A 3 2

Integrated Design and Construction Planning System for Computer Integrated Construction

by

Yusuke Yamazaki

Manager
Technology Division
Shimizu Corporation
No. 15-33, Shibaura 4-Chome, Minato-ku
Tokyo 108, Japan

ABSTRACT

One of the current challenges in the field of building construction is integration of the design and construction processes. Since building construction involves cooperation of numerous designers, engineers, and project managers, a comprehensive organizational planning and management tool is required. The main objective of this paper is to describe an approach to establish Computer Integrated Construction for improvement of planning and management productivity, and propose an integrated design/construction planning system which provides an interactive cooperation between design, engineering, and construction. This paper presents the results of research on several issues such as: representation and organization of planning processes, management of information, knowledge and constraints, and hierarchical network of object-models which represent a building space model, building system models, construction method models, construction activity models, and construction site layout models. Applications of hierarchically networked object-models to representation of interactive planning processes between design and construction in several planning stages will be presented. Also future research issues to be explored will be described.

. Introduction

Recent improvements in computer technologies in such areas as: Artificial intelligence, database systems, and network systems have expanded the spectrum of potential applications. One of the remarkable computer applications in the field of manufacturing industry is Computer Integrated Manufacturing, which also affects construction industry to attain higher productivity as Computer Integrated Construction.

However, several factors unique to the construction industry have restricted the application of such innovative computer methods. Among these factors are the lower volumes of mass production and the larger-scale products of building elements in construction than manufacturing, complex and variety of construction conditions, and overlapping of the product design and construction phases in many projects.

Since building construction involves cooperation of designers, engineers, general contractors, sub-contractors, manufacturers and suppliers, a comprehensive organizational planning and management system, and common data representation schema are important. Failure to dedicate sufficient communication between designs, engineering and construction planning, and inadequate project monitoring and evaluation all work to the detriment of productivity, incurring heavy losses at the company level.

2. Background and Current Status

In the past several years, traditional building construction has changed due to complexities in and the variety of building systems, construction methods, and planning methodologies. As the constructed facility approaches higher levels of sophistication, the need to innovate organizational and technological background of building construction has also arisen. Three areas have been identified as requiring either further development (cases a, and b) or more rigorous implementation (case c). These areas are: a) cooperative investigation into issues of constructability throughout the planning and management stages; b) to improve productivity, conversion to more flexible designs, engineering, and construction organization; and c) overall strategic and interactive decision-making for company-wide construction planning and management.

3. Goals in Building Construction

The following subjects were investigated and analyzed in advance to establish a framework for research and development of an integrated design/construction planning system: the types of building systems, construction methods, equipment (machinery and robots), and computer applications utilized to improve labor productivity at the construction site. Consequently, three major problems with the current system were identified: 1) Basic information and knowledge about construction technologies is not shared between designers and constructors; 2) Interactive procedures at the early design stages to apply building systems and construction methods have not yet been developed; and 3) No systematic evaluation and feedback of relevant data an information from construction sites is prevalent [Yamazaki 86].

Three solutions were proposed to solve these problems: I) Design and develop well-structured data-and-knowledge based systems for building systems and construction methods; II) Build a system for planners to allow them to study and check building systems and construction methods for a project at the various planning stages; III) Establish a system for feeding-back actual construction data to consistent and flexible project and production information system databases.

Therefore, Computer Integrated Construction should first be addressed on improvement of designing, planning and management productivity rather than of labor productivity of construction process at site.

4. Concept of Design and Construction Integration

Computer Integrated Construction is composed of design and engineering system, construction planning and management system, and construction system, including building systems, construction methods, and facilities(robots and machinery), which are adopted to construction automation. Consistent and flexible databases which store design and engineering information, planning and management information, manufacturing information, transportation information, and production information, with conditions and constrains which draw the conclusions, are required to connect each components effectively. Also common data and knowledge representation schema for product modeling (building space model, building element etc.) and process modeling (design, construction planning, construction etc.) should be established to exchange information between different functions efficiently.

In building construction, major interface between design and construction is an interactive planning process between building system and construction methods, which also produces construction activities and site layout, reviewing conditions and constraints. This interaction is extended conceptual planning phase to precise planning phase shown in Figure 1, and should be focused as one of key concept for Computer Integrated Construction.

To make optimal use of building systems and methods, early participation of the construction engineers in the design phase, even in the preliminary design stage, is necessary. The integrated investigation by designers, engineers and project managers at the early planning stage improves productivity at the construction stage and reduces construction cost through the better utilization of building systems, construction methods and the resources available at the construction period. This cooperative planning is defined as an integrated construction system planning which incorporates all levels of the project planning process [Yamazaki 87].

. System Architecture for Integrated Planning Process

he process of integrated construction system planning can be nvisioned as a cooperative endeavor undertaken by a team of pecialists. Each specialist is typically knowledgeable about ne particular aspect of the planning process. To explore istributed planning, an object-model [Ueno 86] and blackboard rchitecture are applied to illustrate comprehensive planning.

tegrated construction system planning is consists of building stem planning, construction system planning, construction tivity planning (scheduling), and construction site layout anning. Each planning module is expanded according to progress planning through conceptual (initial) stage, fundamental ntermediate) stage, and practical stage. This procedure is scribed in planning procedural knowledge module. Since these anning modules relate and communicate interactively each other, ly a subsystem cannot draw the optimum planning [Yamazaki 90].

To realize the requirements for an integrated design/construction planning system, the functions in such as planning procedural knowledge module and constraints management module, and databases such as production database and construction system database must be thus structured and represented as shown in Figure 2.

6. Data and Knowledge Representation

Two types of data and knowledge were acquired and implemented. First type depends on purpose and is acquired through the following analysis: a) Classification of characteristics between building systems and construction methods; b) Technology availability as determined by constraints and characteristics; c) Strategic knowledge and procedures implemented to manage constraints to solve problems efficiently. The Knowledge was implemented in construction system database, also the actual results of projects were stored in production database.

The other type depends on the domain and is structured as follows: a) Hierarchical network of objects which represent a building space model, building system models, construction method models, construction activity models, site layout models and resources; b) User defined relations which represent connections between elements and components, resource availability and sequence of activities; c) Methods or attached procedures which control the information between objects; and d) The structured object-model can be more available through consistent planning stages and can be modified without special operations when a linked object-model is changed [Yamazaki 88].

7. Object-model Applications to Integrated Construction Planning

Applications of object-model are implemented in two major stages: master scheduling at conceptual planning stage and construction method selection at fundamental planning stage.

Project scheduling at the schematic design stage is very important as it allows for the optimal efficient use of resources, which include not only labor, equipment, building components and materials, but also technologies acquired and developed to improve productivity in the construction process.

Master scheduling is to be performed under uncertainty due to the insufficient information of design and construction planning, so that many assumptions such as building system, construction methods and available resources have to be set up efficiently. Therefore, management of constraints are required to perform an interactive planning between design and construction since early planning stage through the best use of constructability knowledge.

Also construction method selection is defined to be an activity which produces the best combination of building systems, construction methods, and major temporary equipment (crane and scaffolding) with design specifications and construction conditions, hierarchical assumptions are thus setting up.

The building system model was expanded to a set of building elements representative of a typical floor or foundation. The construction activity model was expanded to a set of work package level activities such as formwork, steel work, and concrete work.

When a block or a grid reflecting the building size, amount of required labor and machinery and duration is set up, interactive planning between building elements and construction methods can be performed by comparing the given conditions or assumptions with the characteristics of construction methods. This process influences design specifications, such as connection of building components and standardization of building elements, especially when automated construction system is applied.

. Conclusions

To effectively realize Computer Integrated Construction, an integrated design and construction planning system is important. Representation and organization of planning processes using hierarchical networked object-models were efficiently applied. Further research issues such as: a) more efficient methodology of constraints management [Logcher 89]; b) planning technique to utilize actual results of projects by case-based reasoning method; and c) hierarchical management of KBs and DBs which store information, standards, and functions of building systems and construction methods are necessary for improving cooperative planning and management productivity between design and construction.

. REFERENCES

Logcher 89] Logcher, R., "Knowledge-Based System Applications in Engineering and Design : Research at MIT", AI magazine, Vol.10, No.3.

Ueno 86] Ueno, H., "A Knowledge Representation based on the Concept of an Object Model", IEICE, 1986.

Yamazaki 86] Yamazaki,Y., and Uchiyama, Y., "Development of construction method selection system", 2nd symposium on organization and management of building construction, AIJ, Tokyo, 1986.

Yamazaki 87] Yamazaki, Y, Ito, K., and Terada, N. "An expert system for construction technology selection", Part 1, 3rd symposium on organization and management of building construction, AIJ, Tokyo, 1987.

Yamazaki 88] Yamazaki, Y., Ito, K., and Terada, N., "An expert system for construction technology selection", Part 2, 4th symposium on organization and management of building construction, AIJ, Tokyo, 1988.

Yamazaki 90] Yamazaki, Y., Tokuda, H., Akimoto, M., Honda, S., and Terada, N., "Application of object-models to integrated construction system planning", 6th symposium on organization and management of building construction, AIJ, Tokyo, 1990.

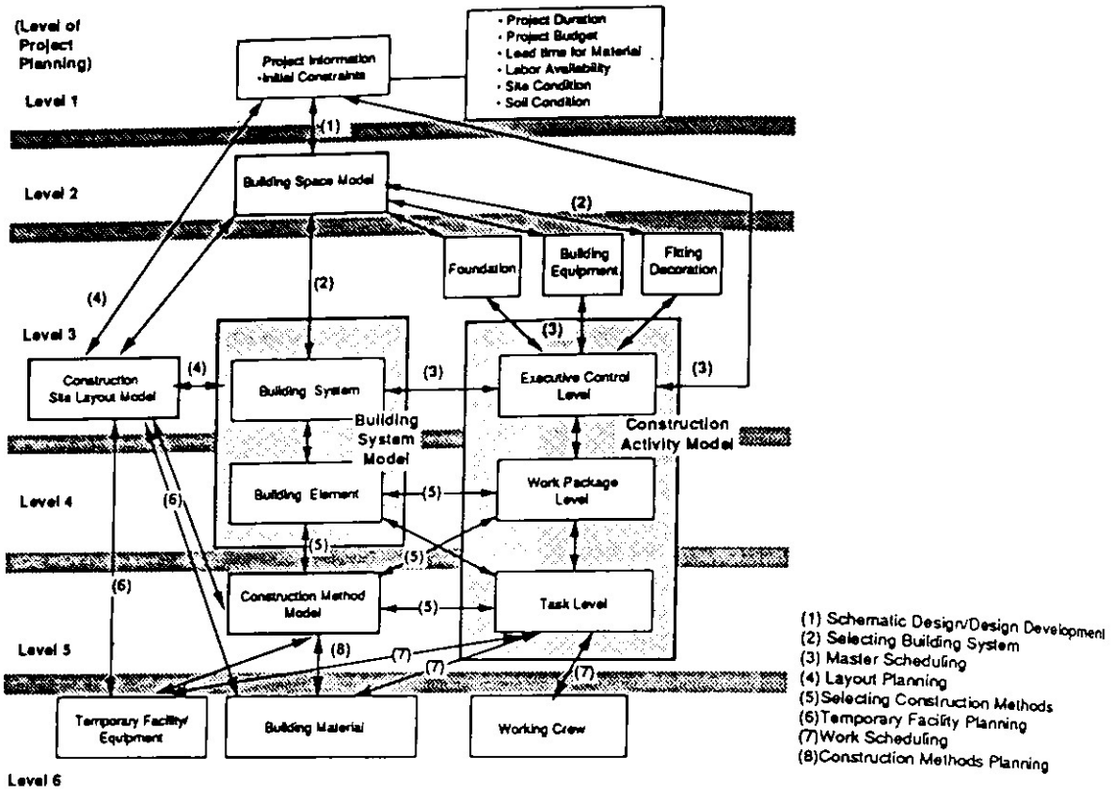

Figure 1 Object model hierarchy for integrated construction planning

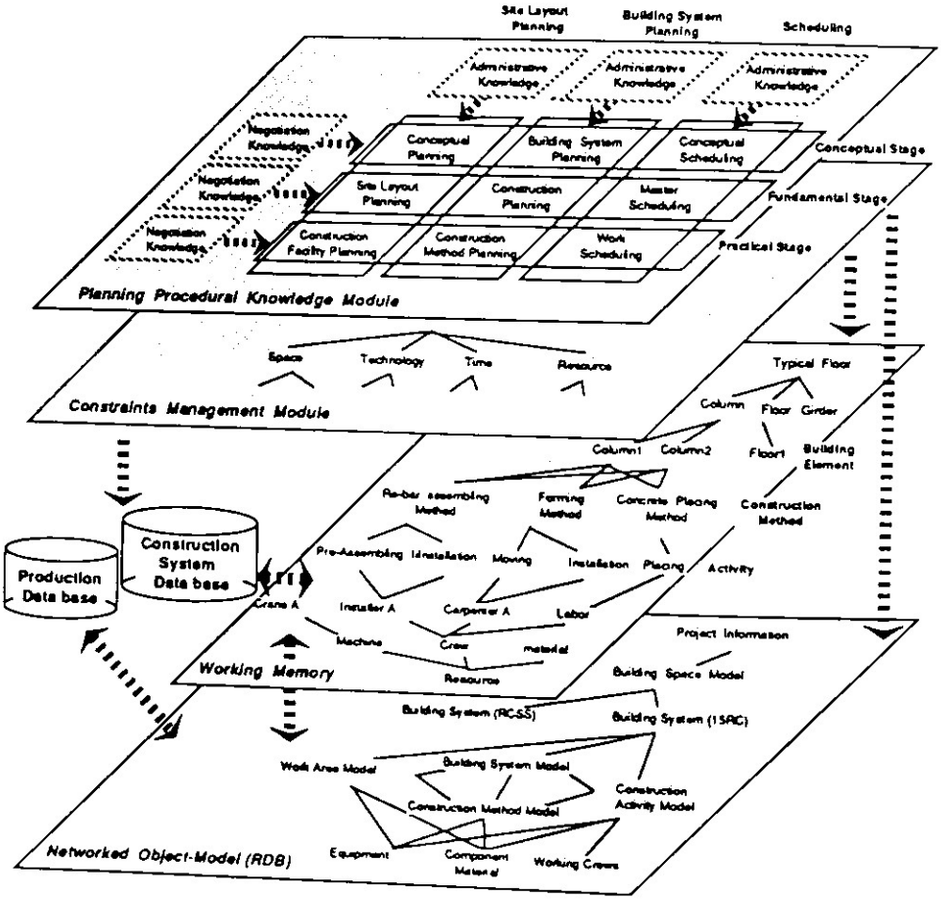

Figure 2 SYSTEM ARCHITECTURE