CONSTRUCTION PLANNING SYSTEM FOR HIGH-RISE BUILDINGS USING AN OBJECT-BASED MODEL

Masaaki Ikeda Yasunari Sekihara and Naoyuki Itoh

ABSTRACT: Fujita Corporation, a leading general contractor in Japan, has sought to apply the products of CIC research to middle and high-rise buildings constructed using the PC (precast concrete) method. CIC activities focused on the development of a framework comprised of a family of products that share information for centering around 15-storied steel-frame reinforced concrete (SRC) buildings constructed using the HPC method . This output from the structural design process is manipulated further by other products that support construction planning and management.
In this paper, we will explain in detail two products that were developed to generate a product model for buildings and to utilize this information for preliminary construction planning such as the crane selection ,evaluation of scheduling of this , and preliminary cost estimation . Lastly we state about present problem of this framework and a future direction of these systems.

KEYWORDS: Computer Integrated Construction , Building Product Model , Construction Planning, Three-Dimensional CAD

1. INTRODUCTION

With the current emphasis on re-engineering and the improvement of productivity of white-collar jobs, CIC (Computer Integrated Construction) has been recognized in the Japanese construction industry as a highly effective tool in increasing productivity.

The primary objectives to realize CIC are "information sharing" and "cooperative work". A cooperative work at early design stage is more important especially in industrialization building construction project. Because in industrialization building project , exact menbers information is necessary in order to designprecast concrete members. Immediately in this case, design to consider the construction condition (production design) is necessary, and the cooperative work to use a computer, therefore gets important more and more.

A main ingredient for the success of CIC activities is the development of a powerful and flexible product model. However, this is a cumbersome task since (i) abstractions of buildings vary significantly depending on the their purpose such as architectural design, structural design, estimating, or construction; and (ii) the information is constantly changing and evolving as the project progresses; and (iii) there is a need for better standards for information exchange between contractors. Currently, there are two general approach to realize CIC in Japanese construction industry . The first is to convey building data as two-dimensional CAD (Computer Aided Design) information from upstream (e.g. design division) to downstream (e.g. construction or maintenance division). The second is to treat building data based on a three-dimensional building product model created at the structural design phase, which is modified incorporating operation results attained by each division.

2. SITUATION OF CIC

2.1 The Position of CIC in Japan

Economic stagnancy in recent years and government deregulation has intensified cost competition within the Japanese construction industry. Until recently, research and development conducted by the government and general contractors concentrated on the development of construction machines and equipment and new building materials, reflecting the emphasis placed on the development of new construction methods that could be applied directly to operations at construction sites. This emphasis grew during the boom of the bubble economy when skilled workers in high demand. While productivity of the construction site operations improved, other areas suffered, including business planning, designing, estimation, and construction planning.

Of late, a widespread awareness of the necessity to systematically redesign such office-related procedures ,so called “re-engineering”, has grown in the industry, resulting in the call for "Improvement of Productivity of White-collar Workers". CIC, which fully utilizes innovative computer applications, has been recognized in the Japanese construction industry as a highly effective tool in increasing productivity.

2.2 Steps to Adapting CIC

As previously stated, the keys to CIC are the integrated project database and working cooperatively. The integrated project database plays the most essential role because it provides the environment necessary for cooperative work. However, realization of CIC is not always easy, since (i) conceptions of building vary significantly depending on the purpose of each task such as architectural design, structural design, estimation, and construction; and (ii) the data accuracy increases as the project progresses. Thus, a building is recognized as the space of rooms in terms of architectural design, while in terms of structural design, the same building is taken as the sum of structural components. In addition, the accuracy of data required for construction planning differs from that needed for component manufacturing.

Solutions for such conceptional problems are a prerequisite to making building product models. Until now, however, no construction modeling techniques have fulfilled this prerequisite. Currently, two general methods are employed to evade such problems. The first is to treat building data as two-dimensional CAD information, as is conventionally done with pen, so a single piece of paper conveys such information to every division from design through construction and maintenance divisions. Since quite a few construction projects in Japan are integrated from design to construction by a single general contractor, the number of using this method is increasing. The second method is to treat building data based on a three-dimensional building product model created at the structural design phase, which is modified incorporating operation results attained by each division. This method starts from structural design data because three-dimensional data is produced during structural analysis. It is quite difficult to apply the architectural design data to the building product model, because the architectural design which is carried out simultaneously to structural design usually uses the two-dimensional CAD, except for in client presentations which required three-dimensional information at the beginning stages of a construction project.

In any case, CIC is currently used to transfer information produced by the design division positioned at the earlier stages of a construction project to later project stages, such as the estimation and construction division. In other words, even when three-dimensional CAD is used, the data structure is so simple that they are not utilized by many divisions. In order to effectively use an integrate project database, it is essential to utilize building models created using an object-oriented programming technology such as that described below.

3. CIC FRAMEWORK IN FUJITA

3.1 Background of CIC research

In August 1991, Fujita Corporation, a leading general contractor in Japan (hereinafter, FUJITA) and Pennsylvania State University (hereinafter, PSU) signed a five-year Joint Research Agreement on CIC. FUJITA placed its Technical Research Institute (headed by Dr Masaaki Ikeda) in charge of the joint research efforts in Japan while PSU's Architectural Engineering Department (headed by Dr. Victor Sanvido) led efforts in the U.S.

The parties chose projects using PC (precast concrete) construction method, as it is considered to be a promising architectural engineering for the future. In the first year of the project, the team analyzed internal work procedures and information flow between work divisions with "IDEF0", a special method used to analyze work systems in FUJITA.

This method, however, does not have a mechanism to specifically express the relationship among departmental works which are carried out simultaneously and cooperatively. Thus, application of this method by Japanese organizations, which are commonly comprised of many internal departments, is limited to a certain extent. Nonetheless, aided by this method, the team was able to analyze and describe flow of work for up to four strata, and thus gained an understanding of the actual situation of existing work systems.

In the second year of the project, the team focussed its efforts on the fabrication of building product models, experimenting with a building modelling system to be used with Object-Oriented Programming environment, called "Nexpert Object", and a preliminary construction planning system using this building model system. (Messner 1993) The primary objective of FUJITA's efforts was to develop a versatile building model database and an intelligent planning system making use of this method. FUJITA, however, eventually concluded that development and utilization involved too many problems to actually apply such a system to any construction project.

From the third year of the term onward, PSU experimented with a ground information system for use in shield tunnel construction, as well as an object-oriented simulation system, under the supervision of Dr. AMR A.Oloufa. Prototypes of these systems are currently being studied for adaptation by FUJITA. (Oloufa 1995)

FUJITA, who has concurrently carried out a study on object-oriented development as discussed later in this paper, intends to again address the challenge of developing an integrated project database applicable to future building construction.

3.2 Establishment of the CIC Project

In April 1993, three years after joint research commenced, FUJITA established a CIC project team in its engineering division, called "CIC PROJECT," in order to apply results of its basic research. With the CIC PROJECT thus established, FUJITA sought the possibility of applying CIC engineering to middle and high-rise buildings, centering around 15-storied steel-frame reinforced concrete buildings (SRC buildings) constructed using the HPC method. HPC method is an architectural engineering application of PC engineering that is often used in Japan for the construction of SRC buildings, whereby shear walls with girder, non-bearing walls, slabs, balconies, corridors and other building materials are categorized and handled as PC building components. The HPC method was employed in this instance because (i) it has a 30-year history of successful achievements in the construction industry and has reached a high degree of completion, and (ii) through actual application a great amount of performance information and knowhow has been accumulated which is available for immediate use.

The CIC PROJECT carried out several important assignments for HPC applied construction projects, including (1) examination of existing work systems, (2) collection of performance information on construction projects conducted in the past and inputting such information into a database, (3) studies on methods to make use of planning charts drawn with two-dimensional CAD even for construction management, (4) examination of methods to employ EDI (Electric Data Interchange) for exchanging building information with architectural design firms and with architectural components manufacturing firms, and (5) using three-dimensional CAD, development of data-linked software containing building information.

3.2 Development of Data-linked Software

Data-linked software was developed to apply three-dimensional data produced by the structural Planning system (FIND) to work systems such as preparation of PC component charts, estimation, construction planning, and construction management. In the system, as shown in the following *figure1*, there are two flows by which building project data obtained from the structural design. One option is to input data into PC component manufacturing charts, while the other is to process the data and input it concurrently for each work system, such as preliminary construction planning, construction management, and an site information collection systems.

Building project data is outputted from the structural design system by converting the data into what is called the "standard format", an intermediate file format, while the receiving system converts such data from the standard format for its intended use. This mode aims at integrating the exchange of data between more than one design system and more than one receiving system into one format, thus improving efficiency of data conversion.

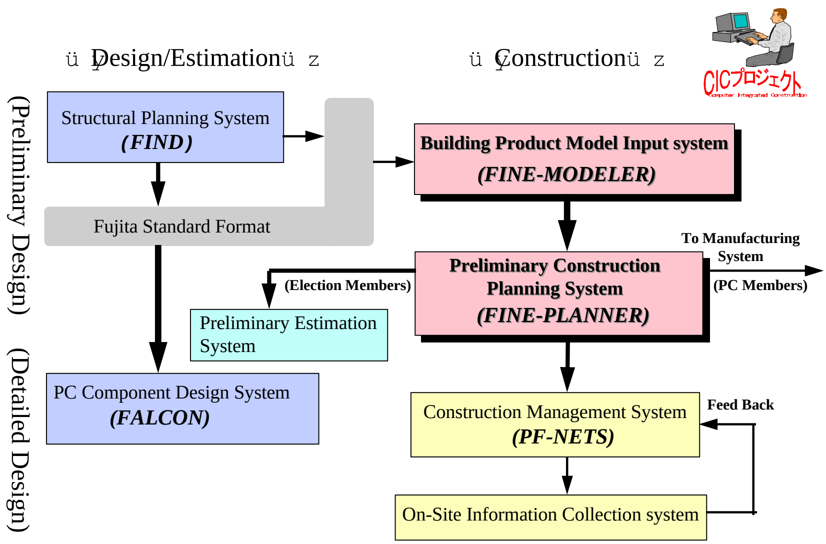

Figure 1:Framework of the Data-Linked Software

The following outlines the major systems covered by the *figure1.*

(1) Structural Planning System (FIND)

This is a system designed to estimate sectional property of construction components on the basis of building project data previously inputted and to work out structural designs by verifying the propriety of the components, using the conventional structural analysis system.

(2) Building Product Model Input System (FINE-MODELER)

This is a system by which building product data can be output in the standard format and a complete three-dimensional building product model can be fabricated by supplementing such component materials as non-bearing walls or balconies that are missing from the structural design data. This system is also capable of fabricating a construction model from scratch and with no structural design data for projects that have been designed by other firms.

(3) Preliminary Construction Planning System (FINE-PLANNER)

This system checks if there are any remaining problems with respect to preliminary design following an examination of the preliminary construction method (which is conducted prior to the construction design process). Work data and resource data produced at this phase may be input into the construction management system and the estimation system.

(4) Construction Management System (PF-NETS)

This system can make a schedule calculation based on work data produced by FINE-PLANNER, thus supporting detailed construction planning and progress management once a construction project has commenced.

(5) On-Site Information Collection System

This system, which can be run on palm-top computer at the construction site, supports the recording of instructions rendered for daily routines and the results thereof with the aid of schedule data produced by PF-NETS.

(6) PC Component Design System (FALCON)
This system inputs building product data in the standard format and supplements such data with information on electrical services, air conditioning, and plumbing, in order to design PC component. CIC has thus developed FINE-MODELER and FINE-PLANNER to serve as core-usage, data-linked software that incorporates three-dimensional CAD (Micro GDS), Visual Basic, and MS/Excel, all of which were considered to be highly advanced in our survey conducted two years ago (See *Figure2*).

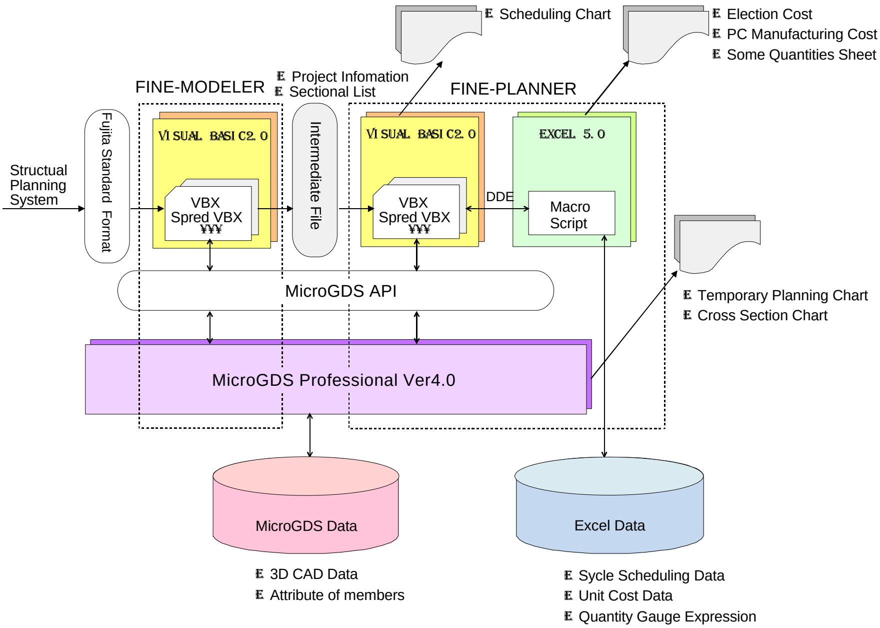

Figure 2:System Structure of FINE-MODELER & PLANNER

4. BUILDINGS PRODUCT MODEL INPUT SYSTEM (FINE-MODELER)

4.1 Purpose of this System

To use CIC in building construction projects, it is necessary to input into a computer a variety of information about a building, including information that will be used by various parties at different stages of the work such as design, estimation and construction. Since all building information is computer processed, conventional two-dimensional drawings cannot be used in this system.
In order words, to use CIC, it is necessary to convert three-dimensional information about the shapes and allocation of members that constitute a building into numeric data, so that the attributes of each member (material, weight and strength) can be recorded in relation to this data.

In this paper, the above-mentioned procedure to convert information about a building into three-dimensional numerical data to be stored in computer is referred to as the "modeling of a building", and information generated by thismodelling procedure is referred to as the "building model". "FINE-MODELER", which will be introduced here, is a system that can be used to input building model into a computer using a three-dimensional CAD system.

4.2 Buildings as the Subject of this System

Various types of buildings, from those with only a few stories to high-rises, from buildings with limited spaces to those with vast spaces, and from factories to apartment houses and hotels, can be used as architectural subjects. To use CIC, it is necessary to carry out modelling work on all of these various types of buildings and input information about them into a computer. However, it takes a lot of time to develop a computer system that can accommodate such data.

Therefore, when we developed this system, we tried to make it as easy as possible to input information concerning mid-to-high-rise buildings of about 15 stories, since such buildings were our immediate target. Generally, such buildings are constructed with steel-framed reinforced concrete (SRC), while industrialized construction methods such as the HPC method, which uses precast concrete (PC), are often adopted as the construction method for such buildings. Therefore, this system was designed to accommodate information about these construction and structural methods. Even if the subjects are limited to mid-to-high-rise housings, there are still many variations in shape and the usage of PC members. Therefore, this system was designed to handle only the following types of buildings.

- plan types: (1) linear type, (2) dog-legged type, (3) L-shaped type
- roof shapes: (1) flat roof, (2) gable roof
- slab construction methods: (1) conventional method, (2) half PC method, (3) full PC method

Because it can also handle the setback of buildings which those upper stories step back from the wall line, this system can be used with about 70% of the mid-to-high-rise housings that our company will actually construct.

4.3 Functions and Characteristics of this System

The fundamental functions of this system are summarized as follows.

(1) Input of project information:
It is possible to store and deal with outline information and building information for each project.

(2) Input and display of information about the environment of construction projects:
It is possible to input and display, by a segment of a line, the boundaries of the lot and the locations of peripheral roads, neighboring buildings, and peripheral obstacles. It is also possible to display them together with images read with a scanner.

(3) Input of basic information about buildings:
It is possible to separately record information about each of the buildings of a particular project. This information can then be used as basic data for the generation of members constituting a building.

(4) Input of grid information

(5) Input of sectional information about members:
It is possible to input the specifications for each section of each member constituting a building (external shape, and information about reinforcing bars and steel frames), according to type.

(6) Input of the key plan:
Using a model drawing known as a "key plan", it is possible to input a building's constitution representing the location of each member.

(7) Three-dimensional generation members:
A building's main members, that is, its columns, girders, walls, floors, balconies, and external corridors are automatically generated as the three-dimensional objects based on key plan information and sectional information about these members.

(8) Generation of roof and foundation members

(9) Modification of information about the attributes of members:
It is possible to add information about the attributes of members such as type of concrete, slab construction method, dimensions of the opening, and degree of segmentation.

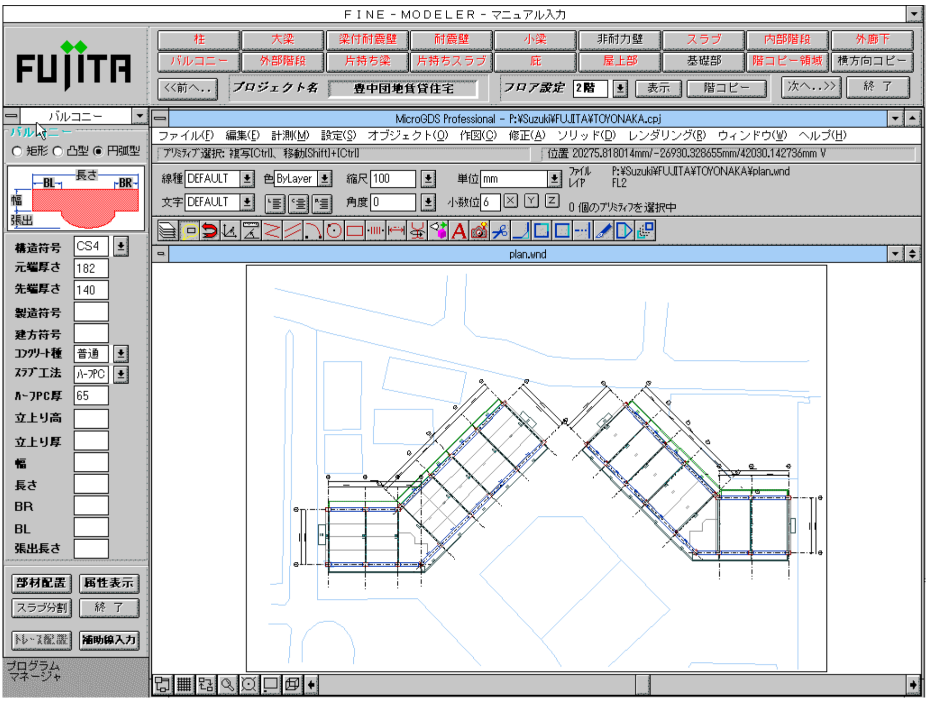

Figure 3: An example ofSlub members input by FINE-MODELER

4.4 Use of Design Information

This system was basically designed to construct a new building model. However, if one company will carry out all the works of a project, from design to construction, the data may be used in the structural design system.
In this system, we adopted a method of converting building information transferred from the design system into data suitable for this system through a text file. To do so, it is necessary to determine the format for converting data from one system to another. However, if we try to prepare such a

format for each pair of design systems, many formats will be required. Therefore, we prepared a new data conversion format known as a "standard format", and used it.

Nevertheless, a problem remained because the data which could be used with this method was limited to data about structural members such as columns, girders, and shear walls. The reason for this is that the system that generates this data is the structural design system. Because structural design deals exclusively with structural members, it is natural that such a problem would arise.
It is desirable to allow common use of all the building data generated in the design , construction management and maintenance stages . However, as a matter of fact, most of the CAD information in the design stage is in the form of two-dimensional drawings. Particularly in the case of architectural design, this tendency is marked which creates a problem since it is difficult to use this type of information in a construction plan, which generally requires three-dimensional data.

4.5 Method of Input Information about Members

In this system, members such as columns, girders, shear walls, slabs, and beams are registered using a method known as the "key plan", in which these members are represented by symbols. Each symbol registered in the key plan is recorded as an object with a structural code and with the location of each member, as well as with information showing the relation of each member to the other members. Based on this information, three-dimensional members are automatically generated. The characteristic feature of this method is that it is easy to modify the objects of members because the constitution of a building is defined based on only the allocation of members and the relation of one member to another, without necessitating the generation of the three-dimensional objects of members. If we try to modify some members after the three-dimensional objects of those members are being generated, it will become necessary to modify all the related members. For example, although the shape of a girder will vary according to locations and shapes of columns to be connected to it, the dimensions and the location of the girder will be decided based on information about the related members when the three-dimensional objects of members are generated based on the completed key plan. Therefore, useless work involving the modification of members is greatly reduced.

5. PRELIMINARY CONSTRUCTION PLANNING SYSTEM (FINE-PLANNER)

5.1 Purpose of this System

As part of efforts to realize computer integrated construction (CIC) at Fujita Corporation, the Preliminary Construction Planning System (FINE-PLANNER) was developed to analyze fundamental problems associated with the construction of a building after the preliminary design has been established and early stages of construction have begun, in order to incorporate the analysis results in subsequent design modifications.

It is often the case in construction projects that a few design modifications will greatly facilitate construction. The ease with which construction occurs based on designs termed "constructability". The FINE-PLANNER strives to realize building designs by integrating constructability concepts. With the FINE-PLANNER the user can analyze construction plans in three phases, based on the three-dimensional building data which is obtained from the Building Product Model Input System (FINE-MODELER). In Phase 1, the user identifies temporary roads and selects a crane, then makes a general temporary planning chart. In Phase 2, the user divides the scope of work into zones and performs various calculations to determine the number of members required for each zone based on

Phase 1 results. In Phase 3, the user evaluates a cycle schedule, then makes a master schedule and roughly calculates project costs. At this point the user can return to Phase 2 or 3 and examine alternative plans under different conditions. Moreover, the user can compare various alternative plans and evaluate each through the Hyper Text interface.

5.2 Construction Projects to which the FINE-PLANNER is Applicable

Construction plans for the buildings and conditions detailed below can be formulated with the FINE-PLANNER.
(1) Building Type and Size
A 15-storied or lower, single building apartment house consisting of 20 flats or less on each story; or two buildings of equal size, housing 10 flats or less on each story of each building.
(2) Crane classes
Three classes of the tower crawler crane: 80-ton, 100-ton, and 150-ton.
(3) Precast (PC) members that can be divided
During crane selection, PC members that are used for shear walls (with girders), floor slabs, balconies, and outer corridors may be divided when determined to be overweight.
(4) Number of work divisions
The entire building must be two-dimensionally divided into two construction zones. For a two-building apartment house, each building is assumed to be one construction zone.
(5) Cycle scheduling

The work schedule for one story in one construction zone is called "cycle scheduling", because a whole building is constructed by repeating this procedure for each story in the construction zone. An example of cycle scheduling is provided as a reference.

In the FINE-PLANNER 15 cycle scheduling options are available, with variant combinations of (1) slab placement methods (conventional, half PC, full PC), (2)non-bearing wall installation sequences (cast-in, cast-out), and (3) number of construction days (8, 10, 12). For full PC, non-bearing walls are installed only by the cast-out method, so the number of available cycle scheduling patterns is (3 x 2 x 3) - 3 = 15.

5.3 Functions of this System

5.3.1 Temporary Planning

First, the user identifies the crane's travel path and selects a crane class; next he or she evaluates the adequacy of the net lifting load of the selected crane. There are two ways to do this. The computer may automatically verify whether there are any parts that the selected crane cannot lift; alternatively, the user may designate a member and verify whether the selected crane can lift it. If a member unable to be lifted is identified the user determines whether to select a higher class of the crane or to divide that member. The user then makes a cross sectional drawing of the positional relationship between the crane and the building to verify the adequacy of the net lifting load of the selected crane given the building height.

The user can also plan temporary offices and stockpiles in the construction site and output the layout as a general temporary planning chart. (See *Figure 3*)

5.3.2 Dividing the Scope of Work & Calculating Quantities

Next, the user divides the entire building two-dimensionally into two construction zones, and the computer calculates (1) quantity of each PC member, (2) amount of cast-in-place concrete, (3) quantity of each form, and (4) amount of concrete to cast PC members in place according to construction zone, story, and member type, based on types, weights, and materials of PC members as well as on positional information, all of which are accumulated by the FINE-MODELER. Finally, these calculations are output on packaged spreadsheet software (MS-Excel). By studying this output, the user can assess the reasonableness of the work volume balance between the two construction zones.

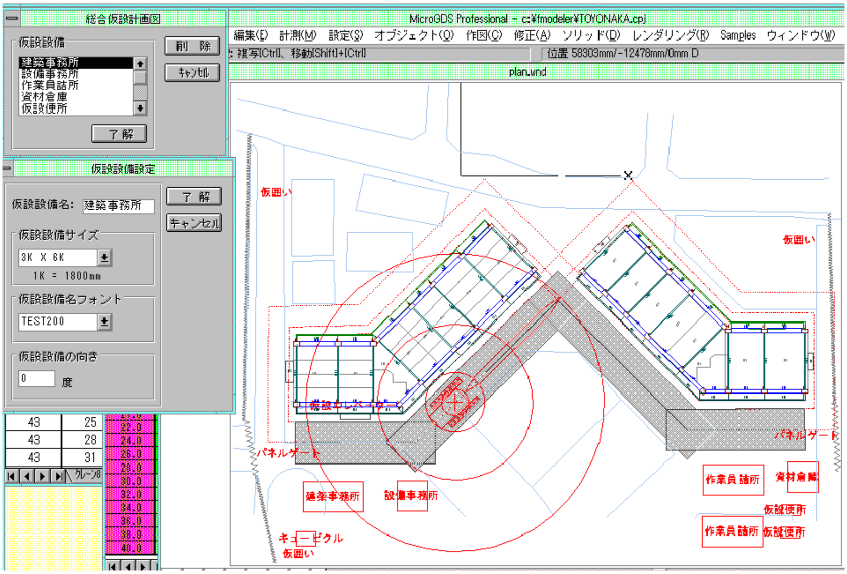

Figure 3: An Example of Temporary Planning by FINE-PLANNER

5.3.3 Cycle Schedule

The user can draw up a cycle schedule based on the previously input conditions. A cycle schedule for the building is developed based on the number of days to complete a standard story (called the typical story) in one construction zone and on the assumption that the same procedure will be repeated for each story of the construction zone.
The user first selects (1) the number of days required to complete one story (8, 10, 12) and (2) the non-bearing wall installation sequence (cast-in, cast-out), and adds to these the previously-input (3) slab placement method. Then the user selects the applicable cycle scheduling pattern from the FINE-PLANNER.

Cycle scheduling patterns are presented in MS-Excel format. The MS-Excel incorporates a feature that not only displays the work steps from start to finish but also automatically calculates the number of PC members to be erected, the volume of labor required for structural work, and the hours of crane uptime on a daily basis. Once cycle scheduling is selected in this manner, the computer displays the cycle schedule together with these calculations. This enables the user to judge whether the selections were appropriate.

5.3.4 Master Schedule

The next step is making a master schedule based on the established cycle schedule as shown in the figure. Repetition of the cycle schedule is called erection work, in which building body structures are assembled and fixed in place (called the erection process). In practical building construction, however, the preparation, earth work, and foundation work (inclusively called the pre-erection process) are necessary before the erection process. The equipment, finishing, and external work and landscaping (inclusively called the post-erection process) come after the erection process. The master schedule covers pre-erection, erection, and post-erection processes.

The number of days required to complete the pre-erection process and the post-erection process are separately and automatically determined from the track record to date and in accordance with information supplied by the user, e.g. size of the building and piling method. The election process is determined by the selected cycle scheduling pattern and the number of stories of the building. Thus, the user can readily make a master schedule. FINE-PLANNER incorporates features that consider work volume on a monthly basis and allow for the New Year holidays, "Golden Week" (a holiday week in May), andObon holidays (around mid-August) as non-working days.

Moreover, when the process data generated here (e.g. the type of work and its sequence) is automatically transferred to the Construction Management System (PF-NETS) developed at Fujita Corporation, the user can make a more detailed schedule or utilize the data for progress assessment after the start of construction.

5.3.5 Erection Costs

Cost, an important factor when comparing and evaluating alternative plans under various work conditions, can also be calculated. Major factors affecting cost in alternative plans are (1) crane class, (2) cycle scheduling (the volume of labor required for erection work), and (3) crane installation period, all of which change the erection work itself. In other words, a comparison of the costs required to do the erection work helps enable the user to effectively evaluate alternative plans. Construction costs are generally itemized into (1) material cost, (2) labor cost, (3) machine damage cost, (4) subcontracting cost, and (5) overhead. Of these, the labor cost, crane damage cost, and subcontracting cost (for temporary work or connection of members) are variable, and inclusively called the erection costs. The FINE-PLANNER can calculate the erection cost in detail.
The above information applies when the HPC construction method are used. Anticipating the need to compare one construction method to another, the FINE-PLANNER also can estimate the manufacturing cost of PC members. Furthermore, this generated cost data can be used in Fujita's Estimation System after it is converted.

5.3.6 Comparison of Alternative Plans

By performing the above steps, more than one alternative plan can be efficiently and effectively prepared with the FINE-PLANNER. The FINE-PLANNER is equipped with a feature that allows easy comparison and evaluation of these alternative plans on the monitor. This feature employs a Hyper Text structure. First, a table showing typical items for comparison appears on the monitor. By clicking on one item, more detailed information appears on the monitor in the forms of a figure or table.

The first table to appear lists (1) crane specifications, (2) cycle scheduling, (3) master scheduling, and (4) erection cost. If the user clicks on "crane specifications", a table of crane net lifting loads appears. If the user clicks on "cycle scheduling", a table of cycle scheduling patterns, labor volume, and the crane's uptime are displayed. Clicking on "master scheduling" displays a table of master schedules. In this way, the user can call up the information on the monitor and make comparisons at any time.

6. DIRECTIONS OF THE FUTURE

The above data-linked software employ a method under which building project data that has been produced in the structural design process is processed and sent one after another to the systems located further downstream. By doing so, "information sharing," CIC's primary objective, can be achieved. However, this method alone cannot realize "cooperative work," another of CIC's primary objectives. In short, it is of absolute necessity that an integrated project database be developed that can store three-dimensional building project data, and to which a series of work systems can be linked to with the database support construction project work. Furthermore, in order to develop such an integrated project detabase, a highly advanced system development environment will be needed, one that incorporates object-oriented technology.

The present FINE-MODELER building model is made for FINE-PLANNER, data is not compatible with other systems, a building model data depends on stricture of the specific CAD (MicroGDS) used. However it is essential to develop integrated project databases if the widely varied information requirements of the various specialized participants in a building life cycle (i.e. division or company) are to be fully served. The challenge of developing generic building product models for the construction process is receiving considerable interest , and we hope to research the results. We think it too difficult at present to represent an integrated product model, especially in Japan, due to the heterogeneous nature of the information generated in the design stage (i.e. design information) and needed in the construction stage (i.e. construction information). Generally speaking, in a Japanese construction production system, design information is to describe "what a building is to be", while construction information is to show "how to constructs a building". Even in most construction applications,informations tend to evolve and change as the project progresses. In some situations, an object may ever change form, as for example a concrete form is stripped to expose a new wall.

In order to propel a future CIC, not only must we advance the integration of information inside the framework of a present building production system, but we must also work to reform building production systems ourselves. Therefore at first, it is necessary to advance "a type of building production system", i.e., to systematize construction process including procurement, transportation and prefabrication of building components at first. (Yamazaki 1995)

In Japan as one of attempt to fill the gap between design and construction, a new organization will be created, called "production design". This organization will be available that feedback from construction to design information is available, thereby enabling costly, precise designs to be produced without delay.

Looking forward, we see two direction for expansion. One is expansion to another construction method (e.g. SRC construction) as an extension of a current framework. With this approach it is possible to achieve correspondence to a wide range of projects, and even to expand to a method for comparison of construction systems (e.g. the conventional and PC methods of construction). The other direction is to make a building model using an object-oriented method and to structure a project database capable of being accessed from other applications.

We believe that the goals of a information sharing and true cooperative work will be advanced as well.

Acknowledgements
The authors wish to thank Pennsylvania State University for the continued support for this research and particpants for CIC project in theFujita Corporation .

References
Messner,J., and Sanvido,V. (1993). “Developing an integrated database structure for lifecycle of precast projects”, Proceedings of the Fifth International Conference (V-ICCCBE), Anaheim, CA, June
Jas P. van Leeuwen and Rob H.M. van Zutphen (1994), “Architectural Product Modelling A Case Study”, CIB W78 Workshop,Helsink,Augaust 1994
Yamazaki.Y (1994), “An Object-Oriented Process Modeling to Support Cooperative Planning in Industrialized Building Construction Project”, Computing in Civil Engineering, pp998-1005, ASCE, 1994
Froese,T.(1995). “Models of Construction Process Information”. Journal of Computing in Civil Engineering, ASCE
Amr A.Olufa, Ikeda,M. (1995). “Object-oriented simulation of shield tunnelling projects”. Computing in Civil and Building Engineering, 1995 Balkeme, Rotterdam
Amr A.Olufa, Ikeda,M. (1995). “An automated environment for soil-and terrain-dependent applications”. Automation in Construction 4, 1995
Ikeda,M. Amr A.Oloufa and Sekihara,Y. (1996), “An Object-Oriented Environment for the Construction Planning of High-Rise Buildings”, Proceedings of the International Symposium on Automation and Robotics In Construction (ISARC),Tokyo ,Japan, June 1996