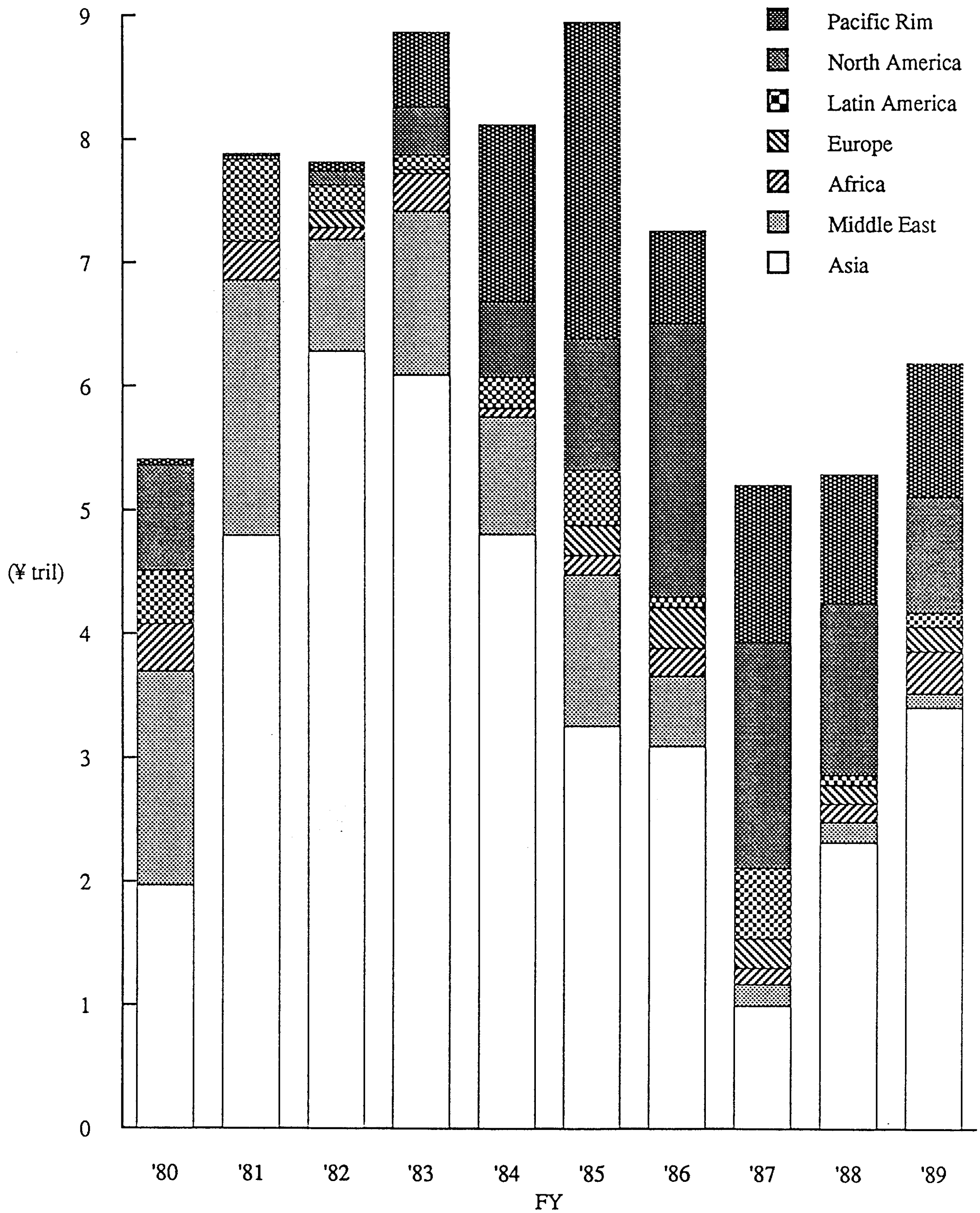
Where to go?

In 1980s, there was "a significant redirection of Japanese overseas" (Bennett, 1987). The importance of the Asian market became obvious. The U.S., Australia, and China had been attractive to Japanese contractors since around 1986, because projects were unlikely to be interrupted by political change. Recently, overseas contracts in Asian countries, especially the Far East, and Pacific Rim markets are increasing (see Figure 3.3.3). In contrast, contracts in the U.S. are decreasing. Considering the decreasing investment by Japanese due to the cessation of the bubble economy, the center of the international market for Japanese construction firms will be in Asia.

Japanese "long-term relations in the region and long-term approach to developing business "in the Asian market is important (ENR, July 22, 1991). Localization is one of the common strategies in overseas operations for Japanese GCs. They have been acquiring and developing local staffs. The costs of sending people overseas and training local staffs are high, critical.

It is also true that most of "international business is with Japanese clients, largely for manufacturing facilities" (ENR, July 22, 1991). It is desirable to offer the same services in the overseas construction as in the domestic one.

Figure 3.3.3 Change in Overseas Contracts by Region



(source: KENSETSU KEIZAI KYOKU (Construction Economy Agency), 1990)

Chapter 4

Potential of Strategic Information Systems for Japanese Construction Firms

In chapter 2, it was shown that the strategic use of IS/IT in Japan's construction industry is important. Fragmentation of the industry has resulted in low productivity. SIS will help to improve productivity by integration of information. IS/IT has the potential to be a powerful weapon for Japanese construction firms to gain a significant competitive advantage.

As shown in chapter 3, Japanese GCs are playing an important role in the industry. They are engaged in a diversity of specialized expertise in order to offer vertically integrated services to their clients. In addition their R&D capability is making great contributions to the development of new and high technologies in construction. At the same time, increasing fragmentation and specialization in construction are occuring. Interactions among stakeholders in construction processes are becoming more complicated and design specialties are being diversified. Integration and management of information is becoming of critical important in order to remain competitive.

IS/IT offers the capabilities to better manage information. The strategic use of IS/IT will have a great influence on competitiveness. Thus IS/IT will become essential to the survival of the firm in the future.

Furthermore, the rapid but careful and thoughtful introduction of IS/IT at this time can also give a firm a significant competitive advantage.

4.1 IS/IT in Japanese Construction Firms

In Japan's construction industry, major Japanese GCs began using main-frame computers in the early 1970s and CAD in the early 1980s. Now every employee and construction site has a personal computer, and every major construction site has a work station. But it cannot be said that Japanese GCs have SIS.

There are many programs for similar purposes in a GC. Although major GCs have been developing technical and analytical computer programs aggressively, these program are independent and almost never interact with each other. In the beginning, some GCs developed clerical information systems, and very basic human resource information systems as a part of the firm's database. They began adding estimating data and construction records several years ago. However, no integrated information systems by which technical applications can share data and information have been developed because the programs related to technology, that is, structural and analytical calculations, and so forth, operate on individual computer systems dispersed throughout the firm.

Betts, et al. (1991) notes, "the application of IT can be used to strengthen the power of some sections of the organization against others. Therefore, the involvement of senior management will prevent the development of sectional interests." This appears to be the situation in Japanese GCs, which have developed IS/IT either by individual division or by specific task. Although GCs are structuring networks among branch offices and LANs (local area network) among divisions, they are not sharing information and data, but rather are sending data or mailing messages. Communication is still at a very elementary level.

One way to involve executives in the development of IS/IT is to seek information needed by different levels of management. The Critical Success Factors (CSF) methodology suggested by Rockart, et al. is considered an effective methodology for seeking information needed. In the CSF methodology, "managers from multiple levels of an organization's hierarchy must be interviewed and the resulting CSFs, which are critical areas of concern for the managers, are synthesized into a collective set for the entire organization." Through this process, executives can be involved in the development of IS/IT.

4.1.1 Example of One Major GC (HAZAMA, Co.)

In order to show the evolution of IS/IT in Japanese GCs, one of the major Japanese GCs, Hazama Co., is given as an example. Its profile is the following:

Establishment....................................1889

Capital size...........................¥ 24.3 billion
($ 180 million)

Total contract in FY1991................¥ 640.4 billion
($ 4.74 billion)
(civil = ¥ 229.1 bil., architectural = ¥ 411.2 bil.)

Net income in FY1991.....................¥ 41.2 billion
($ 305 million)

Ranking..8

(note: based on value of net income in FY1991

exchange rate: $ 1 = ¥ 135)

The company introduced a main-frame computer in 1972. The main-frame computer continues to be extended as shown in Table 4.1.1. Its main branch offices had host computers which were connected with the main-frame by telephone line since 1985. The technical research institute had a super-mini-computer in 1980 and a host computer in 1986. By 1988, the office transaction system, estimating system, accounting system, architectural CAD, and structural design system had been completed and analytical programs such as structural analysis, seismic analysis, FEM analysis, and so forth were developed in the lab.

Since 1989, as the result of the development of a number of work stations, each division had its own computer system for its own task, such as clerical calculations in the clerical center, technical calculations in structural design, structural analysis calculations in the lab, architectural CAD in architectural design, civil construction design CAD in

Table 4.1.1 Evolution of IS/IT in Hazama, Co.

Year	71 72 73 74 75 76 77 78 79 80 81	82 83 84 85	86 87 88	89 90 91 92
Organization	Dept.of Electronic Data Processing (EDP)	Dept.of EDP / Center for Clerical Processing	Center for Clerical Processing-Information System	Dept.of Information System
Activity	•Dept.of EDP started •On-line started	•Clerical center started •PC educational program •Lab computerized	•Consumer taxation	•Re-structuring IS •LAN in lab
Main-frame	(shaded) / F230-45S / F230-58 / M180IIAD	M380R		VP:30E / M760-8
Branch Offices	(shaded) / U200 (communication)			M310, 330 (host)
Lab	(shaded)	PRIME750 (mini-com) / U1500 (comm.)		PRIME9750 / S3300 (host)
Development of Software	•Personnel Information •Accounting •Estimating	•Structural design •Seismic analysis •Structural analysis •FEM analysis	•Architectural CAD	•Construction records database •Animation CAD

(source: Dept. of IS, Hazama, Co.)

civil design, etc.

The popularity of personal computers grew in the late 1980s and personal computers with large 32-bit memory, appeared at that time. There is now a personal computer at almost every desk.

In 1992, LAN was in use in the newly constructed lab. LAN is intended to transfer data and information between the headquarters and the lab.

The company has started a three-year plan for the continued development of an integrated technical information system. Its clerical IS/IT has been integrated to some extent because a single division is dealing with those transaction tasks. On the other hand, technical IS/IT has not been integrated, and data and information is not used efficiently. It is difficult to structure a common database, because technical programs and systems have been developed by many specialty divisions.

4.1.2 Requirements for Implementation of SIS

Development of technical programs and systems in Japanese GCs has created "islands of automation", that is, improved productivity of individual tasks without interaction with other divisions. Therefore, the interests of each division have been emphasized rather than the improvement of organizational effectiveness by sharing information and data. It is necessary for Japanese GCs to have a strategic perspective on the implementation of technical IS/IT.

Considerations in the following three dimensions - technology, strategy, and organization - are necessary for successful implementation of SIS (Madnick, 1987).

1. Technology

"It is important that the information technology strategy selected match the organization's strategic posture. (Madnick, 1987)"

Information systems and technology (IS/IT) are being developed very rapidly. Although there are problems in the implementation of IS/IT in construction due to the difficulty of standardization of design and construction processes, lack of progress is not only due to technological difficulties. More research is necessary to understand what kind of information is needed for the integration of design and construction. GCs which are engaged in both design and construction processes can take the initiative in collecting information and data needed for standardization. For successful implementation of IS/IT, research and analysis of information and data requirements in design and construction are indispensable.

2. Identifying strategy

In terms of IS/IT, top management in Japanese GCs recognize that "many of the investments in the past failed to deliver anticipated business benefits" (Ward, et al., 1990). IS/IT have not created absolute competitive advantage. At the same time, they see that successful implementation of SIS in other industries has led to beneficial results. The impacts are very attractive to Japanese GCs' top executives because their firms are not technologically differentiated from each other. Although SIS is perceived as an effective tool to be competitive, executives don't know how SIS should be implemented yet. It is necessary to identify an appropriate corporate strategy for the effective use of SIS.

3. Organizational flexibility

Many GCs frequently change their organization. However, these organizational changes correspond to increases in the number of employees or to changes in the social environment. They do not change organization due to changes in computer systems, but they change computer systems due to organizational changes. This is because changes in computer systems have been conducted by bottom-up suggestions. Only top-down decision-making on IS/IT will lead to the organizational flexibility needed for the implementation of SIS.

An important function of SIS is the integration of information on different phases of the construction process. Lack of integration among players in construction "misses important opportunities for improved project performance." (Howard, et al., 1989) SIS will make it possible to integrate design and construction processes. Furthermore, "integrated design and construction will require new organizational structures" (Howard, et al., 1989). Howard points out that although computers have become very widely employed by specialists in all phases of AEC process, information and data are not being exchanged among them due to divisional barriers. These barriers between divisions have to be removed to share information and resources.

4.2 Opportunities for SIS in Japan's Construction Industry

Construction projects include complicated interactions between stakeholders and fragmented design and construction processes. It is necessary to determine clearly what impact SIS may have on the players and processes in construction.

Integration of information and sharing data or knowledge between divisions in a firm and between stakeholders in the construction industry should be considered for the implementation of SIS, because inefficiencies between divisions and stakeholders prevents improvement of productivity. Fragmentation fosters the inefficiencies in the design and construction processes. As Howard mentions (1989), "the use of computers in the AEC industry has tended to reinforce rather than weaken the organizational fragmentation that already exists." Emerging IS/IT can provide opportunities for integration in a fragmented construction industry.

4.2.1 Impacts of SIS

As mentioned in chapter 2, implementation of SIS requires a strategic perspective. The strategic perspective can be obtained by considering in what effect IS/IT will have business. Impacts of SIS have been revealed by analyzing successful cases of strategic use of IS/IT in other industries. According to Murakami (1991), the impacts of SIS can be divided into three categories: 1. Creating four competitive advantages; 2. Spawning new business; and 3. Innovating organization. Considering the impacts of SIS will give us insight into opportunities for strategic use of IS/IT in Japan's construction industry.

1. Creating four competitive advantages

Murakami (1991) points out four competitive advantages which SIS creates:

(a) Improving effectiveness of management

Labor savings, reduction of goods in stock, and speed-up by IS/IT lead to improving management effectiveness. Remarkable improvement of effectiveness is needed in order to create competitiveness. Therefore, IS/IT which has an influence on the whole firm is necessary.

(b) Differentiating product

Differentiating product and service is needed to satisfy diversified customer needs. Customer needs are diversified and people's sense of values are changing rapidly. Therefore, using IS/IT to collect customer needs is necessary. By using IS/IT to respond flexibly to customer needs, firms can offer differentiated service.

(c) Enhancing relationship with customer

Enhancing relationships with customers can be achieved by offering convenient and advantageous systems for them. If a system meets customer needs, the customer will not change to other systems. The systems will create continuous relationships with the customer.

(d) Expanding market

Expanding market means to expand customer service area or time. Computer networking will expand marketing area. Marketing ability strengthened by gathering and analyzing information through IS/IT will expand marketing area to a nation-wide level. In terms of time, 24-hours customer service systems are emerging.

2. Spawning new business

SIS can spawn new business. IS/IT's ability to handle large amounts of information and data enables firms to utilize previously unavailable data to obtain new business. SIS can be used to create new linkages with customers by collecting and analyzing approaching information in new and different ways.

3. Innovating organization

SIS can be used for making communication among employee vital and for changing employees' ways of thinking about business. In an innovative business environment, improved speed and quality will be emphasized.

4.2.2 Summary of Japanese GCs

In order to develop strategies of SIS for Japanese GCs, it is necessary to summarize the nature of Japan's construction industry and Japanese GCs' roles in the industry.

Small and medium-sized firms dominate Japan's construction industry. They can hardly improve their own productivity under the existing multi-layer subcontracting system. Compared with large firms, they don't have effective means to improve productivity by undertaking R&D, or using extensive computer systems.

Traditionally, Japanese construction firms have placed priority on maintaining schedule and quality control as the way to retain relationships with clients. However, these strengths are largely dependant on construction workers' human efforts. It is difficult to resolve inefficiencies existing in design and construction processes due to the complicated interactions of players in construction and diversified design specialties.

Japanese GCs are playing an important role in Japan's construction industry. Major Japanese GCs are engaged in every part of the construction business. Their business strategies vary widely - civil and architectural construction, international market, real estate development, design and R&D capability, and so forth. They are also taking the initiative with respect to integration of design and construction, industrialization of construction, and development of new kinds of business.

Major GCs have similarities in domestic construction activities and overseas activities. They are not differentiating from each other by type of construction or geographically.

Major GCs share many important characteristics in common - design divisions, a great variety of human resources, and R&D capability. Their multi-disciplinary organizations create barriers between divisions and create difficulties in the integration of design and construction.

4.2.3 SIS for Japanese GCs

No Japanese GC has created competitive advantage by using IS/IT. Innovative construction techniques, cost reduction methods, and effective management for construction scheduling have not led to great competitive advantages. Because of the extreme subdivision on the construction field, application areas of these innovations are extremely limited. Moreover, since data and information are rarely shared among those areas, great advantages cannot be obtained. Effective application of IS/IT in conjunction with these innovations can create much greater advantages.

Improving effectiveness of management

Improved management effectiveness can be obtained by optimizing the firm's value chain. Three ways can be considered in construction. The first is to develop an integrated CAD system. Sharing data between design and construction processes will reduce redundant tasks like re-input and re-output. The second is to develop computer integrated construction (CIC). CIC holds the potential to enhance effectiveness on the construction site and to directly reduce construction costs. The third is to develop computerized construction management.

SIS can also effect other firms' value chains. Integrations with suppliers and with subcontractors will hold opportunities for implementing SIS for GCs. Integration of CAD with construction related-products suppliers or makers will improve design performance. Integration of IS/IT with subcontractors will affect productivity in construction.

1. Development of integrated CAD

In order to enhance design-build capability, Japanese GCs should make efforts to reduce inefficiencies between the design and construction processes. Development of CAD in GCs so far has emphasized supporting the design process rather than the construction process. Since major GCs are engaged in every aspect of design and construction, the integration of data could create greater effectiveness in design and construction.

Using the same data on design and construction processes can reduce redundant tasks. Since it is difficult to use the same data for different drawing purposes, such as basic, structural, construction, etc., data must be reentered for different design and construction stages. Structuring a common database will make data retrievable and bring great effectiveness to design and construction processes.

Construction drawing data can be shared to a certain extent between each step of design and construction; basic drawing, structural design, estimation, and construction drawing (see Figure 2.3.2 again). It is necessary to develop a standardized product model by using the latest database technology. It will take a long time to establish common standards in the construction industry, but it is relatively easy to solve standardization issues within a single firm.

2. Development of control system for CIC

Japanese GCs should be engaged in development of control systems for CIC. Faced with shortage of skilled workers and aging workforce, GCs have to seek ways to improve productivity in construction. Improvement of productivity on construction sites can be achieved by multiple use of robots. At the present time, a single application of robot is intended to free workers from unpleasant tasks. Different kinds of robots must be used systematically.

Development of control systems for multiple use of robots on site is indispensable. Multiple use of robots in construction requires two things. First, it is necessary to take account of movement of robots for individual construction tasks. Second, the construction robots must be controled responding to different configurations of the structure. It is important to develop IS/IT as interface between construction processes and robot control systems.

CIC can be a key for enhancement of attractiveness to young workers. In contrast to high-level of GCs' R&D capability, most of construction sites are still perceived to be dirty, dangerous, and hard-working. Construction automation will attract young people through a high-tech image.

3. Computerized CM (construction management)

Almost very few, if any, construction management processes are computerized in Japanese GCs. It is not uncommon that it takes two or three years to train newly hired employees. Japanese GCs could save time and cost in training by using computerized CM systems; that is, automated work processes. On the other hand, in order to compete in the international market, sophisticated CM (construction management) ability is also indispensable. Flexibility in CM is required so as to respond to different regional conditions.

New employees learn about construction management by experiences on-site, communication with various kinds of professions and with experienced managers, drawing construction drawings, and so forth. When construction managers move from project to project, it usually take time for them to get used to a new business environment.

In order to save time and cost in training and moving people, it is effective to share knowledge by using computerized CM programs in common, cost estimation, accounting, scheduling, and so forth.

4. Exchanging data with supplier

Japanese GCs procure almost every construction-related product individually. Thus, obtaining product information accurately and quickly can improve effectiveness of design process. Electronic catalogue data, which is easy to use with CAD, will allow designers to easily keep up with the latest product information, and save time spent in looking into huge catalogue books. To use the most recent product information in designs can be an important way to differentiate design services.

Construction product manufacturers are beginning to provide designers with an electronic product catalogue database. A number of different products - sanitary, finishes, exterior wall, mechanical and electrical products - are used for construction. Data on these products are usually contained in several thick catalogues. Construction managers and designers must refer to these books to get cost and physical data on products. These books require annual revisions and constant updating, every time new products come out. According to Japan IBM report (1991), questionnaires on purpose of data exchange revealed that manufacturers aggressively support data exchange with GCs for strategic purposes and thus an increasingly prepare electronic catalogue data on their products.

5. Integration with sub-contractors

Integration with subcontractors is useful not only to improve productivity in construction as a whole, but also to retain a quality workforce. Such integration can lead to changes in the traditional multi layered subcontracting system which so far has fragmented construction management and has prevented improvement of productivity.

Although Japanese GCs have many cooperative subcontracting firms, they have no interactions which affect both GCs and subcontracting firms' value chains. GCs' current relationships with them are based on simply obtaining supplemental workforce.

Improvement of productivity has become one of the most important concerns in the construction industry. Low productivity of small and medium-sized construction firms causes the low productivity of the whole construction industry in Japan. Positive effects of IS/IT integration can be great for these firm because they are unable to spend lots of money on IS/IT in isolation.

Spawning new business

6. FM (facility management) service

It is very valuable for Japanese GCs to provide FM service. GCs will be able to further enhance their vertically integrated services. Since Japanese GCs have mechanical and electrical design specialties, it is advantageous for them to respond to the growing interest in FM service. IS/IT can expand opportunities of FM-oriented integration by converting construction data to data needed for maintenance and for monitoring building conditions. If FM service can be linked to an integrated CAD system, construction data can be utilized effectively from conceptional design to FM.

FM service is emerging as new business in the construction industry. As demand for intelligent buildings grows, offering building data for maintenance management becomes important. Also, since the concept of life cycle cost for constructed facilities requires higher quality products, monitoring the operation and condition of these products will become necessary in order to guarantee the quality.

FM service can help retain relationships with the owner and help identify new owner needs on a timely basis. It is also important to monitor performance and reliability of new technologies and materials which are applied to facilities in order to identify the best directions for further R&D.

Chapter 5

Summary, Conclusion and Further Studies

5.1 Summary and Conclusion

Computerization in many areas of Japan's construction industry is rapidly proceeding through main-frame computers, CAD, accounting and estimating systems, etc. Major Japanese GCs take advantage of the latest analytical technologies for construction by using advanced computer technology. Many excellent researchers are engaged in seismic analysis, geotechnical analysis, ocean engineering, mechanical engineering, and so forth. But Japanese GCs are not necessarily making full use of computers in terms of information system and technology (IS/IT). None of them are able to create competitive advantage by using IS/IT.

Many companies in industries other than the construction industry are creating competitive advantages by strategic use of IS/IT. This type of IS/IT is called strategic information system (SIS), as distinguished from traditional IS/IT. The traditional IS/IT is used to improve productivity for individual tasks. SIS is related to corporate strategies and affects organizational structures. SIS creates competitive advantage affecting a firm's value chain and the whole value system where the firm exists.

Fragmentation of the construction industry results in low productivity which has been characteristic of construction and makes it difficult to implement SIS. There are many kinds of design specialties and very complicated interactions among the players in construction projects. Information and data are still exchanged in very inefficient ways. Integration of information by SIS could have a great significance for the construction industry.

Japan's construction industry is fragmented in terms of both the number of establishments and the diversification of specialties. Small and medium-sized firms dominate the industry. Intelligent buildings and high quality materials required for recent construction projects require a number of specialties. There are many inefficiencies due to this fragmentation, especially when it comes to the exchange information and data directly between construction processes and between players in construction. Effective use of IS/IT can be expected to reduce these inefficiencies.

Construction activities are managed still by means of traditional manual management. Everyday meeting and superintendent's personal management have maintained project schedules, and great efforts are made for quality control on-site.

However, the construction industry is changing in several ways: the development of intelligent buildings; industrialization of construction; and entry into international markets. In order to survive and remain competitive, it is essential to create competitive advantage by the strategic use of IS/IT.

Japanese GCs with their multi-disciplinary organizations have been able to offer vertically integrated service. However, as customer needs are growing and diversifying, GCs are required to have additional kinds of knowledge and technology. It is becoming extremely urgent to construct efficient systems for integration of information. In order to improve productivity in construction, integration of construction processes is essential.

In order to successfully implement of SIS it is necessary to consider three dimensions - technology, strategy, and organization. First, with regard to technology, IS/IT is enhancing so-called "islands of automation". However, these islands lack opportunities for sharing data and developing common information infrastructure. In order to structure integrated IS/IT, it is necessary to make clear what data and information should be shared. Second, it should be recognized that IS/IT can create competitive advantage by enhancing a firm's strategic operations. SIS must be linked with corporate strategy. Finally, of course, development of SIS needs changes to the organization. In making these changes one should take full advantage of the vertical integration which already exists in Japanese construction firms.

The impacts of SIS can be divided into the following categories:

1. Creating four competitive advantages

   (1) Improving effectiveness of management

(2) Differentiating product

(3) Enhancing relationship with customer

(4) Expanding market

2. Spawning new business

3. Innovating organization

Major GCs' vertically integrated services are supported by design divisions, human resources and R&D. They play an important role in Japan's construction industry with respect to the development of the latest construction technologies, such as construction robots, intelligent building, and new construction materials.

Implementation of SIS in six areas was suggested.

1. Development of integrated CAD

Data and information in design and construction processes are not integrated, and there are many inefficiencies in data exchange. Integration of design and construction has a special significance for Japanese GCs, which are engaged in every aspect of design and construction.

2. Development of CIM in construction (CIC)

Improvement of productivity in construction can be achieved by use of multiple construction robots. GCs should be engaged in development of suitable control systems. Integration of information in construction processes is essential for systematic use of construction robots. Innovation in construction will also attract young workers.

3. Computerized CM

Sophisticated CM ability is necessary for competing in overseas markets. Sharing knowledge on CM will save time and cost for training new employees and for employees who move from project to project.

4. CAD data for product catalogue

It is important to keep up with the latest information on new products. Manufacturers are aggressive in their support of exchanging computerized data with GCs. It is necessary for GCs to take further initiatives to develop integrated CAD systems with product manufacturers.

5. Integration with sub-contractors

It is necessary to improve productivity of small and medium-sized firms in order to improve the overall productivity of construction. Yet it must be recognized that they cannot afford large investment in IS/IT. Also, it is advantageous for GCs to integrate with them in order to assure the quality of the workforce.

6. Development of FM program

As new construction products increasingly require multi-functions and high quality, the importance of FM (facility management), periodic maintenance, and monitoring conditions is also increasing. FM service will be able to differentiate on GC's vertically integrated service from another's.

Opportunities for strategic use of IS/IT are great in Japan's construction industry. It is necessary for Japanese construction firms to implement SIS with strong linkage to overall corporate strategy. SIS is important not only for Japanese major GCs, but for also improvement of productivity in Japan's construction industry.

5.2 Further Studies

Integration of information was the focus of this thesis. In order to plan SIS, the information that is needed by different levels of management should be investigated and defined.

As described in this thesis, the CSF methodology is helpful to develop information system department executive's effective relationships with peer executives. It might to be interesting to investigate CSFs for a Japanese GC.

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