

Research on the intelligent construction system

- Distributed automatic construction planning system with JAVA -

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Abstract

As a result of automated construction methods, which many construction companies have worked on these days. Consequently, the following construction planning systems are needed :1) the best framework partition plan, 2) the best layout plan of the hardware and the best usage plan of workers at the construction site, 3) the output of the stage of execution works, in a short period of time. This system also sends the feedback to the design phase.

Therefore, we have developed the distributed automatic construction planning system. With this system, the construction planners in the office simply input the design plan (CAD data), carriers data, and stock yields data using computers. The system, with the latest artificial intelligent technology, outputs 1) the best partition plan of the framework, 2) the best sequence of the framework to be built, 3) the best path for each framework to be carried, 4) the best workers plan 5) the best layout of the hardware.

As a development environment, we didn't use the conventional client-server model, nor a simple object-oriented model. Rather, we used JAVA, which is independent from the computer hardware, and the latest object-oriented computer language, CLOS (Common Lisp Object System).

In this paper, we describe the contents of distributed automatic construction planning system, and the result of applying this system to a relatively high office building.

1. Introduction

In the construction industry, it is common to assign large number of labors when constructing buildings. However, because it is expected to experience the labor shortage in the future, the next generation construction system, which works as efficient as the manufacturing industry, has to be developed.

In this paper, we will introduce the intelligent construction planning system, which automatically produce the detailed construction plan.

2. The next generation integrated information system for Architectural Production

2.1 Problems in the construction industry

Currently, the experiment architect engineers create the construction plan for each phase. As shown in Fig.1, the information flow is one-way; from the design phase to the construction phase. Because no feedback such as the optimized material partition plan is required from the construction phase back to the design phase, a productivity is low. At the beginning of the construction, there remain some ambiguities in drawings and specifications; the design phase is done simultaneously with the construction phase.

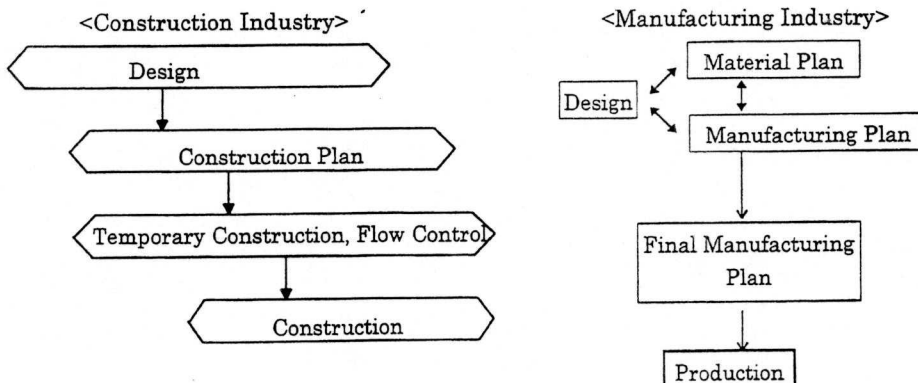


Fig-1 The difference of the production system between the construction industry and the manufacturing industry.

On the contrast, it is common, in the manufacturing industry, to be cost effective, by production planning, which concludes the standardization of the materials, better line designs in the factories, and cost analysis.

Currently construction companies have been developing the automated construction systems, aiming at the level of efficiency as with the manufacturing industry.

2.2 Problems in the construction industry

As shown in Fig 2, in the construction industry, the unnecessary amount of labors are used as not enough time is spent for the evaluation in the design phase.

In the future, the intelligent construction system will be necessary. This system will help us establish the construction plans in the early stage of the planning, including the optimized materials and labor assignments. Therefore the quick feedback from the construction phase back to the design phase will be possible. Furthermore, at the construction site, the real-time intelligent system should be able to monitor and judge the construction phase, based on the actual achievements. These two systems should be integrated together by sharing the same project database.

3. Distributed automatic construction planning system

3.1 Target area for the research

The concept of an intelligent construction system is shown in Fig.3. The problems of the current systems are 1) a data entry for each system takes up lots of time, 2) difficult to determine the best sequence and the best route to transform the materials.

These problems lead us to develop the new system, which uses the modeling technology and the optimization technology for each planning stage, during the preliminary planning phase when CAD data is not available. The construction planning manager still evaluate the basic construction method, while this system keeps simulating the schedules with various parameters. Database has been merged into Project Database, which will be shared among the distributed system.

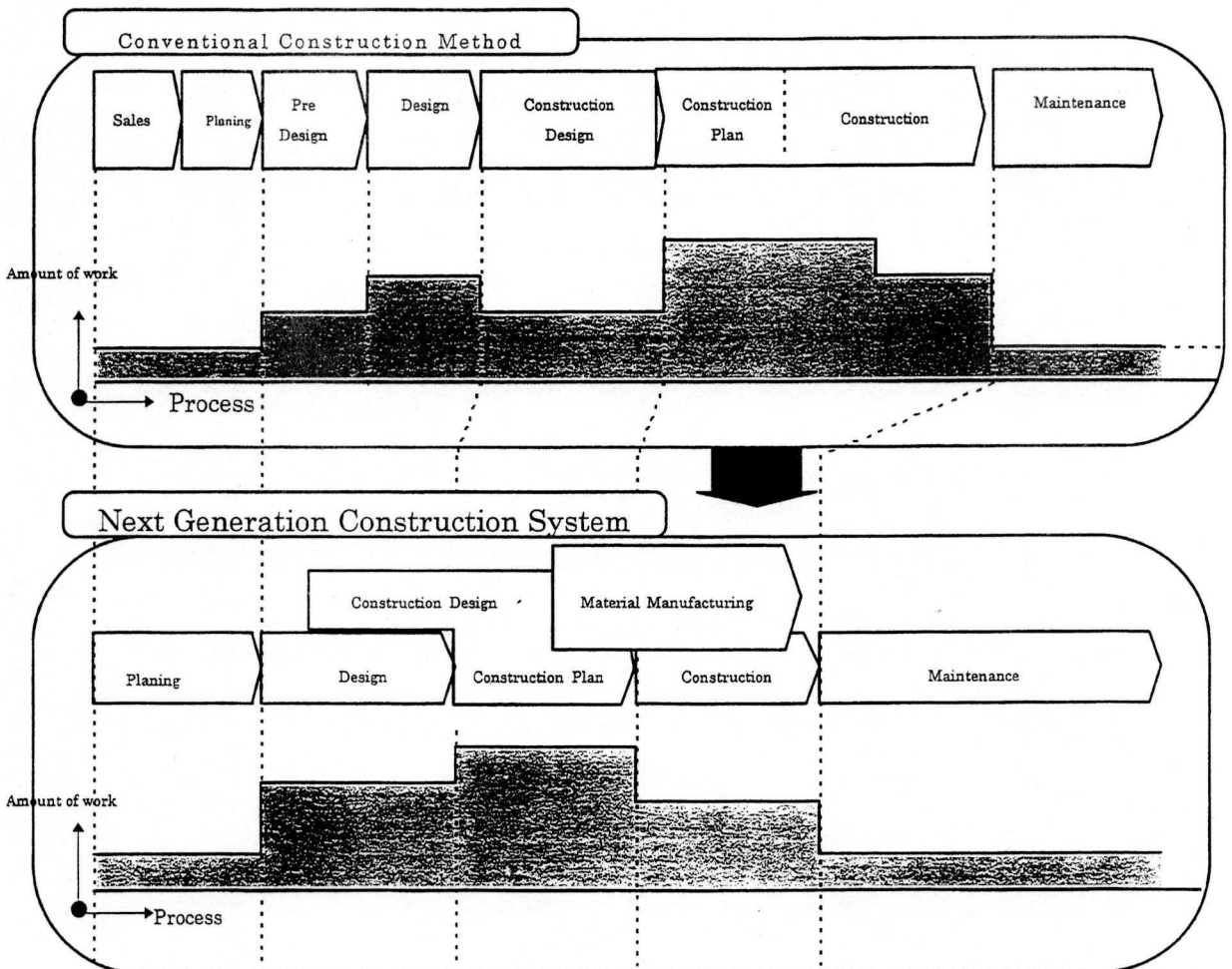


Fig-2 The amount of work required for each process

of the material attachment, the interval of the attachment, and the best work procedure had to be input by an experienced engineer.

Therefore, the dedicated simulation system, which can output the best sequence of the material attachment and the best route for lifting, was developed in 1991. For the future enhancement and the maintenance, CLOS (Common Lisp Object System) was used as the development language.

3.4 System Environment

As shown in Fig 4, when this system was developed in 1991, only SUN Common Lisp ver 4.0 was available as ANSI X3J13 compatible CLOS. Therefore we used the workstation as the system platform. CAD system and Object Database were developed by CLOS, as well.

We kept enhancing the system with the third generation distributed technology. In 1995, we started the next version of the system with the fourth generation distributed technology by JAVA, as shown in Fig 5. This system is easy to maintain. Also various computers can be used as terminals from the network.

3.5 Operation Flow

The system consists of the simulator and four sub-systems; Project Input subsystem, Project Database subsystem, Best Sequence of Material Attachment Determination subsystem, and Result Display subsystem). The operation flow of the system is shown in Fig.6.

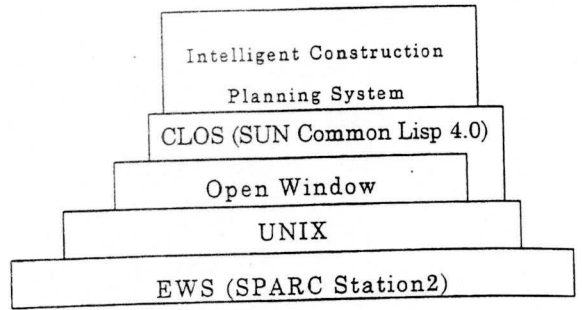


Fig-4 Configuration of the first Generation System

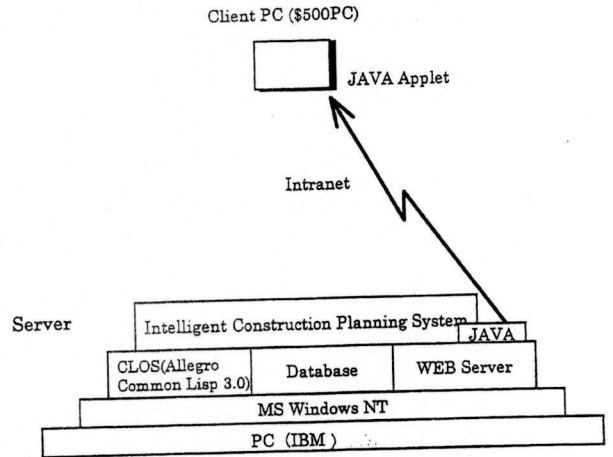


Fig-5 Configuration of the second Generation System

Step1: Based on drawings and specifications, a building model and a temporary work plan are input by

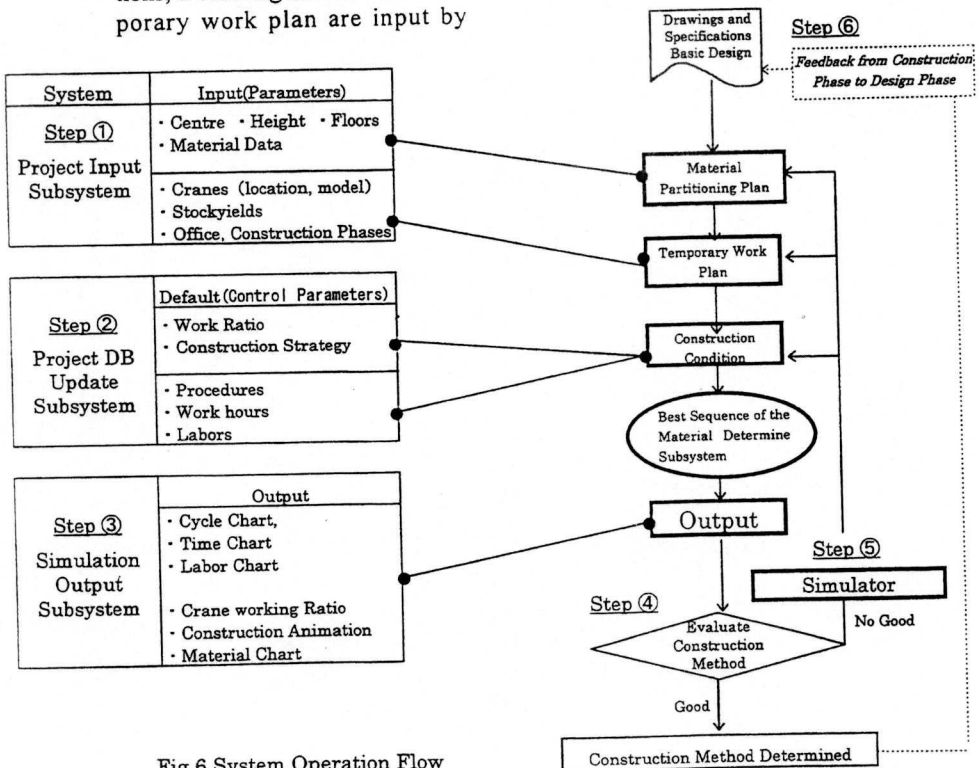


Fig 6 System Operation Flow

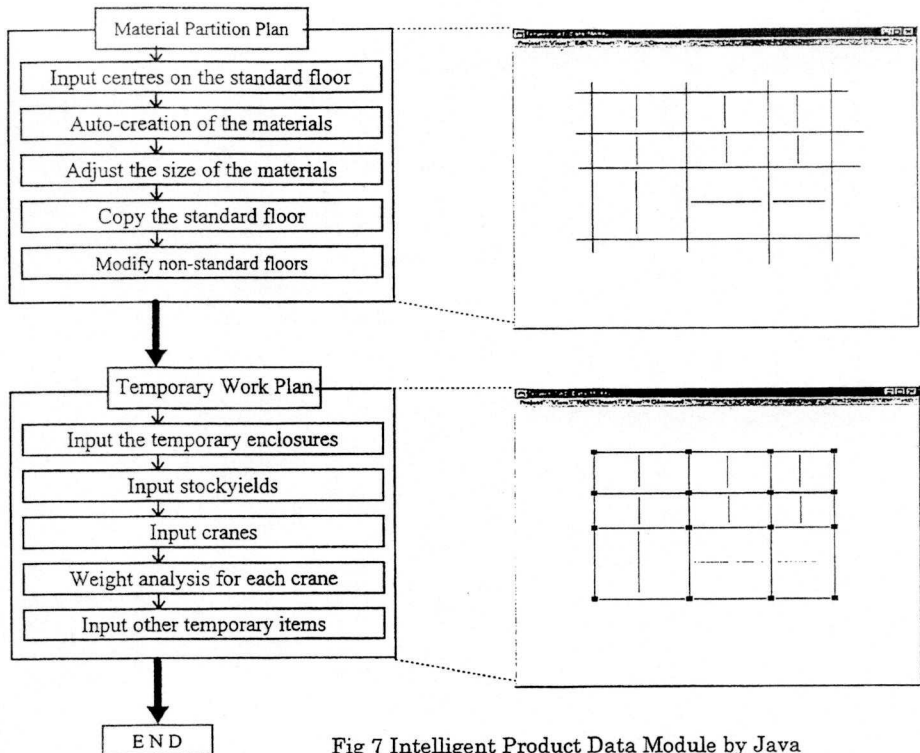


Fig 7 Intelligent Product Data Module by Java

- Step2: Project Input subsystem. Confirm the construction condition (default values of work time, work procedure, number of labor, work ratio, experience, coefficient of variation) and modify them if necessary.
- Step3: Output a cycle schedule, time chart, total schedule, labor chart, operation ratio of the cranes, animation of the construction process, base on the output of the simulator (Inference Engine).
- Step4: Evaluate the output in term of security, cost, analysis, work period, quality.
- Step5: Optimize labor, machines, and materials.
- Step6: Feed back the optimized construction plan to the design.

3.5.1 Project Input subsystem. During the basic design phase (when no CAD data is available), this subsystem enables to input of the material data needed to create a construction plan in a short period and capable to establish the temporary work plan including cranes, stockyards, temporary office, a site. Fig. 7 shows the operation flow of this subsystem.

After drawing the center lines, this subsystem automatically generates three dimensional object data of frameworks such as columns, beams, floors, and facings. The default dimension of each framework is calculated automatically based on the height of the floor, the length of the span, the area of the floor and the common knowledge for a steel frame office building. By changing the attributes

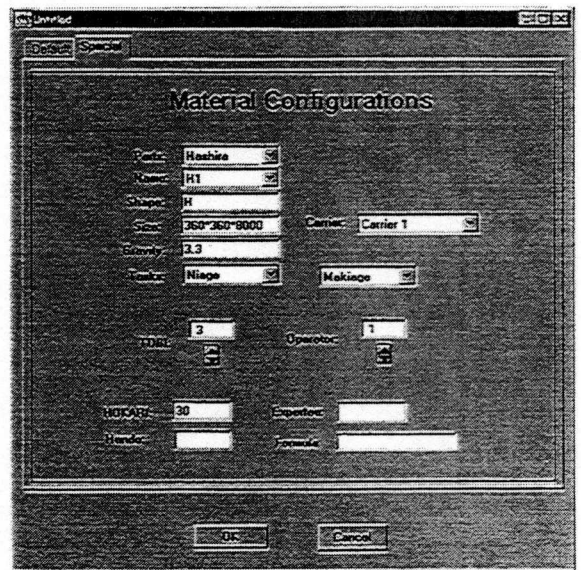


Fig 8 Confirming and Changing Module of Project Database

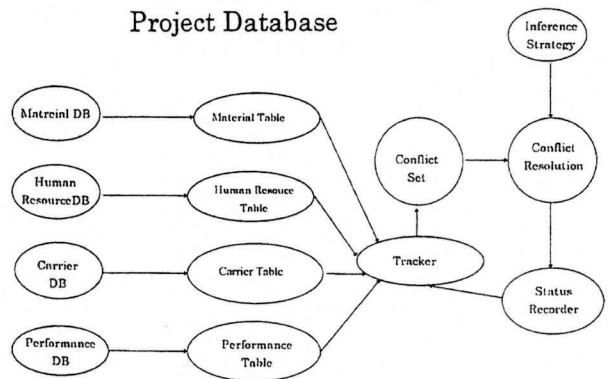


Fig 9 Best Sequence Flow of the Material Attachment Determine Subsystem by CLOS

(dimensions, materials, shapes) of the frameworks, merging, deleting, and moving the frameworks on the referenced floor, the building model necessary for the construction plan can be easily created. Next step is to locate cranes, stockyards, temporary enclosures. A crane object contains attributes such as a work radius, a rated weight capacity, speeds (rolling-up, rolling-down, relief, turning), a location. Therefore based on the weights of frameworks and the locations of cranes and stockyards, the recommended crane model and location can be calculated.

3.5.2 Project Database subsystem. In order to handle various construction methods, all the resources such as materials, cranes, labor, are stored as objects. Among those objects, objects that are influenced by the special limitation can be modified in this subsystem as shown in Fig 8.

3.5.3 Best sequence of the material attachment determine subsystem. The inference flow is shown in Fig.9. Materials, labor, cranes, and performance DB are all pre-compiled for efficiency purpose and all stored in the form of tables. Tracker selects the possible items in each table and creates the conflict set. According to the inference Strategy (knowledge such as "minimize the work period", "materials further from cranes have better priority to be moved", "maximize the performance ratio of each crane), resolve the conflict set, execute the movement and record it to the tracker, and update the conflict set based on the previous actions. This inference is repeated until all the

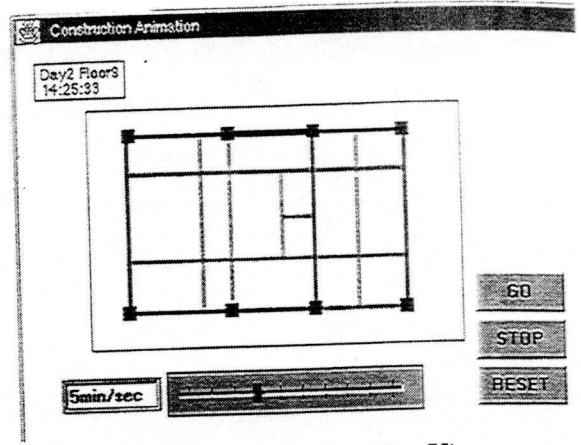


Fig 10 Construction Animation Viewer

conflicts are resolved.

3.5.4 Simulation result display subsystem. This subsystem is to show the overall plan produced by the simulator systematically. The output information consists of the labor, materials, and the schedule of cranes both in hourly and daily basis. Also as shown in Fig.10, the animation of the construction image can be displayed. A specific time during the construction period can be selected.

3.5.5 Simulator. The procedure to obtain the best process plan has been shown so far using subsystems described above. This system optimizes the overall construction plan

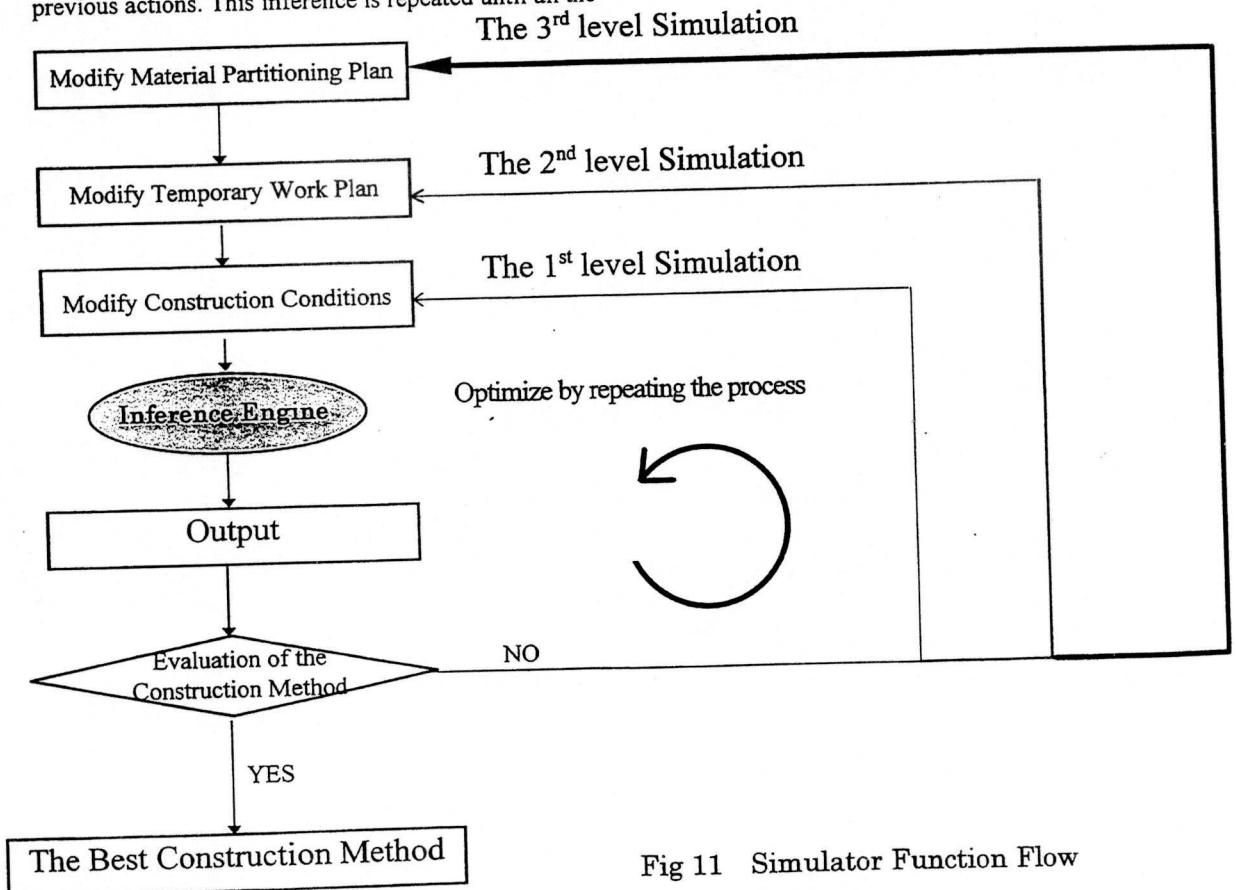


Fig 11 Simulator Function Flow

by means of three level simulations using the Object Database as shown in Fig. 11. The first level simulator is used to optimize labor and work period parameters. The second level simulator is used to modify the temporary plan and the third simulator changes the partitions of the materials.

3.6 Result of the simulation

3.6.1 Specification of the building. This system was used to create the construction plan for D building (S, PCa, 16F, Total floor area: 11,000 Square meters), as shown in Fig. 12.

3.6.2 Simulation of the construction planning. Based on the basic drawings and specifications, the building model was created and the temporary plan was input. On the construction floor, there were two cranes on the ceiling, one vertical crane, one movable crane on the roof floor (for columns erection). 7.5 hours was set as a length of one working day. The default values were used for the number of laborers and their work ratios. As a result, the labor chart, the crane operation ratio, the cycle schedule (6 days) were output, as shown in Fig. 13. The planner then evaluated the output and concluded that he need to:

- 1) average the labor on each day
- 2) shorten one cycle to 5 days, rather than 6 days
- 3) raise the operation ratio of the slide crane
- 4) eliminate idle time.

By the first level simulator, the limitation of the number of labor and the work length of the day were modified. As a result, the new output shown one cycle as 5 days and the labor schedules were averaged by means of the automatic optimization. Furthermore, by the second level simulator, the rolling-up speed was modified from 30m/s to 40m/s, in order to raise the operation ratio of the slide crane and to eliminate idle time. The new output from the second level simulator showed that the operation ratio of the slide crane became higher and there was less idle time with the cycle schedule being the same (5 days).

3.6.3 Result of the simulation. Only 15 minutes was used to input the building model in the system, another 25 minutes was used by the system for simulation. Modifying the parameters by the first and second level simulators took approximately 33 minutes. An architectural engineer with 5 year experience tried to create the same construction plan without this system. It took him 5 hours to create the construction plan, another 4 hours to output the construction table, the labor chart, the material chart and the operation ratio of the cranes, which were NOT optimized. Therefore, the system reduced the labor force by 90%.

4. Conclusion

We have discussed the idea of the next generation integrated information system for the construction industry. As a research for this new system, we have developed the intelligent construction planning system using JAVA and CLOS, and confirmed the efficiency of the system.

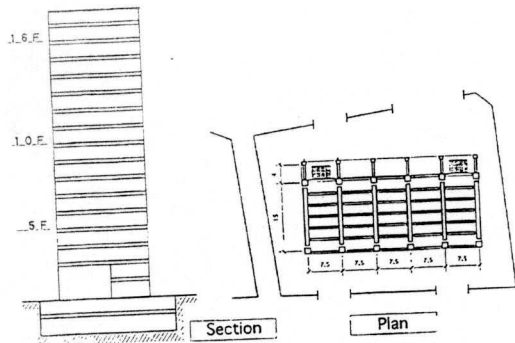


Fig 12 The Building applied System

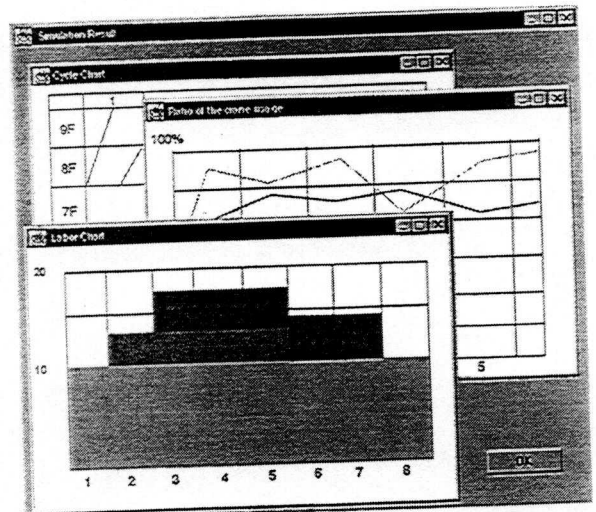


Fig 13 Simulation Result Output Example

For the future, we would like to develop the construction monitoring system, and the support system for the design.

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