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On Computer Aided Project Design, Planning and Management

Conception, projet et gestion assistées par ordinateur

Projektierung, Planung und Management von Bauwerken mit Computern

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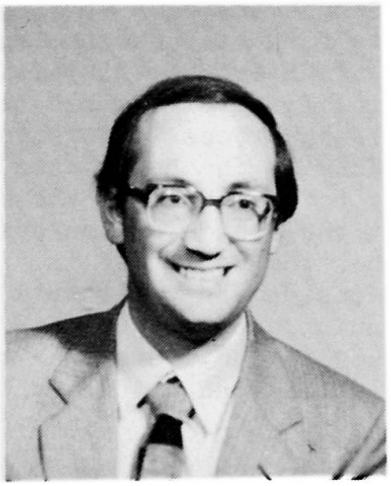

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SUMMARY
The procedure for the design of a project by a contractor is briefly described. Basic facts about an integrated computer system consisting of a CAD subsystem linked directly to a subsystem for planning and management of projects are given. The significant features of both subsystems are indicated. Main principles of a new network analysis method and its functions in the system are emphasized. Procedures for using databases and data transfers to on-site computers are mentioned. Further perspectives in developing an integrated expert CAD/CAM system are summarized.

RÉSUMÉ
La méthode de projet utilisée par un entrepreneur est passée brièvement en revue. Des données fondamentales sont rappelées pour un système intégré d'ordinateur composé d'un sous-système de conception aidée par ordinateur relié directement à un sous-système pour le calcul du projet et la gestion de la réalisation. Les éléments essentiels des deux sous-systèmes sont présentés. Les principes généraux d'une nouvelle méthode d'analyse de réseaux et ses fonctions dans le système sont présentés. L'article mentionne des procédés d'utilisation de bases de données et de transferts de données sur des ordinateurs de chantiers. De nouvelles perspectives dans le développement de systèmes experts pour la conception et la fabrication aidées par ordinateur sont présentées.

ZUSAMMENFASSUNG
Das Verfahren der Projektierung der Bauten durch einen Unternehmer wird kurz beschrieben. Die Grundprinzipien des integrierten Computersystems, das aus CAD Subsystemen besteht und direkt mit dem System für Planung und Management der Bauten verbunden ist, werden angegeben. Die Hauptprinzipen einer neuen Netzplanungmethode und ihre Funktion im System werden hervorgehoben. Die Vorgehensweise bei der Verwendung der Databasen und der Datenübertragung zu den Computern auf den Baustellen werden beschrieben. Weitere Perspektiven der Entwicklung das integrierten Expert-CAD-Systems werden zusammengefasst.

1. INTRODUCTION

When new structures are to be build it is necessary to visualize all the operations of the building process of the structure, arrange these operations in their proper sequence and achieve confidence that every participant of the building process, that means the investor, the architect and the contractor understand each of his tasks. Thus all projects have to be efficiently designed, planned and their building process has to be managed in optimum way.

For applying computers in all of these phases in Czechoslovak conditions an attempt to create an integrated computer aided project design, planning and management system has been made in Průmstav Prague, one of the biggest Czech contractors, recently. This firm has been chosen by the Ministry of Building Industry as a participant of an experiment that has to verify the possibilities of shortening and simplifying of the project design stage and of its direct linkage to the building process management with the help of computers. The project design phase done by the contractor who has his own architectural studios in this experiment covers not only the architectural and constructional part of the design but the design of the optimum procedure of production of the project as well. Thus the design of the project has two stages - architectural - constructional design and construction technology design with the direct linkage to the planning and management of the production process of the project. This integrated design system has to pass his outputs, especially those concerned with planning and production to the recent system of management of the firm described shortly in /5/ or /4/.

Because of lack of high quality computer hardware and CAD software in ČSSR the Norwegian firm ICAN of Kongsberg supported by Data Design System of Sandnes was chosen to cooperate in developing of the integrated design system. The Norwegian side offers the main hardware of the system which is a mainframe ND 505 minicomputer linked with working stations based on Datagraph PC AT microcomputers equipped with two displays (1 traditional and 1 colour graphic monitor with high screen resolution), a digitizer, matrix printer and plotter. The Norwegian firms afford also the main CAD software for the architecture - construtional phase of the design process. This software consists of the complete 3 D model of the building and enables to create a bill of quantity file automatically. This is the main linkage to the software for the construction technology design, budgeting, cost estimations and quantity surveying that has been developed by our Research and Development Establishment and by Průmstav Prague computer centre. Both software packages use input and feedback data bases. The outputs of the system are passed from the design establishment directly to the production establishments of the firm, the architectural part as drawings, the construction technology part either in computer printouts and drawings or on a floppy disc suitable for an 8 bit microcomputer of the Czechoslovak production which is at the disposal on larger building sites or in technical groups of the production establishments of Průmstav. This part is then used for the direct management of the production process of the project by updating and optimizing the course of construction processes and balancing costs and other significant resources flow.

2. BRIEF DESCRIPTION OF THE ARCHITECTURE-CONSTRUCTIONAL CAD SUBSYSTEM

The Data Design System, a separate company within Block Watne a/s, Norway's biggest housebuilder, has developed a sophisticated CAD software suitable for IBM PC compatible microcomputers, see /8/. This system includes a powerful General Draughting Program (GDP) and a series of application user oriented programs that have been adjusted according to conditions and requirements of Průmstav Prague for the need of an architect or a civil engineer.
The system has a "ghost drawing" feature that permits previously completed

drawings to be called up and important elements recorded. These elements can be freely referred to when creating a new drawing. The system maintains a continuous record of information about all rooms contained within the building. A "room table" can be called up and printed on the drawing in any position, giving a complete overview of all rooms in the building, including dimensional and other details.

The "genetic code" used in the general draughting program fully documents a 3-dimensional model of a building. Thank to this feature the system permits to create automatically a file of volumes of products used in the building that links the system directly with programs for bill of quantity calculation. Thus the system can be easily linked to existing programs for specification, cost control, planning, construction technology design and production management.

The GDP enables the establishment of libraries of standart components or details, corresponding to the actual production. The symbol libraries are usually kept in two detail levels according to scales and in 2 and 3 D. Libraries include components like doors, windows, wall panels, fittings etc. and are based on a database system. The stored data include not only graphical information but the technical - economical information, e. g. labour consumption, materials and their volume, prices, costs, etc., too.

The function for scaling, zooming, panning and the free rotation possibility around any three dimension axis are at user's disposal too. The GDP has good facilities to complete drawings, e. g. texting, area calculation, automatic or manual dimensioning etc. Hidden lines can be removed and shading can be performed according to a free position of the sun point. After generating the ground plan of the building the automatic production of cross-sections, elevations and perspective views is possible.

The general draughting program is complemented by application modules designed specially with respect of needs and requirements of architects and civil engineers. These modules have been adapted for special conditions of Průmstav Praha. They are oriented especially for module house design. They consist of the house, floor and wall panels program (HFW), heating, ventilation, air-conditioning schematics and installation program (HVSI), electrical schematics and installation program (ELSI), terrain program (TER), excavation program (EXC), foundation and basement program (FUB), concrete reinforcement program (CRE), hidden line and shading program (HLS) and bill of quantity main module (BQ).

All programs are written in FORTRAN 77 language and work under the MS DOS operating system. They require 540 kB of operating storage and a screen with minimum recommended resolution of 640 x 400 pixels. The inputs to the system are entered via flat menu , hierarchic menu , digitizer menu , alphanumeric menu , function keys, pen or mouse or a bar code reader.

3. BRIEF DESCRIPTION OF THE CONSTRUCTION TECHNOLOGY CAD SUBSYSTEM

3.1 Methodology of construction technology design

Basic documents in construction technology designs include files of planning cards (at the level of construction technology conceptual designs), files of technological standarts (at the level of construction technology operational designs). In both types of construction technology designs network diagrams are used which are closely linked with the quoted documents and permit to elaborate bar charts, line-of-production graphs and resource allocation graphs. The simultaneous elaborating of technological standarts and network diagrams is necessary for the construction technology CAD system, see /4/, /6/, as it

precludes the processing of network diagrams without previous construction technology analysis and synthesis.

The technological standart determines the technological structure of the production process (sequence of construction processes, volume of production, labour and costs consumption, number and profession of workers etc.). It usually includes a bar chart which indicates the time structure of the production process; a technological diagram showing the spatial structure of the process is usually added. The construction technology design includes the quality assurance checklist which consists of instructions for the quality control of the resulting product at every significant construction process.

According to the duration of the processes, which is calculated according to the automated bill of quantities, number of workers and time standarts, and the minimum working space necessary it is possible to determine with regard to the directions of the course of processes the critical approximation of the processes and to link such processes immediately in optimum way in the network diagram.

3.2 Basic principles of the CONTEC network analysis method

For the mentioned subsystem a new construction technology (CONTEC) network analysis method was developed in our establishment. It is determined for simultaneous processing of technological standarts and network diagrams and for the optimization of linking the construction processes from the point of view of maximum use of minimu working space on site, /3/.

The CONTEC network analysis method uses the activity-on-node network diagram and it follows the precedence graph method. All four types of links introduced in the precedence graph method (finish - start, start - start, critical approach and finish - finish), see /1/, /7/, are included in the CONTEC method too. The main disadvantage of the precedence graph method is the necessity to know the actual values of lag times between every two activities that are linked while createing the network diagram. To exclude errors by usein the start - start link one has to know the durations of linked activities in advance before the network diagram is computed. This would make the concurrent computation of technological standart where activity durations are computed and of the network diagram where the terms of start and finish of activities are determined, impossible.

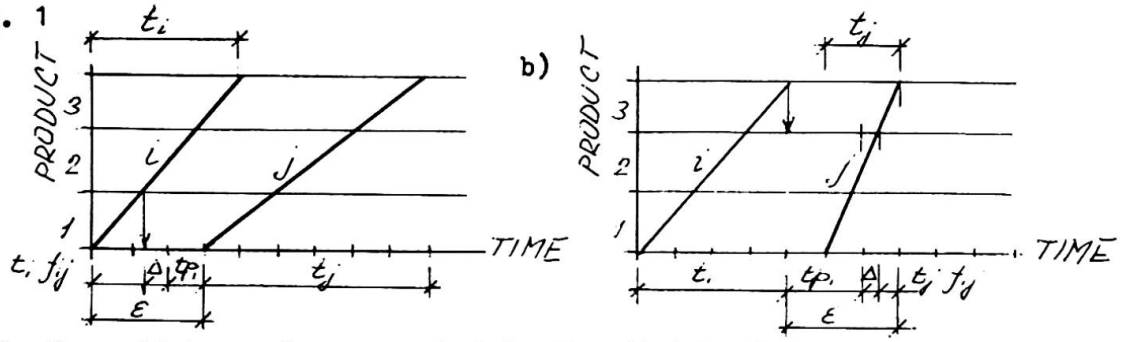
Therefore the CONTEC network analysis method introduces the 5th type of link, the construction technology link, that results from the condition of release of minimum working space on a structure by the previous work gang so that the following work gang could start their work as soon as possible. The lag time is not given by an actual time value but it is calculated according to the durations of linked activities and to the spacial structure of the building represented by a working space index f. This index is determined by the ratio of the minimum working space needed for the gang to the total working space in a building, e. g. in a 8storey block of flats the usual minimum working space are 2 storeys, so the working space index is 2/8, this is 25 %.

The situation of linking two activities i and j is illustrated in the line-of-production graph on fig. 1 a, b. Values t_i and t_j represent the duration of those activities, tp_i the technological pause after completing the i activity, f_{ij} is the working space index. In the first case (fig. 1 a) if the first activity i is shorter, that means $t_i \leq t_j$, the construction technology link can be transfered to the start - start link and the lag time ε can be automatically calculated according to formula (1). In the second case (fig. 1 b) if the

$$\varepsilon = t_i \cdot f_{ij} + tp_i + \Delta \qquad (1)$$

following activity j is shorter, that means $t_i > t_j$, then the construction

Fig. 1



technology link can be converted to the finish-finish link and the lag time ε can be calculated according to formula (2). The Δ value rounds the lag ti-

$$\varepsilon = t_j \cdot f_{ij} + tp_i + \Delta \qquad (2)$$

mes up so that the work gang j would start their work at a certain time unit in the morning.

Next the CONTEC network analysis method introduces the 6th type of link - the flow link that results from the condition of continuous course of a construction process on different products, e. g. sections, buildings etc. The situation is illustrated on fig. 2. Using the flow method of building a stage activity i with the duration of t_i and the time of launching T_i' works at the product 1 and proceeds continuously to the product 2 as the activity j. This can have ist duration of t_j and because of different spacial structure of product 2 its time of launching T_j' can be different of T_i'. Then the flow link can be automatically converted to the finish - start relationship and its lag time ε can be calculated according to formula (3).

$$\varepsilon = - T_i' \qquad (3)$$

Introducing these links in the CONTEC method means not only a significant simplification of inputing the data about the network diagram but it permits a wide utilization of typical network diagrams for certain sorts of buildings and their modification according to the spacial structure of the actual building. Usually only three types of construction technology links are sufficient to evaluate all technological constraints in the building process. In the typical network diagram the values of the working space indices can be stated parametrically, e. g. as 0, -1, -2. While inputing data about the actual building the typical network diagram can be automatically modified by the system only by stating the concrete values of these 3 working space indices.

Using the flow link modified typical network diagrams can be automatically linked into a greater network that may represent the building process e. g. of the whole housing estate. In this case the flow links are generated by the system at activities that are performed by special work gangs that proceed from one building to another.

The CONTEC network diagrams can be calculated on the deterministic or stochastic bases.

3.3 USING CONTEC METHOD FOR PROJECT PLANNING AND MANAGEMENT

The principles of CONTEC method assure a significant simplification of data input while creating the network diagram of a new project. The direct connection with the architecture - constructional CAD subsystem via the bill of quantities file enables after certain aggregations to put in the data about volumes of production and costs for all activities automatically. The resource leveling option based on methods mentioned in /1/ is included in the subsystem. The main out-

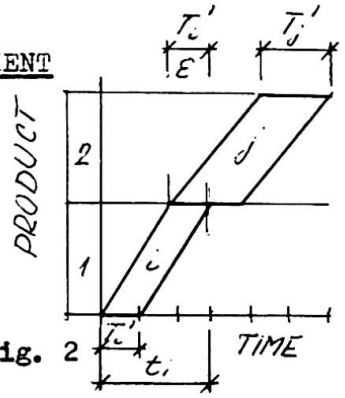


Fig. 2

puts of the CONTEC subsystem are: technological standart, network graph, bar-chart, line-of-production graph, resource allocation graphs and quality assurance checklist. Simultaneously, cost estimations and budgets can be calculated according to the bill of quantity file by other programs.

All programs of the CONTEC system are written in TURBO PASCAL language and work in connection with the architecture-constructional CAD subsystem on the IBM PC compatible computers under MS DOS operating system. The CONTEC itself can be used on 8 bit microcomputers under the CP/M operating system too. The data are passed to these computers on floppy discs. Thus the system permits simple updating of all documents according to the actual date and percentage of completion of construction processes on site. If there is a delay at the deadline of the project the computer may find where more resources are necessary to shorten them to keep the deadline.

The CONTEC system has been in use for project planning and management on many building sites recently, e. g. Czech National Council, Řepy housing estate, Police headquarters in Prague etc. Due to the optimization the total time of completion was decreased for 5 - 7 %, thus the total costs were dedreased too.

4. CONCLUSIONS

The first integrated system for the design, planning and management of projects in ČSSR was assembled as stated. This system practically follows the complete design and management chain: architect, civil engineer, contractor, supplier. Průmstav Prague is now at the beginning of utilizing the system. The first experiences gained are positive. But themes for further development occur. In the next future the system will be complemented by programs for static calculations, heat and energy loss calculations, new technologies of foundations calculations, optimum design of means of production in mechanized construction processes /3/ and programs for production program balance.

Thus, step by step an integrated expert CAD/CAM system for the structure design, planning and management of projects will be created. One can not count on that it will solve all problems in Czechoslovak civil engineering overnight, but it will surely bring a lot of progress for extending the total building production, shortening the terms of building and time, labour and energy savings and it will lead to higher standart of Czechoslovak structures.

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