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## Planning, Management and Quality Assurance in Civil Engineering

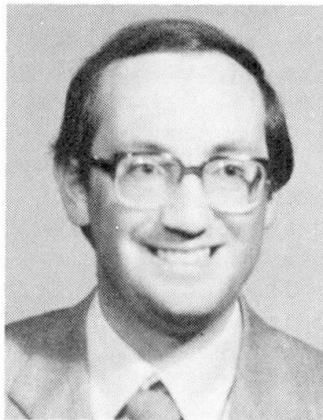
Concept, gestion et assurance de la qualité dans le génie civil

Planung, Leitung und Qualitätssicherung im Bauwesen

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### SUMMARY

The system of management in civil engineering in Czechoslovakia is briefly described. Basic facts about contracting and the procedure awarding for contracts in socialist countries are given and the way to improvement is discussed. The main principles of the system of contractor's preparation of building production, which has been developed recently, are determined and the way to apply it in practice is indicated. The functions of subsystems for creating and balancing the production programme of a contractor and that for automatic elaboration of construction technology projects are emphasized.

### RÉSUMÉ

Le système de gestion des constructions en Tchécoslovaquie est passé en revue. Les principes de base de l'adjudication des travaux de construction dans les pays socialistes sont présentés ainsi que leurs possibilités d'amélioration. L'article présente les bases systématiques – développées récemment – de la préparation du travail, ainsi que des applications pratiques. Il souligne l'importance fonctionnelle des sous-systèmes pour la création et l'équilibre des programmes de production de l'entreprise et pour l'établissement automatique des documents de projets de construction.

### ZUSAMMENFASSUNG

Die im Bauingenieurwesen der Tschechoslowakei üblichen Methoden des Managements werden beschrieben. Die in sozialistischen Ländern bei der Vergabe und Vertragsgestaltung angewendeten Grundsätze sowie auch Verbesserungsmöglichkeiten werden vorgestellt. Der Beitrag beschreibt die kürzlich neu entwickelten Prinzipien der Arbeitsvorbereitung und zeigt ihre praktische Anwendung. Schliesslich wird auf die Funktion von Subsystemen für die Entwicklung von Produktionsprogrammen und für die automatische Erstellung von Projektleitungs-Dokumenten eingegangen.



## 1. INTRODUCTION

When new projects have to be undertaken it is necessary to visualize all the operations of the projects, arrange these operations in their proper sequence, achieve confidence that every participant of the building process, that means the investor, the architect and the contractor understand each of his tasks, acquire the know-how and means necessary to perform them and feel convinced that the method thought out for performing all tasks is the most progressive and economical. Thus all projects have to be efficiently planned at the investor's, architect's and contractor's sides. The quality assurance plan is one of the main parts of such a plan.

Especially in socialist countries including Czechoslovakia proper planning and balancing of the building process of all structures plays a vital role because all management of the national economy is based on the state plan. The main sign in socialist economy is the social ownership of all means of production. All enterprises, firms, factories and establishments are owned by the state and their production is thus directed. No private persons are entitled to undertake. Main tasks of all firms including building enterprises are stated in the five year economic plan which is worked out by the State Planning Committee. This committee determinates in global the mass of production of every building firm and the mass of financial means given to different investors (e. g. firms from other branches, national committees etc.). In this process these financial means (the investment capital) of all investors are balanced with regard to the production possibilities of all civil engineering firms. The approved five year plan is updated and defined with more precision every year.

There are lots of differences between the building process management in socialist and capitalist countries. In socialist countries there are standard prices for construction works in building industry as in other branches. The average contractor's firms are usually bigger with approximately 8000 - 9000 employees and those with similar production programme are associated into so called production-economical units what is a sort of a trust. The trust is directed by the general management with the director general as its head. All trusts in building industry are then directed by the Ministry of Civil Engineering.

Global tasks determinated by the state plan for the civil engineering branch are divided by the Ministry to different trusts according to their sort of production and production capacity by stating the global financial volume of total production per time period (5 years, 1 year). The planned financial volume of production of individual enterprises associated in the trust are determined by the general management of the trust according to the size of different firms.

Similar process of dividing financial means for investment appears at the investor's side. The investment capital can be given not only from the state institutions (e. g. State Planning Committee, Ministries and other institutions of the government etc.) but from the means of different other firms gained by their production and profit as well.

Though at the peak level of planning the sum of investment capital is balanced with regards to the production capacity of the civil engineering branch conflicts between claims of individual investors and production possibilities of individual contractors may occur at the level of concrete contracts negotiations. As the volume of investment capital is rather high in Czechoslovakia the investors' requests for construction works is usually higher than the production capacity of a construction firm, especially in structural engineering. Claims and production possibilities have been recently in harmony in transport, bridge and waterwork engineering in Czechoslovakia.

Recently a new method of balancing the production programme, planning and management of constructions with respect to their quality assurance has been developed in our research establishment. The main purpose of the method is to increase the production capacity of the enterprises of our trust and the resulting quality of buildings by improving the utilization of all resources (as manpower, machines, fuel, material and capital) and by simulating and balancing the consumption of those resources in different variants of production programme from the five year plan level in the whole trust, one year plan level in the trust and in the individual enterprises till to the operational level of management of construction processes on sites. According to the method a system of contractor's preparation of building production has been worked out. Some parts of the system are used in practise by now, other parts are still in the research stage.

## 2. PRINCIPLES OF THE SYSTEM OF CONTRACTOR'S PREPARATION OF BUILDING PRODUCTION

The aggregated flow chart of the system is shown on Fig. 1. The system consists of 6 main subsystems: creation of the 3 - 5 year production programme of the contractor, creation and optimization of the 1 - 2 year production programme, automatic elaborating of basic documents of construction technology projects at the level of construction technology studies, construction technology conceptual projects (CTCP) and construction technology operational projects (CTOP) and production control. The main principle of the system is to ensure the optimal process of production of a contractor's firm with respect to certain given conditions that would lead to fulfilment of all tasks of the individual enterprises and of the whole trust.

The system can be divided into three time levels: planning and creating the production programme with respect to investors' intentions and construction technology studies for the period of 3 - 5 years, production programme with respect to more precise investors' requests and construction technology conceptual projects for the period of 1 - 2 years and operational planning and production process control with respect to construction technology operational projects for the period of 3 months to 1 year. Every subsystem on higher time level has significant relationships to subsystems on the lower time level and vice versa. The main feedback comes from the actual course of the production process on site and has a significant influence on time plans of erection of buildings. It must respect casual delays or condition changes that occur on site. This feedback leads to the automatic modification of basic documents of construction technology operational projects, to alteration of the operational plan and helps to find optimum measures to compensate the delays etc.

The main inputs into the system are: investors' intentions at the side of production programme creation, architectural designs and projects at three levels of detail (structural studies, introductory projects and operational structural projects) at the side of construction technology project elaborating. External influences and technological progress have effect especially on the databases of technical and economical indexes that respect the recent data about productivity of labour, prices of construction works, time standards etc. The main output from the system is the technologically realizable five year plan and one year plan that should correspond with plans given by the state authorities.

Practically all operations in the system are to be computerized. Nowadays the computerized subsystem of creating and financial balancing of the production programme comprising awarding works and contracting procedure and subsystems for automatic computerized construction technology designing including elaborating and optimizing technological standards, network diagrams,



line-of-production graphs, bar charts, resource needs diagrams, automatic budgeting and estimating are in full use. Recently new programs for dispatcher's production control and operational filing of the actual state of site production with the relationship to automatic updating of construction technology operational projects have been developed and are in experimental use.

Therefore further parts of this contribution are dedicated to explaining the procedure of contracting and awarding works with the help of the system and to illustrating the automatic creation, optimization and updating of the basic documents of construction technology projects with respect to quality control and assurance and to the actual course of construction processes on site.

### 3. PRODUCTION PROGRAMME CREATION

#### 3.1 General conditions

Contracting or awarding works procedure at a building firm in socialist countries is based on selecting structures and buildings which should be built in the years to come according to the investors' requests, production possibilities of the contractor and the state plan while respecting the significance and priorities of planned structures. The investors' requests are usually higher than the contractor's production capacity. The contractor may then choose works that are advantageous for him but he has to respect the investors' interests given by the state plan. The selected structures create the production programme of the contractor. According to the approved production programme contracts with the investors are drawn up. As prices for construction works are the same at all firms in Czechoslovakia no tendering or bidding as in western countries take place. The process of bidding comes true when exporting investment units abroad. Then the procedure is much the same as in other countries.

In Czechoslovakia there exist a central computerized database of all structures that are to be built in next 5 years or that are being built. Every contractor has his own files of data about his structures which include especially: name and place of the structure, term of planned start and finish of the erection, planned budget costs and planned and actual financial volume of the annual production for all years of erection. This database is updated by all contractors twice a year at the occasion of negotiations between the investors and the contractors when so called contractor - investor relations (CIR) are determined (see Fig. 1) and the production programme is actually created. These negotiations proceed in two stages (CIR1 and CIR2). In the first stage possibilities of building new structures for the next 5 to 3 years are investigated according to investors' requests and free production capacities of the contractor in the coming time period. In the second stage the requested tasks for the coming year are determined more precisely and agreed both by the investor and contractor. The agreement has been made only on the basis of financial volume of the year's production at the contractor's side since. Therefore only financial comparison of the total annual production programme with total production capacity of the firm can be done. So far this balance has not included technological points of view, e. g. number of workers of different crafts, number of different machines available, production possibilities of concrete and panel plants, fuel consumption etc. In most firms the database updating has been done on a big computer after all negotiations were over, that means that in the course of negotiations the contractor's agents have to balance the actual production capacity and the investors' requests "by hand". The number of structures at an average building firm in Czechoslovakia is about 800 - 1200 all of which have to be negotiated.

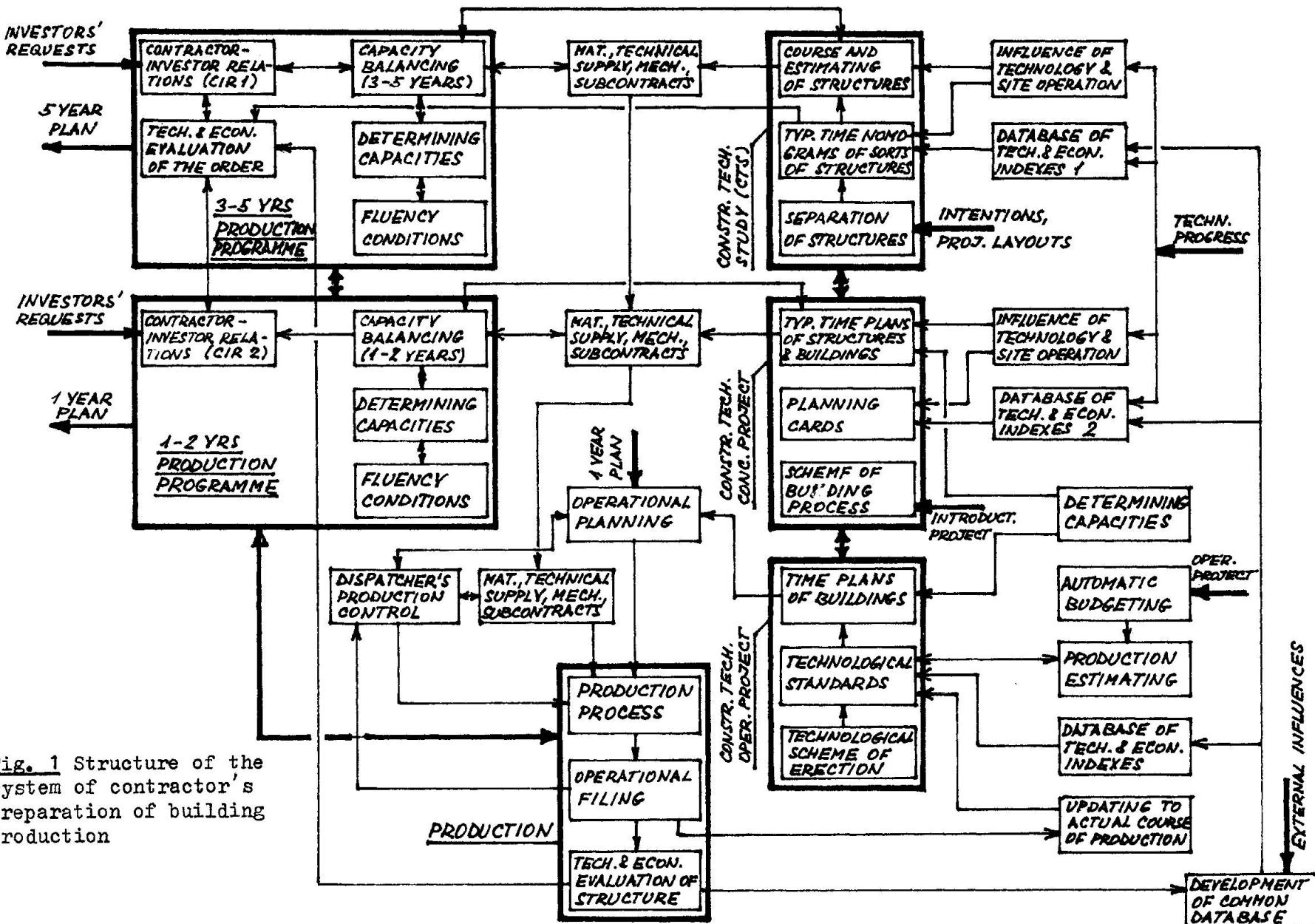


Fig. 1 Structure of the system of contractor's preparation of building production



### 3.2 Improvement of the contracting procedure by the system

The proposed system of contractor's preparation of building production has brought into the contracting procedure two main improvements.

When the contractor - investor negotiations are in progress the data about structures of a building firm are transferred from the central database into a microcomputer. The microcomputer serves to the contractor's agent to updating the financial volumes of production that were agreed in the database continuously in the course of negotiations directly. There is a possibility to balance the total financial volume of the requested production with the actual production capacity of the firm at every moment of negotiations and thus to make corrections necessary for the balance to be in harmony. As stated higher the investors' requests are in most cases higher than the production capacity of the firm. The system helps to find the time interval when the production capacity is free for beginning the construction process. If the 1st stage of this negotiations comes to the agreement the structure requested to be built is put into the database of the production programme, terms of start and finish are stated and the contract is drawn up. The 2nd stage of CIR proceeds in similar way, only the financial volumes for the period of one year are stated more precisely.

If there is a conflict between the request of an investor and the interests of a contractor (e. g. because of overfilled production capacity) it has to be solved at the level of the trust's general management. The agents at this level are entitled to correct the firm's intentions so that the production programme of the entire trust could be in harmony. This procedure based on microcomputers is in full use in our trust now /5/.

The basic principle of the second main improvement of the contracting procedure is in balancing not only financial volume of structures requested by the investors but other technological resources too, e. g. labour force in special crafts, needs of basic sorts of material and fuel etc. When the investor comes to the building firm with his request he naturally does not know anything about the needs of technological resources, he knows usually only the approximate financial cost of the proposed project and some facts about what purpose the complete building should serve to. In order to state the start and finish of the erection of the structure as precisely as possible the contractor should know his production possibilities in the future not only from the financial point of view but especially from the point of view of technological resources in the very first phase of the negotiations. This significant knowledge should comprise all facts about the balance of technological and financial resources in next 5 years for erecting all structures that are being built or are to be built. The proposed subsystem that is now being created should enable to have this view at the contractor's fingertip on the microcomputer.

The subsystem will consist of a database of models of the course of the building process of different sorts of typical buildings and structures that are most common in the production programme of the contractor. It will comprise the typical network diagram of the erection and on that basis it will be possible to simulate the production and to find the moments of starts and finishes of significant construction processes and thus the needs of technological resources in the course of time and to optimize them. These simulated data will be defined with more precision as soon as more precise facts about structures are available, e. g. when architectural projects are ready, or construction technology projects are worked out, or according to the actual course of construction processes on site. Thus it will be possible to find the free production capacity at the earliest possible moment. This would enable to satisfy most contractors at the earliest time.

On the other hand the proposed subsystem will be able to optimize the advance-

ment of specialized work gangs on several building sites, the resource allocation for most significant projects or find the optimum progress of erecting several structures according to the main limited resources at the contractor's disposal by using optimum resource allocation methods and resource leveling procedures described e. g. in /1/, /6/ and /7/. Conditions of the fluency of construction processes, machines available etc. are naturally taken into account. By using this subsystem it will be possible to allocate the main resources in the optimum way in order to fulfil the state plan and the investors' requests and to prepare the conditions for optimum production for all plants and sites of the contractor. Nowadays a lot of typical network diagrams of technological and organizational relationships were compiled according to the Czechoslovak nomenclature of buildings. Next the typical courses of different sorts of structures consisting of several buildings will be created.

#### 4. CONSTRUCTION TECHNOLOGY PROJECTING

##### 4.1 Methodology of elaborating construction technology projects

Basic documents in construction technology projects include files of planning cards (at the level of construction technology conceptual projects), files of technological standards (at the level of construction technology operational projects. In both types of construction technology projects network diagrams are used which are closely linked with the quoted documents and enable to elaborate bar charts, line-of-production graphs and resource allocation graphs.

Hitherto the said documents, on one hand planning cards or technological standards and on the other hand network diagrams were mostly processed subsequently, separately. Their close construction technology relationship was often disregarded and network diagrams which were elaborated without consistent technological analysis and synthesis contained a number of errors which made them useless for construction project control with all consequences thereof regarding economic, time and qualitative losses. The simultaneous elaborating of technological standards, planning cards and network diagrams used in our system /3/, /4/, precludes the processing of network diagrams without technological analysis and synthesis.

The technological standard determines the technological structure of the production process (sequence of construction processes, volume of production, labour and costs consumption, number and specialization of workers or machines etc.). The technological standard 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. It includes the quality assurance checklist which consists of instructions for quality control of the resulting product at every significant construction process.

According to the values of the duration of the processes 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.

Documents mentioned above do not depict floats in construction processes. A network diagram which will follow up on elaborated technological standards must be therefore worked out.

##### 4.2 Automated elaborating of basic documents

The method for automated elaborating of basic documents for preparation of structures is designed for simultaneous processing of planning cards, technological standards and network diagrams. The output includes a single bar chart, a comparative bar chart of the course of construction processes in the original and updated variant of the documentation according to the actual



course of processes on site, line-of-production graph and resource allocation graphs. The BKN (Baukastennetzplanung) method is used for network diagram computation. This method introduces 4 types of relationships between the processes (finish-start, start-start, critical approach and finish-finish /3/) which represent the condition of minimum time gap  $\varepsilon$ . These 4 types were complemented with construction technology relationship, type 5, for automated calculation of the optimum approach of two processes. The network analysis is possible to do on the deterministic or stochastic basis. The proposed method enables a very simple updating of all documents according to the date of updating and percentage of completion of construction processes at this term. If there is a delay at the deadline of completion the structure the computer finds processes where more resources are necessary to shorten them to keep the deadline.

## 5. CONCLUSIONS - PRACTICAL USE

The method of automatic creation of basic documents of construction technology projects is in use for construction process control on many building sites, e. g. Czech National Council in Prague, Trade Unions Hotel in Giant Mountains etc. Due to the optimization of the network diagram from the point of view of the best utilization of the working space on site the total time of completion was decreased for 5 - 7 %, thus the total costs were decreased too, while the resulting quality thank to the checklist on technological standards was higher than on other building sites. The method has been recently linked with the microcomputer system of operational filing and site monitoring that brings automatically the input data for updating time schedules and other documents. It is used for dispatcher's building production control and invoices calculation.

The system of contractor's preparation of building production has been developed in our research establishment with cooperation with building firms of the Structural Engineering Trust Prague. After completing the system there will be a very useful implement for extending the total building production, shortening the terms of building, time, labour and energy savings and quality assurance and control leading to higher quality of Czechoslovak structures.

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