CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

CIM Implementation in the Japanese Construction Industry

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CIM IMPLEMENTATION
IN THE JAPANESE CONSTRUCTION INDUSTRY [1]
— Case Studies at an A/E/C Company in Japan —

By Toshio Ishii [2], Yuzo Kato [3], Osamu Morimoto [4], Yasuo Endo [5], Yasunaga Tatsumi [6] and Hisao Goto [6]

Abstract: The history of the use of computers in the Japanese construction industry and the issues facing the industry are described by examining the situation at one of the major general contractors in Japan. In the brief history of the company since the inception of computers, we focus our attention on the current implementation of two new information systems (IIS-M and IIS-E) which we believe will lead and reform the Japanese construction industry in the near future. These newly developed systems will serve as kernels of the CIM (Computer Integrated Manufacturing) in the construction industry. Finally, based on our experience during the course of the implementation of these systems, some pointers for a successful CIM implementation in the construction industry are highlighted.

INTRODUCTION

A quarter of a century has passed since the introduction of computers in the Japanese construction industry. Nowadays, computers have become indispensable in some tasks and their use has been widely accepted by the industry. In the near future, the rationale for using computers based solely on considerations of just the efficiency of task processing will be supplanted by the need to perform a more effective and strategic improvement of intellectual productivity.

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In other branches of industry, computer applications in the form of Computer Integrated Manufacturing, CIM, is presently arousing much interest. Its definition and implementation in actual operations differ depending on the type of application, however, a common basic principle in CIM is "Integration". It seems that in every industry the concept of "Integration" is becoming a key issue in the attempt to increase productivity.

In this report, we describe the present status of the Japanese construction industry and the role of computers at Takenaka Corporation, one of Japan's major general contractors or A/E/C (Architecture/ Engineering/ Construction) companies. We also discuss the approach taken by the company for establishing CIM and the problems faced in structuring CIM for the construction industry in general.

SITUATION FACING THE JAPANESE CONSTRUCTION INDUSTRY

General Perspective

There are a total of 510,000 Japanese construction companies of which there are five to six major general contractors which operate on a scale of 1 trillion yen in annual orders received and employ about 10,000 people each. The Japanese construction industry employs 5,330,000 people which represents 9% of Japan's total industrial work force. Therefore, a boom or a depression in the construction industry could have a potentially strong impact on Japanese society.

The value of Japanese construction investments for 1988 totaled 63.5 trillion yen, which amounts to 17.4% of Japan's GNP of 365 trillion yen (Fig. 1). This sum exceeds that of the United States on a dollar basis and the ratio to the GNP rates high compared to those of Europe and the United States. However, there is a declining trend in this large flow of GNP and in the repletion of social capital. There are five to six major general contractors which operate on a scale of 1 trillion yen in annual orders received, and employ about 10,000 people each. Although, the last one or two years have shown a trend toward prosperity due to an expansion in domestic demand and increases in equipment investment, this could easily be submerged under the waves of business fluctuations given the industry's total dependence on receiving orders.

In addition, the construction industry is heavily labor-intensive with much lower productivity than in the manufacturing industries (Fig. 2). Furthermore, the average

age of employees has been getting higher. Given these factors, the improvement of productivity has always been an issue for company management. Above all, activation of the Japanese economy, changes in the industrial structure and the increasing level of competition among various companies for receiving orders have served to stimulate reforms in the management of the company and have lead to changes in the structure of the construction industry. New concepts are being formulated to address the changes going on in the construction industry, some of these are Total Quality Control, TQC, Engineering Contractor, EC, Intelligent Systems and Facility Management, FM. These and other concepts point the direction in which the construction industry is headed towards in the near future. In addition, there are proposals for stimulating reforms based on new points of view of the industry such as from a "Production Industry of Buildings" to "Space-Optimizing Creators" (Matsumoto et al. 1988).

At present, the issues confronting the major general contractors are:

1. Movement towards internationalization
   - Expanding the number of orders for foreign construction projects
   - Competition or cooperation with foreign corporations which are entering the Japanese construction market
   - Responding to the influx of foreign laborers into Japan
2. Technical development
   - Development of new fields (New frontiers: underground space, outer space and ocean facilities, biological facilities, super-precision space facilities, etc.)
   - Development of new technology (large-space structures, structural control/base isolation, etc.)
   - Development of new materials and construction methods
3. Improvement of productivity
   - Conversion from labor-intensive-type production to production by machinery (robots etc.) and manufacturing (precast concrete etc.)
   - Introduction/popularization of CAD/CAM
   - Implementation of CIM
   - Utilization of OA (Office Automation) for administration/management tasks.
4. Labor safety and quality assurance

– Prevention of accidents and quality assurance in the construction field

Another aspect of the situation facing Japanese general contractors, is the problem of increasing competition from architectural offices which specialize in design. Orders received for construction works in Japan may consist either of cases where design work is not included in the contract or where design is a part of the contract. The major general contractors in Japan have high caliber design teams so that they are ably qualified to handle the latter kind of order.

For this reason, controversies often develop between general contractors and architectural design offices regarding vocational "shares". Our company, unique among the major Japanese general contractors, has made it a company policy to achieve a consistency of design and construction. Presently, at Takenaka contracts involving design and construction make up 55 to 60% of the company's total construction orders, compared with 30 to 40%, at most 50%, at the other major Japanese general contractors.

Level and Extent of Computer Utilization

In this section we provide a brief summary of the application of computers at major Japanese general contractors.

In general, the host system consists of two mainframe computers, one of which may be an IBM 3090 class and the other a Japanese production type. Both feature a DASD capacity of 50-90 GB. Some corporations have introduced supercomputers and have used them in hydraulic analyses, image processing, etc. At the next level there are office computers, 20 to 65 sets, personal computers, 400 to 1,700 sets, and on-line terminals, 300-600 sets. The distribution ratio for the above three types of computers ranges from five to ten persons per set.

Communication between computers at head offices and branch offices is done by means of high-speed digital lines and computers at the construction sites are linked by VAN (Value Added Network). Recently, one of the major contractors announced a service plan for a network within the entire corporation called the "multi-media global network". It consists of a LAN within the premises (using ETHERNET) for communicating various media information including images, a high speed digital link (using HYPER CHANNEL) between the head office and branches and VAN between offices and construction sites.

The introduction and use of computers in the construction industry has been promoted by a combination of administrative guidance and enforcement. The Goverment of Japan through the Ministry of Construction is currently promoting research and studies of VAN, specifically aimed at construction companies (CI-NET study group), and the Ministry is introducing and promoting systems offering various kinds of information related to construction (JACIC-NET). In addition, the Ministry is promoting the use of OA for applications of building permits. The role of the Ministry has been in effect to popularize computer use throughout the construction industry.

COMPUTER UTILIZATION AND THE IMPLEMENTATION OF A NEW INFORMATION SYSTEM AT OUR COMPANY

Chronology of Computer Use and the Present Situation

Our company introduced a large-scale, general-purpose computer in 1965 aimed at taking some workload off its employees by computerizing such tasks as payroll computations and structural calculations as well as for streamlining its corporate operations. This host computer, the only one at that time, was used to perform various kinds of batch-processing operations.

During the latter half of the seventies, the branch offices were linked with the head office through on-line networks and information systems which made it possible to remotely enter accounting data and interactively perform data-processing operations via terminals went into operation. One such representative system was a planning/designing system, CANDIS. This system was touted as an epoch-making, progressive system at that time because it provided means for interactively conducting feasibility studies. The system was able to draw up income-and-expenses prospectus for building-construction and building-management, estimate construction costs and terms, compute the largest possible building volumes under applicable laws and ordinances and check environmental conditions such as sunshine and wind patterns. Even today, the system continues to prove its practical usefulness in the order-receiving activities and the conceptual design stage.

Around the turn of the eighties, personal computers began coming into widespread use. Since the liberalization of communication regulations as a result of the 1985 revision of the Telecommunications Act, on-line networks began proliferating. This coupled with the enhanced performance and lower cost of hardware has contributed to the process of transforming society into a so-called "Information-Oriented" society at a rapid pace.

Realizing the importance and the need to make better use of information, our company reorganized its EDP department in 1980. The name of the department was changed from "Computer Center" to "Information Management Center" and a new information-management system upgrading plan (the V85 Plan) was implemented with the objective of better utilization of information. Under this plan, efforts were made to put on-line equipment into widespread use, open frequently used data files to the public and popularize the use of languages such as MARK IV and SAS. Those efforts have indeed borne fruit. However, when those efforts are reviewed now they appear, in hindsight, to be burdened with some inadequacies which we will discuss later on.

Today, our company is fully equipped with a centralized information system, which in turn commands company-wide information systems. The company has in place an upgraded on-line network which has resulted in widespread use of personal computers. At this point in time, the company is on the verge of entering the age of end-user computing (Fig. 3).

Also in the fields of engineering, computers have already made their way into such key operations as planning/proposal writing, design, structural analysis, simulations, estimation, construction drawing, etc. These kinds of computer applications have achieved widespread use in the form of the so-called C-4 technology, CAD/ CAM/ CAE/ CIM, and are now indispensable to the construction industry.

Objective and Organization of the Information System

The goal of the implementation of the information system is the improvement of productivity, especially intellectual productivity, and utilizing it in administrative strategy. The ultimate objective is to create works (buildings) of higher quality and by doing so contribute to society at large. This is the basic philosophy of our company.

Fig. 4 shows our plan for implementation which is carried out by 4-M Thrust Areas (Man, Machine, Method and Material) each with its own assigned functions.

Fig. 5 shows the organization for the implementation, in which the related departments cooperate under the auspices of the Administrative System Development Committee (whose chairman is the president of the company) to build the information system in the entire company. The major operations of the Information Management Center which functions at the core of this organization are shown in Fig. 6.

Training to Promote the Use of the Information System

Our company has been providing various training courses for managerial, administrative and technical groups, and also for new employees according to their levels (Table 1).

Especially notable is the training course in which 5 members a year are selected among employees with 5-year experience to undergo practical training at the Information Management Center for a year. This training course has been in existence for eight years and the forty members who have completed this course are playing an important role in various departments in the promoting the use of the information system. New employees in departments charged with performing management tasks are assigned to Information Management Center for four months of their first year to master basic OA knowledge and then reassigned to various departments to promote the use of OA.

Implementation of a New Information System (IIS-M)

1. Necessity and background

In the normal day-to-day administrative tasks (such as in the sales general-affairs, general accounting, personnel and the construction departments), various information systems have been developed for processing regular, routine-type work to save labor and enhance productivity. The introduction of on-line terminals, the spread of personal computers and the growing use of user-oriented languages such as MARK IV and SAS have further enhanced the computer-application environment. As a result, there has been a increasing trend in the number of users who access and retrieve stored data on their own (Fig. 7).

Progress in the use of computers made even bigger gains starting from the beginning of the eighties. However, the job-processing systems developed up until 1980 were closed-end systems tailored for specific tasks. Since individual systems separated their respective data files or databases, they could not fully meet the new needs of users who wanted to grasp the state of affairs, identify problems and facilitate their decision-making processes by freely tabulating and analyzing data by themselves.

The idea of revamping the existing closed-end information systems emerged against the backdrop of our rapidly advancing information-oriented society. The upgraded information processing environment is the result of extending user-implemented office automation, increased knowledge and expertise in the utilization of computers and enhanced awareness of the importance of making good use of information resources. As a result, the construction of a new company information system — an Integrated Information System for Management (IIS-M) centered on a common database — has begun.

2. Features of the new information system

Against the backdrop of the advances in computer hardware and software and under the necessity of increased productivity Takenaka is currently building a new company-wide information system. The objective of this project is to reconstruct the company's conventional job-processing-type information systems into information-utilizing-type information systems. In other words, the company is upgrading its information-processing infrastructure for improving the strategic use of information resources by strengthening its information-oriented structure and also by upgrading its information systems application environment. The environment the company is aiming to build is an end-users' computing environment, called the Integrated Information System (IIS) centered on a database, in which importance is placed on the utilization of data. Our activities in building this system are:

(1) Construction of convenient DBs
- Unified DBs independent of each task system
- Quick retrieval of any necessary data
- Rapid processing of data for creating graphic images, reports, drawings, etc.

(2) Connecting mainframes with office automation systems
- Standardization of connections and interfaces
- Avoiding data input overlaps

(3) Systematization of everyday processing tasks
- Tasks such as daily accounting which require immediate processing

(4) Concentrated DB management
- Complete analysis of all data at the company and planning of unified DBs.
- Adjustment and control of DB designs based on an unified plan in order to avoid a dependence on specific purposes or tasks

- Well-maintained condition of DBs at all times

(5) User support for active use of DBs

- DBs accessible to general users
- Instruction and support given to facilitate retrieval and processing of data by users on their own
- Complete users' operation manuals of DBs

(6) Improvement of communication networks

- Advice on appropriate introduction of terminals and office automation equipment at major offices and field offices
- Connection with other companies such as banks using outside networks
- Utilization of VAN (Value-Added Network) in order to increase number of places DBs can be applied
- Use of sound and images as communication media

Data Transfer Improvement Project (IIS-E)

1. Summary of ideas and plan

The use of computers in the construction industry specially in those divisions that carry out engineering tasks such as design, estimation, construction, etc., has been expanding with the object of enhancing productivity and quality and also with the view to supporting order-receiving activities. As for the design concept of the information-processing systems developed for use in the engineering fields and the way that these systems are being used, they are individually optimized for their respective applications within the bounds of the functions and departments where those systems are used. Take a building construction project as an example. The structural design division enters data by itself and obtains results in order to perform its own task, while the estimation department likewise enters data concerning the same building so as to carry out the job of estimation. As illustrated by this example, the data entered by a given department is used within the bounds of the department and seldom shared among departments. Furthermore, in the engineering fields the computer processes various types of data, numerical, text or graphical. It takes considerable training and manpower to enter such data.

The productivity of a corporation depends not only on the productivity of individual departments involved in one phase of a project but on all departments that are associated in the various phases of a project. In other words, it is necessary to devise ways of enhancing the efficiency of each individual phase, that is the planning, design, construction or management stage but at the same time each phase has to be looked as an integral part of a whole so that the productivity of the whole enterprise can be enhanced.

For the reasons stated above, the productivity over all the phases of a project can be enhanced effectively by sharing data, computer-generated or otherwise, among various departments. In other words, it is necessary to reconstruct the existing department-specific closed-end information systems into an information system centered on a database with the enhancement of company-wide productivity in mind (Fig. 8) (Ishii et al. 1988).

With this end in mind, we embarked on a data transfer improvement project (Integrated Information System for Engineering, IIS-E). The aim of this project is to enable data-sharing across various departments. The three main components of the project are:

(1) Creation of a data-sharing facility

An engineering database (EDB) which serves as the nucleus of a data-sharing network will be built. Through this EDB data will be exchanged among systems that are in use in key operations ranging from the design stage to the construction stage (Fig. 9). Designers and engineers can reduce the need to enter data by sharing data across the bounds of their departments and job categories. What is more, they can obtain the required data early on.

As a result, it becomes possible to do away with conventional stepwise and serial-processing mode of work flow patterns and, in turn, adopt concurrent and parallel-processing mode work flow patterns. In other words, it becomes possible for individual departments to perform their respective jobs in step with one another, and thereby scale down their overall time requirements.

(2) Improvement of man-machine interfaces

There is a need to provide ergonomically designed, easy-to-use computer systems to designers and engineers. This is because difficult-to-use man-machine interfaces for entering data prevent designers from operating computers by themselves and thereby constitute a serious bottleneck in the proliferation of CADD systems.

To solve this problem, research/study and development/introduction efforts are currently underway in the following areas:

i) Introduction of easy-to-use engineering workstations (EWSs) which enable designers and engineers to interactively perform data-processing operations

ii) Development of easy-to-use software for pre-/post- processing applications

iii) Introduction of equipment for automatic reading of drawings incorporating automatic graphics recognition capability which reduces the need for manually entering graphical data

iv) Development of a drawing input system (Context-Based Graphic Input System) capable of reading freehand drawings

(3) Creation of a robust procedure for improvement of data transfer

We are considering setting up a centralized, specialized computer process as a transitional measure. The computer proficiency of the employees at Takenaka ranges from older employees, those over forty, a lot of whom are allergic to computers to the younger employees in their twenties who have a good grounding of computers and the employees in their thirties are in-between.

In the future, as more and more younger employees join the work force, most, if not all, employees will be capable of operating computers by themselves. It is conceivable that with time computers will become more personal and dispersed throughout the entire company. However, in some task divisions coexistence of dispersed and centralized computer processing may be efficient.

2. Case Studies

(1) Effect of a data-link system (LINKS) interconnecting a volumetric estimation system (KUTAI) with a concrete-placement drawing system (SECODES)

KUTAI is an estimation system designed to estimate the quantity of concrete, molds and reinforcing steel bars required for constructing a building. The processing is carried out in the host computer. On the other hand, SECODES is a concrete-working drawing system and it uses a personal computer to process data.

The above-mentioned systems were developed and used independently of each other.

KUTAI has been used in most of the reinforced concrete (RC) building construction projects undertaken by our company. In order to make it possible for SECODES to share data which has been entered into KUTAI, a data-link system (LINKS) was devised (Ishii et al. 1988). As a result, the time required to enter data into SECODES has been cut by as much as about 45 percent as compared with the previous data-entry time requirements when no such link system was available (Fig. 10).

(2) Utilization of EDB for construction management tasks

As in first case study, various quantitative information can be linked so that data can be interchanged between various activities, for example between quality control, terms and cost estimation of a steel frame construction.

Data obtained by the steel frame estimation system and stored in the EDB are sent to personal computers at the field offices and steel frame fabrication factories through VAN (Value-Added Network) (Fig. 11). At the field offices the steel frame erection plan, the progress condition and information on steel frame quality are input and is relayed to the steel frame fabrication factories. The steel frame fabrication factories then fabricate and deliver the steel frames according to the construction data.

In this way, the input of a large amount of complicated data on the form of the steel frames etc. not only has become unnecessary but, also, the early application of data to the construction plan and accurate management during construction terms is possible. In particular, it has much value in that it provides better accuracy for an immediate feedback on the error, if any, in construction involved in steel frame erection to the steel frame fabrication stage.

Moreover, since the progress of steel frame erection can be visually grasped, the management of fabrication, delivery and erection can be made more efficient and accurate.

CIM IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY

Procedure for Integrating and Structuring the Information Systems at Takenaka Corporation

The earlier discussions on IIS-M and IIS-E described the implementation of information systems in use in departments charged primarily with conducting management tasks or those involved in engineering tasks.

There are, of course, databases that are consulted by both departments. Moreover, one basic concept of CIM which is shared by both groups centers around databases, or "system integration" which becomes possible through the sharing of data.

Since the engineering-work-oriented departments and management-work-oriented departments differ from each other in function and job classification, two project teams have been formed for the sake of convenience for handling the two departments separately. To be exact, an additional base team was formed which is charged with implementing data management and setting up a network to create a common data-sharing environment. These three teams have been working in concert with one another to push forward with the system-integration project at Takenaka (Fig. 12).

In the management side, the integrated information system available to the individual management-work-oriented departments is composed of a database as its nucleus, a regular/routine-work processing system and data-processing systems that are operated by individual employees who are charged with performing irregular/non-routine jobs (Fig. 13).

In the engineering side two databases, the first an engineering database (EDB), which helps implement engineering tasks as a project and the second a project management database (PMDB) which helps carry out project-management tasks are installed. In addition, a reference database (RDB) is set up for storing and retrieving various kinds of engineering information. Efforts are being made to upgrade the company's integrated information systems which are centered around these three databases (Fig.14).

Some Points in Structuring the CIM System for the Construction Industry

The role of a general contractor is to comprehensively manage a large number of job categories and processes considering Q, (Quality), C, (Cost), D, (Delivery) and S, (Safety) by gathering information, marshaling collected information, conveying processed information and making timely, apt decisions. Ultimately, a general contractor's basic role is to create facilities or spaces that meet the needs of the clients and the society.

The general contractors use CIM to optimize the utilization of computer power and computer-application technology in order to perform the above-mentioned role. Fig. 15 shows areas, which utilize computers, in the implementation flow of a project.

The major general contractors in Japan have all been pushing forward with large numbers of construction projects, which vary greatly in scale, terms and conditions. Depending on such conditions as the usage, scale, term and site, CIM can be gainfully applied to each project. In the future, it will probably become necessary to implement company-wide CIM which cuts across all intra-company departments (among them are the head office and branches, the head quarter's administrative departments, etc.)

Generally speaking, a group of systems centered on databases such that data are freely shared among the various systems is the key to a successful implementation of CIM. The beneficial results of such a CIM are a reduction of costly reiteration in data-entry, an accurate and rapid transmission of data and a ready availability of the required data, among other things. As a result, various departments can concurrently perform their respective tasks. To determine to what extent data-entry reiteration can be reduced, our company conducted a survey in preparation for the construction of its EDB. Table 2 shows the results of the survey which indicates that 20 to 30% of data established by an upstream system could be utilized by a downstream system.

The introduction of CIM makes it possible for a construction company to do away with its traditional serial-type work-performing practices, and in turn, enables its individual departments to concurrently run their respective tasks in step with one another. Some of the CIM concepts developed in the United States also have as one of their major objectives "the facility for concurrently implementing tasks in parallel with one another" (Engineering Advancement Association of Japan) (Fig. 15).

Problems to be Solved

In this report, we have so far described how our company's new information system has been developed. Next, we are going to discuss problems that have cropped up as the project ran its course and R&D challenges that need to be tackled in the future. We hope our discussions to follow will prove to be of some benefit to those who are charged with the responsibility of building CIM facilities in the construction industry.

(1) Building awareness of the need to move away from department-wide self-terminating-type systems to company-wide systems for enhanced overall company productivity

So long as the traditional organizational structure remains intact, all employees working in it are conditioned to find ways of enhancing the efficiency of their departmental closed-end-type job-handling systems through localized optimization. Under the circumstances, they may loathe shouldering even small amounts of other departments' workload even though they are fully aware of the benefit of sharing data with other departments. The construction of CIM facilities will require a reappraisal of the existing organizational structure/system and the distribution of manpower.

(2) Improvement of man-machine interfaces

Since computer application environments are still in the early stages of development from the point of view of ergonomics, not all employees may be able to directly operate computers on their own. Even though efforts are underway to extend the use of CADD systems, data-input operations constitute a serious bottleneck. At our company, several R&D projects have been initiated to improve man-machine interfaces as discussed earlier in the section " Data Transfer Improvement Project (IIS-E) ".

Future advances in computer application technology such as image and sound recognition are expected to provide workable solutions to some of the problems we face today. The future technology will facilitate the development of artificial intelligence applications notably in the form of neural networks and fuzzy computers that are capable of mimicking human thinking and decision-making processes.

(3) Development of decision support systems of high practical utility

Expectations of the utility of Decision Support Systems, DDS, run high not only in the construction industry but also in a wide variety of other fields. However, in reality, the number of on-the-job DSSs that can fully measure up to their generic name in function and performance in a strict sense may be extremely small. In the construction industry, each project is being implemented daily by making a number of decisions, large and small, on top of an earlier one. In the final analysis, it is these decisions that keep construction companies up and running. For this reason, expectations of an early development of DSS of high levels of practical utility run high in the construction industry.

For example, there are some cases where it is necessary to make a decision in a competitive market between accepting an order and forgoing it in an early stage with only sketchy information on hand (without detailed information about the specifications of facilities to be constructed and the particulars of the facilities' construction plan). As discussed in section " Chronology of Computer Use and the Present Situation ", our company developed the planning/designing system (CANDIS) in 1975. This system, which has since been in use by the company, is capable of making rough estimations and generating construction schedules in the early stages of a project. It, also, has functions and capabilities that closely resemble those of a DSS.

Among CANDIS's menus, the drafting of constructable volume for buildings, sunlight effect planning and simple checking of wind effect on environment continue to prove its practical usefulness. However, its menus for approximate estimation of construction cost and schedule planning are not so reliable and consequently these have not been utilized in practice. Today, it is considered quite possible to develop a more useful DSS by adopting even more sophisticated state-of-the-art technology such as knowledge-bases or AI.

(4) Measures to enhance the productivity of the construction phase

The construction industry is noted for being labor intensive and its low labor productivity, with no signs of improvement in sight. Also, it is becoming increasingly difficult to secure competent laborers. To cope with this problem, it is necessary to devise ways of enhancing the productivity of the construction phase of each project.

One approach is to adopt high-productivity construction methods right from the beginning when a project is still in the design stage. For example, at Takenaka Corporation, designers are encouraged to combine several streamlined elemental technology into a composite streamlined construction technique for adoption in the design stage.

Another approach is to adopt labor-saving construction methods that make extensive use of equipments such as construction robots. Recently, among the major Japanese general contractors, robots have been developed and used in practice for conducting a broad range of tasks such as spraying rock-wool fire protection, checking tiles covering external walls for secure adhesion, finishing concrete surfaces and painting external walls. However, the extent of robot application in the entire construction arena is extremely small. These robot applications have as yet been mostly used as advertisement or demonstration of their technology and potential. In the future we expect significant breakthroughs in the application of robots through the adaptation of neural network and fuzzy computer technology in the field of control engineering.

CONCLUSIONS

There is no doubt that the use of computers will increase and their capability to further support corporate activities will grow in sophistication and effectiveness in the future. Two major computer application technologies that make this possible are databases applications and AI applications (which will incorporate neural network and fuzzy computer science). Future advances in the above technology are expected to result in the improvement of man-machine interfaces and the upgrading of decision support systems, and to revolutionize control engineering which will find its way into robots and equipment.

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APPENDIX. REFERENCES

Engineering Advancement Association of Japan, (1988), "The Market Trend Investigation of CIM Technology in U.S.A.", 6th Report, Overseas Information System Investigation Team (in Japanese).

Ishii, T., et al. (1988), "Building an Engineering Database and Integrated Information Systems in Construction Industry." 5th ISRC.

Ishii, T., et al. (1988), "Approach Toward the Integrated Information Systems in Construction Industry." 3rd ICCCE.

Matsumoto, H., et al. (1988), "Space-Optimizing Creators." The Best Paper of the 60th Anniversary Contest of the Nikkan Kensetsu Kou-gyou Shinbun (in Japanese).

Table 1 Training Courses at Takenaka

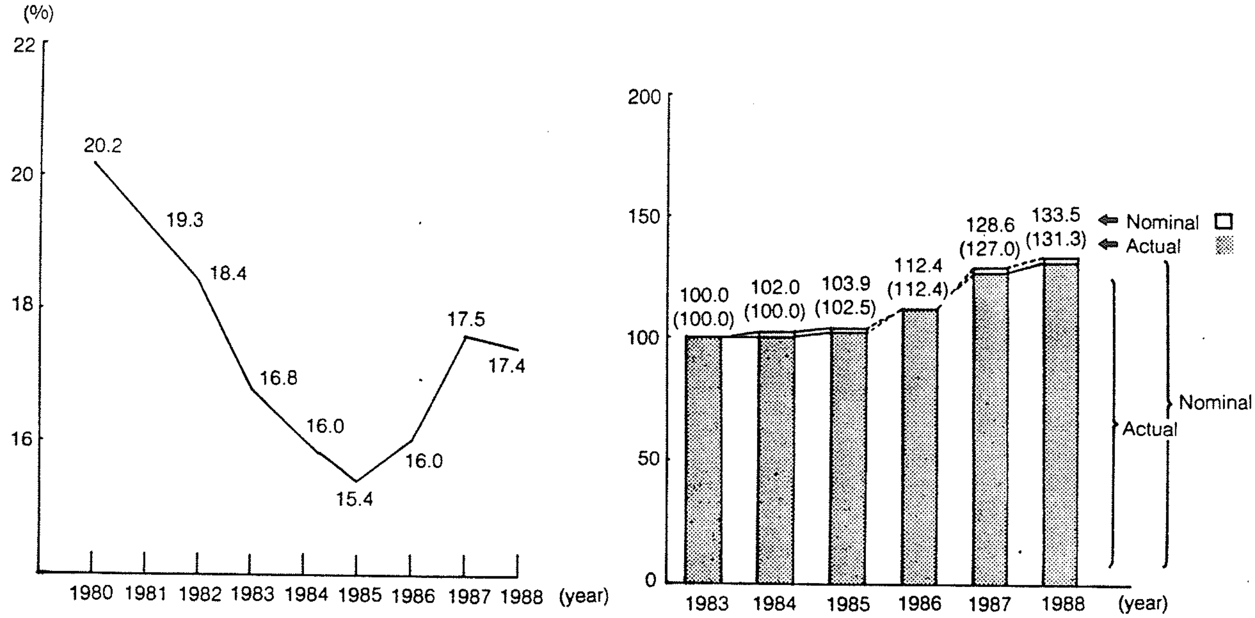
Objectives of Training	Level	Training Course
Mastery of Information System	Managerial	· Managerial Information System Course
	General	· OA Training Course for the Backbones · Personal Computer Course · Statistical Application Course · Application Course
	New Employees in Engineering Field	· Computer Course
Special Training	General Employees in Managerial Field	· Introductory Course · OJT (regular themes, independent themes) · Seminar · Training Courses held outside the company
Introduction for New Employees	New Employees in Managerial Field	· Introductory Course · OJT (themes) · OFF-J-T

Table 2 Correlation Rate of Data in the Engineering Database

Job Flow ↓

Upstream System	Downstream System	Data Correlation Rate (with Downstream System)
Design and Drafting (CAIDET)	Structural Design (AUSTIN)	(%) 20 ~ 30*
Structural Design (AUSTIN)	Structural Material Estimation (KUTAI)	30 ~ 40
Structural Material Estimation (KUTAI)	Concrete Working Drawing (SECODES)	50 ~ 60
Structural Design (AUSTIN)	Concrete Working Drawing (SECODES)	30 ~ 40

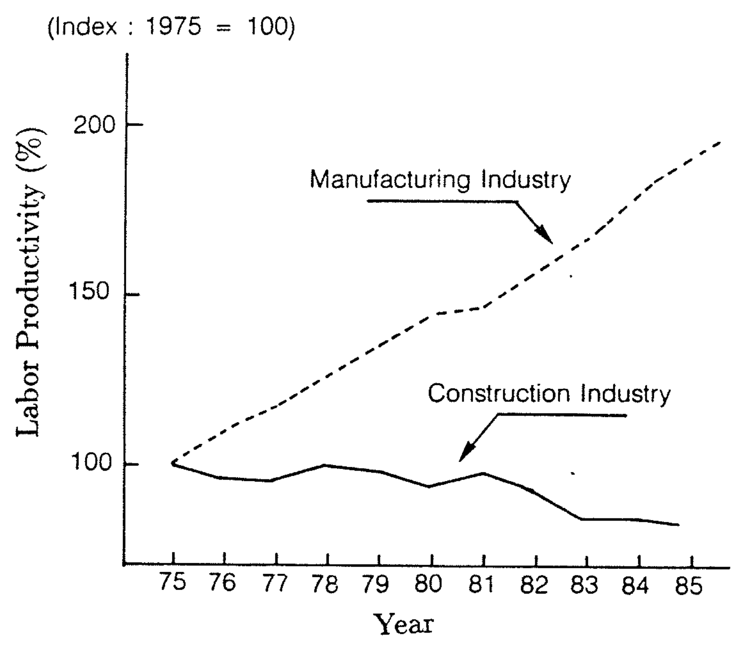
* 20 to 30 % of data established by the upstream system could be utilized by the downstream system.



(a) Ratio of Construction Investment to GNP

(b) Changes in Construction Investment Over the Years Using an Index

Fig.1 Annual Rate of Construction Investment in Japan



Note: 1. Prepared using the Economic Planning Agency's "National Economic Figures, Annual Report" and the Management and Coordination Agency's "Labor Force Survey"
2. Actual value based on the 1980 price index
3. Labor productivity = RV / NL (RV: Rough value-added product, NL: Number of laborers)

Fig.2 Annual Labor Productivity

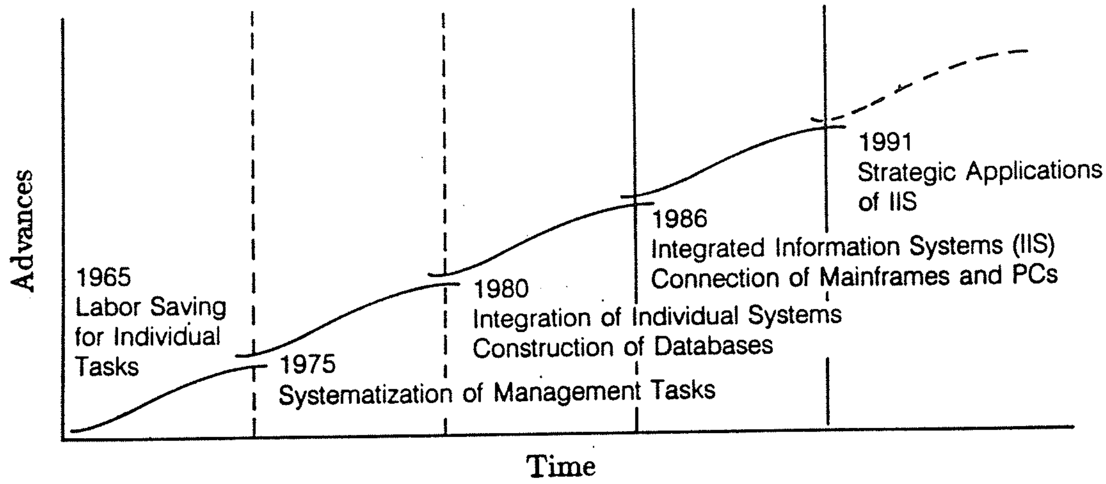


Fig.3 Advances in the Information System

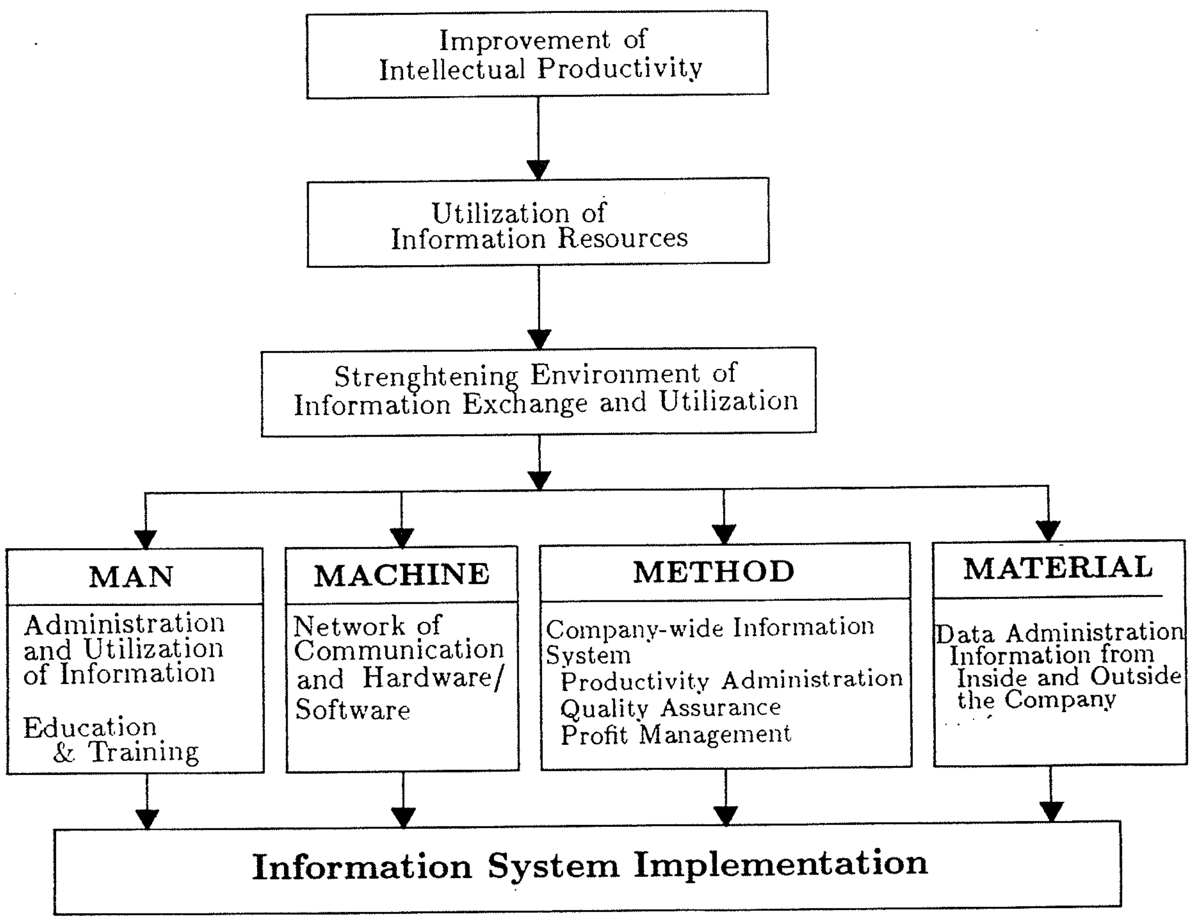


Fig.4 Plan for the Information System Implementation

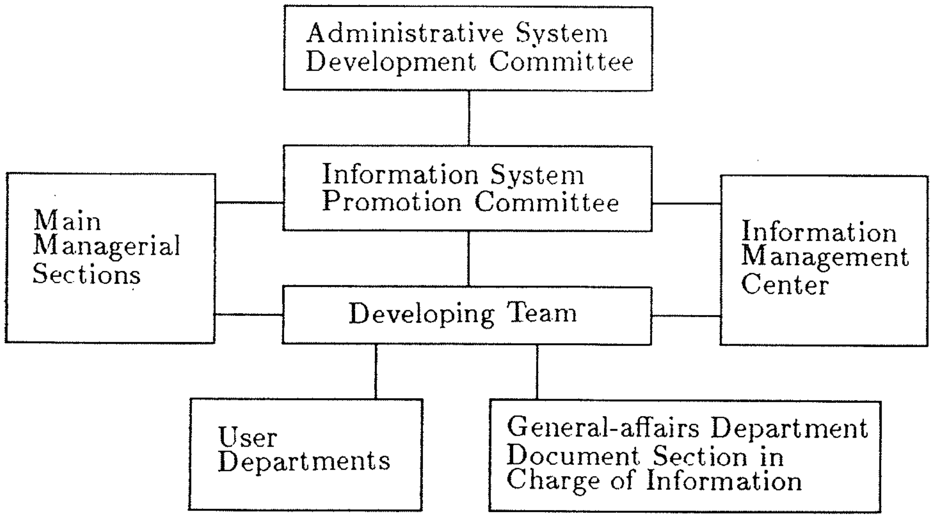


Fig.5 Organization for the Information System Implementation

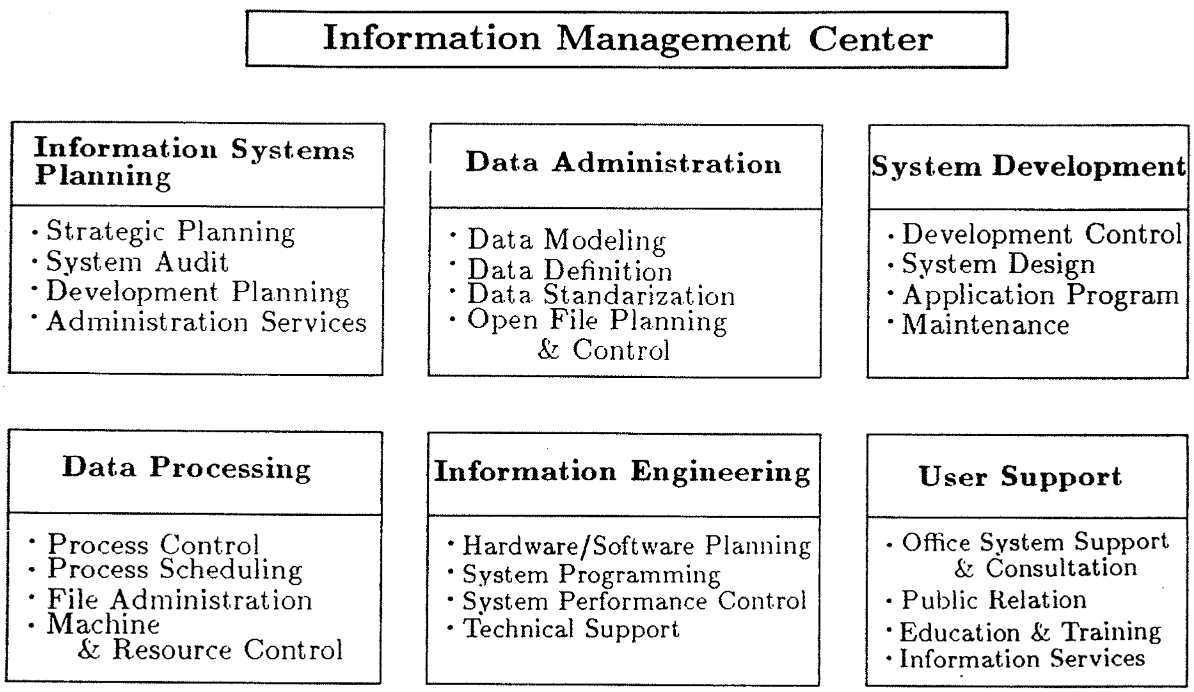
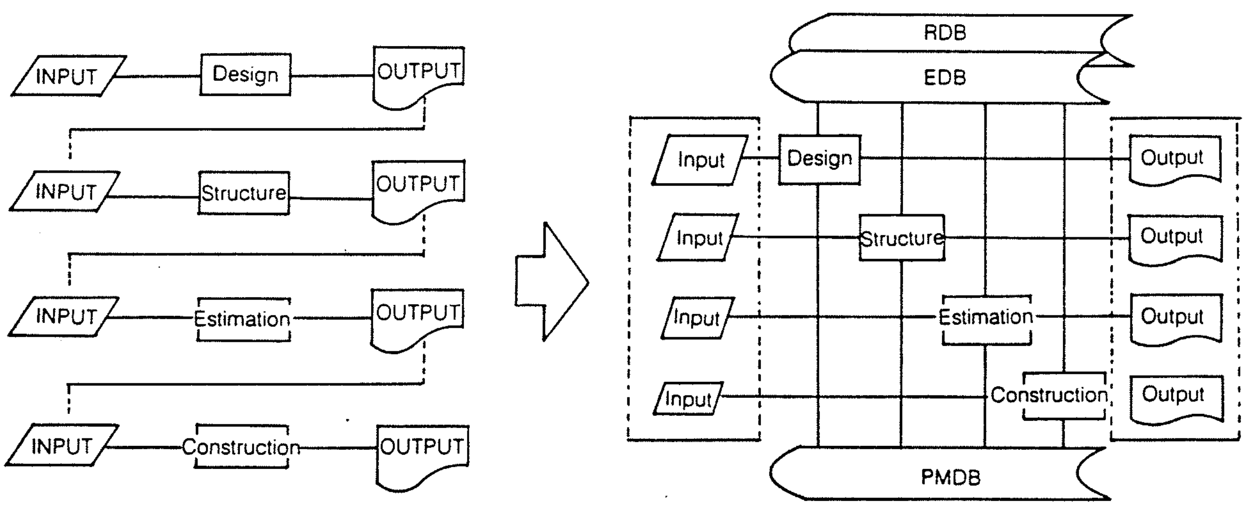


Fig.6 Major Operation of the Information Management Center

Type of Task \ Type of Processing	Regular	Irregular
Routine	(A) • Batch processing • Real-time processing • Inquiry/report writing	(B) • Operations support – Document processing – Liaison work • Decision making support
Non-routine	(C) • Inquiry/report writing • Planning and design • Structural design • Estimate calculation	(D) • Decision making support

Fig.7 Expansion of Application Fields of Systematization



EDB: Engineering Data Base
PMDB: Project Management Data Base
RDB: Reference Data Base

Fig.8 Integration of a Divisional System

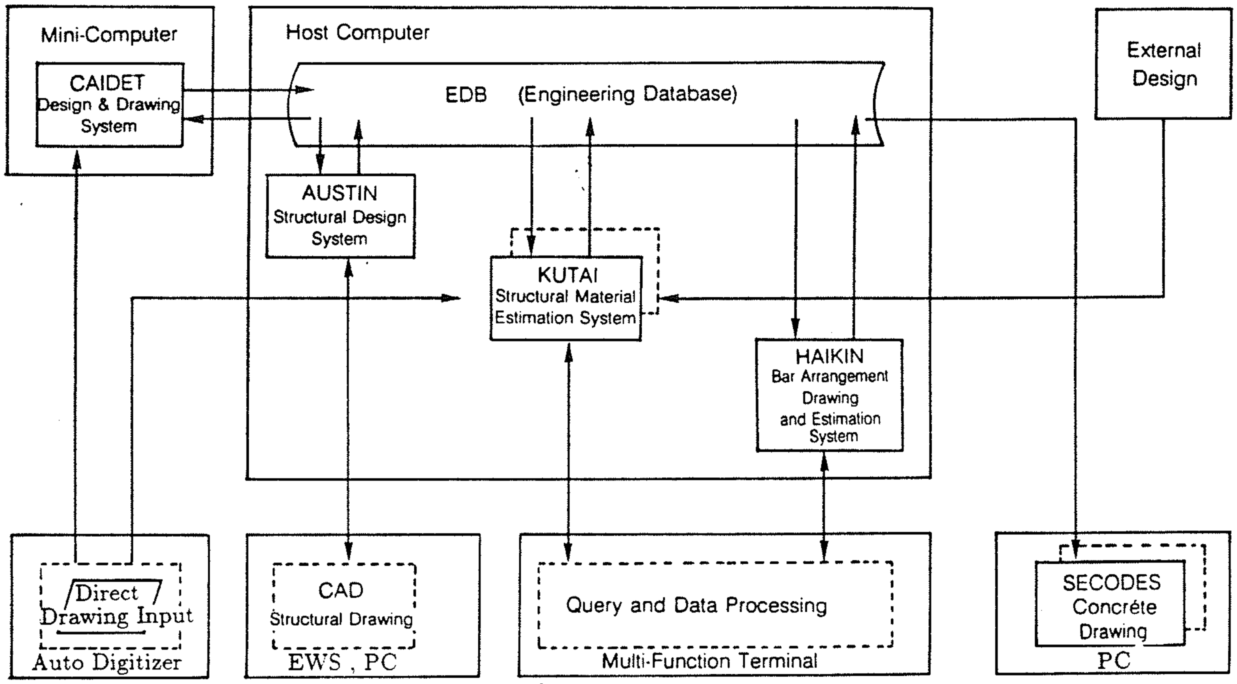
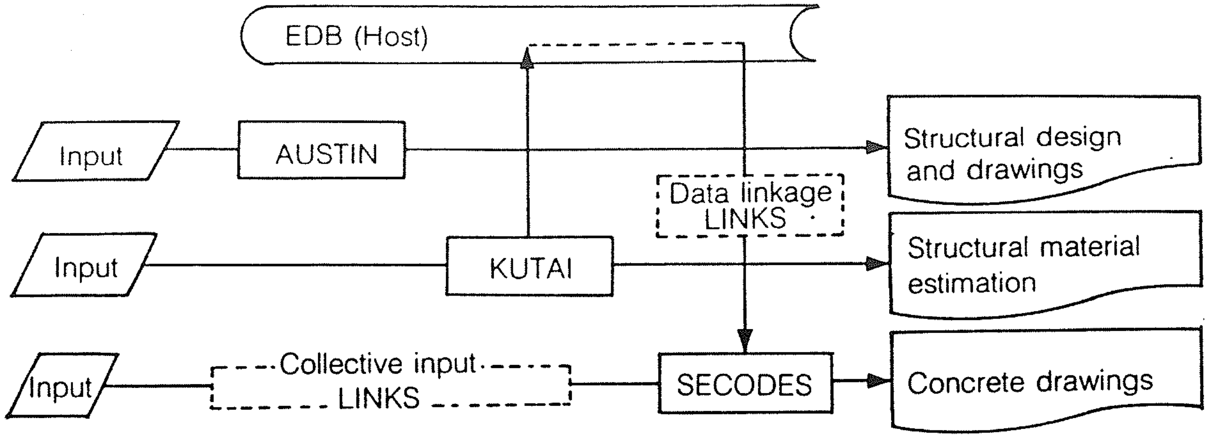
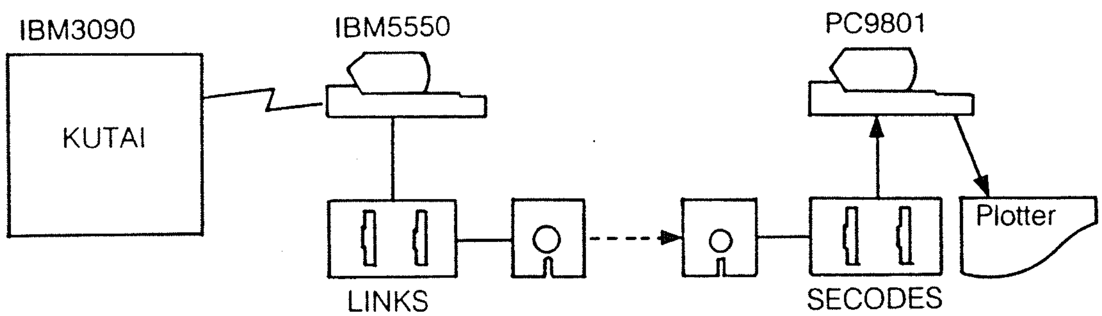


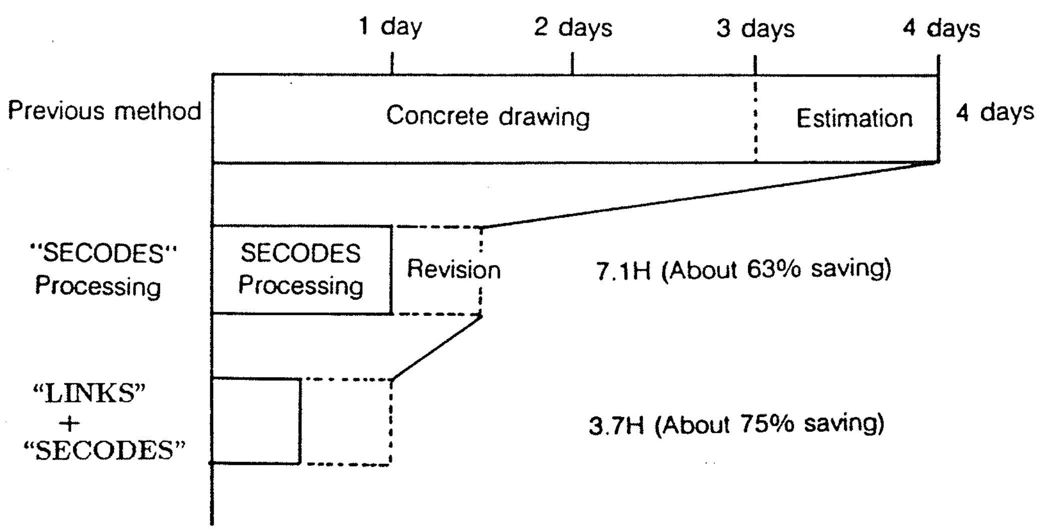
Fig.9 Data Linkage Using the Engineering Database



(a) "LINKS" Outline



(b) "LINKS" System Configuration



(c) Labor Saving by the "LINKS" System
(Average process time for One A1-size sheet in 1987)

Fig.10 Labor Saving in Concrete Working Drawing by the Introduction of the "LINKS" System

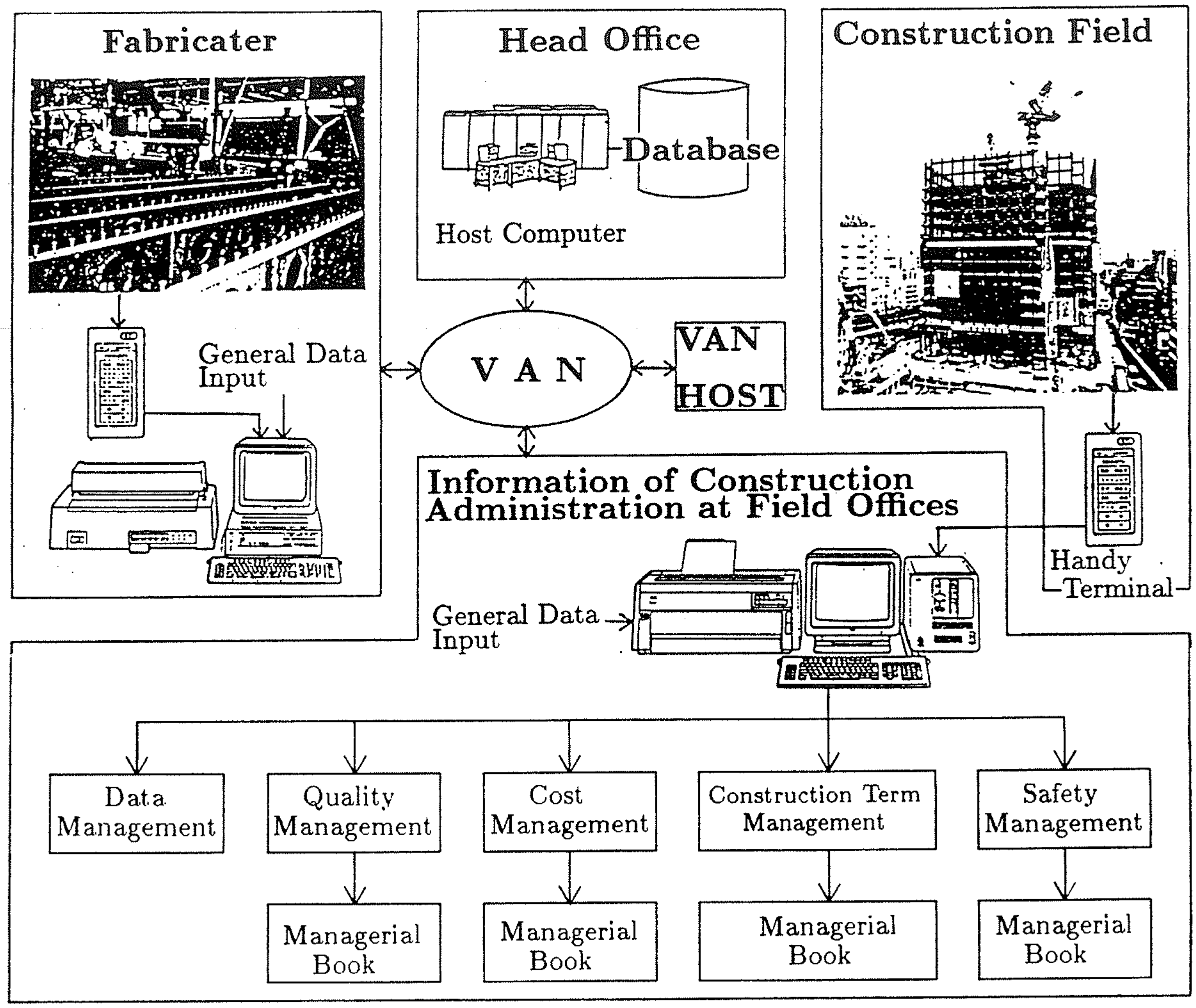


Fig.11 Data Flow through VAN (Steel Frame Erection)

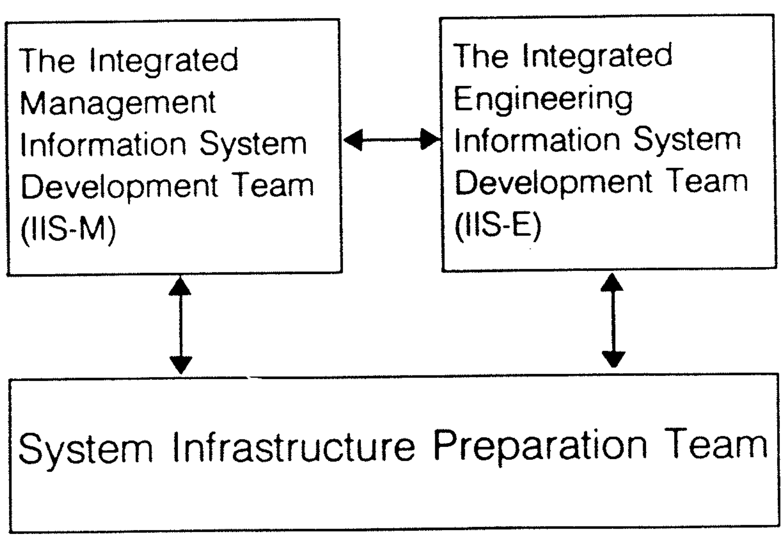


Fig.12. Organization of the IIS (Three-Team Approach)

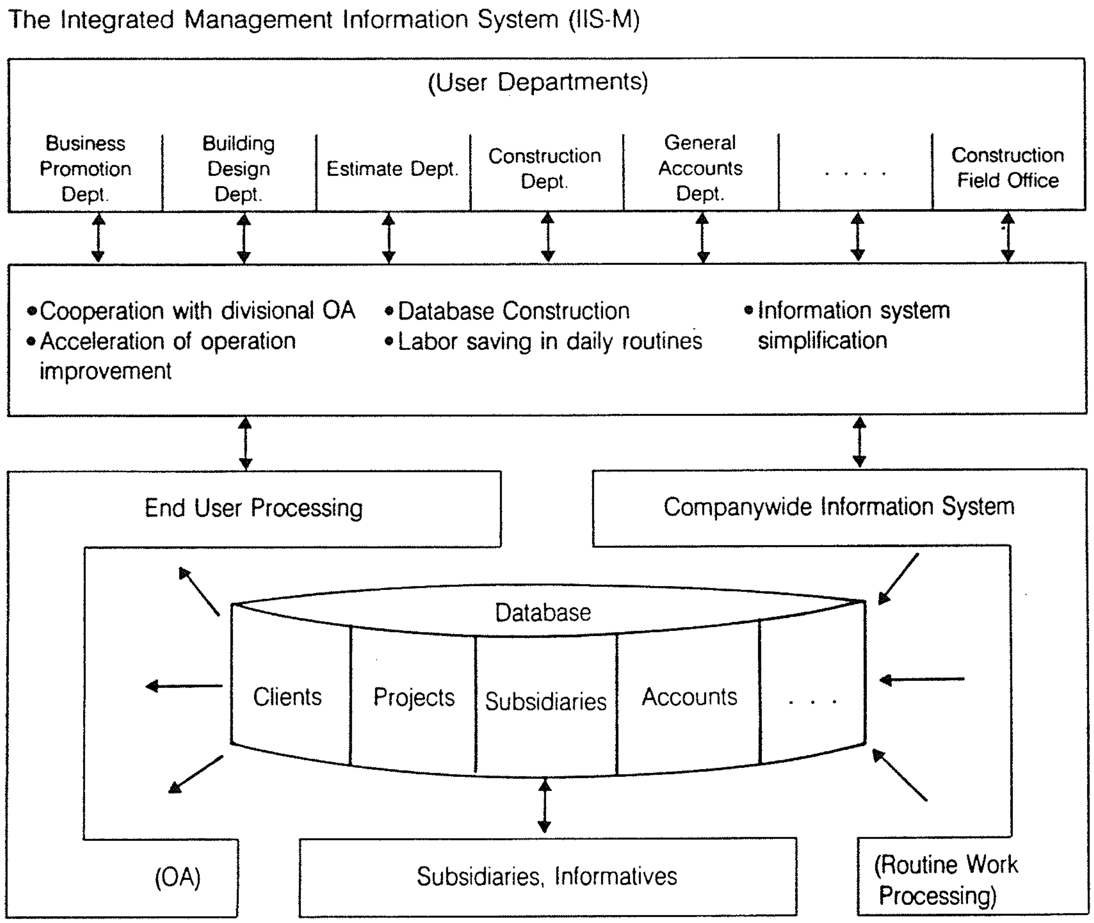


Fig.13 Concept of the Management Subsystem (IIS-M)

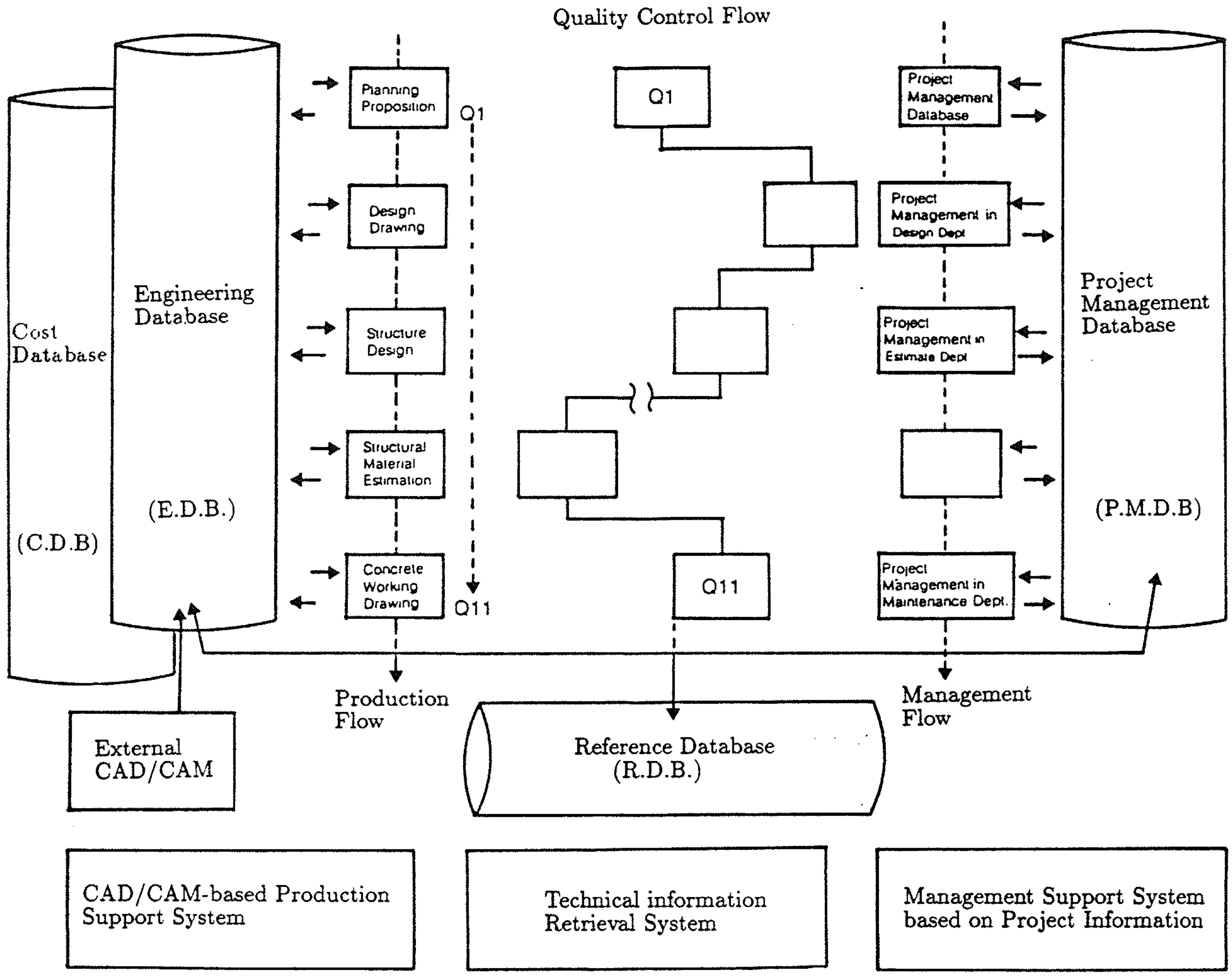


Fig.14 Concepts for Computer System Integration in Engineering

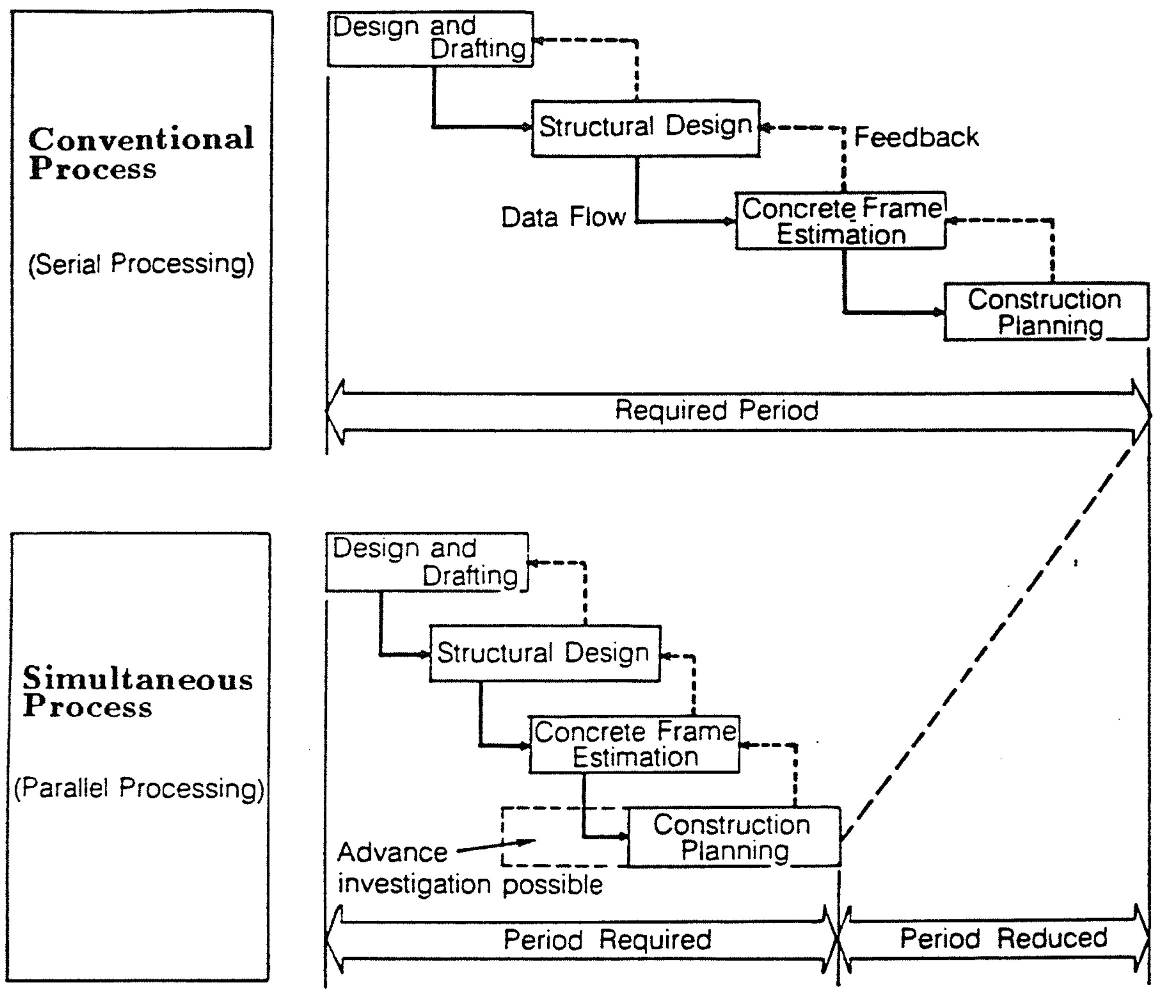


Fig.15 "Simultaneous Engineering," an Important Factor in Structuring CIM