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Principal Investigator: Dr. Daniel W. Halpin

Sponsor: National Science Foundation

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Sponsor Contact Person (s):

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*Proposed project period (12 mos.) ends 4-14-74; all commitments to be met by grant expiration date unless formal extension is obtained in advance

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Project No: E-20-651

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Sponsor: National Science Foundation

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SUMMARY OF COMPLETED PROJECT

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| 1. INSTITUTION AND ADDRESS Georgia Institute of Technology, Atlanta, Georgia | | 2. NSF PROGRAM Office of International Programs - Romania | 3. GRANT PERIOD 15 Apr. 1974 from to 31 Dec. 1976 |
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SUMMARY (Attach list of publications to form)

The objective of this research has been to study the construction environment and construction management systems utilized in Romania for the purpose of implementing simulation techniques as a planning and scheduling tool. This has been achieved within the context of exchange visits by both Romanian and U.S. participants. These exchanges have resulted in the redesign and extension of the Romanian systems called PLU and SICOP to incorporate simulation and data base management concepts. Implementation of these concepts on computers located at the Centrul de Organizare si Cibernetica in Constructii (C.O.C.C.) in Bucharest has been accomplished. Test programs run during this phase of the research indicate that information regarding both the functional as well as the construction sequence characteristics of major physical components must be defined and maintained. Types required are:

1. Resource information regarding physical resources such as labor, equipment and materials.
2. Organizational information regarding the groups involved in the project and the basis of information transfer between these groups, their responsibilities and structure.

These categories provide the design basis for establishing a management information system (MIS) which is capable of supporting simulation methodologies. This information also supports the functional systems of (a) planning, (b) estimating, (c) scheduling, (d) cost control and (e) accounting, which are among the basic decision making tools available to the manager.

Good statistical information on past field experience is essential to the utilization of simulation in planning and scheduling future projects. Because the complexity of the relationships involved, the collection and documentation of productivity in a statistical format is a major function of the project control system. Such statistical data is also basic to the development of the background information required for simulation of project decision making. Simulation provides the manager with a tool based on actual field performance which allows him to locate scarce resources.

| | | |
|----------------------------------------------------------|-------------------------------------------|----------------------|
| SIGNATURE OF PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR | TYPED OR PRINTED NAME Daniel W. Halpin | DATE 10 Jan. 1977 |
|----------------------------------------------------------|-------------------------------------------|----------------------|

PUBLICATIONS

- (a) Halpin, D. W., H. Manescu, N. Tutos, and R. W. Woodhead, "Simulation Models as a Predictive Tool in Construction Management," Proceedings, Fourth International Congress on Project Planning by Network Techniques, Paris, France, Vol. II, 1974, pp. 285-289.
- (b) Halpin, D. W., M. Nemteanu, and Ronald Woodhead, "Structure of Construction Industry in Romania," Journal of the Construction Division, ASCE, Vol. 100, No. C02, Proc. Paper 10600, June 1974, pp. 141-152.
- (c) Halpin, D. W., "Queueing Models in Construction," Bulletin of the Technical Institute of Jassy (Romania), 1976.
- (d) A. M. Burger and Daniel W. Halpin, "Application of Data Base Methods to Complex Project Control," Proceedings of the Symposium of the Working Commission, International Council for Building Research, Washington, D.C., May 1976, pp. III 42-58.
- (e) Halpin, D. W. and N. Tutos, "Construction Information Systems in Romania," Journal of the Construction Division, ASCE, Vol. 102, No. C02, Proc. Paper 12176, June 1976, pp. 335-345.

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA 30332

SCHOOL OF
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10 January 1977

Subject: Final Technical Letter Report

To: Robert F. Hull
Program Manager
Office of International Programs
National Science Foundation

1. Name of Institution: Georgia Institute of Technology
2. Name of Principal Investigator: Daniel W. Halpin
3. Grant No.: OIP74-03845 A02
4. Starting Date: 15 April 1974
5. Completion Date: 31 December 1976
6. Grant Title: Simulation Models in the Management of Construction Industry
7. Brief Description of Research and Results:

The objective of this research has been to study the construction environment and construction management systems utilized in Romania for the purpose of implementing simulation techniques as a planning and scheduling tool. This has been achieved within the context of exchange visits by both Romanian and U.S. participants. These exchanges have resulted in the redesign and extension of the Romanian systems called PLU and SICOP to incorporate simulation and data base management concepts. Implementation of these concepts on computers located at the Centrul de Organizare si Cibernetica in Constructii (C.O.C.C.) in Bucharest has been accomplished. Test programs run during this phase of the research indicate that information regarding both the functional

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8. Publications:

- (a) Halpin, D. W., H. Manescu, N. Tutos, and R. W. Woodhead, "Simulation Models as a Predictive Tool in Construction Management," Proceedings, Fourth International Congress on Project Planning by Network Techniques, Paris, France, Vol. II, 1974, pp. 285 - 289.
- (b) Halpin, D. W., M. Nemteanu, and Ronald Woodhead, "Structure of Construction Industry in Romania," Journal of the Construction Division, ASCE, Vol. 100, No. CO2, Proc. Paper 10600, June 1974, pp. 141 - 152.

- (c) Halpin, D. W., "Queueing Models in Construction," Bulletin of the Technical Institute of Jassy (Romania), 1976.
- (d) A. M. Burger and Daniel W. Halpin, "Application of Data Base Methods to Complex Project Control," Proceedings of the Symposium of the Working Commission, International Council for Building Research, Washington, D.C., May 1976, pp. III 42 - 58.
- (e) Halpin, D. W. and N. Tutos, "Construction Information Systems in Romania," Journal of the Construction Division, ASCE, Vol. 102, No. C02, Proc. Paper 12176, June 1976, pp. 335 - 345.

9. Thesis: None

10. Scientific Collaborators:

- (a) R. W. Woodhead, Head, Department of Engineering Construction and Management, U. of New South Wales, Kensington, Australia.
- (b) Mihai Nemteanu, The Railroad Trust, Bucharest, Romania.
- (c) A. M. Burger, School of Civil Engineering, Georgia Institute of Technology.
- (d) N. Tutos, COCC, Bucharest, Romania.
- (e) R. Sasu, COCC, Bucharest, Romania.
- (f) H. Manescu, COCC, Bucharest, Romania.

11. Comments:

A proposal for extension of the Grant is in preparation.

12. Signature: _____

Daniel W. Halpin, Ph.D.
Project Director
Assistant Professor
School of Civil Engineering

REFERENCE

Halpin, D. W. "Final Report - Simulation Models in the Management of Construction Industry," Technical Report SCEGIT-77-135, School of Civil Engineering, Georgia Institute of Technology, Atlanta, January 1977.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

OFFICE OF
THE DIRECTOR OF
FINANCIAL AFFAIRS

January 27, 1977

Grants and Contracts Office
National Science Foundation
Washington, D. C. 20550

Gentlemen:

Enclosed is the original and two copies of the final fiscal report for grant number OIP74-03845 A01, formerly GF-42490.

If you have any questions or desire additional information, please let me know.

Sincerely yours,

C. Evan Crosby
Associate Director of
Financial Affairs

CEC/bs
enclosures:

cc: Dr. D. W. Halpin
Mr. E. E. Renfro
Mr. A. H. Becker ←
File E-20-651/E-20-325

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E-20-651

CONSTRUCTION MANAGEMENT SYSTEMS IN ROMANIA

FINAL REPORT

NSF GRANT NO. OIP-74-03845

Simulation Models in
the Management of Construction Industry

by

D.W. Halpin and N. Tutos

TECHNICAL REPORT SCEGIT-77-135

School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia

JANUARY 1977

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Because of the compact nature of the Romanian construction industry and the scarcity of required resources a level of resource control unknown in the United States is both possible and necessary. The structure of the Romanian construction industry is examined and interesting parallels between Romanian and American practice are presented. In particular, contracting procedures as well as the use of incentive programs to increase productivity are described. The Romanian construction management and contracting approach offers interesting insights into the construction process as organized in the socialist states of Eastern Europe.

CONSTRUCTION MANAGEMENT SYSTEMS IN ROMANIA

FINAL REPORT

NSF GRANT NO. OIP-74-03845

Simulation Models in
the Management of Construction Industry

by

D. W. Halpin and N. Tutos

TECHNICAL REPORT SCEGIT-77-135

School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia

JANUARY 1977

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ABSTRACT

Because of the compact nature of the Romanian construction industry and the scarcity of required resources, a high level of control is required. The structure of the Romanian construction industry is examined and parallels between American and Romanian practice are presented. Management systems developed in conjunction with the research are discussed. The SICOP and PLU systems are discussed in detail. These systems offer interesting insights into the construction process as organized in the socialist states of Eastern Europe.

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CHAPTER 1

STATEMENT OF PROBLEM AND OBJECTIVES

1.1 Introduction

The planning, scheduling and execution of construction projects require the identification of major project work tasks as well as a periodic redefinition of schedule and field procedures based on the constructor's available resources. This redefinition must ensure the attainment of predetermined milestone events. Milestone feasibility is established by defining both technological and ancillary management logic. Task durations are based on an assumed rate of work productivity commensurate with work methods assumed in the estimate. At present, these concepts lead to the development of network planning models for the project in which management logic is built in as if it were rigid and not subject to management control.

As the detail of project representation increases, the need for definition of management logic also increases to the extent that field management must be provided with certain degrees of freedom with which to adjust the production schedule during the execution of an ongoing project. The major drawback to rigidly defined network scheduling models results from the need to predefine both management and technological logic leading to only one sequencing alternative within the wide range of feasible ones. In fact, much of the management logic must be developed in the field as the project progresses. Attempts to predefine the management logic before the fact pre-empt the manager's

freedom of choice and have led to field management dissatisfaction with existing rigid modeling concepts.

Project management needs a project modeling methodology which clearly differentiates between technological logic and management logic such that during field construction the site manager can easily re-define his project plan to suit the changing states and conditions that he encounters. The manager requires task activity definitions in just sufficient detail to identify the rigorous technological aspects while retaining freedom for the definition of management logic such that he can manipulate work task sequencing by a subsequent field decision process.

Construction contracts state each contracting party's responsibilities by establishing a set of scheduling constraints such as milestone events and completion dates which are considered essential to the timely completion of the overall project. These milestones constitute the fundamentals required for development of a scheduling document which is used for defining the cash and resource flows for a project throughout its life. Further, this chart aids in task coordination and the study of project progress. In Romania, this scheduling document is called a General Contractor's Chart (GCC) and its development is based on a CPM analysis of major activities in the project, constrained predetermined milestone events and completion due dates.

The execution documentation for each major aspect or component (i.e., turbine building, support facilities, etc.) of the construction is broken down into activities, which go into greater detail than the GCC outline and are structured in such a way as to be compatible with

estimating standards. The activities to be executed are recorded in an activity file without rigid sequential logic. To the site manager the activity file provides both a list of tasks to be accomplished and the basis for progress payments. Existing programs at COCC are capable of sorting and listing tasks in the activity files and of establishing the resources required to accomplish them. These tasks are associated with a given milestone event as defined in the GCC.

The field manager's problem is to establish the on-site sequencing of the tasks in the activity files so as to achieve the milestone events as required. This is a dynamic sequencing, carried out as the project develops on the site. Actual sequencing is a function of variables such as: (1) tasks completed to date, (2) equipment and labor resources available, (3) availability of required supply items, etc. These variables are continually changing as the project develops, and, therefore, the site manager's decision is a function of the state of the project at any given point in time.

The manager's dilemma is similar in the U.S. On industrial projects contracted on a negotiated basis, it is common for the owner to provide or cause the contractor to develop a CPM network for the major activities of the project. In addition, a cost accounting system which is agreeable to both owner and contractor is developed and implemented. This cost accounting system describes the tasks to be performed and constitutes the basis for progress payment. In this respect, it can be thought of as generating the tasks which are available in the activity file. Again, the manager's problem is to complete those tasks associated with a given milestone event so that timely turn-over of project components is accomplished. Further, the owner is interested in insuring

that costs incurred in accomplishing a given task are in line with the estimated value of construction placed. Firms such as Exxon and Proctor & Gamble have value standards (Proctor & Gamble use what is called a "bogey" book) which provide cost targets for the contractor. Such owners require the contractor to achieve project milestones while staying within a given percentage of the value standards.

The national standards in Romania and the owner's value standards in the U.S. are based upon standard crews, equipment and technology. In the field, the resources available may not be the same as those assumed in the standards. Therefore, productivity at least equalling that assumed in the standards must be achieved by using available resources, and, in some cases, by varying the technology or approach used. The requirement to meet cost standards is one constraint while the requirement of meeting milestone events provides a second constraint.

The interaction between the milestone events of the CPM and the field tasks inherent in activity and milestone accomplishment suggest a modeling environment which is responsive to the needs of the manager and provides the possibility of experimenting with the task selection within the context of a simulation of the actual field situation. Figure 1.1 shows a conceptual diagram of the problem environment.

The conceptual diagram shows two decision periods along the time line. These periods (11 and 12 are shown) may be thought of as months, quarters, or even weeks as necessary. They define the points at which the manager makes his decisions regarding activity sequencing. Three milestone events, labeled 1, 2 and 3, are shown with 1 and 2 in period 11

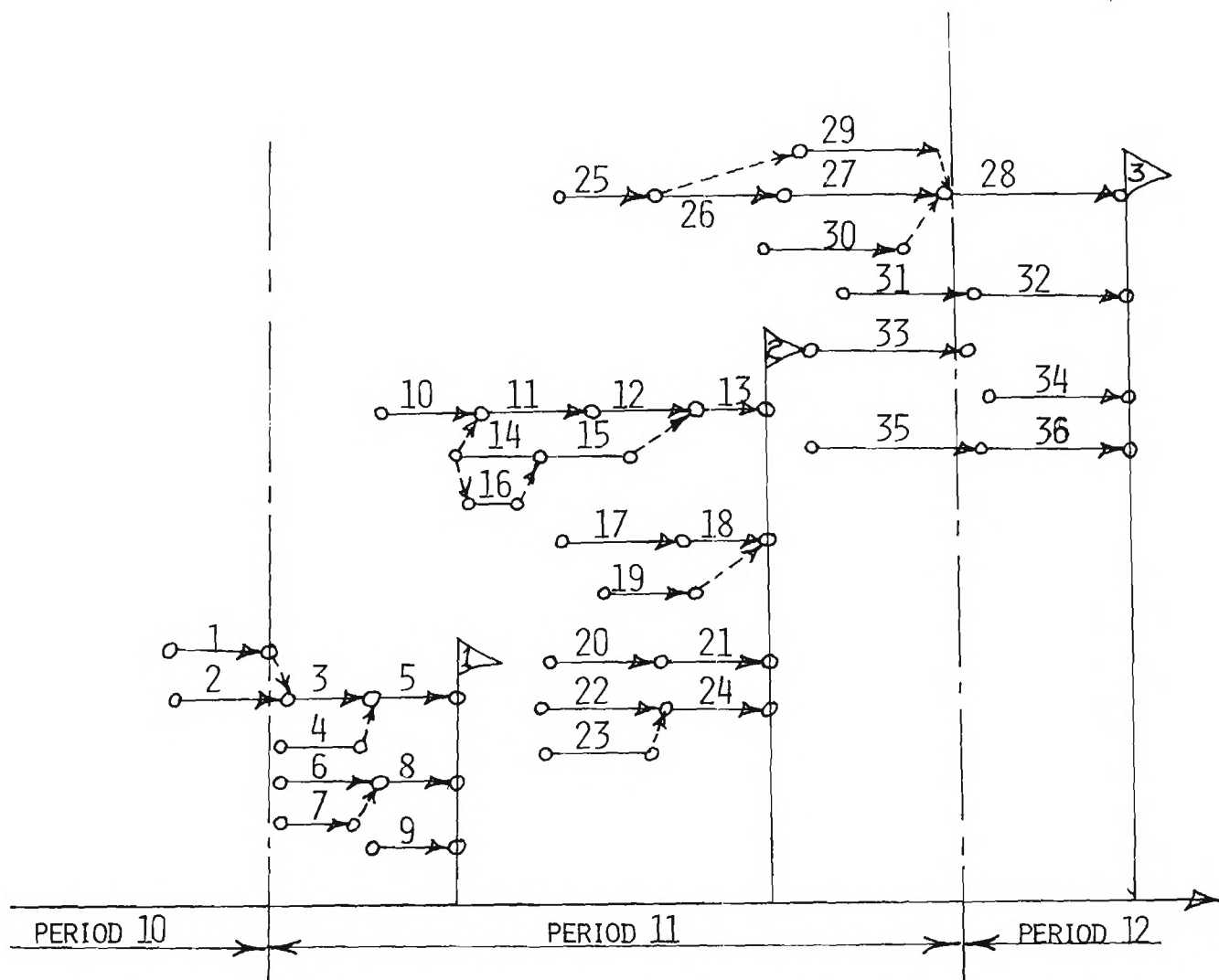


Figure 1.1 PROBLEM ENVIRONMENT

and milestone 3 in period 12. The tasks associated with each milestone event are shown at their latest start time (LST) positions. Tasks 1 through 9 are associated with milestone 1, tasks 10 through 24 with milestone 2, and tasks 25-36 with milestone 3. It is assumed that the latest finish time (LFT) for the last activity in each activity sequence (e.g., 5, 8, 9) is the associated milestone event time. The earliest start time (EST) will normally be defined in time by managerial logic developing from some previous milestone. The latest start schedule for tasks associated with a given milestone provides no floats to absorb

variations in productivity and therefore represents a high risk schedule. The manager wants to schedule activities as early as possible to reduce the risk of overrunning the associated milestone event. However, he is constrained by the resources available and the dynamic logic developing out of preceding milestone scheduling requirements.

In order to minimize the potential for cost and time overruns, a site manager's actions are cyclically divided into two major sub-tasks:

1. Periodic establishment of a work schedule. In order to perform this task, the site management should be provided with the following information at the beginning of each period:
 - a. A description of the process or technology to be used in achieving each project objective or subcomponent;
 - b. The state of available resources;
 - c. Opportunities available to obtain additional resources;
 - d. Progress payment scheme;
 - e. A project efficiency standard to date, defined by productivity and cost price figures;
 - f. Statistical data on weather conditions for the period and other project delay factors (e.g., labor availability, strikes, etc.).

In order to establish his work schedule, the site manager has to answer certain questions, such as the following:

- a. What activities have to be scheduled in the next period?
- b. What will be their sequence?
- c. Will the total value of activities completed meet the cash flow projections originally established by the plan?

- d. Do available resources insure activity completion as scheduled?
 - e. Is resource usage optional?
 - f. Is the level of efficiency projected in the estimate being achieved?
2. The adjustment of the schedule to actual environmental conditions. As the project develops, activity progress parameters show a random variation from those values established in the original schedule. These deviations are caused by:
- a. Unforeseen weather conditions;
 - b. Delays in material and equipment deliveries;
 - c. Labor force variations (e.g., walkouts, strikes);
 - d. Lower productivity of certain jobs.

The high frequency of deviations caused by these parameters makes work schedule updating difficult and leads to the requirement for resequencing tasks. Therefore, throughout the period the manager has to adjust his schedule by coming up with the best solutions for implementing activities. In order to make correct decisions the site manager needs to be provided with information on the impact of the environmental attack and the consequences of various feasible decision sequences.

1.2 Objective

The objective of this research has been to study the construction environment and construction management systems utilized in Romania for the purpose of implementing simulation techniques as a planning and scheduling tool. This has been achieved within the context of exchange

visits by both Romanian and U.S. participants. These exchanges have resulted in the redesign and extension of the Romanian systems called PLU and SICOP to incorporate simulation and data base management concepts. Implementation of these concepts on computers located at the Centrul de Organizare si Cibernetica in Constructii (C.O.C.C.) in Bucharest has been accomplished. Test programs run during this phase of the research indicate that information regarding both the functional as well as the construction sequence characteristics of major physical components must be defined and maintained.

This information provides the design basis for establishing a management information system (MIS) which is capable of supporting simulation methodologies. This information also supports the functional systems of (a) planning, (b) estimating, (c) scheduling, (d) cost control and (e) accounting, which are among the basic decision making tools available to the manager.

Central to the research is the problem of developing a problem environment which allows the manager to dynamically sequence individual activity members of activity files. This environment has been discussed in the context of milestone associated subgraph development in the previous section and illustrated in Figure 1.1. This environment suggests a problem solution methodology based on the development of a site oriented project model which allows the manager to sequence work tasks based upon current project status information. Tasks have to be expressed at the project and activity levels by a flexible logic which provides for emphasis on milestone events and technological logic related to activity chains and management alternatives. This has been accomplished in the PLU and PROMETEU systems.

CHAPTER 2

STRUCTURE OF THE CONSTRUCTION INDUSTRY IN ROMANIA

2.1 Introduction

Romania is a southeastern European country located in the northern part of the Balkan peninsula. It has a land area of 237,500 km² (approximately 85,500 sq. miles), making it roughly one and one half times the size of the state of Illinois. It has a population of 20,240,000, of which approximately 1,600,000 are located in the capital city of Bucharest. The population is divided almost equally between urban centers and agricultural areas.

The Socialist Republic of Romania is experiencing a period of industrial expansion unparalleled in its previous history. Recent statistical data (1) indicate that Romania had a construction volume of 38.25 billion Lei during 1971, up 81% from figures quoted for 1965, and 12 times the construction volume generated in 1950. In American terms, the 1971 volume is roughly \$2.40 billion and corresponds to the bidding volume of the construction industry in New York during calendar year 1973 (5).

2.2 General Industry Overview

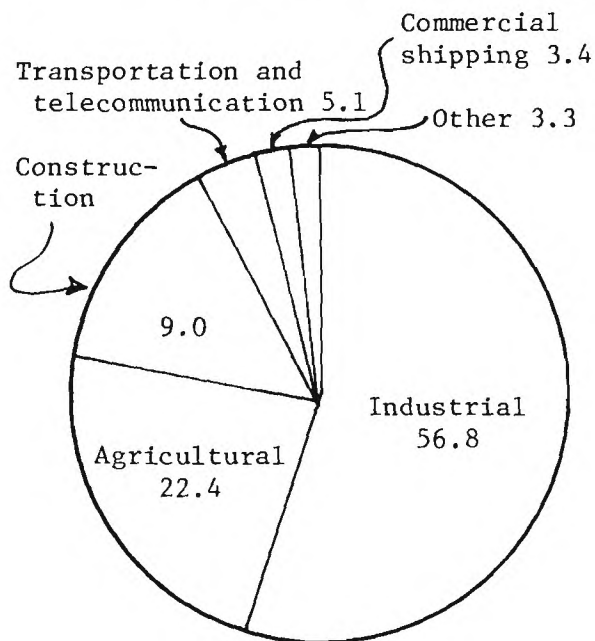
Approximately 13% of the total work force, or about 700,000 persons, is involved in the Romanian construction industry. Of this number, 625,000 are directly involved in construction production or placement, with 75,000 involved in administrative and support functions. This results in a ratio of productive labor to administrative support of approximately seven to one.

Construction accounts for 9.0% of the Gross National Revenue (the economic index comparable to Gross National Product used in the Romanian Socialist Republic) and its relation to other national activities is shown in Fig. 2.1(a). The distribution of the construction effort between the various sectors of the industry is shown in Fig. 2.1(b).

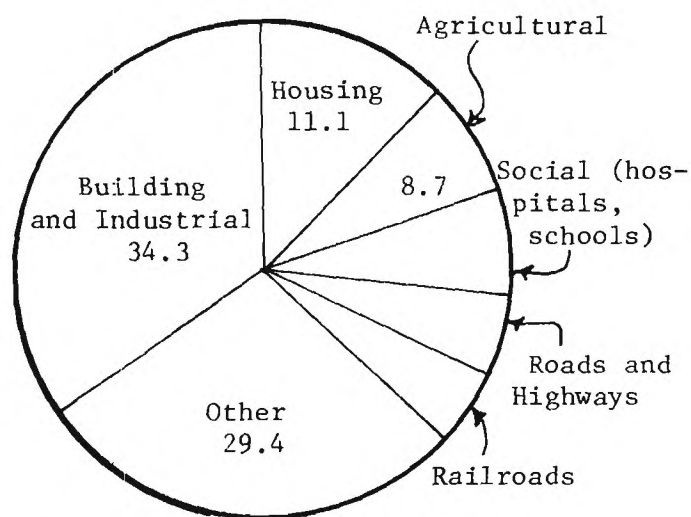
In terms of units executing construction, construction activities can be broadly divided into two categories:

1. Social and cultural construction, which includes housing, theaters, hotels, schools, etc., is handled by local construction companies, which are under the control of the regional county or department governments.

2. National developmental construction has impact upon the nation as a whole and includes industrial, transportation, and telecommunications facilities, etc. This type of construction is normally assigned to units which are controlled by the State Ministry having major responsibility.



(a) Distribution of Gross National Activities



(b) Construction Activity Distribution

Figure 2.1 CONSTRUCTION INDUSTRY PROFILES

2.3 Organization of Industry

Within Romania there are 39 counties or departments, each controlling their own local construction company. In addition, the municipality of Bucharest is considered a separate unit and has its own construction company. Consequently a total of 40 local companies carry out social and cultural construction in Romania. Fig. 2.2 shows the 39 departments superimposed on the map of Romania (as dotted lines).

Although some industrial construction is carried out by other ministries (e.g., Ministry for Transportation and Ministry for Chemical Production), by far the largest percentage of work (35% of total construction and 80% of the total industrial construction volume) is contracted by companies responsible to the Ministry of Industrial Construction. The companies controlled by this Ministry are called construction trusts and are generally of two types, i.e., general contractors or specialty contractors, as explained in the following:

1. General contractors are legally autonomous and authorized to act as prime contractors on industrial construction projects. Each general contractor operates within a well-defined geographic area, but opportunities exist for bidding on a project in an adjacent area.

2. Specialty contractors are essentially subcontractors. They confine their work to some specialty area, e.g., process line assembly, insulation (covering a broad scope of activities ranging from insulation of line connections to roofing a process line building), slip forming, pile driving, and quarry operation.

Presently there are 11 general contracting trusts within the Ministry for Industrial Construction, each handling construction in an assigned geographic area. Fig. 2.2 shows the geographic distribution of trust

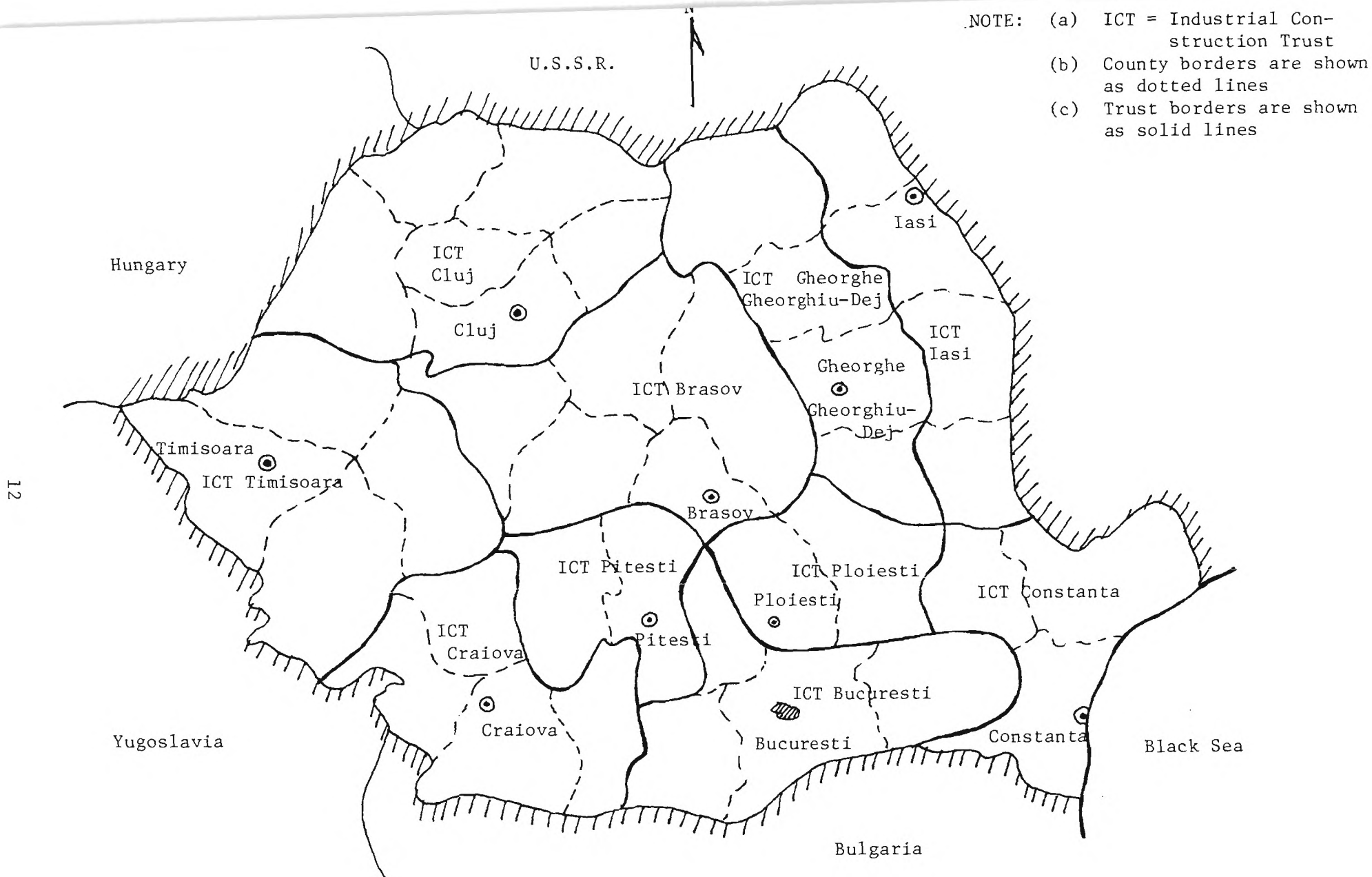


Figure 2.2 ROMANIA DEPARTMENT (COUNTY) AND TRUST BOUNDARIES

headquarters and their areas of responsibility. Of the 10 specialty trusts presently constituted within the Ministry, all have their headquarters located in Bucharest, with the exception of two process line assembly trusts. These two trusts are located in Brasov, approx 140 km north of Bucharest, and Iasi, near the Russian border in the northeastern part of the country. In addition to the construction units belonging to the Ministry of Industrial Construction, some other ministries (e.g., Ministry of Transportation) maintain their own construction units which perform some industrial construction tasks, e.g., railroad and major highway projects, telecommunication facilities, and power line construction.

Two other types of units contribute to the construction effort in Romania. First, there are the construction companies belonging to the various cooperatives (e.g., dairyman's milk cooperative and hotel and tourism cooperative) which perform certain small and relatively specialized projects relating to the cooperative. For example, a hotel cooperative company would be totally committed to the construction and maintenance of motels and inns operated by the cooperative. Secondly, maintenance companies belonging to the town councils in certain localities perform maintenance and small construction projects as well as limited contracting for private individuals. Fig. 2.3 shows the units typical of the Romanian construction industry schematically.

In addition to the productive units (i.e., the trusts) within Romania, the Ministry for Industrial Construction operates an international contracting company which bids for contracts outside of Romania. This company is called ARCOM and presently is working on projects in Austria, Czechoslovakia, and West Germany. The ministry also maintains several

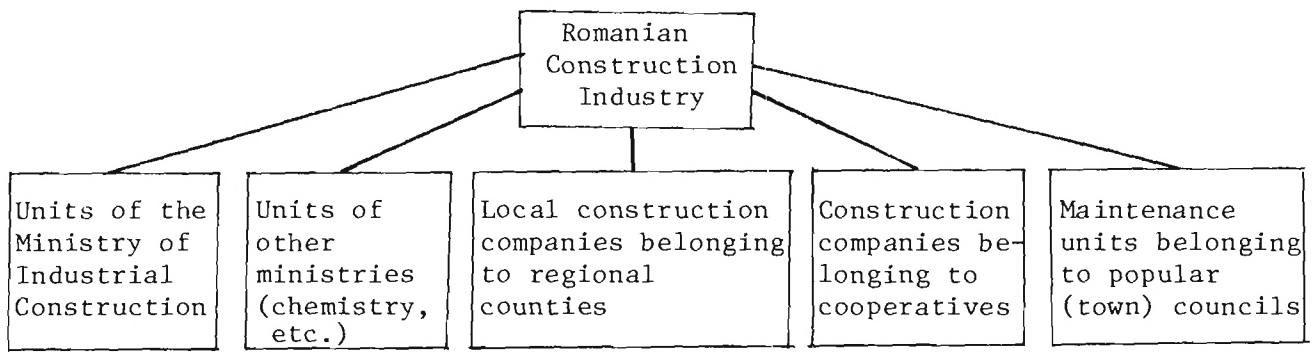


Figure 2.3 TYPICAL CONSTRUCTION UNITS

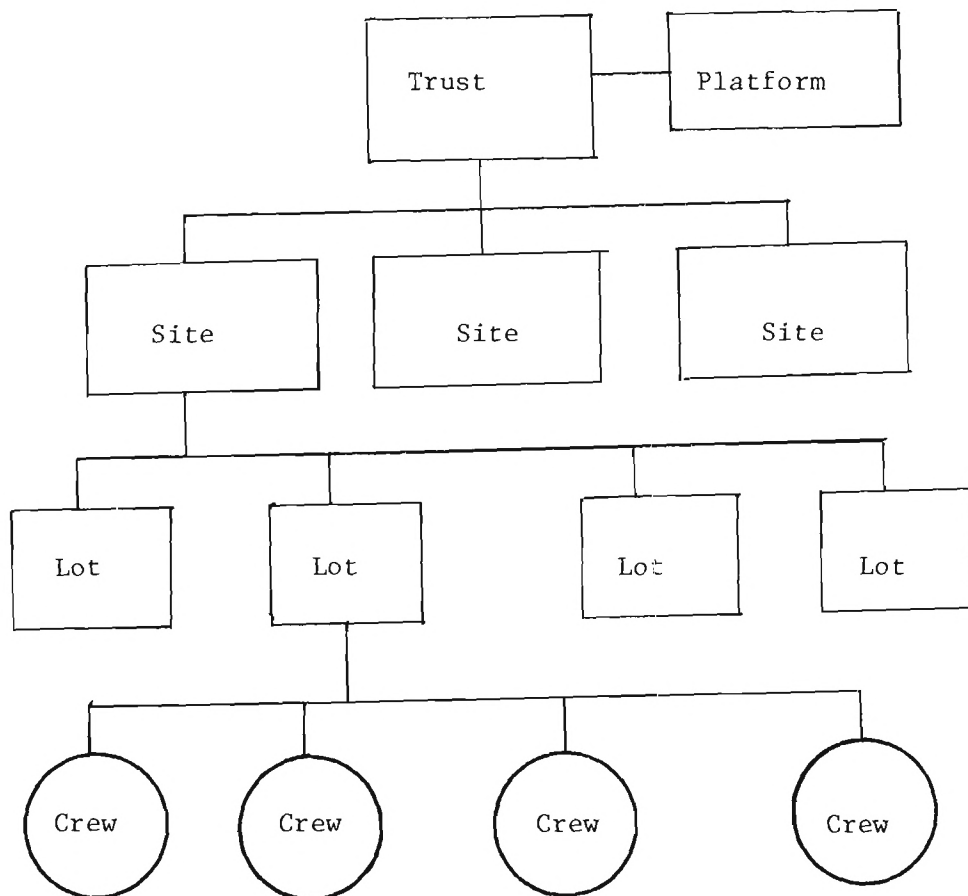


Figure 2.4 CONSTRUCTION UNIT HIERARCHY

research institutes which support work in the field. These institutes have been established to serve the entire Romanian construction industry and thus have very broad roles to perform. The two largest institutes are referred to as INCERC (Construction Research Center) and COCC (Center for Management and Cybernetics Study in Construction). The INCERC conducts research and studies relating to construction assembly techniques, materials properties certification, and time standards. The COCC conducts research into the area of systems concepts applied to the field of construction management. The INCERC has its headquarters in Bucharest with branch stations located at Iasi, Timisoara, and Cluj, while COCC is located directly in Bucharest. Two other support facilities of note within the Ministry for Industrial Construction are the Central Laboratory, in Bucharest, which conducts special testing (e.g., triaxial shear soil tests and structural prototype tests) and an Institute (CDCAS) specializing in architectural and systems building problems. In addition to these centralized facilities, each trust and job site have their own field laboratories for conducting on-site concrete strength tests, compaction tests, etc.

2.4 Construction Unit Organization

There are several units which are typical of the various operational levels of the Romanian construction hierarchy. The concept of a general construction trust as an organization which acts as a general or prime construction contractor has already been introduced. Within any construction trust, there are two types of subunits. The most typical subunit is the site, which is administratively self-contained and operates as a separate unit under the trust headquarters. As its name implies,

this organization is located where it can control one or more construction sites and it functions as a regional office. In some trusts, several sites located at a considerable distance from the trust headquarters may be controlled administratively by a site group headquarters.

The second type of subunit is called a platform. This unit is similar to a site, but it differs primarily in that the administrative functions normally intrinsic to a site organization are handled at the trust headquarters. The platform is autonomous in operational matters but administrative matters (e.g. payroll) are handled at trust headquarters. Thus, platforms are usually located close to the trust headquarters to facilitate communications. Typical of the platform concept is the organization used for construction of the polytechnical institute at Bucharest. Although the project headquarters is operationally independent, it is controlled administratively by the Industrial Construction Trust (ICT) of Bucharest.

Within a site or platform, the actual operational units are referred to as lots. These units vary in size but normally consist of 20-80 workers and direct management personnel (e.g., junior engineers and foremen), depending upon the type of work being done. These units operate as a large team in undertaking specific tasks and, as will be examined subsequently, can actually "contract" for various components of the project. The lots themselves consist of teams or crews which are under the operational and administrative control of the chief of the lot and his headquarters section. These teams are similar to American crews in that they are controlled by a crew foreman. However, they are slightly larger, in general, consisting of 8-10 men. Fig. 2.4 shows schematically the lines of control and communication between the various units of the Romanian construction trust hierarchy.

2.5 Project Development Process

Although all construction firms are state-owned and there is no competitive bidding, the owner-designer-contractor relationship is quite similar to that used for negotiated unit price contracts in the United States. Normally, the general contractor is chosen based on the geographic location of the project and the owner (i.e., beneficiary) enters into negotiations with the responsible general contracting trust. However, prime contractors from adjacent areas who are capable of constructing the project can also negotiate with the owner and in some instances underbid the general contractor resident in the area. In fact, the owner-designer-contractor interaction begins in the earliest planning stages of major projects. During the concept stage of development, a Technical-Economic Study (TES) is initiated to investigate and establish capital investment costs, procurement, and other special problems relating to the project (i.e., the investment). As a product of the TES, an Investment Sequence Chart (ISC) is developed showing the anticipated capital expenditures relating to the project or investment throughout its life on a year by year basis. The general contractor plays an active part in the development of this documentation. The TES and ISC are forwarded to the Council of Ministers and, following approval, the detailed design phase begins. At this point, depending upon the urgency of the project, design and construction can proceed in parallel with field implementation as soon as design information is made available.

The design function is handled by a group of design institutes which specialize in a particular type of construction. Chemical plant design functions are carried out by one institute, whereas agricultural facilities, e.g., chicken farms or wine production plants, are assigned

to a separate design institute. In addition to these major design institutes, each general contracting trust has a "design workshop" which is capable of generating working and shop drawings (as required) as well as total design for smaller facilities, e.g., prefab warehousing and small supporting facilities added to an already operating facility.

Initial estimates of facility cost and value are based upon a set of national standards or norms which give standard costs for labor, equipment, and materials. These norms are similar in concept to certain estimating handbooks in the American literature [e.g., Means (3) and Dodge (2)] but are considerably more comprehensive and extremely detailed. These standards provide an owner's estimate of the projected cost of the project and the comprehensive estimate, based on national standards, constitutes a list of payment items, as well as the basis for progress payments to the general contractor. Additionally, each estimate item provides a target value which is used as the basis for a wide-ranging incentive program which will be examined later in this presentation.

As design is finalized, the general contracting trust develops a General Contractor's Chart (GCC) which establishes detailed milestones to be achieved in the scheduling of the project. These milestones are based on an activity network or critical path analysis of the project as a whole.

The GCC constitutes the time scheduling control document common to all industrial construction projects. Based on the GCC, activity files are prepared for each project. These activity files consist of tasks which are required for completion of a major section of the work. A single file constitutes about 20 days of work. The tasks in the activity file

are compatible with and based upon task descriptions as given in the national standards. However, they are not necessarily consistent with the activity descriptions given in the GCC. This is similar to the difference between estimating accounts and time scheduling activities in the United States. The field manager's problem involves logically sequencing activity file tasks to achieve the milestone events required by the GCC.

2.6 Project Cost Determination

In Romania, the appropriate State-owned Institute of Design (e.g., Institute of Chemical Plant Design, and Institute of Agricultural Facilities Design) compiles a list of quantities based on the drawings and makes an estimate of required man-hours and cost based on a set of national standards or norms valid throughout the country. The standards cover the entire spectrum of construction activity and are similar in concept to the national standards used in some middle European countries. For example, West Germany uses a national standard establishing bid items and performance norms called the Allgemeine Technische Vorschriften fuer Bauleistungen (The General Technical Specifications for Construction Projects). In Romania there are different standard books published and updated periodically for each category of construction work (e.g., buildings and general construction, heavy construction, and special installations). In other words, in Romania the designer establishes the target price for a project while in the United States the price for competitively bid contracts normally is established by the low bidder. The estimate prepared by the design institute contains direct costs based on the national standards, indirect costs which are normally calculated as 8% of the direct cost, and a conventional management fee or

"profit" which is 1% of the total of direct plus indirect costs.

The estimate summary sheet contains the sum of the direct, indirect, and management fee costs plus 5% of the sum as a contingency reserve and 3%-5% for mobilization costs, e.g., site warehouses, workshops, and worker dormitories. The mobilization cost account can be charged according to a schedule provided in the contract. The cost total to include contingency and mobilization costs represents the total value of the project. The trust awarded the contract has the prerogative of contesting the estimated cost during a period of one month following receipt of documentation. If the constructing trust finds a discrepancy or oversight in the estimate, the designer must change the estimate bill. During construction, if differences versus the estimate materialize, change orders are issued. As a rule the total value of the change orders must not exceed the 5% contingency reserve. If discrepancies result in more than a 5% overrun, the design institute responsible must prepare a new estimate and submit it for approval to the same authorities who approved the original estimate. For large projects of nationwide importance this approval must be obtained from the Council of Ministers.

2.7 Cash Flow and Progress Payments

The amount and value of construction placed is calculated monthly, based on the unit prices in the estimate and field measurement of quantities. Reports on cost and quantity of construction, on a cumulative basis from the beginning of the project, are made at the end of each quarter. The progress payment request specifying the quantities placed and the reimbursement due the constructing trust is verified and signed by a representative of the beneficiary and funds in the appropriate amount

are transferred to the trust's account at the national bank. There is no retainage per se. However, the owner's representative will not sign the payment request if the quality of the work is not acceptable. As in the United States, the quantities and other aspects of the progress payment request are frequently a matter of dispute between the contractor and the beneficiary (i.e., owner) and the contracting trust. Further, differences sometimes result between the contractor and the bank. These differences must be settled by negotiation.

2.8 Labor Cost and Pay Scales

Generally, all craft workers are paid according to the quantity of work performed. Work standards for all crafts are published on a national basis and constitute guide values for payment. Using these standards, payment values are developed based on quantity of work placed. The work standards and payment norms are considerably more detailed than those used for estimation (mentioned previously). A typical line item of the national work standard listing would appear as follows:

| <u>Description of Work</u> | <u>Crew</u> | <u>Time norm</u> | <u>Unit price</u> |
|-------------------------------------------|--------------|------------------------|-------------------|
| Bricklaying, masonry brick with backup | 1 Bricklayer | 5.20 hr/m ³ | 28.6 lei |

The wage scale for all skilled workers in construction, regardless of their craft (the only exceptions being mechanics, operating engineers, and teamsters, who have a separate scale), is based on six specialty levels, each subdivided into four pay steps. Table 2.1 gives the scale.

For each specialty level and pay step certain standards of experience and competence are established. The promotion from one category to another is based upon professional examinations and the time spent in grade at a

| Pay Step | Specialty Level | | | | | |
|----------|-----------------|------|------|------|------|-------------|
| | 1 | 2 | 3 | 4 | 5 | Specialists |
| Base | 5.30 | 5.50 | 5.95 | 6.90 | 8.15 | 9.80 |
| I | 5.40 | 5.60 | 6.25 | 7.30 | 8.55 | 10.30 |
| II | 5.50 | 5.85 | 6.55 | 7.70 | 9.00 | 10.80 |
| III | 5.60 | 6.00 | 6.95 | 8.20 | 9.55 | 11.35 |

Note: 1 Lei is approximately equal to \$0.08.

Table 2.1 CONSTRUCTION WORKER PAY SCALE
Hourly, in Romanian Lei

| Pay Step | Specialty Level | | |
|----------|-----------------|------|------|
| | 1 | 2 | 3 |
| Base | 5.10 | 5.30 | 5.55 |
| I | 5.20 | 5.40 | 5.65 |
| II | 5.30 | 5.50 | 5.80 |
| III | 5.40 | 5.65 | 6.05 |

Note: 1 Lei is approximately equal to \$0.08.

Table 2.2 UNSKILLED LABOR PAY SCALE
Hourly, in Romanian Lei

given level. Promotion from one specialty level to the next higher level usually requires at least 3 yr in grade. Promotion from one pay step to the next requires from 9 months to 12 months.

For unskilled laborers the pay scale consists of only three specialty levels and four pay steps. This scale is given in Table 2.2.

The wage scale for truck drivers is dependent upon the size of the truck capacity. The scales for 12 ton-24 ton trucks vary from 7.45 lei to 9.75 lei as shown in the following:

| 1 | 2 | 3 | Specialist |
|------|------|------|------------|
| 7.45 | 8.15 | 8.95 | 9.75 |

The scale for mechanics is similar to the one shown for skilled workers.

2.9 Production Incentive Concepts

In the past few years, a great deal of emphasis has been placed on the introduction of what has come to be known as the "global contract" payment scheme. This incentive scheme resembles in some respects the profit concept which motivates the construction entrepreneur in the United States. By this method a project or portion of a project is contracted for by a construction team which may range in size from a crew, or several crews, or a lot, to an entire site. These groups include workers and managerial personnel, who contract as a team to do a project or portion of a project. The amount of money which can be earned by such a team is calculated by reference to the work standards or by comparing the man-hours required to a target value given in the estimate. The incentive pay is established prior to starting work and is not subject to change. This payment scheme stimulates the workers to innovation and ways of saving time and money on the required installation.

The global contract format also stipulates final due dates, when the work contracted must be completed. A guarantee or retainage of 10%-20% is provided for in this type of "contract." If the segment of work contracted is not complete by the due date, the site or trust manager specifies that a percentage of the retainage is paid as penalty for failure to complete the project by the target date.

2.10 Management Incentive Programs

A specified portion of the salaries paid to management personnel is also held or retained at the end of each month. The salary retained varies from as much as 20% for trust and site managers to 10% for technicians and other engineering overhead personnel. Quarterly, these retainages are returned if the following conditions are fulfilled:

(1) Projects to which the management personnel are assigned are completed by the target date, if due during the quarter; and (2) the amount of construction value projected for the quarter is, in fact, realized (i.e., realization of planned production).

For early completion of project phases or components, bonuses are paid to all management team personnel from a fund which consists of up to 50% of the economic efficiency which results due to the early delivery of the project. The total amount of the bonus paid annually may not exceed 2 month's wages.

Additional bonuses are possible for savings in manpower. These bonuses are paid from a fund which may not exceed 25% of the cost reduction realized due to lowering the manpower required to attain planned production. For savings versus the planned overall cost figure (i.e., planned cost for construction value placed) a bonus fund is established not to exceed 50%-60% of the savings realized. Bonuses from this fund may not be greater than 3 month's wages annually.

2.11 Emphasis on Resource Control

Because of the compact nature of the Romanian construction management environment and the scarcity of required resources, including machines and materials, a level of resource control unknown in the United States is both possible and necessary. This requirement generates the need for good information systems to monitor progress on field activities as well as predictive methods to project future progress. For example, the municipality of Bucharest has a limited number of 100-ton cranes used in the construction of high-rise precast panel apartment buildings. The disposition of these cranes dictates the construction progress on the completion of new housing. In the United States, it is usually possible to call in back-up resources to overcome problems due to equipment shortages. This is not true in Romania since such cranes are typically of foreign manufacture and acquisition of back-up capability is a major procurement requiring high-level approval and weeks of procurement delay. Similar situations exist with reference to materials, e.g., concrete, cement, and steel. In this case the production facilities are "in-country," but demand greatly exceeds supply, again creating a very real resource allocation problem. Due to resource scarcity, data processing systems designed to control allocation of resources of all types are being implemented to better deal with this problem.

The desire to establish large information systems and data banks has led to the increasing acquisition and use of computers. However, these are limited in number and capability. All processing is by centralized batch mode (i.e., no on-line terminal facilities). This means there is presently no capability for direct field management-computer

interaction. The computer located at the data processing center of the municipality of Bucharest is an IBM model 360/40 with 28K of core memory. The Institute for Industrial Construction Management (COCC) has a French model IRIS 50 computer. Computer facilities are also available at other major construction centers, e.g., Iasi and Timisoara.

Despite the attempt to preplan resource commitment, departures from plans and scheduled progress at all levels of management (e.g., facility selection and approval to project management) do occur. This results in interruption and diversion of resource flows. Since the resource situation is so tight, there are no reserves to buffer such effects and they can lead to major problems in terms of project delay and reallocation of effort.

2.12 Expanding Labor Requirements

The rate at which construction requirements are expanding in Romania is high even by American standards. In order to expand the labor force to meet these requirements, the Romanians are retraining labor from the agricultural sector. Typically, labor from the agricultural sector is retrained into the construction area and the worker finally reaches the top of the ladder in the blue collar segment of the working population by becoming an industrial worker. This contrasts with the traditional American labor structure which considers a construction craftsman to be more highly skilled than an industrial worker. The construction industry is affected by this in Romania since it must bid in a more or less free market situation to staff its jobs. Many workers trained in construction want to move "up" the ladder to the relatively stable (i.e., less transient) industrial jobs.

Intensive training schemes are in evidence throughout the construction project hierarchy. However, these have not totally offset the migration of labor to industrial jobs and the demands for highly skilled construction workers generated by Romania's international construction operations in central Europe. These two drains have resulted in a shortage of skilled carpenters and equipment operators throughout the country.

2.13 Conclusions

The types of problems which must be confronted by any country involved in industrial expansion are now being tackled by the Romanian Socialist Republic. The structure of the construction industry in Romania is compact and well-adapted to the centralized management of the diverse projects inherent in such an expansion. The contracting procedures and labor incentive programs used are designed to exploit centralized management concepts. The central planning function is more broadly and rigidly applied in Romania than in the United States, but comparable management concepts may be found in large corporations, e.g., Proctor and Gamble, General Electric, and Exxon. The construction management organizations of such corporations can be used as yard stick models for comparison.

The following points are relevant to the total management process as implemented in Romania:

1. In order to deal with a resource constrained situation, managers in Romania attempt to predefine and constrain the construction process along accepted norms which damp out variation in supply and resource requirements.

2. There is recognition of the need for extensive data collection to establish norms and targets, and to control the construction process

when unforeseen variations occur.

3. The central institute for research in construction management (COCC) is undertaking the layout, planning, and implementation of a centralized management information system.

Presently project planning and development follow well-defined stages through the organizational hierarchy and focus on levels of investment funding, process technology design, investment sequence definition, scheduling, and field implementation. Owner, architect-engineer, and contractor roles associated with the planning and development process can be identified within the framework of relationships that develop in the construction hierarchy and organization. Despite the fact that ownership concepts and state control in the socialist republic result in basic differences between the hierarchical structure of the construction industry in the United States and Romania, a great deal of similarity in the operating procedures and management concepts used by the two countries exists. This forms the basis for a fruitful exchange of information and expertise on subjects of common interest.

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CHAPTER 3

CONSTRUCTION INFORMATION SYSTEMS IN ROMANIA

3.1 Introduction

The task of defining a project for estimating and bid purposes in Romania is a highly complex undertaking. Project description takes as many as 40,000 estimate items and project execution can require the assembly of 80,000 - 100,000 material components. As many as 400 equipment classifications and 150 craft specialities are not uncommon on complex jobs. Rather than producing a product that can be assembled along a moving production line, the construction manager applies resources to a fixed or immovable job site or location. Therefore, the manager's organization of the construction activities emphasizes application of movable resources to a fixed or immobile end product - the constructed facility.

Application of resources for the accomplishment of the construction normally must take place in an environment that is not totally subject to the control of the manager. This environment is characterized by the strong impact of weather factors that are difficult to forecast. Further, the nature of construction leads to wide dispersion of projects, requiring movement of men and machines across long distances. The volume of work at various locations fluctuates sharply compounding the problems of resource application.

Managing a highly variable process such as construction involves the rapid processing of huge volumes of information in order to properly

monitor and control project progress. Data processing methods are a must in accomplishing this task. However, existing management concepts and philosophies are not well adapted to the utilization of computer techniques and must in many cases be modified to allow application of modern data processing methods. In order to meet this challenge, information systems especially adapted to the peculiarities of the construction environment are required. Such a system is presently being developed and tested by the Industrial Construction Ministry of the Socialist Republic of Romania.

The Romanian Management System for scheduling, start-up and control of construction projects is called PLU. It is a component of the Integrated Management System developed by the Industrial Construction Ministry. This system, which is referred to as SICOP, is shown in schematic format in Fig. 3.1. The objective of SICOP is to get superior results in construction by reducing project durations, making better use of resources, incrementing labor productivity, and decrementing cost/price by means of overall management development.

The SICOP System consists of six management subsystems as follows: (1) planning; (2) project preparation scheduling, mobilization and follow-up (PLU); (3) supply; (4) equipment; (5) personnel; and (6) finance and accounting.

3.2 Planning Subsystem

In Romania, planning of allocation of state funds is carried out in a centralized manner at the national level. The financial commitments of the Ministry are broken down into individual construction company plan tasks for both general contractors and subcontractors. The Industrial

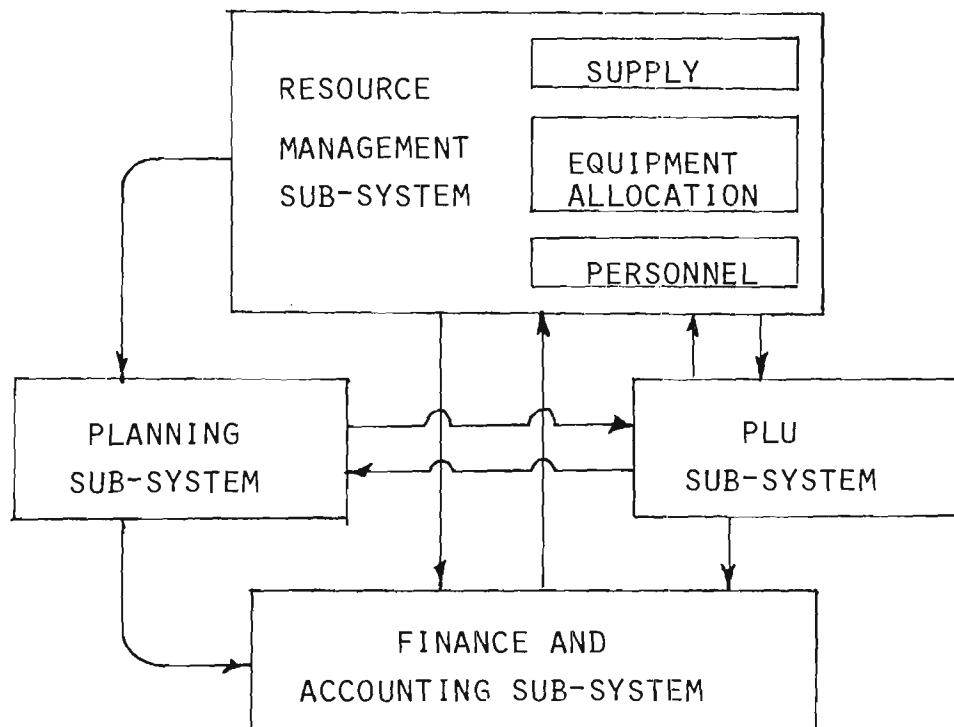













Figure 3.1 SICOP SYSTEM CONFIGURATION

Construction Ministry controls all general contracting companies located throughout Romania. These companies are referred to as "trusts" (2).

The planning subsystem provides for the coordination of plan tasks between the agents involved in project accomplishment. To this purpose, a document called an Investment Sequence Chart (ISC) is used. This financial plan is worked out and processed by means of a set of Critical Path Analysis Programs incorporated into SICOP. A portion of a typical ISC for a Plastics Manufacturing Complex is shown in Fig. 3.2.

The planning subsystem prepares a set of planning schedules in bar chart format. These planning schedules are developed from the ISC and coordinate the activities of the owner (e.g., industrial firm or agency), the designer, the fabricator of major procured items, and the construction contractor or trust (Fig. 3.3).

During the planning phase of the project, the trust is required to develop a detailed schedule of the field construction of the project once "notice to proceed" has been given. This schedule is referred to as the General Contractor's Chart (GCC) and delineates all activities to be performed during the construction phase as well as the sequence of work in network (i.e., CPM) format. The detailed project network that is developed from the GCC becomes the basis for project planning, control, and start-up at the trust and site level. A typical GCC is shown in Fig. 3.4. The SICOP system subelement that implements these trust and site level activities and develops progress reports is called PLU.

| ACTIVITY DESCRIPTION | CONST. TRUST | VALUE IN THOUSANDS (LEI) | 1972 | | | | 1973 | | | | 1974 | | | |
|------------------------------|-----------------|-----------------------------------|--------------------------------------------------------------------------------------|-----|----|---------------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------|----|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----|----|--|
| | | | II | III | IV | I | II | III | IV | I | II | III | IV | |
| SUPPORT FACILITIES | TCIB* | | | | | | | | | | | | | |
| DESIGN | | 113.0 |  | | | | | | | | | | | |
| CONSTRUCTION | | 1090.0 | | | |  | | | | | | | | |
| MAIN PLANT | TCIB | | | | | | | | | | | | | |
| DESIGN | | | | | | | | | | | | | | |
| SITE PREPARATION | | 16230. |  | | | | | | | | | | | |
| SANITARY INSTALLATION | | 683. |  | | | | | | | | | | | |
| MAIN STRUCTURE | | 1800. |  | | | | | | | | | | | |
| MECHANICAL SYSTEMS | | 6776. |  | | | | |  | | | | | | |
| SPECIAL EQUIPMENT | | 960. |  | | | | | | | | | | | |
| PROCESS LINE INSTALLATION | | 18220. | | | |  | | | | | | | | |
| IN COUNTRY PROCUREMENT | | 87783. | | | | | | | |  | | | | |
| FOREIGN PROCUREMENT | | 7804. | | | | | | | | |  | | | |

*T.C.I.B. = Ind. Construction Trust of Bucharest

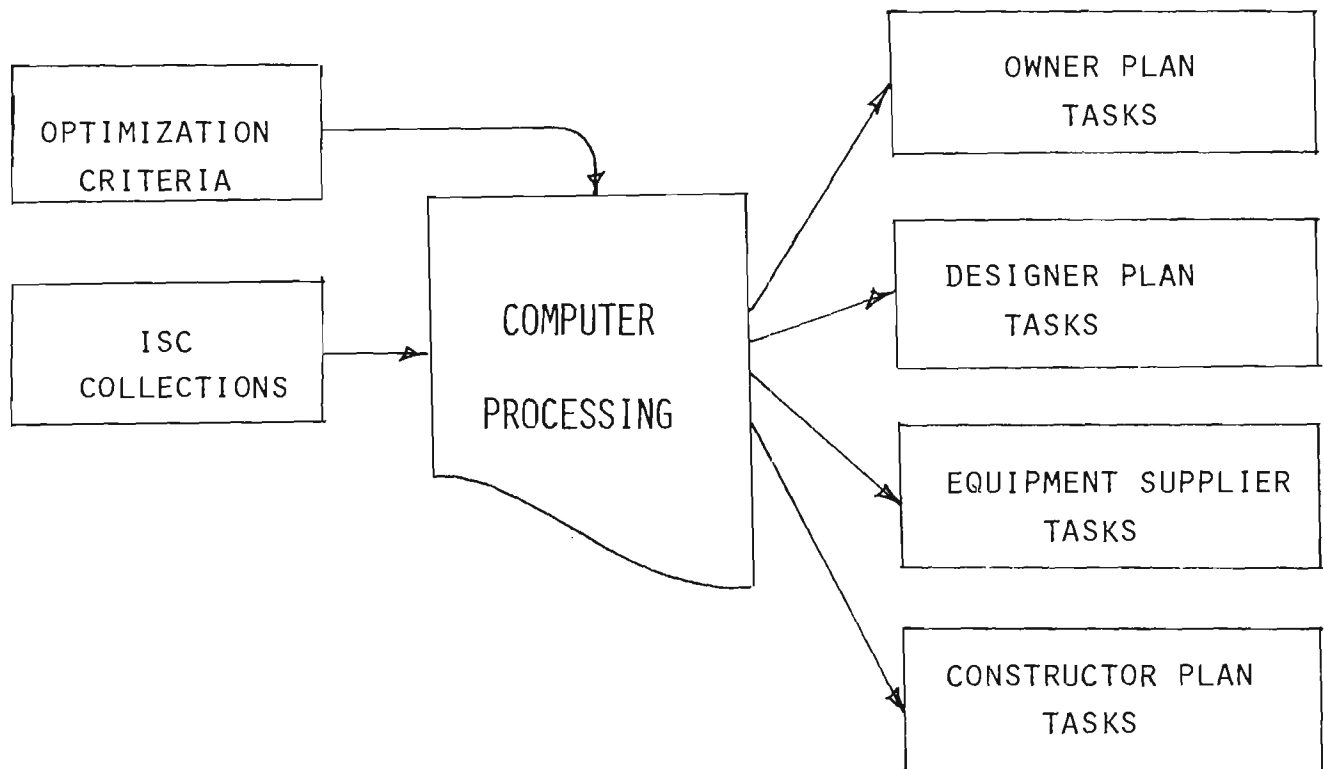


Figure 3.3 INVESTMENT SEQUENCE TASK DEVELOPMENT

| WORK DESCRIPTION | QTY | VALUE | WORK SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------------------|------|-------|---------------|---|---|----|---|---|-----|---|---|----|----|----|------|---|---|----|---|---|-----|---|---|--|--|--|
| | | | 1973 | | | | | | | | | | | | 1974 | | | | | | | | | | | |
| | | | I | | | II | | | III | | | IV | | | I | | | II | | | III | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | |
| FOUNDATION CONSTRUCTION | 120 | 250 | | | | | | | | | | | | | | | | | | | | | | | | |
| ERECT STRUCTURAL FRAME | 2240 | 3140 | | | | | | | | | | | | | | | | | | | | | | | | |
| INSTALL ROOFING & WEATHER PROOFING | | 1800 | | | | | | | | | | | | | | | | | | | | | | | | |
| AUXILIARY FOUNDATIONS | 180 | 250 | | | | | | | | | | | | | | | | | | | | | | | | |
| WASTE WATER INSTALLATION | | 638 | | | | | | | | | | | | | | | | | | | | | | | | |
| LIGHTING AND POWER | | 2995 | | | | | | | | | | | | | | | | | | | | | | | | |
| EQUIPMENT FOUNDATIONS | 1800 | 1380 | | | | | | | | | | | | | | | | | | | | | | | | |
| PROCESS LINE INSTALLATION | | 2250 | | | | | | | | | | | | | | | | | | | | | | | | |
| SPECIAL EQUIPMENT INSTALLATION | | 959 | | | | | | | | | | | | | | | | | | | | | | | | |
| START-UP | | | | | | | | | | | | | | | | | | | | | | | | | | |

3.3 Project Preparation, Scheduling, Mobilization and Follow-up Subsystems (PLU)

The tasks associated with this subsystem commence as soon as initial contact is established between owner, designer, and constructor, and continue until project completion. The PLU subsystem establishes the schedule for procedures required of the trust from the initial award of the job until acceptance by the owner. These procedures include:

- (1) work task scheduling in coordination with the ISC and the GCC;
- (2) project subcontracting; (3) definition of activities to be worked based on plans and quantity measurements in conformance with the national standards; and (4) development of a period by period production schedule (quarterly) in terms of available resources and established milestone events. The PLU subsystem provides the manager with the capability of coordinating the management of the construction projects which are part of a company's overall work load. Control of each project is within the context of milestone events that are established during the planning phase and are incorporated into the General Contractor's Chart. The system further provides information relative to the resource constraints that must be observed in completing the project. In addition to the foregoing procedures, the subsystem handles the following types of planning and management tasks: (1) job scheduling and updating at the project level; (2) quarterly scheduling for the entire company (i.e., composite scheduling of all projects); (3) break-out of job tasks by crew to include profit targets for individual crews if assigned activities are completed on time; and (4) generation of progress reports and documentation.

The PLU scheduling differentiates between the total project schedule that establishes project milestones and short horizon schedules that are developed for 10-day intervals and indicate site level management objectives. The short-term schedules indicate projected progress based on the actual equipment profile at the beginning of the planning interval (10 days). These short horizon schedules are based upon balancing of equipment and labor resources across the entire company. This balancing is carried out within the constraints imposed by the total project (master) schedule milestone events.

PLU Management Philosophy

It has been observed that:

"In order to MANAGE, one should be able to CONTROL

In order to CONTROL, one should be able to MEASURE

In order to MEASURE, one should be able to DEFINE

In order to DEFINE, one should be able to QUANTIFY (1)."

These concepts are basic to the operation of the PLU subsystem. This philosophy implies a hierarchy of detail which must be considered in breaking out and managing a construction project. This hierarchy as defined in the PLU subsystem is shown in Fig. 3.5. In this hierarchy, the last level establishes the labor and machine resource requirements as well as the unit price to be assigned to each estimating (cost) account. The accounts themselves are defined by the Romanian national standards (2). These standards specify the work task (in a descriptive sense), the productivity norms to be expected, and the expected unit price for each estimating cost account. The standards provide a basis for QUANTIFYING the accomplishment of the work and measurement of progress.

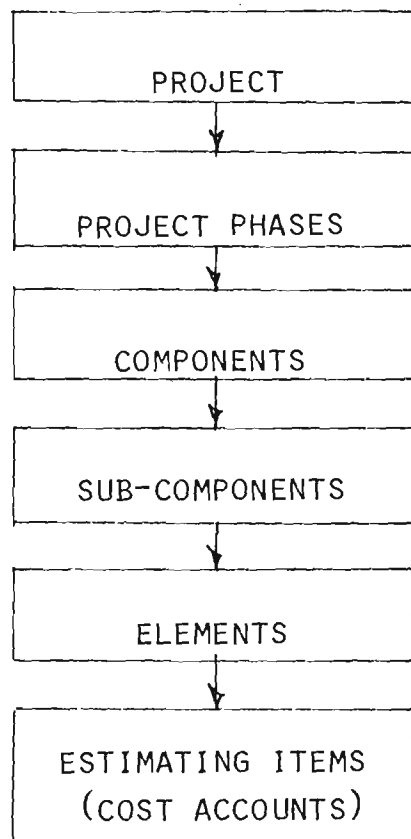


Figure 3.5 LEVELS OF PROJECT HIERARCHY

Using this framework, PLU introduces a method of subdividing, quantifying, and measuring project progress. Initially, the project is broken into phases that must satisfy the following criteria:

(1) C_1 : all jobs J_i included in a PHASE and requiring a set of resources R_{ij} should be uniformly spread across the PHASE period; and

(2) C_2 : the resource set R_{ij} is committed such that the jobs J_i within the PHASE can be carried out without interruptions resulting from resource diversion to other PHASES. From a formal point of view, the PHASE can be defined by a set of informational attributes (I, L, F, S) as follows: (1) I = the informational subset that describes or specifies the PHASE and its logical relationship to any other PHASE. (2) L = the information subset establishing the individual work tasks and their associated quantities (as developed from the national standards) which are common to the PHASE. (3) F = the information subset that describes the materials required for completing the PHASE to include items fabricated off-site and materials required for on-site construction processes. (4) S = the status subset that indicates the level of actual progress to date on the work tasks (accounts) defined within the PHASE. The setting up of PHASES is a continuous process that starts as design documentation arrives at the job site. This continuous generation of PHASES results in a reservoir of activities feeding the project and vying for position on the short-term schedules. This is shown conceptually in Fig. 3.6. The scheduling of activities is not unlike the queueing of passengers awaiting processing at an airline terminal. The work tasks (i.e., passengers) are generated from documentation and tentatively assigned a PHASE (i.e., an aircraft). As the PHASES are started, certain tasks are deleted and others added. This is similar to adding

higher priority passengers to an aircraft and displacing lower priority passengers. The tasks that are deleted during one period are recycled for consideration during the following period.

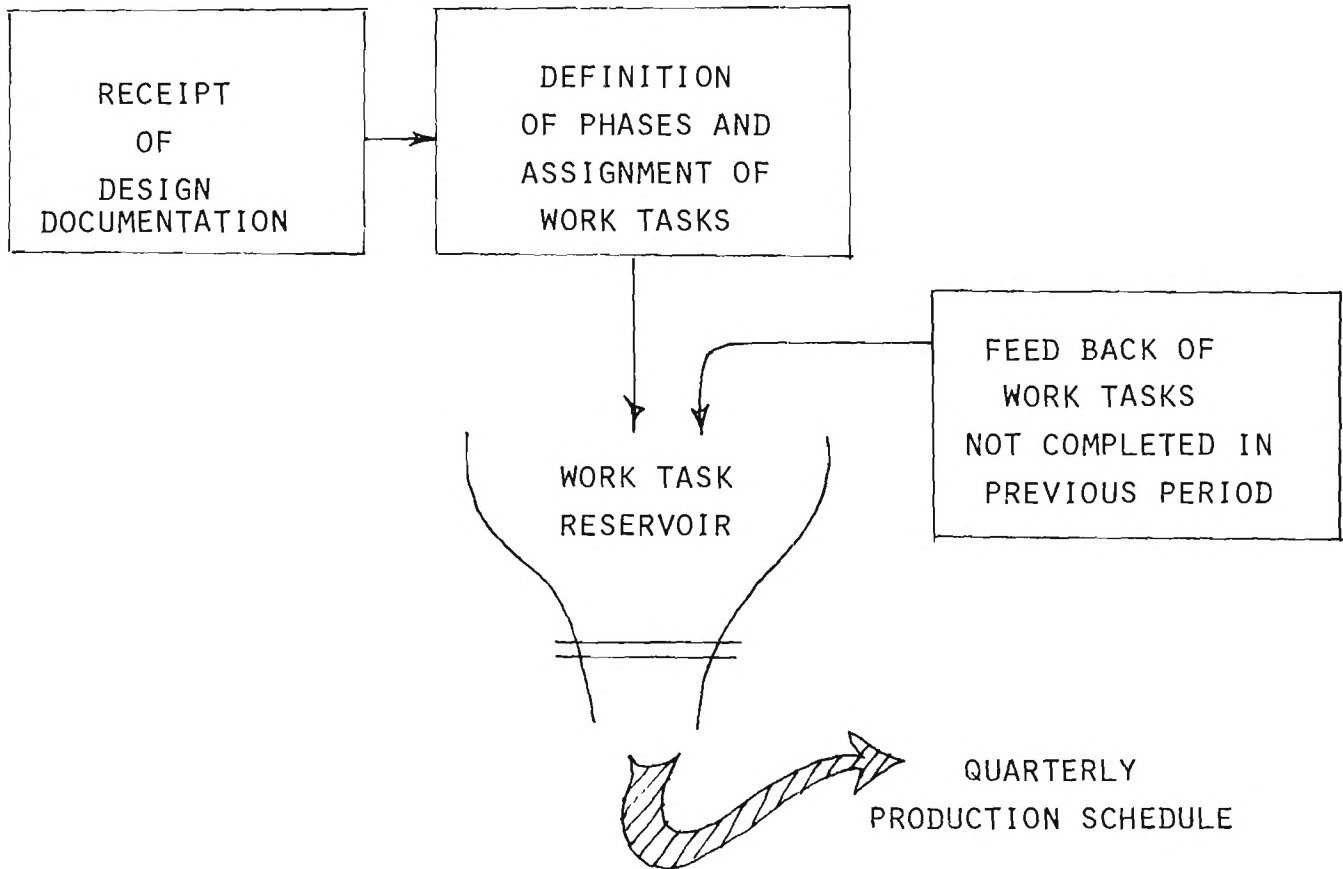


Figure 3.6 PERIOD PRODUCTION SCHEDULE

3.4 System Operation

Master planning referred to the control milestone events and the master schedule is carried out on a quarterly basis. Schedules for ministerial level planning purposes are prepared at the beginning of each quarter and are updated at the end of each month. These quarterly

schedules reflect the latest information regarding major procurements and field unit progress as of the end of the previous period (quarter). A segment of a typical quarterly production schedule is shown in Fig. 3.7.

Short horizon planning schedules referenced to the quarterly projections are maintained at the job site level. These 10-day schedules are updated at 5-day intervals. They incorporate information regarding delays due to weather and other non-management controlled variables such as delays in shipment and materials shortages. Labor and equipment fluctuations affecting job progress are also indicated in these job level schedules. In special cases, the 5-day update cycle is modified to fit features of nonstandard projects.

The scheduling process at the site level consists primarily of selecting from the reservoir those activities whose execution is required in the quarter presently under consideration. These activities are sequenced logically within the quarter and time-scaled to the months of the quarter. The positioning within each month is indicated by the cumulative percentage of a complete figure for each activity scheduled as of the end of the monthly planning periods. This is indicated schematically in Fig. 3.8. An interpretative analysis is carried out so as to balance available resources against resource requirements. The selection of the activities to be worked is based on a "preference criterion" which takes into account the cash flow requirements of the project as well as other required data (e.g., beneficial occupancy date). Once activities for work have been selected, resource profiles for the quarter and each individual month are generated. This takes

JOB SITE TULCEA

ACTIVITY DESCRIPTION:
MAT FOUNDATION INSTALLATION

| FAC. CODE | ACTIVITY DESCRIPTION | QTY | TOT. VAL. (a) | DATES | | PRODUCTION AS OF START THIS QTR. | | PROJECTED QUARTERLY PRODUCTION | | | | | | | | |
|---------------|--------------------------|-------|---------------------|-------|-----------|----------------------------------------|-----|-----------------------------------|-----|-------|-----|-------|-----|-------|-----|-----|
| | | | | START | FIN | | | TOTAL QTR | | MON 1 | | MON 2 | | MON 3 | | |
| | | | | | | % | VAL | % | VAL | % | VAL | % | VAL | % | VAL | |
| 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 0111- 0115 | EXCAVATION & GRADING | 17500 | 250 | 1 MAR | 15 MAY | P* | 85 | 213 | 14 | 34 | 95 | 338 | 100 | 250 | | |
| | | | | | | R+ | 86 | 216 | | | | | | | | |
| 0111- 0217 | PLACEMENT OF RE-STEEL | 85000 | 2800 | 1 MAY | 15 JUN | P | 5 | 140 | 25 | 700 | 13 | 364 | 21 | 588 | 30 | 840 |
| | | | | | | R | 8 | 162 | | | | | | | | |
| 0111- 0223 | CONCRETE PLACEMENT | 15190 | 3200 | 1 JUN | 15 AUG | P | 0 | 0 | 30 | 960 | 10 | 320 | 20 | 640 | 30 | 960 |
| | | | | | | R | 0 | 0 | | | | | | | | |
| | | | | | | | | | | | | | | | | |

* PROJECTED

+ REALIZED

(a) VALUE IN THOUSANDS OF LEI

Figure 3.7 PLANNED PRODUCTION BY QUARTER

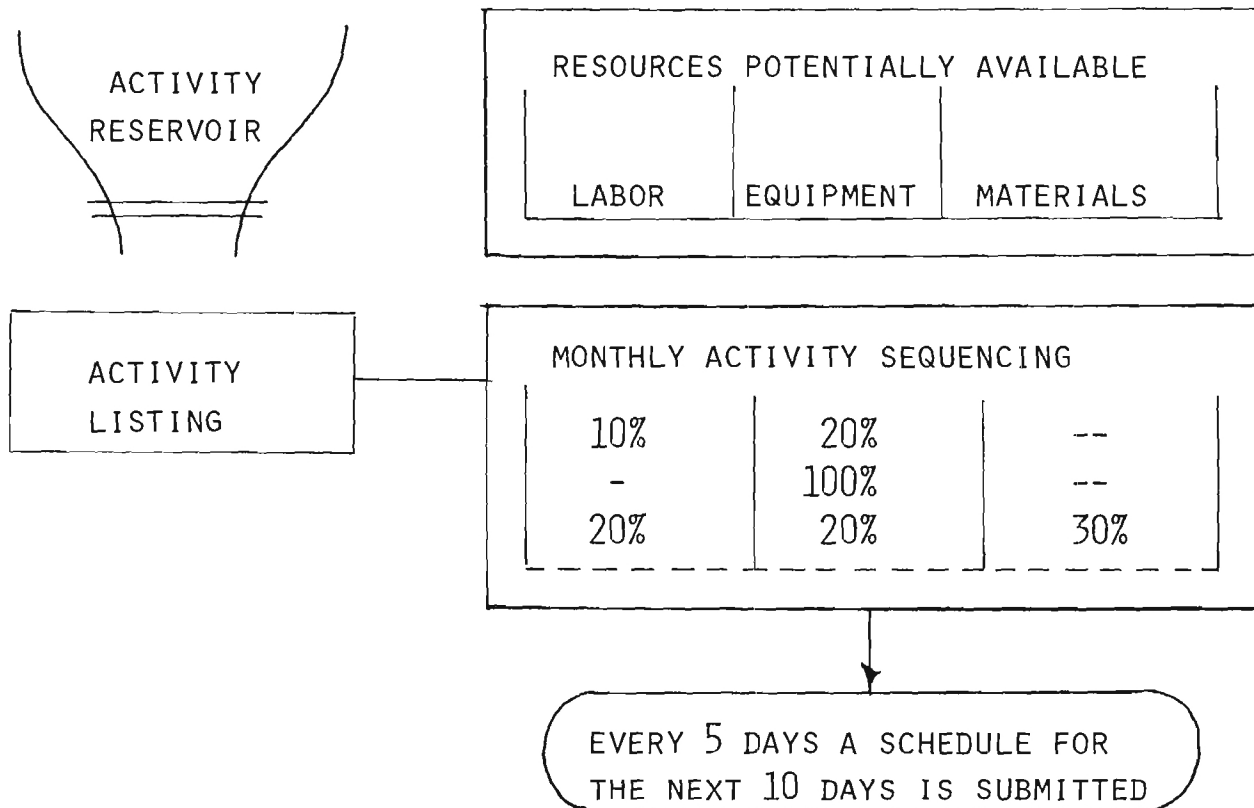


Figure 3.8 UPDATING AND PROGRESS REPORTING

into account the percentage of complete activities in progress, and the projected percentages complete across the coming quarter.

Job quantification by means of an activity breakout provides a simple and easily maintained feedback mechanism for the PLU system. Job status can be quickly established from field reports using this mechanism and the speed of data processing procedures.

SICOP Subsystems

The supply subsystem deals with insuring that materials are available for the trust or site as required according to the production schedule. The PEGAS system of programs controls order, input and output accounts, as well as reports of the material inventories in the field (site, company or trust, and Ministry) for major materials. Managers and accounting departments are provided with current reports on inventory status.

The equipment subsystem handles allocation of heavy equipment for the construction projects and equipment of transport vehicles. The SAMCO system of programs provides maintenance for: (1) records of equipment and transport means; (2) equipment allocation and scheduling; and (3) equipment cost accounts for completed activities. Major reports provided are: (1) equipment charts; (2) site status charts; and (3) equipment status reports.

Equipment allocation is established within the PLU subsystem examined previously.

The personnel subsystem is concerned both with overhead staff (technical and administrative staff) and direct productive labor force (workers). The subsystem establishes recruitment, hiring, promotion

and development procedures as well as distribution of the labor force. This subsystem utilizes two sets of data processing routines. The SIERRA programs pertain to overhead staff accounts, while the SURVEYOR program maintains records of productive labor force at crew level and individually by workers on the job.

The finance-accounting subsystem establishes procedures for development and control of the plan at the ministry, trust, and site level. It also maintains production costs and accounting records (involving direct and indirect costs) as a function of cost categories, and defines procedures for planning and controlling cost-price ratios. The PEGAS system of programs controls asset accounts (equipment, liquidation, distribution, etc.)

Information common to the SICOP subsystems required for management systems operation is organized in files grouped into four classes:

1. Estimating standards, catalogues, lists -- these data files provide a description of the structure within organizations belonging to the Ministry and the constructor's method of construction. They represent roughly 300 million to 350 million characters of data.
2. Order in the plan of the organizations (design, estimates, plan indicators, achievements, etc.) -- a full description is provided of the physical placement and value schedule of the organization (current and prospective value) as well as the progress made in achieving the schedule. This class of data represents a volume of roughly 1.5 billion to 1.8 billion characters at the Ministry level.
3. Production resources -- this file provides a description of current resources and requirements, as well as their flow. Labor force,

materials, equipment and financial information is maintained. At the Ministry level, data of this class represent roughly 3.5 billion to 4 billion characters.

4. Statistical information -- this file represents a synthesis of achievements accrued in preceding years. Information of this class is intended to aggregate company experience in order to plan future schedules. (File data include consumption accrued, costs, productivities, durations, etc.). File collections of this class contain roughly 300 million to 400 million characters.

This data bank of information as well as the computer programs utilized in the implementations of the SICOP subsystems are maintained at the control computer facility located at the Center of Management and Cybernetics in Construction (COCC) in Bucharest, Romania. This center consists of a French built IRIS-50 computer with supporting magnetic and paper tape secondary storage devices. A schematic diagram of the interface between the data bank and the management subsystems is shown in Fig. 3.9.

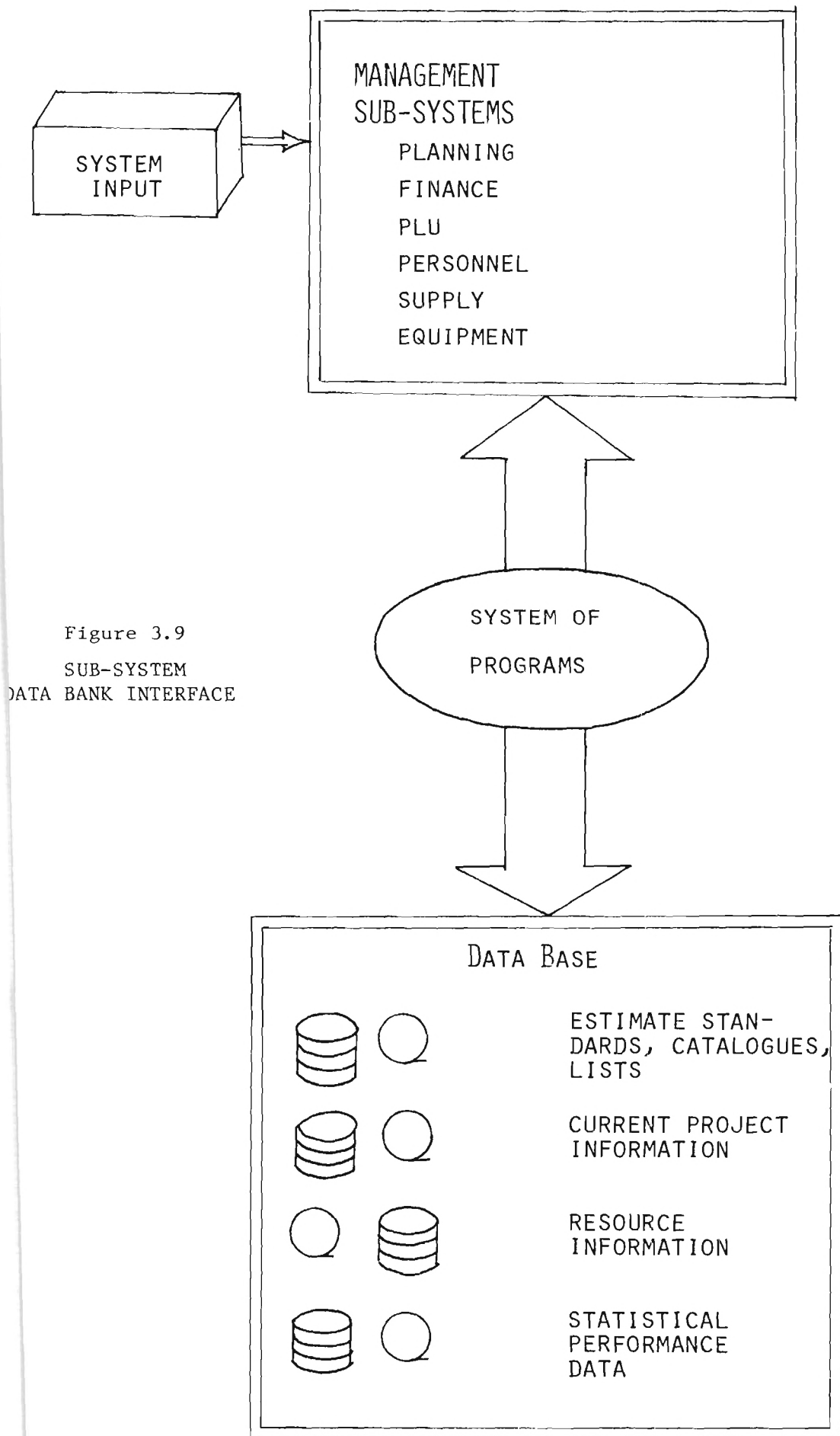


Figure 3.9
SUB-SYSTEM
DATA BANK INTERFACE

3.5 Comparison with Other Systems

The SICOP system approximates in its scope and concept information systems being developed in the United States by such firms as Bechtel and Daniel for the control of complex nuclear and fossil fuel power jobs. Daniel International utilizes a hierarchically constructed system that provides data takeoff at the level of the facility component (e.g., pour number, spool, cable tray, etc.), and allows updating of both cost and time-control monitoring systems. Since the physical components normally identifiable on Federal Power Commission controlled projects are coded, a system referenced to the component numbers (e.g., spool number, weld number, etc.) allows data routing to both time and cost reports. The component is hierarchically lower than and therefore common to the account codes used in the Cost System as well as the activity breakdown used in the time control networks. Referencing data acquisition to numerically coded field components also simplifies the foreman's task in reporting field progress. The SICOP has the advantage that the Romanian National Standards provide a common numerical labeling base for all components and work tasks encountered in industrial construction projects. Therefore, all trusts working throughout the country have a reference system at the element and cost account level in terms of which progress can be defined.

Data based systems such as SICOP have also been used in Germany in conjunction with the control of construction on the Munich Subway System. Such systems depend upon the breakout of the project into hierarchical levels (similar to the ones shown in Fig. 3.5) for project cost and time control. A system described by Nawrath utilized the standardized codes of the Leistungsverzeichnis (LV) to develop a level of component

description called the "collection" level (4). This hierarchical level has the advantage of providing sufficient detail for control without generating so much data that the processing system is overloaded. This Sammel position system allows accumulation of historical cost and control data which assists in planning financing, projecting work task durations, and checking bids submitted for cost accuracy and variation.

3.6 Conclusions

The monitoring capabilities provided by the SICOP system and the qualification of the construction process achieved using PLU result in certain advantages that greatly assist management at all levels:

1. The system allows documentation of the construction process during the preplan phase and logical organization of the work. This assists in defining realistic project milestones and schedules.
2. The system interfaces the cost control aspects of each project as defined by the bid item with the time control of the project as defined by the activity. It insures compatibility between cost accounts and time control activities.
3. Finally, communication between all levels of management from the Ministry to the job site is enhanced by the common definitions of project progress available using PLU.

The development of industrial complexes throughout Romania to meet an expanding market is a challenge to achieve new and innovative methods of control. The SICOP system and its sub-components are a first step towards meeting this challenge and applying system concepts to the management of large-scale construction programs.

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CHAPTER 4

REQUIREMENTS FOR CONSTRUCTION SIMULATION

4.1 Construction Management Aspects

One of the major functions of a project management system is the manipulation of a large and complex body of information relating to:

1. Construction project structure (physical components)
2. Construction cost information (final in place)
3. Resources requested and available
4. Construction company organization
5. Related organizations, to include
 - a. Owner
 - b. Owner's representative or construction manager
 - c. Project design organizations
 - d. Financial institutions
 - e. Equipment and material vendors
 - f. Subcontractors
6. Estimated quantities, estimated costs and estimated activity durations and times
7. Actual status of construction placement (i.e., progress reporting)

The manager needs this information to be able to judiciously allocate resources such as money, labor, equipment, materials and time. Proper information support allows the manager to efficiently use his resources. There are many aspects of construction management which are influenced by information requirements.

The management problem as well as the information and project control problem must be considered within the context of the organizations which must interface with one another. This is shown in Fig. 4.1.

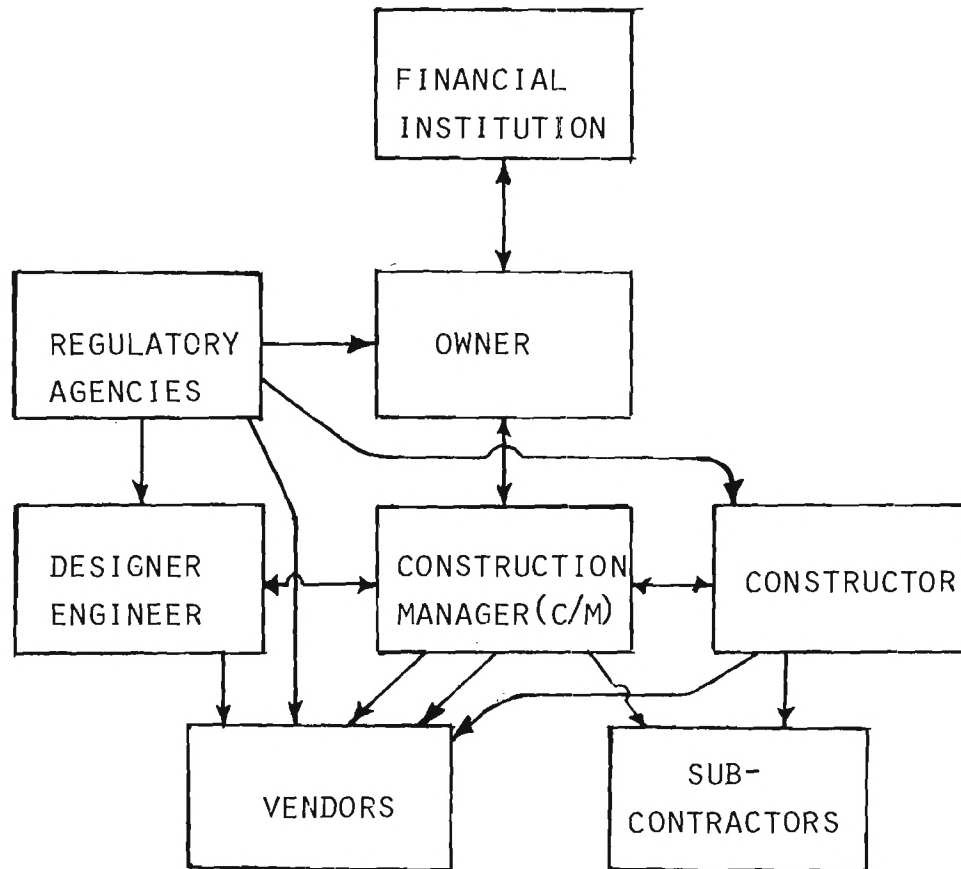


Figure 4.1 INTERFACING ORGANIZATIONS

The large number of actions and decisions on a project which must be made, implemented, and documented also place heavy emphasis on the proper management of information. The system designed for project management must be responsive to the demands for processing generated by these actions.

The wide variety of resources which must be utilized to realize the project add to the complexity of the management problem. Information regarding the status and availability of equipment, material, labor and other resources is critical to efficient decision making at the project level.

The functions necessary to the control and management of a project are diverse and cross many disciplines and fields of expertise. They require the availability and presentation of data in many and diverse forms. For instance, the accounting functional group views the wage paid a laborer for placement of concrete in one way, while the cost department is interested in this information from a completely different point of view. Some of the functional groups accessing and generating information on a typical project are shown conceptually in Fig. 4.2.

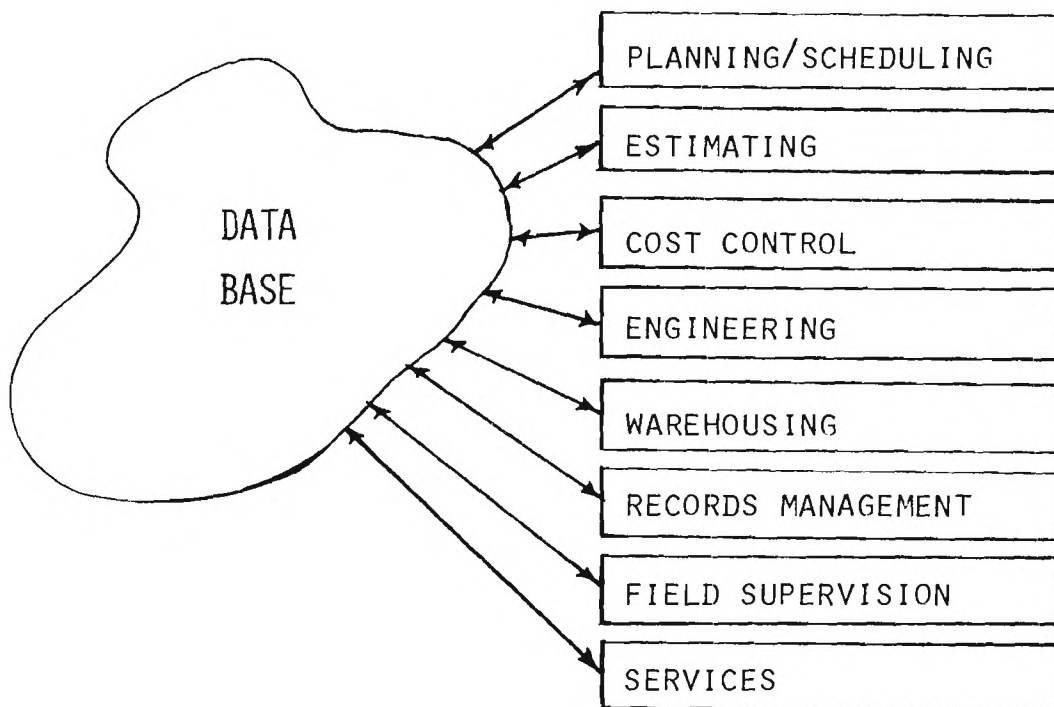


Figure 4.2 TYPICAL FUNCTIONAL GROUPS

The interrelationships existing between construction work tasks lead to a data control problem. Tasks are continuously subject to random events (i.e., weather, shipment delays, etc.) which change their duration and affect the allocation of resources. These changes impact upon other tasks because of the technological and management interdependence among activities on a work site. These fluctuations also impact upon the idleness and availability of resources and must be readily accessible to the manager through reports and updates so that he can respond effectively to deviations from plan.

Finally, due to the time span involved in medium and large size projects, the management environment is dynamic and continuously in a state of flux. The project manager is in the position of a pilot who must continuously check his "instruments" to determine the project status and make proper corrections. Since the manager's instruments for monitoring and detecting deviations from plan consist mainly of the data he has available, the availability and presentation of information in a current and updated format is critical to project control.

Since information is so important to the manager, the definition of important informational parameters as well as the structuring of data is of central interest in developing a workable and efficient project control system. The question must be asked, "What items of data should be maintained, and what is the best way of organizing the information needed for controlling the construction process?" The nature and structure of data can be broken into the following categories:

- a. Construction actions basic to the construction process (e.g., pouring concrete, welding, painting, etc.)
- b. Administrative actions required such as documentation of quality control, safety reports, preparation of payroll and cost accounting.
- c. Construction activities defined in terms of physical components and their interaction. The physical components in construction can be viewed in two ways:
 - 1. Based on the component's function (e.g., a beam, slab, mat footing, electrical system, etc.)
 - 2. Based on the component's role in the construction sequence (e.g., north section of slab 2nd floor, rough electrical work 3rd floor).

Information regarding both the functional as well as the construction sequence characteristics of major physical components must be defined and maintained.

- d. Resource information regarding physical resources such as labor, equipment, and materials.
- e. Organizational information regarding the groups involved in the project and the basis of information transfer between these groups, their responsibilities and structure.

These categories provide the design basis for establishing a management information system (MIS) which is responsive to the needs of the project manager. This information also supports the functional systems of (a) planning, (b) estimating, (c) scheduling, (d) cost control, and (e) accounting, which are among the basic decision making tools available to the manager.

4.2 The Information Cycle

Good statistical information on past field experience is essential to the planning and scheduling of future projects. Because of the complexity of the relationships just described, the collection and documentation of productivity in a statistical format should be a major function of the project control system. Such statistical data is also basic to the development of the background information required for simulation of project decision making. Simulation provides the manager with a tool based on actual field performance which allows him to allocate scarce resources.

Efficient collection, storage, documentation, and retrieval of relevant information both for simulation and decision making purposes requires the use of a data base approach to information handling. The interaction between these four elements of the project control system is shown schematically in Fig. 4.3.

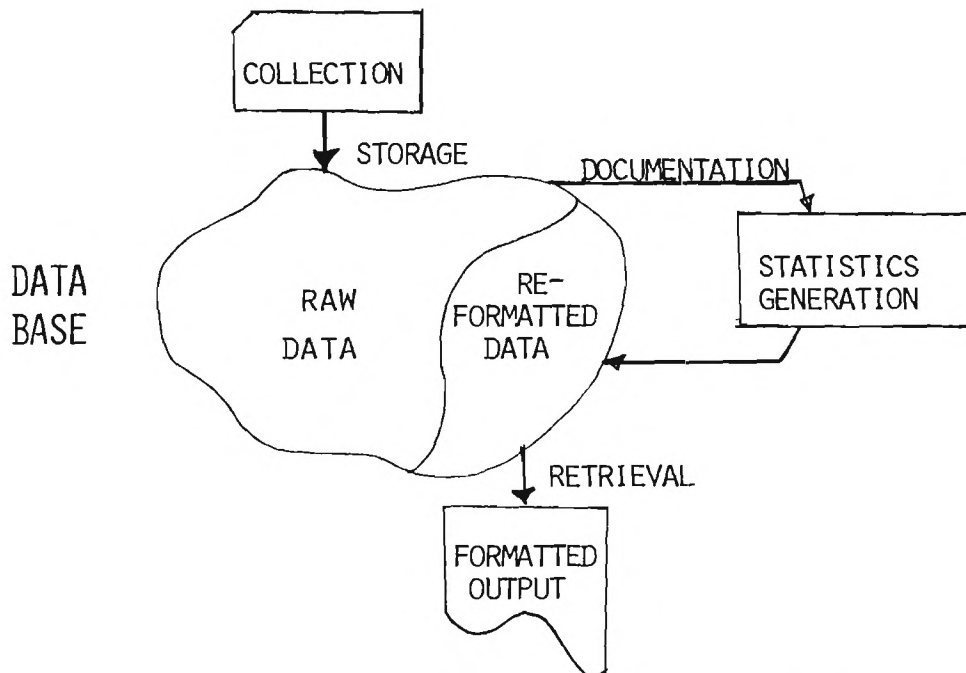


Figure 4.3 FUNCTIONAL PROCESSING RELATIONSHIPS

4.2.1 The Data Base

The data base itself represents the most efficient way of storing information acquired from project activity. It can be considered conceptually as a sophisticated "filing cabinet" which provides not only the means for compactly storing information generated by a diverse group of project organizations, but also facilitates information transfer between these organizations. Various interface programs allow access to and from the data by the relevant user groups based on need and function. This is shown schematically in Fig. 4.4.

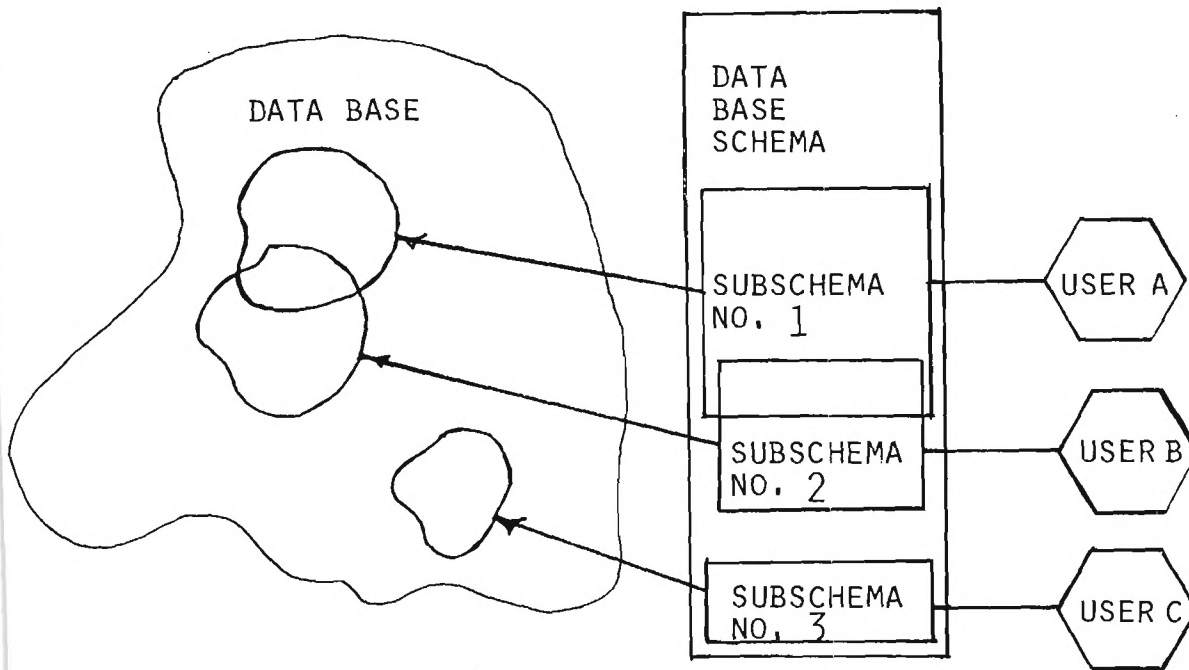


Figure 4.4 USER-PROGRAM INTERFACE

The interface programs are the "doors" by means of which various user groups (e.g. planning, estimating, scheduling, etc.) can access information files in the data base.

The nature of access is dependent upon the requirements of the individual user group and its need to access and update information. Some organizations, such as cost accounting or warehousing, have the privilege of changing and updating data (i.e., writing on the data base), while other organizations, such as headquarters liaison personnel, have a "read only" capability. Additionally, the method of presentation of data as well as input of data will vary from user group to user group. Ministry or company top management people are interested mainly in short "exception" reports presented on display or low-speed terminal devices, while project level control departments require record documentation in report output format. Similarly, time critical information should be submitted to the data base immediately in an on-line format, while large amounts of data such as payroll information should be submitted at low activity periods in batch format.

One portion of the data base is maintained for storing and updating statistical information generated from raw data input. For this reason, the relationship between the data base and statistics generation in Fig. 4.3 is indicated by a two-way arrow.

4.2.2 Statistics Generation

Simulation as a relevant approach to Construction Management is dependent upon reliable and accurate statistical information regarding the construction environment and past projects. As noted, the data base provides an excellent means of developing the necessary background statistics required for simulation.

The data base approach allows for definition of the appropriate selection parameters or "keys" which are required for retrieval of information and the generation of relevant statistics. Raw input information is established in files such as those shown in Figs. 4.5(a), (b) and (c). (See Crandall, 1970).

Record Header

| | |
|------------------------|--------------------|
| # Items | Current Pointer |
| Directory Pointer | Beginning Location |
| Eight Additional Words | |

Activity Schedule Information

| | | | |
|------------------------------------|--|-----------------|-------------|
| % Complete | | Activity Label | |
| Five Words of Description | | | |
| (20 characters) | | | |
| | | | |
| | | | |
| Change Order flag bit | | | |
| Duration | | Free-Float | Early Start |
| Total Float | | Scheduled Start | |
| Labor Activity-Related Pointer | | | |
| Material Activity-Related Pointer | | | |
| Equipment Activity-Related Pointer | | | |
| | | | |

Figure 4.5(a) SCHEDULING FILE RECORDS

Retrieval as required for generation of statistics can be accomplished using an inverted list schema such as that shown in Fig. 4.6, or more sophisticated methods depending upon the computer hardware available and the retrieval and access time requirements.

4.2.3 Simulation Requirements

Using the statistics available in the data base, relevant information regarding weather, environmental factors, craft productivity, and other important background parameters can be provided to simulation routines. The method of interfacing these statistical models is similar to that used in management gaming programs such as CONSTRUCTO and process analysis simulation programs such as CYCLONE (see Halpin and Woodhead, 1973 and 1976). Monte Carlo simulation using discrete next-event methods is used in a modeling environment consisting of templates such as that shown in Fig. 4.7. These templates and their construction are subjects for the second phase of this research program.

4.2.4 Resource Allocation

The simulation environment provides the laboratory in which various resource allocation schemes can be tested on an ongoing basis. The ultimate system will allow on-time experimentation with the existing system state as represented in the data base.

The data base approach provides current levels of resources available and committed as well as current cost information regarding the mobilization and transfer of resource entities. This resource information covers all resources to include labor, materials, equipment and subcontractors. Methods similar to those discussed by

| | | |
|-----------------------------|-----------------------|--------------|
| Status -- | Schedule File Pointer | # Items Here |
| Workmen's Compensation Code | | |
| Units Code | Labor Code | |
| Comm't Date | # Committed | # Req'd |
| Hrs Overtime | Hrs Straight | |
| Accum. Hr. O/T | Accum. Hrs. Straight | |
| Shift Oper. | Last Date | Summ. Date |
| # Estimated | Labor Summary Ptr. | |

Repeat as necessary
one block per each
labor item requested

| | |
|----------------|-------------------|
| Extension Ptr. | Continuation Ptr. |
|----------------|-------------------|

Figure 4.5(b) LABOR-RELATED INFORMATION
"CURNT" "BEGLOC"

| | |
|-----------------------------------------------------|---------------------------------------------------|
| Last Entry in the individual multilists | Pointer to beginning of the individual multilists |
| File 7 | |
| First Labor Requirement by First Activity | |
| n th Labor requirement by First Activity | |
| Extension Ptr. | Continuation Ptr. |
| First Material Requirement by First Activity | |
| n th Material Requirement by 1st Act. | |
| Extension Ptr. | Continuation Ptr. |
| Only Labor Requirement by 2nd Activity | |
| Extension Ptr. | Continuation Ptr. |

Labor Act. 1

Material Act. 1

Figure 4.5(c) GENERAL ORGANIZATION OF ACTIVITY-RELATED FILE

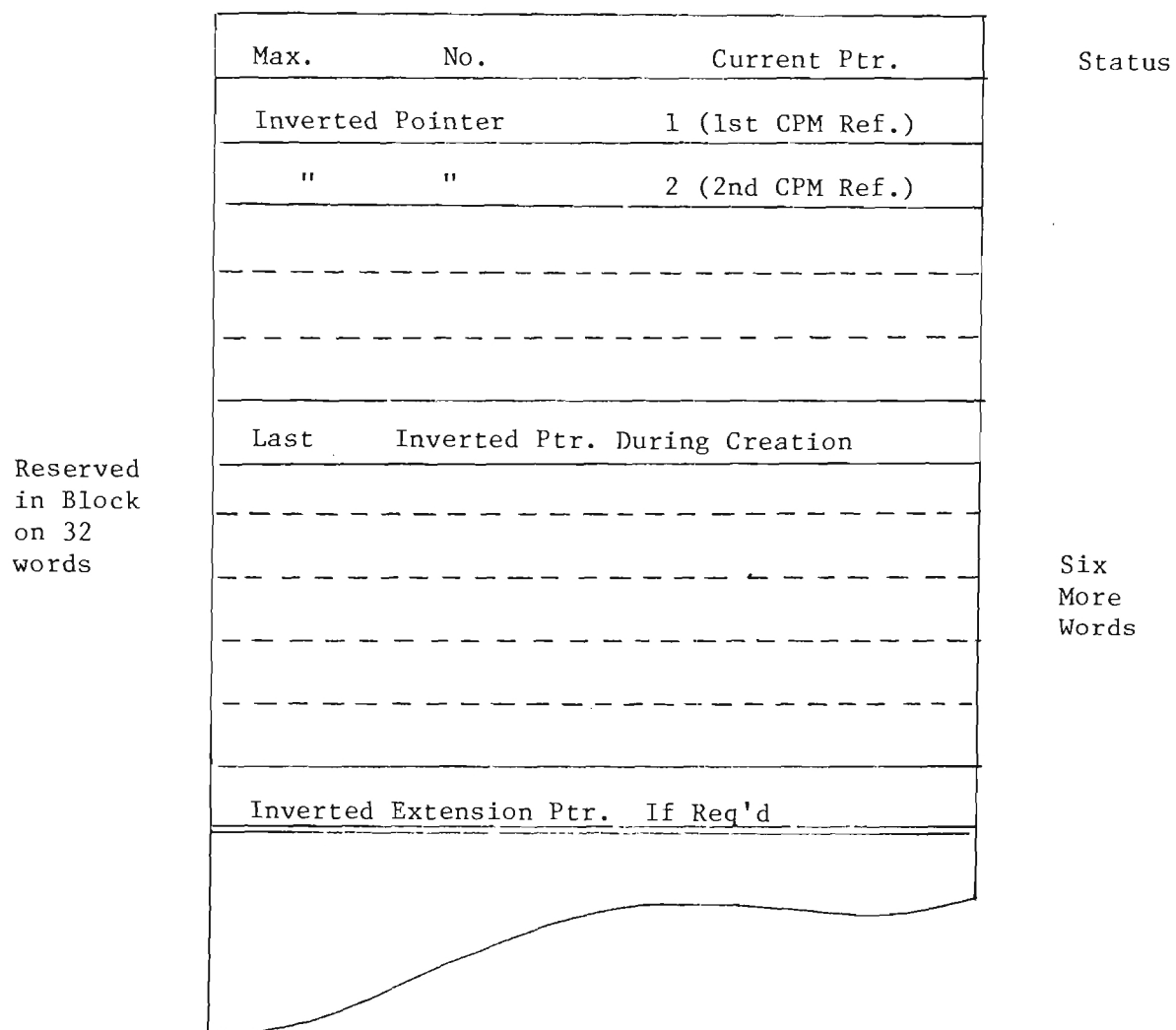


Figure 4.6 TYPICAL INVERTED LIST

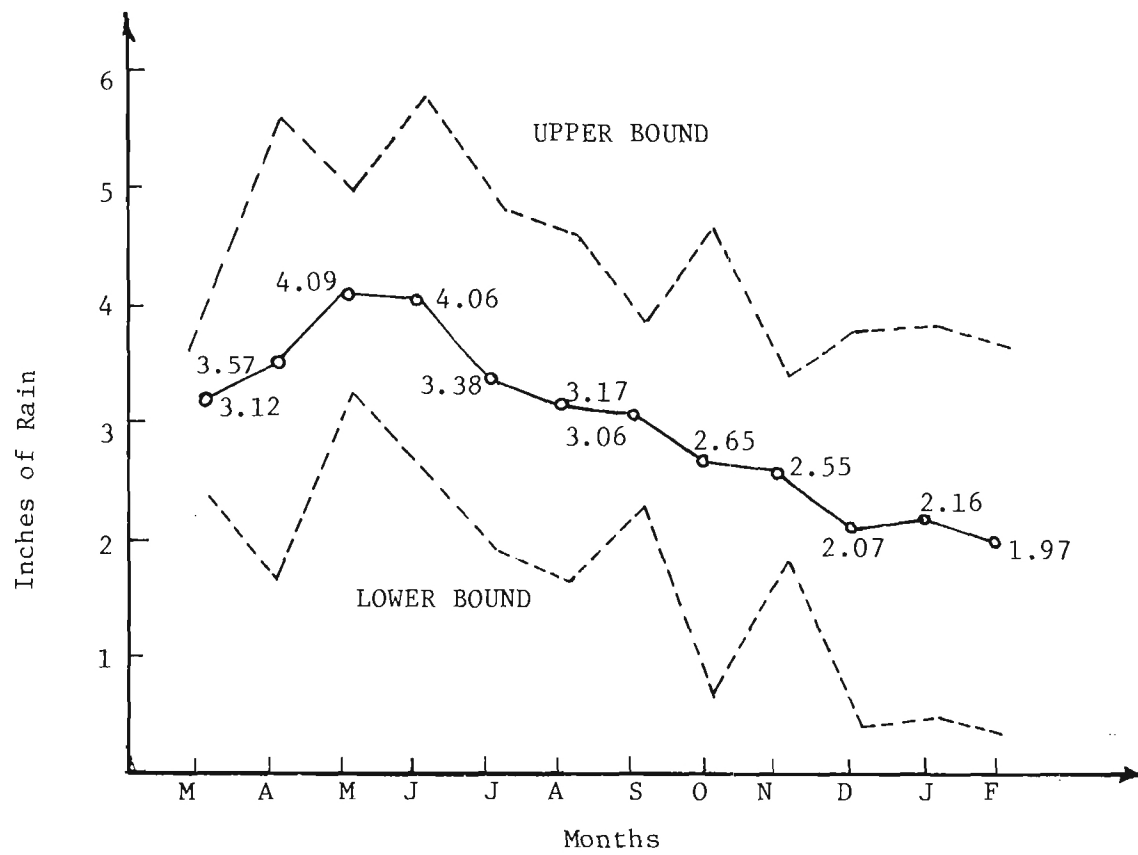


Figure 4.7 RAINFALL TEMPLATE

Preston (4) utilizing dynamic programming as a solution technique are used to generate the set of resource commitment options available to the construction manager.

The layout of the data base and the statistical parameters maintained are closely related to the design of the environmental templates and the resource selection and allocation functions. Preliminary work on the data base described has established the open structure of the data base required and determined the interfacing organizations and programs to be developed. More detailed work on the resource allocation mechanism will be conducted during the next phase of the project.

4.3 Need for a Data Base Approach

From the previous discussion it is clear that current and accessible data is a prime requirement for the use of simulation as a management tool. For this reason, the initial phase of this research has concentrated on the construction of existing project management systems being used in Romania to detect those aspects influencing information flow, organization, retrieval and storage. It has become apparent that the most efficient approach to implementation of simulation techniques is founded on the utilization of data base techniques appropriate to the Romanian as well as the U.S. construction environment. Following chapters indicate in detail the operation of the Romanian project control system, PLU, and establish the basic structure of the data base required to implement this system both in the Romanian as well as in the U.S. construction industry.

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CHAPTER 5

SOLUTION METHODOLOGIES - PLU AND PROMETEU

5.1 Planning, Scheduling, Mobilization and Follow-Up of Construction Projects

The products of the construction activity are physical components and functional systems of the project.

To achieve the completion of any product means to ensure for every moment t_i within a physical stage S_i , a labor force F_i , equipment E_i and materials M_i (Fig. 5.1) are needed to reach the next physical stage S_{i+1} .

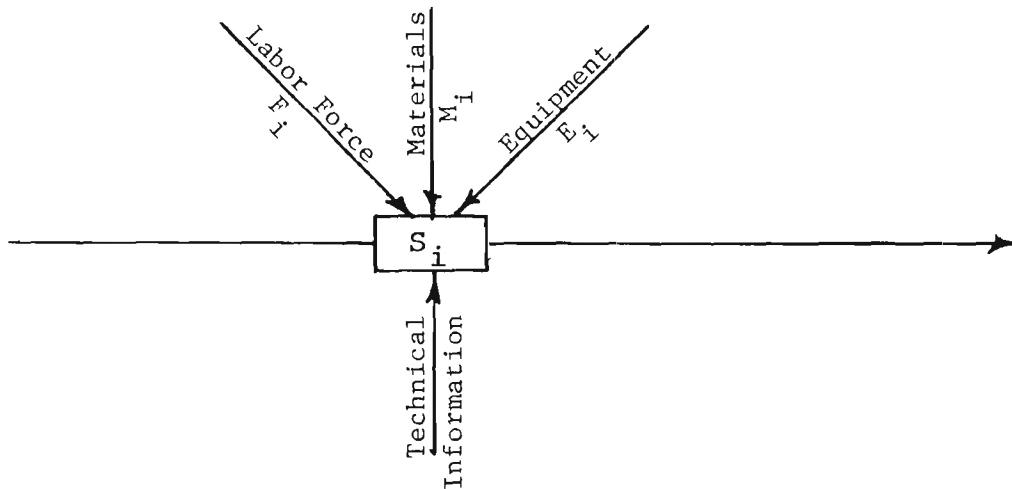


Figure 5.1 DIAGRAM OF THE PRODUCTION PROCESS

Resources F_i , E_i and M_i are a function of the physical stages S_i and S_{i+1} :

$$F_i = f (S_i, S_{i+1})$$

$$E_i = e (S_i, S_{i+1})$$

$$M_i = m (S_i, S_{i+1})$$

We associate a calendar date t_i with each physical stage S_i when we forecast its completion; the sum total of combinations (S_i, t_i) defines the execution chart - G - :

$$G = S_i, t_i$$

According to this time sequencing, a sequence of resources is required over time: $F(t)$, $E(t)$, $M(t)$ respectively.

Any lack of correlation in time between physical stages and resources results in either delays in the chart showing work progress or costly resource idleness.

Maintaining a constant, dynamic balance between tasks and resources involves the operation of a set of processes related to E.D.P. and decision; therefore, the operation of a management system must be capable of:

(1) Processing a huge volume of data in a short time span. Synchronization between physical stages and the required means has to be carried out for as many as 2,500 to 3,000 objects, 50 to 60,000 materials assortments, up to 800 types of equipment and 15 to 20 trades with which a construction unit is currently operating.

(2) Rapidly reacting to unavoidable deviations from forecasted circumstances.

The major component of this entirety is what we call the process of project planning, scheduling, mobilizing and follow-up, which consists of

the following stages (Fig. 5.2):

- (1) Receiving project documentation, technological preparation of execution.
- (2) Analysis of work in time sequence (development and up-dating of execution charts $G = S_i, t_i$).
- (3) Establishing production schedules for the period under consideration (year, quarter, month) so as to carry out tasks (due dates, values) and ensure the balance between requirements and available resources.
- (4) Assigning production tasks to crews.
- (5) Result measurement; comparison with provisions and tasks.

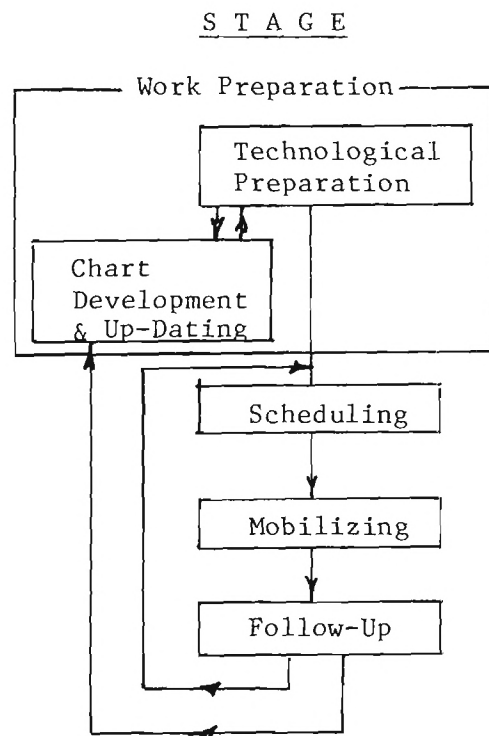


Figure 5.2 PROJECT PLANNING, SCHEDULING, MOBILIZING AND FOLLOW-UP DIAGRAM

Within a construction unit (trust, company), one may distinguish, at a given point in time, an aggregate of subunits P_j (groups of sites, sites, work locations) responsible for the execution of an aggregate of investment targets I_k .

$$\text{Let } P_{jk} = \begin{cases} 1. & \text{if subunit } P_j \text{ must execute work belonging to investment target } I_k. \\ 0. & \text{if it has not been assigned work to execute.} \end{cases}$$

The incidence matrix P_{jk} highlights the distributed subunits, i.e., the allocation of tasks involving the execution of investment objectives:

$$\begin{array}{c} I_1 \cdot \cdot \cdot I_k \cdot \cdot \cdot I_m \\ \begin{matrix} P_i \\ \cdot \\ P_j \\ \cdot \\ P_k \end{matrix} \left\{ \begin{array}{ccc} P_{i1} \cdot \cdot \cdot P_{ik} \cdot \cdot \cdot P_{im} \\ \vdots \\ P_{j1} \cdot \cdot \cdot P_{jk} \cdot \cdot \cdot P_{jm} \\ \vdots \\ P_{k1} \cdot \cdot \cdot P_{nk} \cdot \cdot \cdot P_{km} \end{array} \right\} \end{array}$$

on condition that:

$$\sum_{j=1}^n P_{jk} \geq 1, \sum_{k=1}^m P_{jk} \geq 1$$

Within the preparation, scheduling, mobilization and follow-up process one may distinguish between two kinds of actions:

(1) Actions dealing with investment targets (columns of matrix P_{ik}). Belonging to this class are the actions of technological preparation and chart development, both of which are included in the first phase, that of work preparation;

(2) Actions dealing with the problems of a subunit, therefore, elements of a row in matrix P_{ik} . Included in this class are, for instance, the actions of preparing production schedules which involve an analysis of all jobs assigned to the construction subunit or unit; since resource availability is known (for most resources) only at organizational levels (site, trust, Ministry) and not for each project, the balance between requirements and availabilities has to be achieved at these levels.

One of the major difficulties encountered in developing production schedules occurs since execution charts for construction objects do not observe the time span (year, quarter, month) for which a schedule is developed. That is, they exceed the time limits of the period in question (Fig. 5.3).

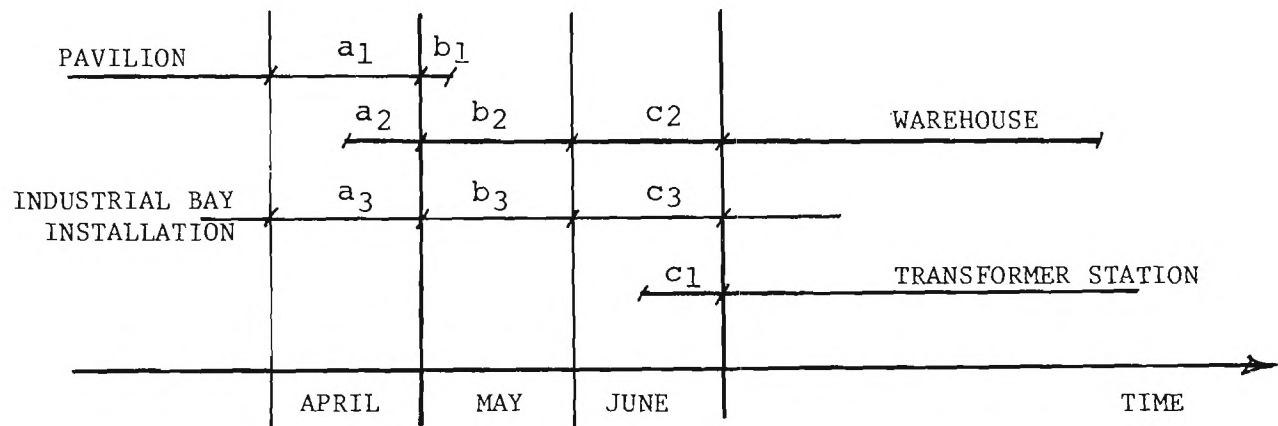


Figure 5.3 BAR CHART FOR 2ND QUARTER

Consequently, one should be provided with a key to quantifying the execution process which should allow us to:

(1) Express segments a_1 , b_1 , a_2 c_4 (parts of objects) in a technical engineering language that visualizes the physical contents of jobs in these segments;

(2) Establish resource requirements for each of these segments by means of accessible procedures.

The present solution consists of developing cost items for "segments" $a_1, b_1, a_3, \dots, c_4$; this is inadequate, as will be demonstrated below.

As for the actual analysis of the balance resource requirements - availability is concerned, one may distinguish between two classes of resources:

(1) Resources lending themselves to storage (e.g., warehousing) whose usage value can be maintained over time. Materials are included in this class (a quantity of cement that has not been used during May is usable during June or much later). The components which must be balanced for this class of resources are:

- forecasted requirements (cumulated quantities)
- forecasted availability (original inventory + orders)

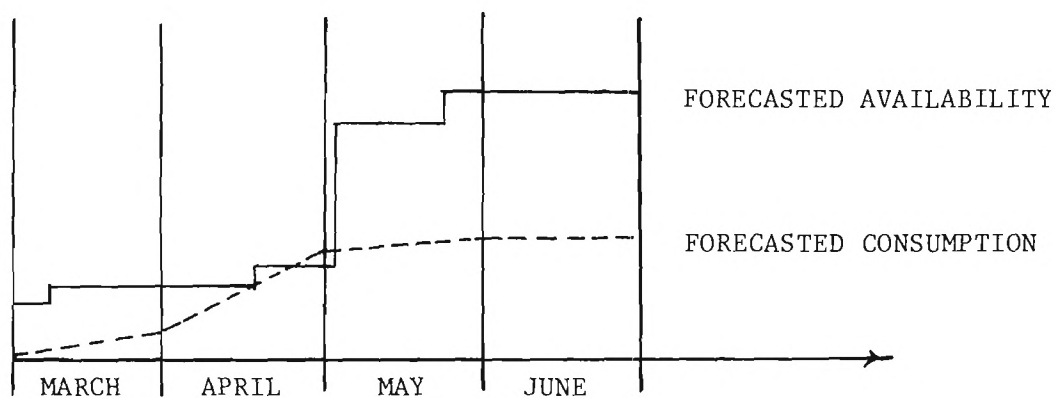


Figure 5.4 CEMENT BALANCE FOR 2ND QUARTER (1st solution)

For each of these resources we must make sure to avoid consumption in excess of available resources (the area encompassed between April and May - Fig. 5.4) as well as exaggerated inventories (the area encompassed by June).

As a matter of fact, the optimal solution is the one that insures available quantities which exceed requirements by a certain quantity within the limits of the safety-stock (Fig. 5.5).

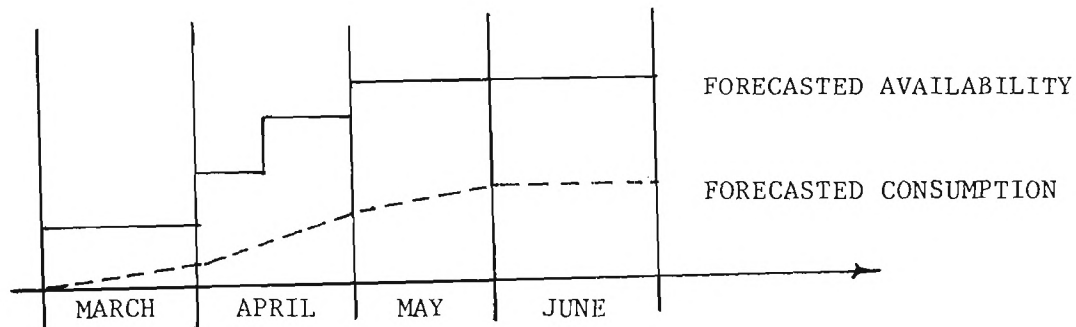


Figure 5.5 CEMENT BALANCE FOR 2ND QUARTER (2nd solution)

This kind of solution implies complex analyses and reallocation at trust or even ministry level. For how many materials out of the tens of thousands of assortments used is such an analysis feasible?

(2) Resources that cannot be stored, and whose usage value cannot be maintained. This class includes manpower and means of mechanization (the 150 man-hour capacity of a carpenter's crew which has not been used on the 2nd of July cannot be used on the 3rd).

For this class of resources one has to ensure their constant use within capacity constraints; in other words, one should secure a leveling of requirements (Fig. 5.6).

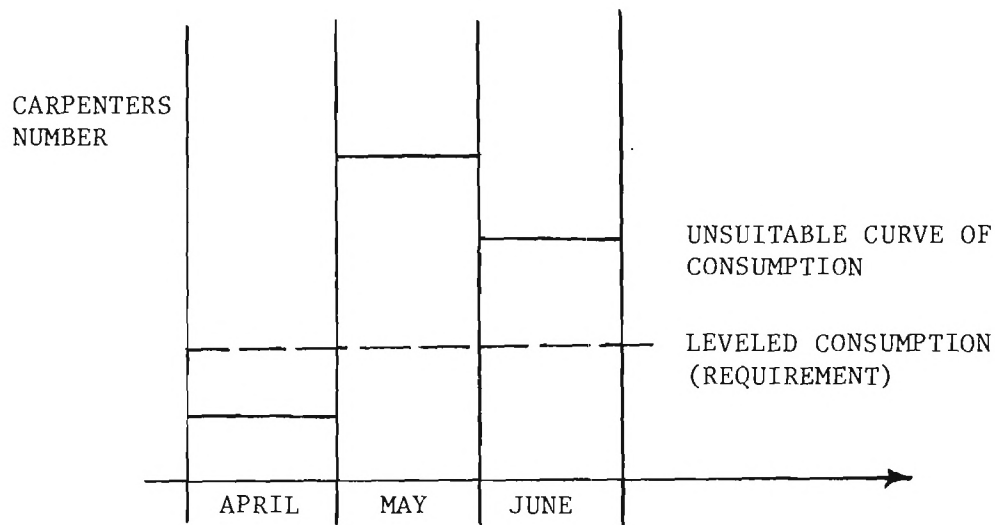


Figure 5.6 RESOURCES LEVELING ANALYSES - FOR 2ND QUARTER

A question whose answer is more difficult to determine than would appear is: "At which level of management should consumption be leveled? Should it be done at project level, site, trust or locality?" In actual fact, consumption should be leveled by areas where resources can be readily moved, i.e., areas which might encompass one or several projects, one or several sets of projects, or even an entire trust.

As far as equipment is concerned, difficulties faced in establishing only the requirements are a well-known fact. The problem of optimally

allocating these means is still not solved.

The involvement of several construction units (general contractor and sub-contractors) in the execution of investment goals requires coordination between the production schedules of those units which must be made specific by stating the conditions of work commencement.

A huge volume of data processing is required to solve both the problems previously stated and some others not mentioned due to limited space.

Are these problems solved through present procedures? The answer is NO.

5.2 Shortcomings of the Present Way of Solving Problems

An analysis of the current situation in a series of construction units belonging to the Ministry of Industrial Construction and to the industry as a whole led us to the conclusion that present procedures for project preparation, scheduling, mobilization and follow-up cannot be put into practice; on the average, the effort required to apply them, i.e., personnel needed, exceeds the available staff by 40 to 45%.

Preparation of "the quarterly operation plan" in an industrial construction trust of medium size^{*} requires employment of personnel whose number exceeds the availability by 100% during peak periods (Fig. 5.7).

The effort peak, between the 3rd to the 9th of the month preceding the quarter, corresponds to the actions of preparing estimate items and computing resource requirements, which requires the processing of 100 to 125,000 cost items.

*As a result of an analysis of the Ministry's units, ART (Average Reference Trust) was defined. A simulation was made of the application of both present and new procedures for project preparation, scheduling, mobilization and follow-up.

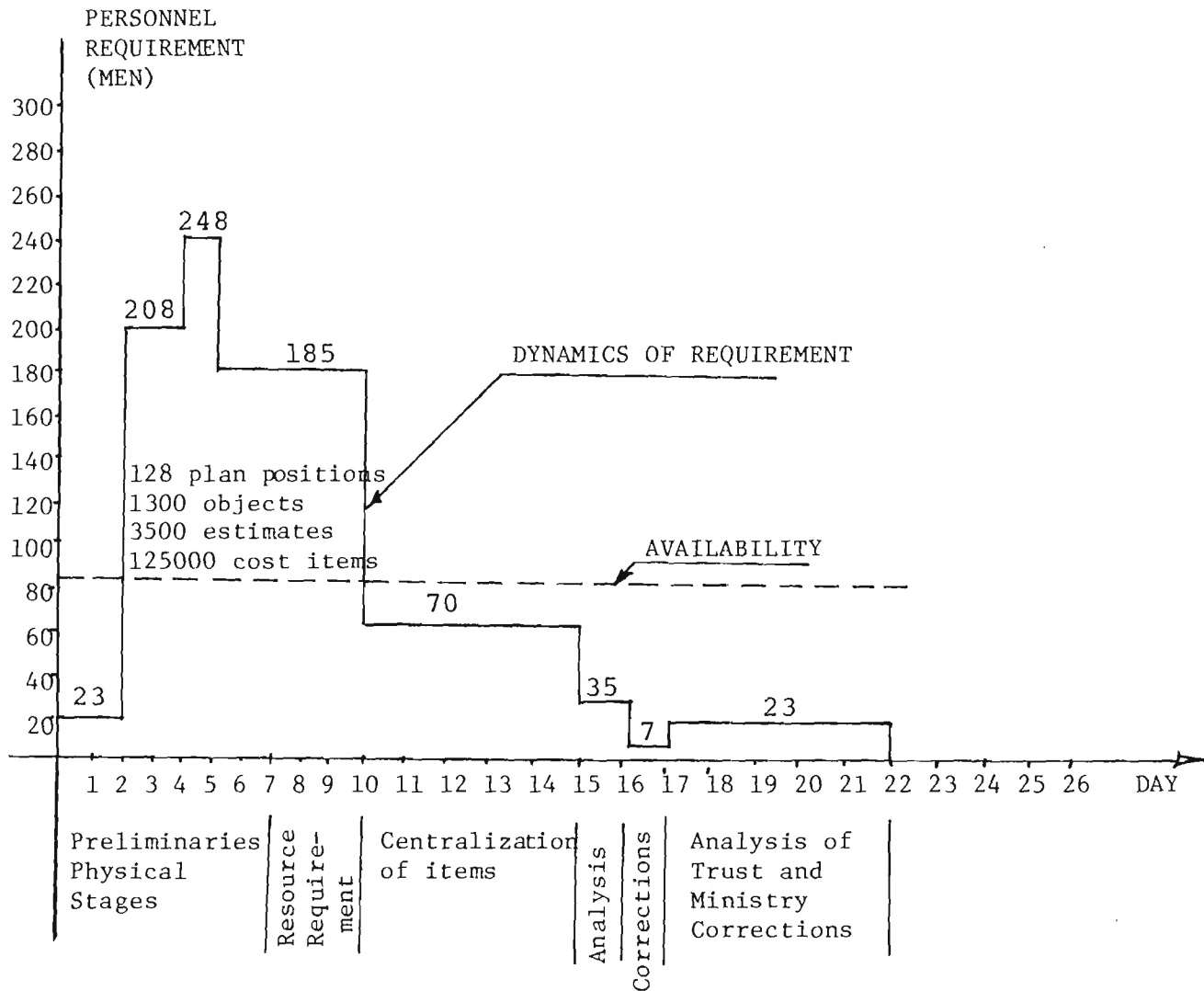


Figure 5.7

PERSONNEL REQUESTED AND AVAILABLE FOR QUARTERLY PROGRAM PREPARATION

This status is, to a large extent, the result of shortcomings rendered by the present procedure in which projects scheduled for a given year, quarter or month are expressed in terms of estimate items (Fig. 5.8).



Figure 5.8 ESTIMATE ITEM SEGMENT FOR 2ND QUARTER

Throughout the execution of a construction object the process of establishing the estimate item has to be revised three to five times in order to develop the plan of operations and work-in-progress status.

Moreover, during the preparation of the plan of operations, estimates should be revised one to two times, at least, until the achievement of value plan tasks and balance with available resources is achieved. Since estimate items must be worked out as close as possible to the end of the quarter (when a more accurate evaluation can be made as to the physical stages at the beginning and end of the next quarter), the process of planning, scheduling, mobilization and follow-up is subject to great effort peaks.

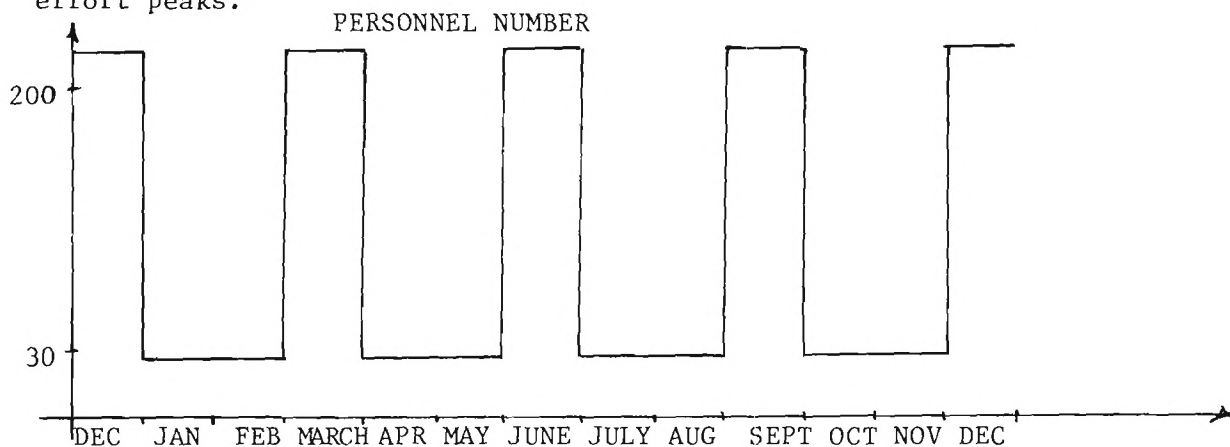


Figure 5.9 PERSONNEL REQUIREMENT IN ART TRUST

This leads to consequences that are well-known:

(1) In order to "develop" the production schedule, each unit (sub-unit) and even each production manager has worked out his own approximate procedures; therefore, in actual fact there is no such thing, at present, as a true management system;

(2) The fundamental action of physical stage becomes second hand; quarterly production schedules vaguely attempt to correlate production values with resource requirements. More often than not, this attempt is translated into exaggerated requests for resources that show a shortage during the period;

(3) A correlated break-up of the production schedule cannot be done down to the crew level, where it should materialize; therefore it remains suspended and not finalized as a schedule.

5.3 PLU's Solution

5.3.1 PLU's Objectives

From the previous chapters, the impossibility of solving preparation, scheduling, mobilization and follow-up problems by means of existing procedures is apparent. Since one can neither do away with these problems nor make them simpler, the only thing left to do is to search for a new way. The PLU was developed in order to find a new way. PLU's objective is to rigorously solve all problems related to planning, scheduling, mobilization and follow-up by establishing a processing and decision effort commensurate with the staff available in construction units.

Achieving this objective means establishment of a new solution for work quantification which is based upon management by physical stages and does away with the shortcomings of the estimate item. Returning to

the simple diagram of the production process (Fig. 5.1), there is no simple logical relationship which leads us from resources to physical stages.

$$SF = S (F, E, M)$$

Instead, only relations leading us from physical stages to resources are apparent. Resource requirements are a function of physical stage $S_i \rightarrow S_{i+1}$; the achievement of the latter is developed as:

$$F = f (SF_i, SF_{i+1})$$

$$M = m (SF_i, SF_{i+1})$$

$$E = e (SF_i, SF_{i+1})$$

Obviously, at organizational level, the production schedule (scheduled physical stages) should be optimized, so that optimal use of resources can be made. However, a decision to schedule and make corrections to the schedule requires decisions to be made by physical stages.

The use of the electronic computer is required to take over most of the data-processing of the huge volume of information resulting from the process of project planning, as well as the processing required to work out charts, annual and quarterly production schedules, and production reports which cannot be achieved using traditional systems.

5.3.2 PLU's Concept

The essentially new elements introduced by PLU, which decisively contribute to reaching the above formulated goals, are:

- (1) The concept of ACTIVITY and
- (2) The computer.

The ACTIVITY is, from a formal point of view, also an estimate item, the only difference being that it no longer corresponds with a calendar period but with a technological stage of execution (execution of insulated foundations, execution of concrete floors, fitting wall panels, etc.).

Let us assume A, B, C, D, and E are technological stages in the execution of an industrial workshop (Fig. 5.10).

The sum total of "segments" a, b, c, d, and e scheduled to be completed during the 2nd quarter (April 1 - June 30) makes up the so called estimate item:

$$ED_{\text{quarter II}} = (a) \cup (b) \cup (c) \cup (d) \cup (e)$$

An ACTIVITY is the contents of work for one of the technological stages (A), (B), (C), (D) or (E).

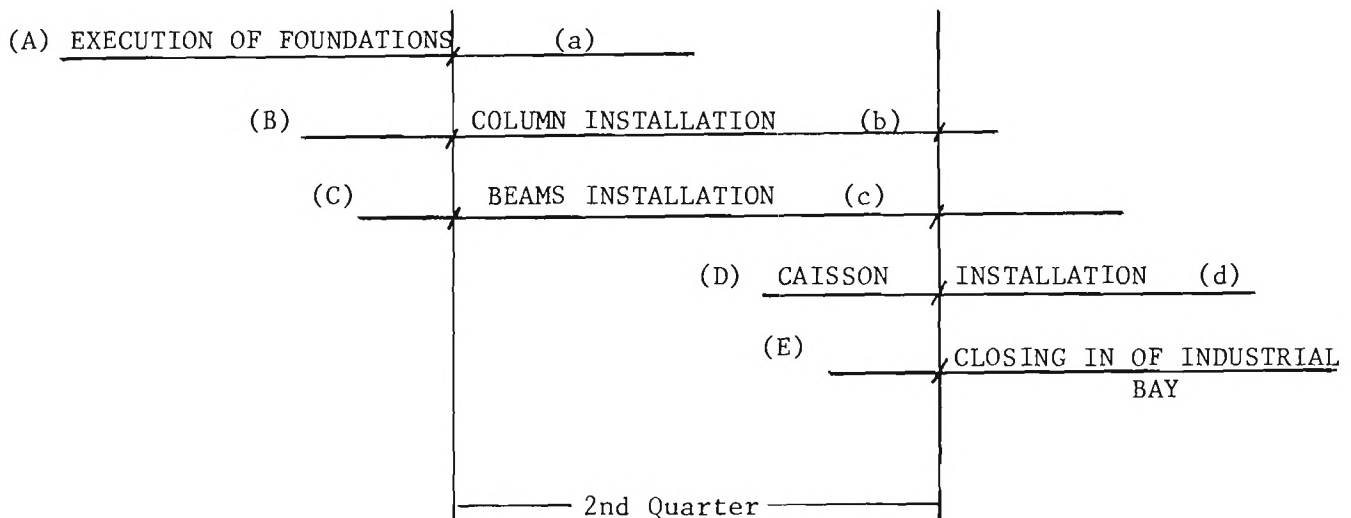


Figure 5.10 BAR CHART FOR 2ND QUARTER

Having defined an ACTIVITY as shown above, its content is not dependent upon the calendar period in which it is to be executed. Therefore, it may, at any time, be defined, starting from the moment when execution drawings arrive. The consequence is very important. The effort of defining ACTIVITIES has a relatively constant distribution in time.

Obviously, "ED_{quarter II}"* is not in the least a hypothesis likely to be achieved. In actual fact, what will be achieved are the segments

(a') \neq (a)

(b') \neq (b)

(c') \neq (c)

(d') \neq (d)

(e') \neq (e)

This requires new action to be taken in order to establish the estimate item for both the current quarter ED_{quarter II}, and for the next quarter ED_{quarter III}.

Establishing ACTIVITIES so as to have all types of jobs included as uniformly distributed as possible throughout their execution underlines a great advantage of PLU, namely, the capability of expressing parts of an ACTIVITY in %. A given p% complete corresponds with the same p% of all component jobs and, therefore, with all resources required in completing the ACTIVITY.

Assuming that:

A_i is ACTIVITY i

C_i - total quantity of jobs included in A_i

*ED = abbreviation for estimate item.

V_i - value of the ACTIVITY (worth)

L_{ij} - quantities of jobs for estimate item j included in A_i

R_{ik} - quantities of resources k required to complete ACTIVITY A_i

The above stated condition implies for every segment (part of object)

$$a_i \in A_i$$

corresponding with any time interval (t_1, t_2) needed in executing ACTIVITY A_i , corresponding elements c_i, v_i, l_{ij}, r_{ik} should exist so that:

$$\frac{c_i}{C_i} = \frac{v_i}{V_i} = \frac{l_{ij}}{L_{ij}} = \frac{r_{ik}}{R_{ik}}$$

In the practice of construction management, the simplest way is to have all achievements (i.e., stages scheduled by technological phases at moment t_i) measured cumulatively, from the beginning moment to t_0 .

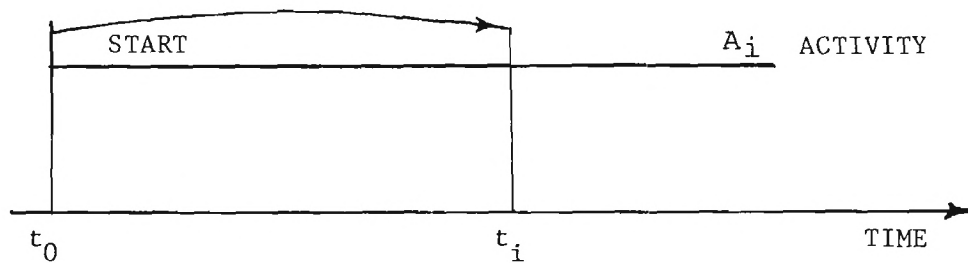


Figure 5.11 CUMULATIVE MEASURES FOR ACTIVITY STATUS

Under these circumstances, quantities and progress (by ACTIVITY) are reported in cumulative percent p_i (Fig. 5.12).

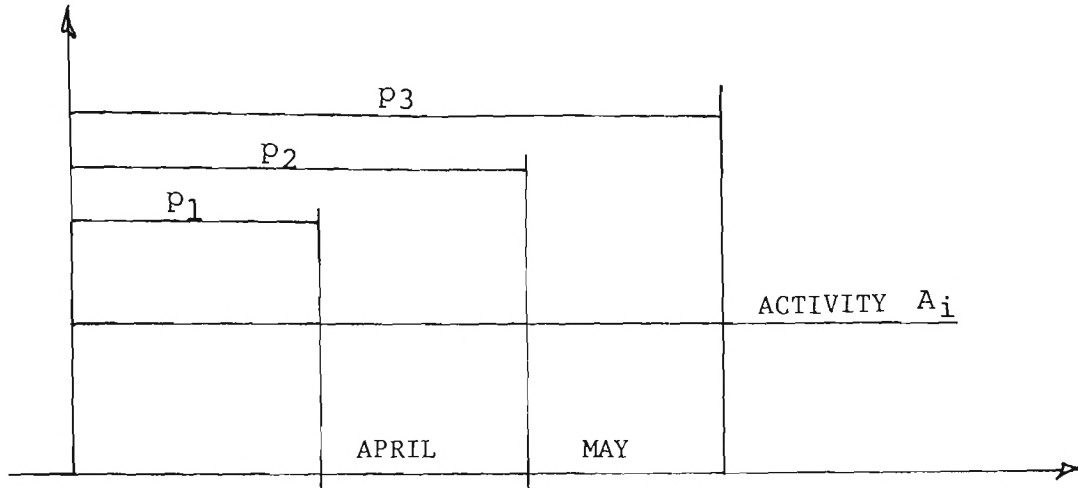


Figure 5.12

CUMULATIVE PERCENTAGE MEASUREMENTS FOR ACTIVITY STATUS AT APRIL AND MAY

Since progress at the end of April is $p_2\%$, the schedule for May providing for $p_3\%$, we have the following expression for May:

$$c_i = \frac{p_3 - p_2}{100} C_i$$

$$v_i = \frac{p_3 - p_2}{100} V_i$$

$$l_{ij} = \frac{p_3 - p_2}{100} L_{ij}$$

$$r_{ik} = \frac{p_3 - p_2}{100} R_{ik}$$

The way in which these levels are reported will be illustrated by two examples:

(1) The installation of 750 column foundations. Each foundation requires 3 to 5 cu. meters of excavation; 0.5 cu. meters of leveling concrete, 170 kilograms of reinforcement, 2.6 sq. meters of formwork and

2.8 cu. meters concrete. This can be viewed as representing an ACTIVITY. Execution is continuous and we may assume that work will not proceed sequentially by first excavating all 750 foundations, then leveling all, etc. In fact, when 75 foundations are complete (10% of the ACTIVITY), 10% of each class or subtask will be complete and 10% consumed from each resource package.

(2) Execution of a mat footing. Assume the following bill of quantities:

17,500 cu. meters excavation

190 cu. meters leveling

15,400 cu. meters concrete

The completion of these subtasks in time is heterogeneously sequenced (Fig. 5.13).

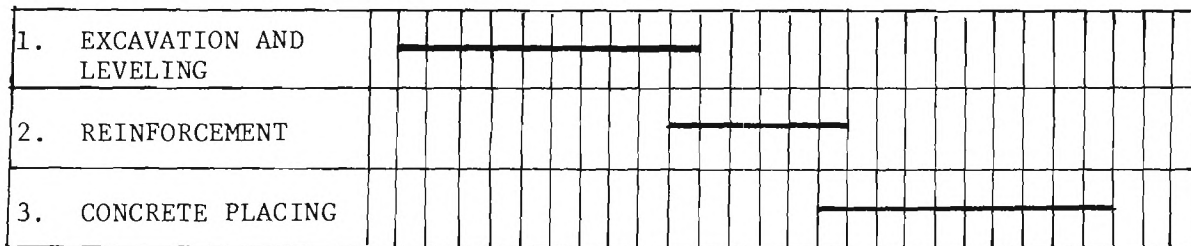


Figure 5.13 BAR CHART FOR A MAT FOOTING EXECUTION PROCESS

At a given point in time we might have 80% of the excavation complete and no reinforcement fitted; therefore, the job cannot be considered an ACTIVITY.

Under these circumstances, three ACTIVITIES are established due to sequence:

- (1) Execution of excavation and leveling for the mat footing
- (2) Fitting reinforcement in the mat footing
- (3) Concrete placement in the mat footing

By observing this condition, the decision for scheduled physical stages or completions can be expressed in %, accumulated from the ACTIVITY commencement onwards (Fig. 5.14).

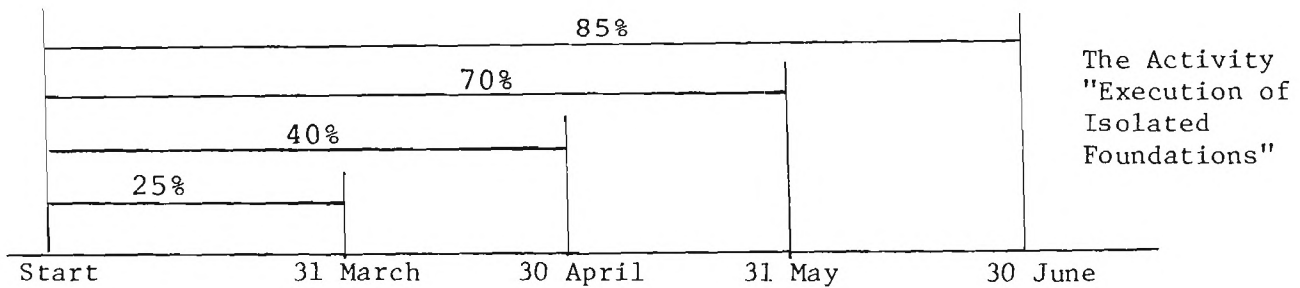


Figure 5.14

SCHEDULED (REALIZED) PHYSICAL STAGES OF ACTIVITY - MUST BE EXPRESSED IN %

As shown in Fig. 5.14, for May we have scheduled $70 - 40 = 30\%$ of the value of that ACTIVITY. This requires 30% of the resources scheduled for completing the activity to be available. Obviously, the condition must not be observed with mathematical precision; negligible deviations can be adjusted at site or trust level.

Thus, ACTIVITIES might be imagined as cubes in a child's game. Once the cubes are defined, by selecting and placing the proper ones

we "build" annual and/or quarterly production schedules, as well as schedules for crews and site management (Fig. 5.15).

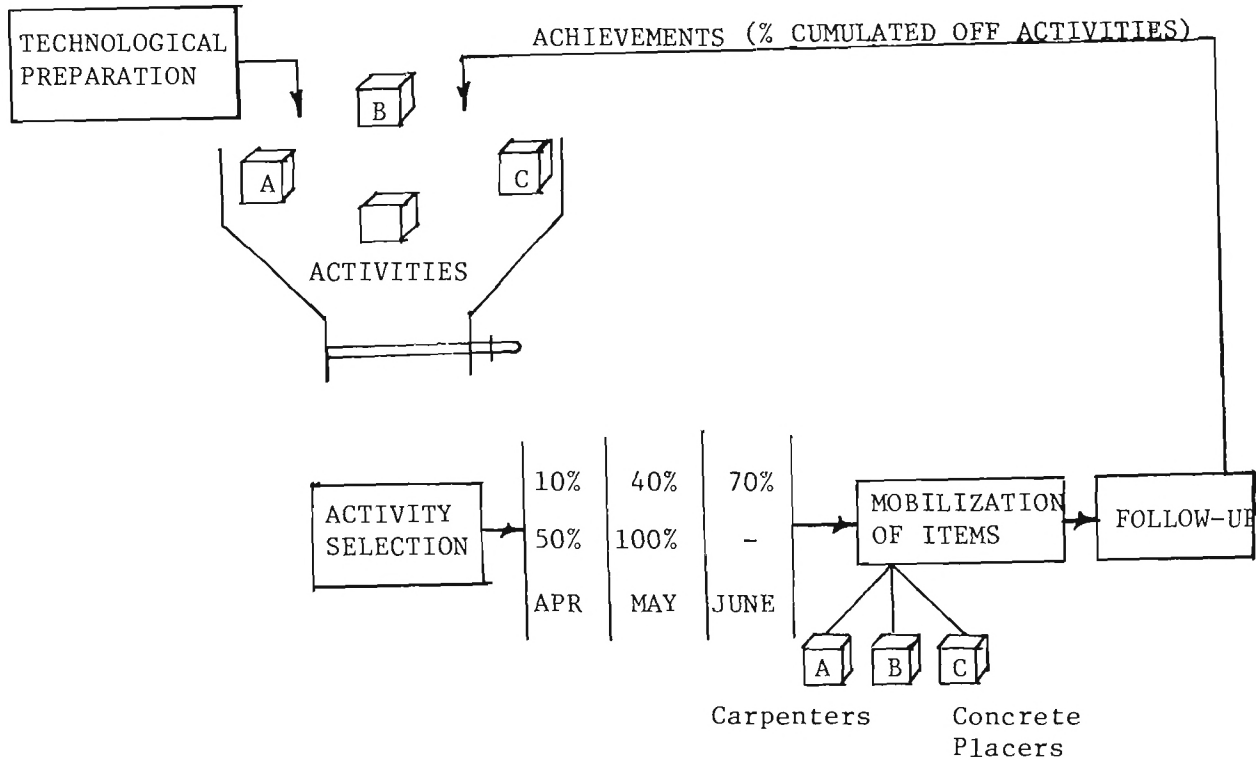


Figure 5.15 THE PLU - PROCESS

Crews are mobilized for either entire ACTIVITIES (one or several) or parts of ACTIVITIES, depending on crew balance, crew profile and the nature of the ACTIVITIES. The crew tasks are stated in work schedules.

These documents also perform the function of employment contract when overall job (subtask) payment is contracted.

In contrast to the process of developing production schedules (which is cyclic in nature), mobilization is continuous. Crews are not mobilized only for the parts of ACTIVITIES included in production schedules, but for entire ACTIVITIES, irrespective of their duration (Fig. 5.16).

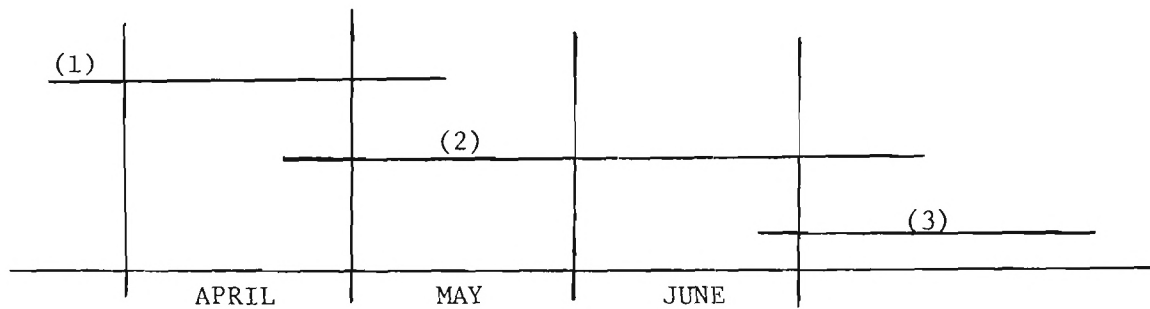


Figure 5.16 2ND QUARTER

ACTIVITY (1) is started during the 1st quarter; ACTIVITIES (2) and (3) are commenced during the 2nd quarter, and are projected for completion in the 3rd quarter.

5.3.3 Computer Usage

The huge volume of data to be processed in a short time span transforms most engineers and technicians working on site into mere "computing"

and data recording personnel. A package of programs entitled PROMETEU, which performs the processing function for PLU, frees the personnel almost entirely from routine operations during all phases of the planning, scheduling, mobilization and follow-up process.

Computer processing is required of all information describing major facilities in the plan, object, estimate and ACTIVITIES accounts (values, due dates, bills of quantity broken into estimate items, orders for fabricated items, responsibilities for their execution, etc.). The following functions must be considered:

(1) Automatic development and updating of networks by CPM.

(2) Computer processing of milestone events for intermediate physical stages, resulting from any kind of chart.

(3) Automatic selection of ACTIVITIES whose analysis should be made in order to develop production schedules (with their status of completion).

(4) The schedule decisions (% scheduled by ACTIVITIES) automatically update and print the cash flow program and resource requirements by job and organization level.

(5) Automatic development of SHEETS by ACTIVITIES required in job mobilization by crews and in concluding contracts of overall job payment.

(6) Computer processing of progress (% off ACTIVITIES) automatically rendering work progress, technical consumption of resources, status of work in progress, etc.

(7) Control of execution drawings supplied to date.

The level of task sophistication reached in most construction units makes data acquisition difficult without use of the computer. The development of annual and quarterly production schedules without a computer would

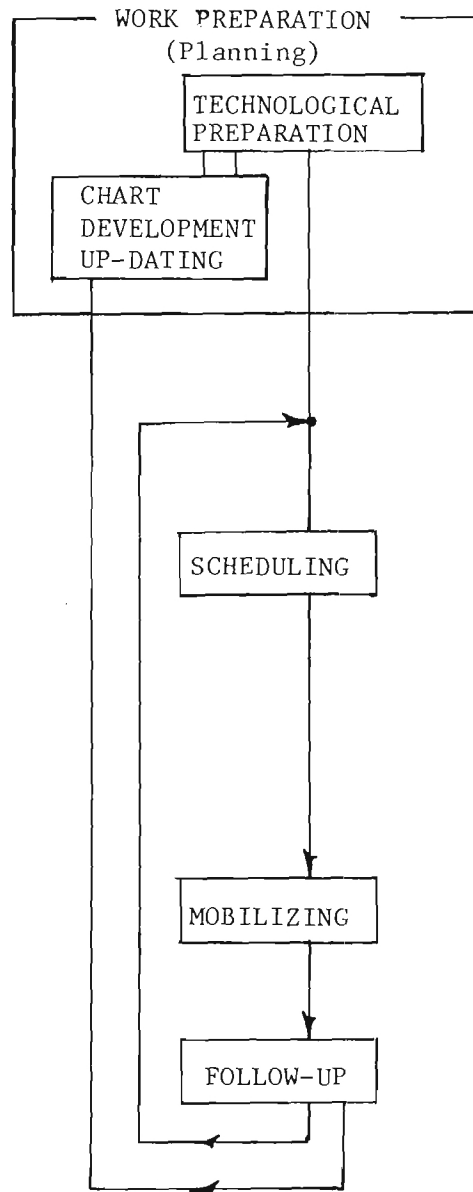


Figure 5.17 THE INTERACTION BETWEEN THE COMPUTER AND PLU

be virtually impossible.

5.3.4. PLU's Efficiency

The PLU solution allows considerable reduction in the effort required to answer preparation, scheduling, mobilization and follow-up problems. Additionally, it ensures a greater uniformity in distributing

this effort over time (Fig. 5.18).

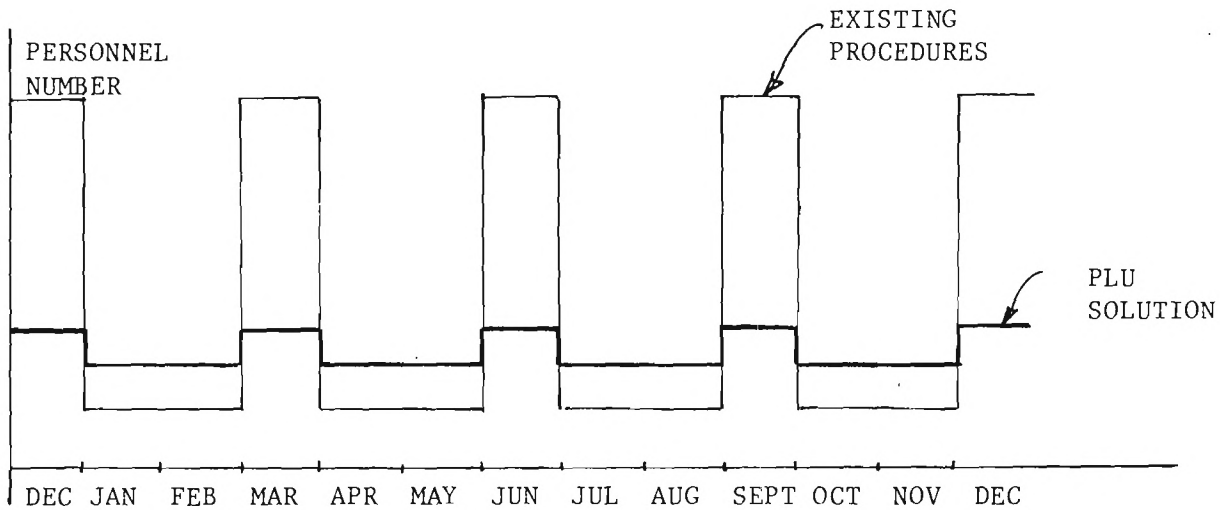


Figure 5.18 PERSONNEL REQUIREMENT - EXISTING PROCEDURES VS. PLU

The figure illustrates that the effort is cut by 40% using PLU compared to the previous procedures.

PLU also provides for a major redistribution of effort from the routine area to the creativity one to project preparation (Fig. 5.19).

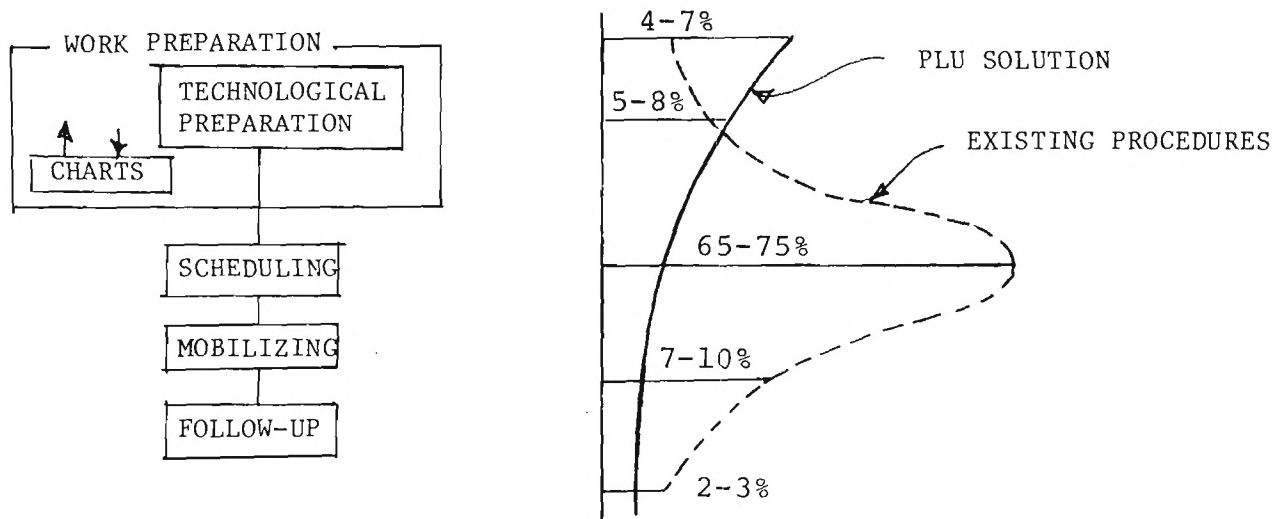


Figure 5.19

THE DISTRIBUTION OF THE HUMAN EFFORT IN EXISTING PROCEDURES VS. PLU

Since the ACTIVITIES remain constant in terms of the calendar period there is no need to revise them as in the case of estimate items. In this way, PLU provides production managers with effective control tools for realizing milestone events in intermediate physical stages and for measuring activity performance. The quarterly production schedule also supplies elements for productivity and cost control during the coming quarter.

5.3.5. PLU's Pools in the Future

The consumption of effort in PLU is largely placed in ACTIVITY definition, during the planning stage. Experience in applying the system and developing CPM-based networks (requiring ACTIVITY definition) has shown that the main difficulties at this stage arise because of the faulty way in which preliminary estimates are worked out. It is difficult to identify bills of quantities broken down into construction elements. Most often, the preliminary estimate has to be reviewed and updated again by consulting the plans.

Because of this, a standard of developing preliminary estimates broken up into sub-components of construction objects (aggregates, sub-aggregates, elements) facilitating ACTIVITY definition has been developed. This has cut the effort required for estimates by 40-60%.

The principles of the new solution are briefly as follows:

Preliminary estimates include the following classes of information:

- Estimate items (symbol and name)

A_j is the "symbol-name" group for a certain item "j"

- Construction elements (name of element)

E_i is the text representing the name of element "i"

- Geometrical calculations of the volume of work

For each element "i" and each estimate item "j" there is given the calculation by means of which volume C_{ij} is attained.

Consider a table of C_{ij} elements, placed so as to provide, on line "i", calculation expressions of volumes for "i" elements and, on column "j", calculation expressions C_{ij} for volumes of work pertinent to estimate items "j". The table would appear as:

$$\begin{array}{c}
 \begin{array}{c} E_1 \\ E_2 \\ \vdots \\ E_i \\ \vdots \\ E_n \end{array}
 \left\{ \begin{array}{c} C_{11} \\ C_{21} \\ \vdots \\ C_{i1} \\ \vdots \\ C_{n1} \end{array} \right.
 \begin{array}{c} A_1 \quad A_2 \cdot \cdot \cdot A_j \cdot \cdot \cdot A_n \\ C_{12} \cdot \cdot \cdot C_{ij} \cdot \cdot \cdot C_{1n} \\ C_{22} \cdot \cdot \cdot C_{2j} \cdot \cdot \cdot C_{2n} \\ C_{i2} \cdot \cdot \cdot C_{ij} \cdot \cdot \cdot C_{in} \\ C_{n2} \cdot \cdot \cdot C_{nj} \cdot \cdot \cdot C_{nm} \end{array}
 \end{array}$$

Obviously, not all C_{ij} elements of the table are significant; therefore, many positions are not filled in. The present way of editing preliminary estimates groups the volume of work under estimate items. Therefore, they are grouped by columns. However, in the process of developing charts and quarterly production schedules, interest is focused on quantities of work grouped under construction elements; therefore, the preliminary estimate has to group the information of the table by lines and not columns (the same contents, organized differently).

More significant, however, is that by this simple change in the organization of information, the effort during the next stage of documentation processing is cut down by 40-60%. Based on an annual production volume of 100 million Lei in construction, this means a diminishing of

effort by 10-15 thousand man-hours. In addition, a great deal of time is saved during the planning stage due to this simplification.

In PLU, this pre-organization of the data of the preliminary estimate is "the stone which slays Goliath." Editing the preliminary estimate by construction elements has been implemented by order of the Ministry.

The implementation of a tree hierarchy describing the projects is presently in process. This will allow for the automatic development of preliminary estimates, estimates and ACTIVITIES. In the structure of the construction facility, aggregates, subaggregates, elements and estimate items can be distinguished in a tree relationship:

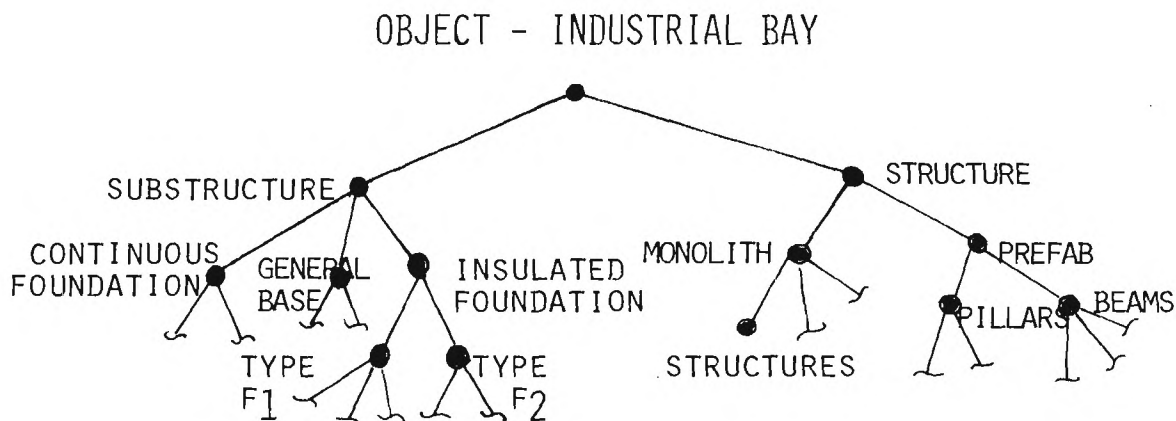


Figure 5.20 TREE STRUCTURE OF THE CONSTRUCTION PROJECT

The last level of the "branches" shows estimate items as components of the construction elements of the preceding level.

Obviously, all information contained in the tree structure is already established by designers at present. However, it is not documented so as to be of later use to the constructor. The Organization Cybernetics

Centre of Construction, in collaboration with several design institutes, is finalizing a solution which will formalize the tree (table format) as design of the project proceeds. The result is maintained by computer disk files.

Once the tree structure of a construction project is established, automation of economic analyses of alternatives, estimate development and ACTIVITY definition are implemented.

In order to develop an estimate, the user declares the "node" of the tree (its symbol and code) for which an estimate is desired, and the estimate is generated.

5.4 PLU's Operation

An outline of the way in which PLU deals with every phase of the planning, scheduling, mobilization and follow-up process is given below.

5.4.1 The Phase of "Project Planning"

This is the phase during which the construction process is "tailored", primarily by defining the E.D.P. of technological execution stages for elements or parts of construction elements (ACTIVITIES). All information describing planned facilities, objects, estimates, additional orders and estimate items, as this becomes available from the Technical-Economic Study (TES) or Execution Design (ED), (values, due dates or milestone events, required dates for site delivery and releasing cash-flow, the chart showing delivery of execution drawings, the chart showing delivery of technological equipment and work commencement) is input to the computer.

The package of programs entitled PROMETEU uses the following input forms:

CODE

| | | | |
|---|---|---|---|
| 2 | 9 | 0 | 2 |
|---|---|---|---|

3
7 8

IDENTIFICATORS

| TYPE | INVEST | HOLD | SUB | DIST | PLAT | LOCAL | DESIGNER | NAME OF INVESTMENT | DUE DATES |
|------|--------|------|-----|------|------|-------|--------------------------------------------|--------------------|----------------------------------------------|
| | | | | | | | | | |
| 1 | 9 | 11 | 12 | 14 | 16 | 20 | 23 | 72 | LAY- OUT 73 FINAN- CING 77 80 |
| D | 5 | 3 | 03 | 12 | 146 | 22 | FACTORY FOR SMALL ELECTRIC ENGINES PITESTI | | |

GEN. CONTRACTOR

| TYPE | TOTAL INVESTMENT | | MINISTRY | | | STATE BY EXECUTANTS | | | | | |
|------|------------------|-------|----------|--------|-------|---------------------|--------|-------|-------|-------|-------|
| | C + A | SHARE | TRUST | C + A | SHARE | TRUST | VALUE | | TRUST | VALUE | |
| | | | | | | | C + A | SHARE | | C + A | SHARE |
| 1 | 9 | 19 | 25 | 27 | 35 | 43 | 45 | 50 | 51 | 63 | |
| N | 228500 | 6200 | 05 | 218840 | 6140 | 05 | 101360 | 2500 | 08 | 49900 | 1900 |
| Y | | | | | | 11 | 1410 | 180 | 14 | 53480 | 1560 |

Figure 5.21 INPUT FORMAT FOR INVESTMENT ITEM

The INVESTMENT FILE form (cards: D, N and Y) is filled in for each facility in the plan (Fig. 5.21).

| TYPE | INVESTMENT | OBJECT | VALUE OF GENERAL ESTIMATE | | | | | DUE DATES | | | | NAME OF OBJECT |
|------|------------|--------|---------------------------|--------------------------|-------------|---------------|----------------|-----------------------|--|--|--|--------------------|
| | | | TOTAL | GENERAL CONTRACTOR SHARE | LAY- OUT | WORK START | TECH CHECKS | PLAN OF FINANCE | | | | |
| 1 | 4 | 7 9 11 | 20 | 25 | | | | | | | | |
| 0 | 290 | 3 | 18100 | 18080 | 07 75 | 08 75 | 09 76 | 10 76 | | | | MANUFACTURING SHOP |
| 0 | 290 | 4 | 1200 | 1160 | 07 75 | 09 75 | 06 76 | 10 76 | | | | HEATING PLANT |
| 0 | 290 | 12 | 1248 | 1248 | 07 75 | 07 75 | 06 76 | 10 76 | | | | TRANSFORMER POINT |

Figure 5.22 INPUT FORMAT FOR OBJECT ITEM

The OBJECT FILE form includes all objects, groups of objects and mechanical work pertaining to an investment (Fig. 5.22).

| TYPE | CODE OF ESTIMATE | | OBJECT | SYMBOL OF EST. ADD. | EXECUTANT | | | | NAME | DATE OF ESTIMATE RECEPTION | | |
|------|------------------|------|--------|---------------------|-----------|--|--|--|------------------------|----------------------------|----|----|
| | INV. | OBJ. | | | | | | | | D | M | Y |
| Z | 290 | 1246 | 3 | | 11 | | | | TERRACE WATERPROOFING | 27 | 04 | 75 |
| Z | 290 | 148 | 3 | 1252 | 09 | | | | ESTIMATE ITEM NO. 16 | 02 | 06 | 75 |
| Z | 290 | 53 | 4 | 1650 | 05 | | | | FORM OF ADDITIONAL OR- | 12 | 06 | 75 |

DER

| | TOTAL | | | | SUM TOTAL |
|---|---------------|-------|----------------|-------|-----------|
| | MATE- RIAL | LABOR | EQUIP- MENT | TOTAL | |
| R | 1216 | 424 | 120 | 1860 | 2310 |
| R | 405 | 105 | 10 | 520 | 635 |
| R | 64 | 26 | 5 | 95 | 123 |

Figure 5.23 INPUT FORMAT FOR ESTIMATING ITEM

The ESTIMATE FILE form communicates both information on estimates and on estimate parts, additional bills of order (ABO) and order call-offs (OCO). (Fig. 5.23).

Data collections files are organized and up-dated periodically. They describe progress to date, broken down by investments (project), objects and estimates. Data collections contain the following type of information:

(a) Investment file:

- Identification area (label, description, etc.)
- Affiliation area (owner label, locality code, etc.)
- Status by constructor. Information describing annual schedule, quarterly schedule and progress is stored by prime

contractor and each subcontractor.

(b) Object File with a similar content.

(c) Estimate File - describes the project with increased detail.

However, the major things achieved during the planning phase are:

- ACTIVITY definition (planning)
- Chart development and updating

5.4.1.1 ACTIVITY Definition

By analyzing project documentation (in written and graphical format) a list of ACTIVITIES is defined for each estimate or group of estimates. Therefore, a list is developed giving the technological stages into which the project is divided. Consider the following example of an ACTIVITY LIST for an "Industrial Building for Mechanical Repair":

- (1) Execution of foundations
- (2) Erection of columns and beams
- (3) Installation of girders and attic beams
- (4) Strip-footing for walls
- (5) Execution of door and window frames
- (6) Erection of wall panels
- (7) Pointing up wall panels
- (8) Execution of concrete floors

For each of these ACTIVITIES, the following elements are defined:

- (1) General information (code, name, relation to the object and facility, individual responsible for execution, etc.)
- (2) Bills of quantities for each estimate item (symbol of the item and quantity)
- (3) Orders for fabricated items required to complete the activity

(4) Bills of quantities requiring equipment (code of group job, quantity)

All of this information is filled in on an ACTIVITY DEFINITION form for input to the computer (Fig. 5.24).

CODE

| | | | | | | |
|--|--|--|---|---|---|---|
| | | | 1 | 1 | 0 | 9 |
|--|--|--|---|---|---|---|

| I- TYPE | NAME | | | | DUE DATE | |
|------------|----------------------------|----|----|----|----------|--------|
| | 10 | 44 | 47 | 52 | 53 | 58 |
| A | ERECTION OF METAL CLADDING | | | | 050975 | 201075 |

| I- TYPE | EXECUTANT | INVESTM | OBJECT | ESTI- MATE | I.S.C. ACTIVITY | QUANTITY | WORTH | DURA- TION |
|------------|-----------|---------|--------|---------------|--------------------|----------|-------|---------------|
| | 10 | 17 | 23 | 26 | 30 | 36 | 42 | 51 |
| B | 05030512 | 290 | 3 | 165 | 413 | K G | 16500 | 40 |

| I- TYPE | GROUP JOBS | QUANT. | % | CODE | TECHNICAL FEATURES | | | | | | | | | |
|------------|---------------|--------|-------|------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 10 12 | 21 | 23 25 | 27 | WORTH | WORTH | WORTH | WORTH | WORTH | WORTH | WORTH | WORTH | WORTH | WORTH |
| M | T3 | 16500 | 00 99 | 20 | 100 | 21 | 68 | 22 | 20 | | | | | |
| M | | | | | | | | | | | | | | |

Figure 5.24 INPUT FORMAT FOR AN ACTIVITY

The problem of coordinating work start-up between engineer, constructor, and subcontractors is a significant one. This problem is largely connected with the scheduling of resources. During the planning phase of the year in question, an agreement is concluded with the owner and stated in the appendices to the construction contract. This agreement includes a chart for delivery of equipment, a delivery chart of engineering drawings, milestone events for intermediate physical stages, etc. By conducting analyses in the field with all of the responsible individuals, mutual commitments are established as to work stage start-up. Decisions are then documented using a special form stating the

completion date of each ACTIVITY (Fig. 5.25).

| 1 | TYPE | CODE OF ACTIVITY | | | | | COMPONENT | | | | | PARTIAL DELIVERY | | | TURN KEY DUE DATE | CODE OF ACTIVITY | | | | | COMPONENT | | | | | PARTIAL DELIVERY | | | TURN KEY DUE DATE |
|---|------|------------------|---|---|---|----|-----------|----|----|----|----|------------------|-----|-----|-------------------|------------------|----|----|----|----|-----------|----|----|-----|-----|------------------|--|--|-------------------|
| | | 3 | 4 | 5 | 6 | 8 | 11 | 15 | 18 | 20 | 22 | 27 | 25 | 33 | | 39 | 42 | 44 | 48 | 51 | 53 | 58 | 59 | 64 | | | | | |
| K | | | 1 | 5 | 1 | 6 | 02 | | 3 | 4 | 5 | 50 | 150 | 675 | 301275 | 29 | 16 | 03 | | 4 | 7 | 6 | 30 | 250 | 975 | 301275 | | | |
| K | | | 7 | 9 | 2 | 02 | | | 9 | 0 | 6 | 25 | 231 | 175 | 200676 | 11 | 2 | 04 | | 1 | 7 | 6 | | | | 250776 | | | |
| K | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 5.25 STATUS REPORT BY ACTIVITIES - (INPUT FORMAT)

This data is maintained in computer files and defines areas of coordination when production schedules are developed, and a resource control is established.

Since all ACTIVITIES executed throughout the next year are not available at the time of developing the annual production schedule (December of the preceding year), a preliminary construction schedule is established by quarters, as new ACTIVITIES are defined (Fig. 5.26).

| 1 | TYPE | CODE OF ACTIVITY | | | | FORECAST | QR1 QR2 QR3 QR4 | | | | CODE OF ACTIVITY | FORECAST | QR1 QR2 QR3 QR4 | | | | CODE OF ACTIVITY | FORECAST | QR1 QR2 QR3 QR4 | | | |
|---|------|------------------|----|----|----|----------|-----------------|----|----|----|------------------|----------|-----------------|----|----|----|------------------|----------|-----------------|----|----|----|
| | | 3 | 4 | 5 | 6 | | 12 | 14 | 16 | 18 | | 27 | 29 | 31 | 33 | 35 | | 44 | 46 | 48 | 50 | 52 |
| P | | 001516 | 25 | 35 | 55 | 80 | 99 | | | | 001517 | 00 | 25 | 50 | 75 | 99 | 001520 | 20 | 40 | 60 | 80 | 99 |
| P | | 001918 | 10 | 40 | 60 | 80 | 99 | | | | 001926 | 60 | 80 | 99 | | | 002110 | 00 | 25 | 50 | 75 | 99 |
| | | | | | | | | | | | | | | | | | | | | | | |

Figure 5.26

INPUT FORMAT FOR YEARLY AND QUARTERLY SCHEDULE BY ACTIVITIES

Using these forms and others which are not herein described, the organization and maintenance of the data collection describing ACTIVITIES is achieved.

The entire process of project processing documentation consisting of:

- (1) Development of documentation, including technical-economic objectives
- (2) ACTIVITY establishment
- (3) Issuance of orders for fabricated items

should be carried out within one department at the level of an independent site or a group of sites.

For special technological processes, it is the design shop that controls design development.

5.4.1.2. Chart development and updating

PLU uses two kinds of charts:

(1) General Contractor's Chart (GAG) whose main function is to correlate the subcontractors' actions and link them with plan tasks (required dates and value plan).

(2) Execution Chart (GE) through which the execution process of an object, group of objects or parts of objects is described in detail.

The role of these schedules within PLU is strictly one of establishing milestone events for intermediate physical stages. The schedule for delivering execution drawings and the chart of technological equipment delivery are coordinated with these milestones. Any difficulty in coordination is reported to those responsible for achieving timely completion of the facility.

The charts do not analyze material and labor resources since the latter have to be considered for the sum-total of jobs performed on a site. Labor resources are leveled on an annual and quarterly basis.

PLU is compatible both with charts developed in network form (with the aid of CPM) and with traditionally developed bar charts. When using CPM, chart development and constant updating is done with the aid of the computer.* Milestone events and completion dates are recorded on the computer, so as to have them listed as constraints associated with ACTIVITIES at the time of quarterly production schedule preparation.

A relationship is established for each ACTIVITY A_i and the activity off the chart $(AG)_j$ to which it belongs:

$$A_i \in (AG)_j$$

Thus, one may establish an automated selection procedure for activities A_k that have to be considered when developing the quarterly production schedule for quarter (t_1, t_2) , t_1 and t_2 being the calendar dates marking the beginning of the quarter and its end, respectively.

Assume that d_j is the duration and T_j the due-date required to accomplish an activity $(AG)_j$ to which ACTIVITY A_i belongs. Consequently $(T_j - d_j, T_j)$ will be the time interval needed to accomplish activity $(AG)_j$ (Fig. 5.27). If: $(T_j - d_j, T_j) \cap (t_1 - t_2) \neq \emptyset$, activity A_i will be selected on the list of those likely to be scheduled in quarter (t_1, t_2) .

* SAGES - system of programs for general contracting charts and ADC - for execution charts.

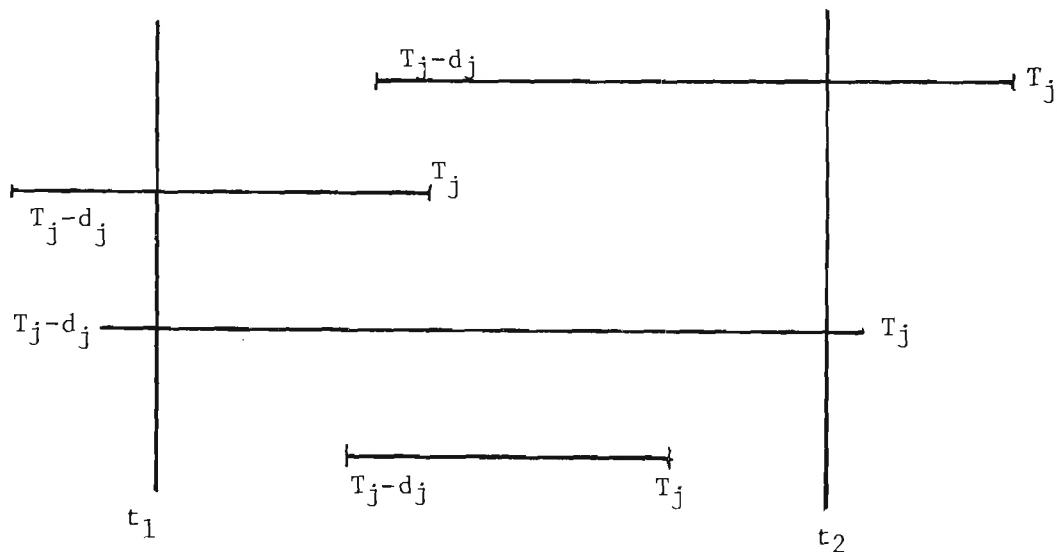


Figure 5.27 SELECTION ACTIVITIES CRITERION

5.4.2 The "Scheduling" Stage

Within PLU, correlation between physical stages and resources is achieved through annual and quarterly production schedules. Annually, in the time interval November - December, a production schedule for the coming year is established at site or trust level, broken into quarters (Fig. 5.28).

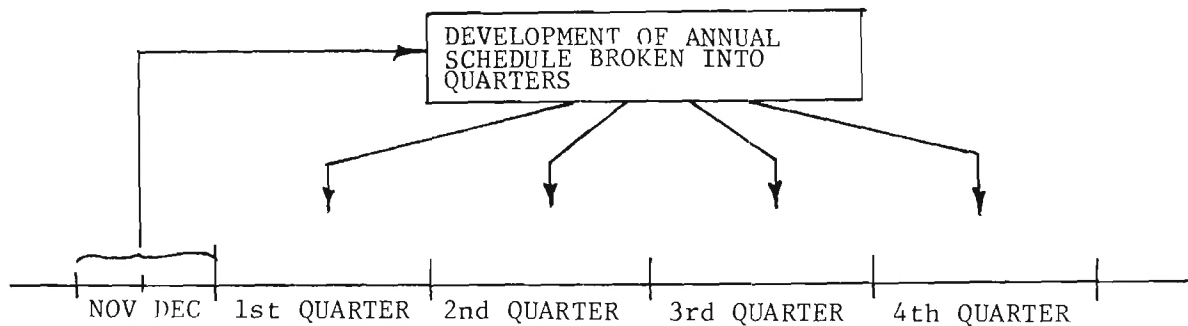


Figure 5.28 ANNUAL SCHEDULE ESTABLISHMENT

The main functions of the annual schedule are as follows:

- (1) Correction of the procurement plan devised in previous stages without access to final engineering drawings
- (2) Balancing of resource requirements and the allocation of equipment among trusts and subunits
- (3) Establishment of work-stages to be performed by subcontractors
- (4) Finalization of the delivery chart for technological equipment
- (5) Development of specific measures to ensure the achievement of "productivity" and "cost" indicators.

The quarterly schedule, prepared between the 3rd and the 20th of the month preceding the quarter in question, is the key management tool in project execution. The schedule establishes, for the entire quarter and for each of its months:

- (1) Work to be completed (physical stages)
- (2) Value plan corresponding with work provided for in the schedule
- (3) Resource requirements and the schedule for ensuring them
- (4) Environmental constraints, whose observance must be pursued

If the quarterly production schedule is to be an effective management tool, it has to meet certain requirements among which we emphasize the following:

- (1) It should be broken-up - correlated, down to crew level.
- (2) It should supply each level in the organization with the elements required to comply with the schedule.

The process of developing quarterly^{*} production schedules means going through the phases presented in Fig. 5.29.

* The development of the annual schedule goes, roughly, through the same process.

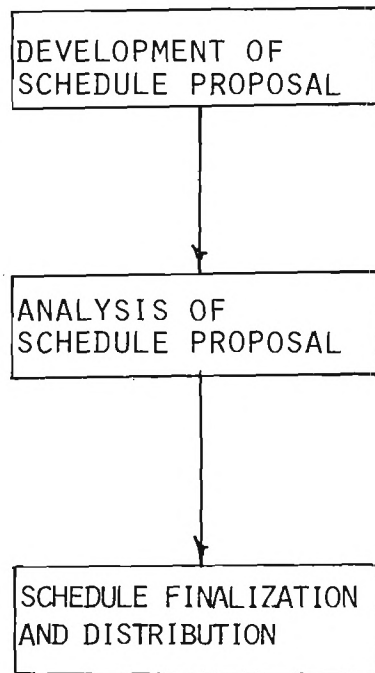


Figure 5.29 QUARTERLY SCHEDULE ESTABLISHMENT

In fact, the process of preparing the quarterly production schedule is an iterative process starting from an original solution. Variation from projected schedule due to constraints is established and a correction developed. This leads to solution S_1 and the process goes on until solution S_n meets, within acceptable limits, the sum total of requirements C (Fig. 5.30).

The sophistication of requirements C and the sum-total of parameters P_i defining solution S_i allow the development of an analytic optimization model compatible with computer processing. At present, the system of programs entitled PROMETEU accepts a small number of iterations (1 - 2 iterations) simulating the main requirements and yielding a corrected schedule. A further stage envisages the development of a

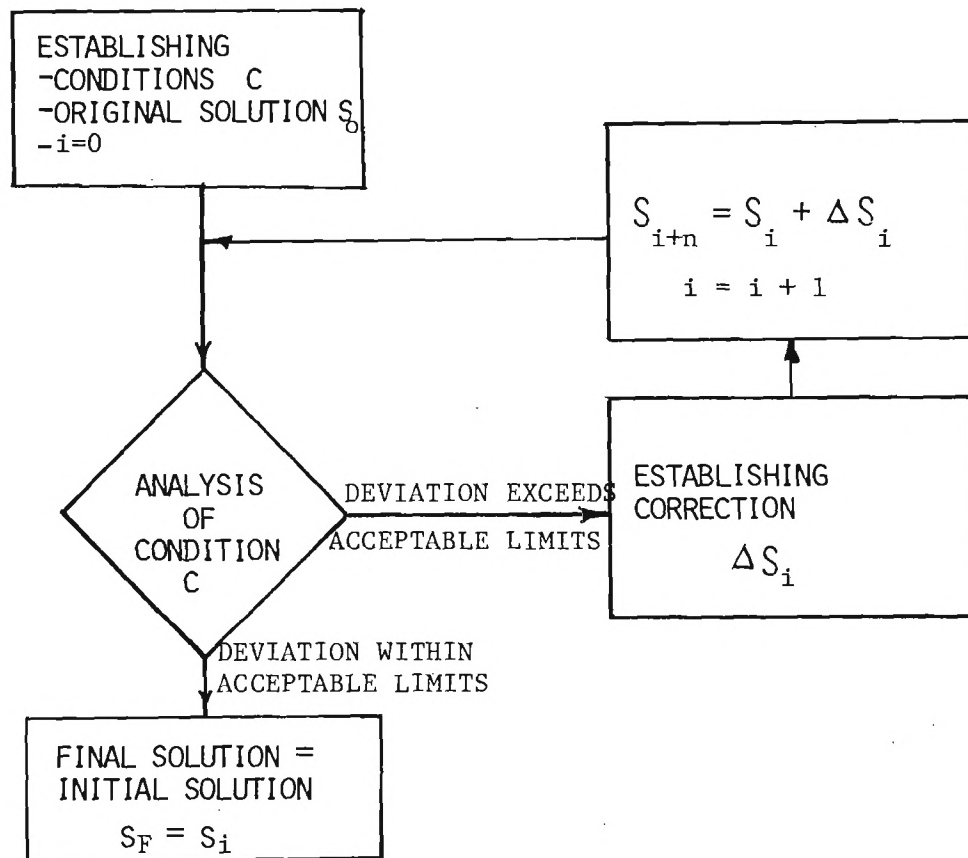


Figure 5.30

ITERATIVE PROCESS TO OPTIMALLY DEVELOP QUARTERLY SCHEDULES

conventional model that should provide for a rapid man-computer dialogue, and, therefore, successive simulations in searching for an optimal solution.

The phase of "development of proposals for the schedule" is aimed at establishing jobs (physical stages and quantities) to be executed in each month of the coming quarter so as to ensure the observance of plan constraints and conditions among participating construction units. This phase means going through the actions presented in Fig. 5.31.

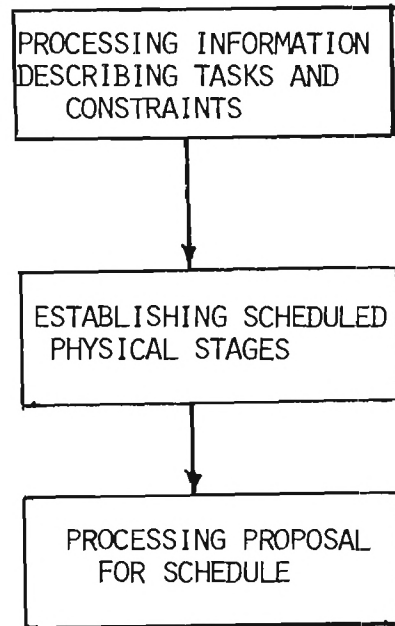


Figure 5.31
FIRST STAGE OF QUARTERLY SCHEDULING PROCESS

The proposals for the schedule are developed during the 3rd - 10th of the third month of the quarter preceding the one for which scheduling is done. Under these circumstances, all that is known is progress during the first two months of the current quarter. Progress status for the 3rd month must be forecast. Consequently, during the phase of schedule development, one has to work out forecasts in the 3rd month of the current quarter and the schedule for each month of the coming quarter (Fig. 5.32).

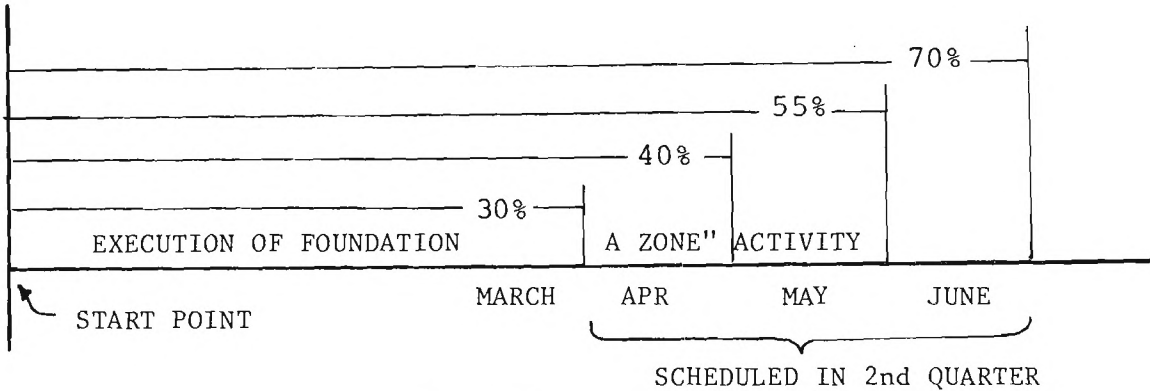


Figure 5.32

PHYSICAL STAGES (%) SCHEDULED FOR AN ACTIVITY

Thus, each activity A_i included in the schedule has an associated percent P_{ci} , P_{1i} , P_{2i} , P_{3i} included in the schedule for each of the three months of the quarter. Based on this, a given S_{ik} solution for a quarterly schedule is developed from the sum-total of elements (A_i , P_{ci} , P_{1i} , P_{2i} , P_{3i})

$$S_k = (A_i, P_{ci}, P_{1i}, P_{2i}, P_{3i})$$

The phase of "Analyzing proposals for the schedule" involves analysis and coordination of schedules at trust and Ministry level. At this review, the value of production proposed for achievement, in terms of the task stated in the national plan, is considered, as well as the resource requirements versus available resources. Reports on available resources (personnel, equipment, materials) are required for this analysis.

Let us assume that \bar{R}_{ik} represents available resources and R_{ik} requirements resulting from the S_{ik} solution of a quarterly schedule.

If R_{ik} is greater than \bar{R}_{ik} , additional information is needed. The C_j consumers of resource i and the R_{ij}^k quantities consumed by each of them must be determined. (The C_j consumers under consideration are work centers in the plan.) The PROMETEU system of programs provides for the electronic development of a r_{ij}^k table of consumption. Analysis of this table leads to an improved solution:

$$S_{k+1} = S_k + \Delta S_k$$

In the process of analyzing the S_k solution of a quarterly schedule, storable resources (materials) cause problems that are different in nature from those raised by non-storable ones (labor and equipment). For storable resources, the S_k schedule under consideration must lead to a C_i^k curve of accumulated consumption which is within the D_i^k forecast of available resources (Fig. 5.33).

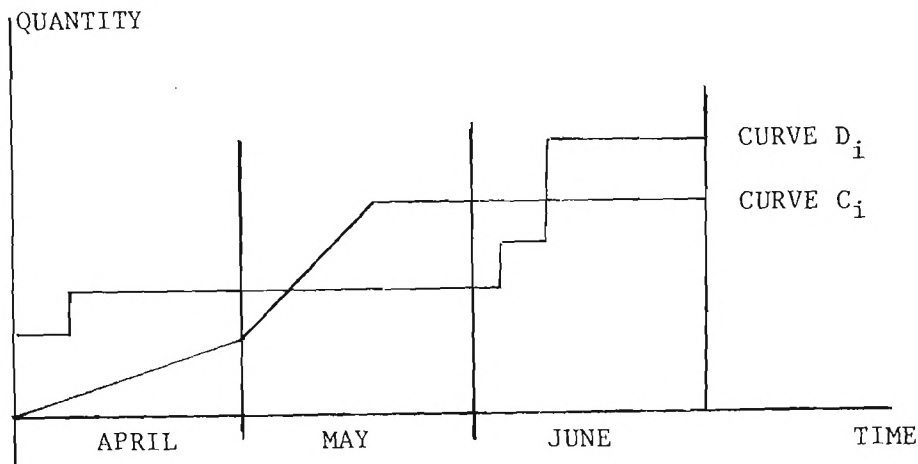


Figure 5.33 MATERIALS BALANCE ANALYSIS

The status of the above diagram requires a change in percent P_{cj} , P_{lj} , P_{2j} , P_{3j} , scheduled for ACTIVITIES A_j representing the main consumers of resource i under consideration. The new S_{k+1} solution requires reduction of consumption over the period of early May through mid June, and its increase during the second half of June. Obviously, the incompatibility can be dealt with by changing the D_i curve of forecasted availability (change in the schedule of deliveries). (Fig. 5.34). A procedure for accomplishing this redistribution has been developed by Preston (1976) as part of this research.

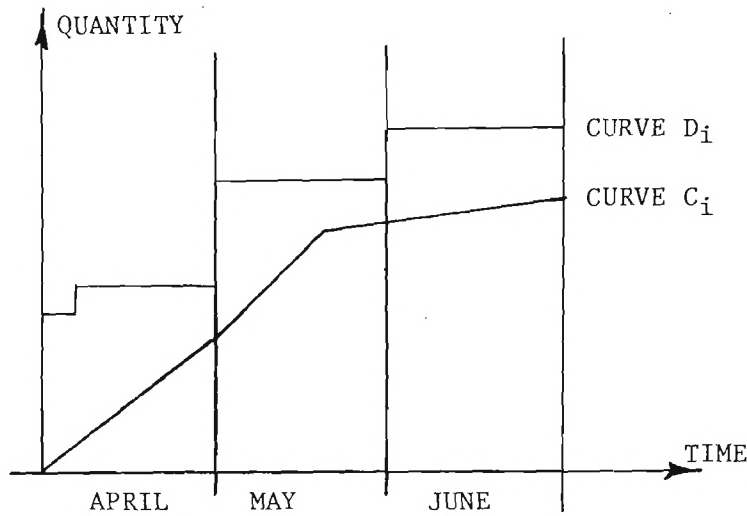


Figure 5.34 FINAL MATERIALS BALANCE

Non-storable resources are much more constraining. At any given point in time, t , consumption $c_i(t)$ has to be within an available $d_i(t)$, such that

$$c_i(t) \leq d_i(t)$$

The $c_i(t)$ curve should be, as far as possible, uniform over time (Fig. 5.35).

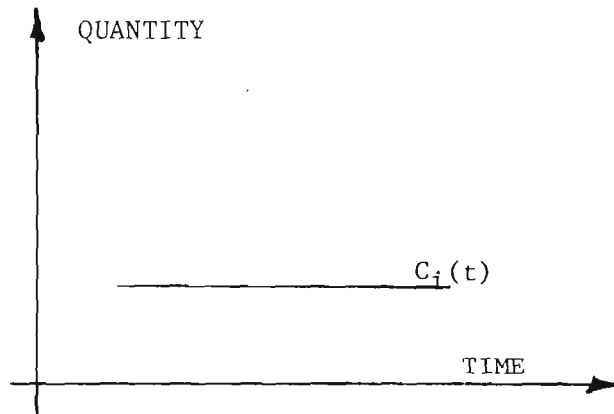


Figure 5.35
OPTIMAL CURVE FOR NON-STORABLE RESOURCES

If it is not possible to achieve a constant consumption $c_i(t) = C_i$, monotonously increasing curves such as $C_i(t)$ (Fig. 5.36) or monotonously decreasing curves (Fig. 5.37) are acceptable.

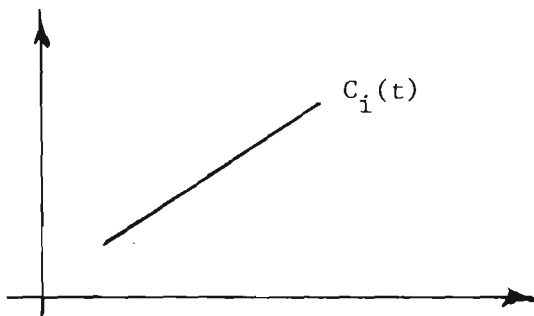


Figure 5.36
MONOTONOUSLY INCREASING REQUIREMENT

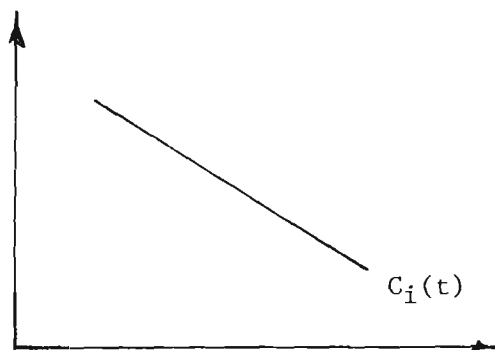


Figure 5.37
MONOTONOUSLY DECREASING REQUIREMENT

The last two profiles are needed whenever one has to combine periods in which the level of consumption varies greatly.

An S_k quarterly schedule which leads to a consumption curve $C_i(t)$ such as the one presented in Fig. 5.38 implies transition to a new schedule S_{k+1} , that should provide for consumption leveling (Fig. 5.39).

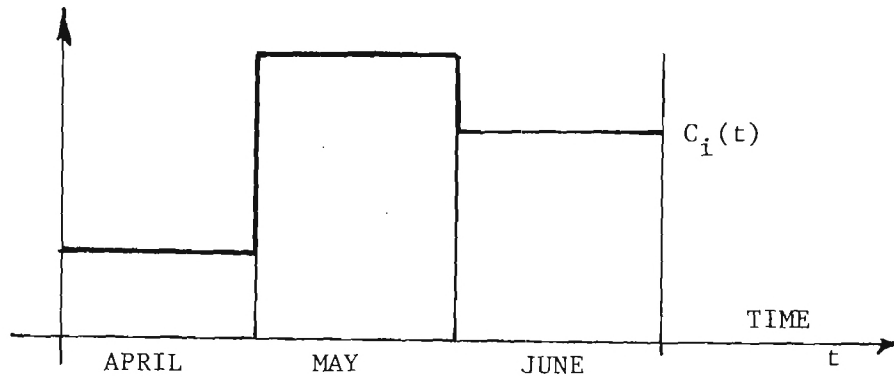


Figure 5.38

NON-ACCEPTABLE CURVE FOR NON-STORABLE RESOURCE REQUIREMENT

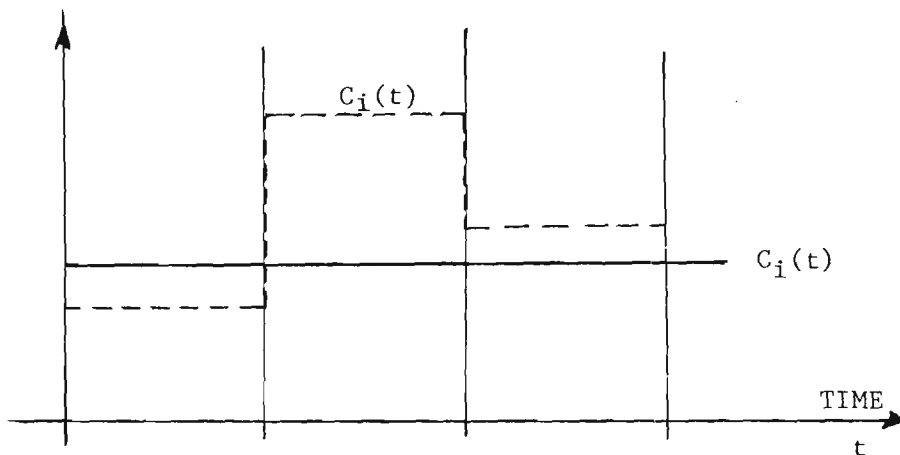


Figure 5.39

NON-STORABLE RESOURCES LEVELING

Analysis of schedule proposals may dictate the following imperatives:

- (1) Recalculation of cash flow
- (2) Redefinition of schedule activities
- (3) Delay of activities

The corrections that have to be made in order to meet these requirements must materialize into physical stages broken down by ACTIVITIES. In order to develop these new physical stages, another iteration of the process carried out during the schedule development phase must be undertaken.

During schedule finalization and distribution , which is the third phase in the process of developing the quarterly production schedule, the schedule is finalized and conveyed to all people responsible and involved in it.

Two classes of responsibility require this schedule:

- (1) Project managers, responsible for the completion of physical stages and
- (2) Resource managers , responsible for ensuring that resources are available as required by the schedule. Schedule dossiers for the two classes of responsibility are developed. The project manager dossier must include:

- Scheduled activities (physical stages and scheduled values)
- Available resources

Establishing schedule tasks broken up into organizational levels: project (L), site (S), group of sites (G), trust (TR), Ministry (M) is done through different "levels" in work hierarchy (ACTIVITY - A, object - OB, plan - P, holder - T) according to the

following relationships:

| | |
|----------------|------------------------|
| MINISTRY | TR (P), T (TR, P) |
| TRUST | T (G, S, P), G, S, (P) |
| GROUP OF SITES | S (L, P, O) |
| SITE | L (P, O, A) |
| PROJECT | P (O, A) |

where notation $\alpha \rightarrow \beta(\gamma, \delta)$ means that at level α in the organization, there are explicit levels β , broken up into levels γ and δ .

5.4.3 The "MOBILIZATION" Phase

(Mobilization of jobs by teams; contracting for overall performance)

The success and effectiveness of any production management system largely depends on the extent to which the system motivates crews in their effort to prepare and execute jobs. Team leaders (crews, brigades) as well as crew members (highly skilled workers with a long experience in the field) are able to conceive and apply highly effective technical and organizational solutions at job level.

In effect, the production process up to crew level means information processing; it is only at this level that information materializes, so that positive crew input and involvement are decisive for the completion of physical stage scheduling.

In order to insure good data acquisition, crews should be kept informed about:

- (1) Physical stages defined by production schedules;

(2) Bills of quantities assigned to each crew for the execution of each physical stage;

(3) The established execution technology and provisions for technical progress reporting and procedures for quality control;

(4) Available equipment;

(5) Progress payment procedures.

These items must be defined during mobilization of the job by teams.

As ACTIVITIES occur in quarterly production schedules, they are mobilized by crews.

Scheduling is connected with a period (quarter, month, 10-day interval). The same does not apply to mobilization; ACTIVITIES are mobilized in their entirety, even if the quarterly schedule provides for only a certain % complete. The document used for mobilization is the WORK SCHEDULE, stating bills of quantities broken down by ACTIVITY, required resources, milestone events, completion dates, technological indicators, payment procedures, intermediate payments and retainage already held. This document also performs the function of contract and commitment between the crew and site management under the overall performance payment.

Through a work schedule, the crew is assigned, based on its specialty, one or more ACTIVITIES or estimate items within an ACTIVITY. At a given point, a crew can work with several work schedules. Let us assume that A_i is the mass of ACTIVITIES that have to be mobilized by crews and M_j the mass of trades involved in accomplishing the jobs contained in ACTIVITIES A_i . Let us also assume that $a_{ij} \in A_i$ represents the works involving trade M_j and belonging to ACTIVITY A_i .

The matrix of a_{ij} elements is defined as:

$$\begin{array}{c}
 M_1 \dots M_2 \dots M_j \dots M_q \\
 \\
 \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_p \end{matrix} \left\{ \begin{array}{c} a_{11} \dots a_{12} \dots a_{ij} \dots a_{1q} \\ a_{21} \dots a_{22} \dots a_{2j} \dots a_{2q} \\ \vdots \\ a_{i1} \dots a_{i2} \dots \boxed{a_{ij} \dots a_{iq}} \\ \vdots \\ a_{p1} \dots a_{p2} \dots a_{pj} \dots a_{pq} \end{array} \right\} \begin{matrix} \\ \\ \\ \xrightarrow{P'_j} \\ \\ \end{matrix}
 \end{array}$$

$$\begin{matrix} p \\ U \\ j=1 \end{matrix} a_{ij} = A_i$$

One or several a_{ij} elements, where $j = \text{constant}$, make up the work schedule P'_j

$$\begin{matrix} P'_j \\ j=\text{const} \end{matrix} = U a_{ij}$$

An optimal mobilization situation, L , establishes a solution wherein work allocation, by crews, meets the optimal requirements set forward.

5.4.4 "Work Follow-Up" Phase

This phase closes the PLU management cycle. The follow-up system ensures control of all parameters defining construction projects in progress, namely:

(a) Control of project documentation and progress payment.

Monthly, based on the information fed into the computer, during the "Project Planning" phase, reports are automatically generated regarding:

- (1) status of drawing delivery by plan positions, plan holder, etc., and
- (2) status of project payment.

(b) Follow-up of physical completion and value. By reporting the physical stages (total %) by ACTIVITIES, output reports are automatically generated on the achievement of projected work (national plan, quarterly schedules) by plan position, object, subunit and unit. Based on the same information, reports on the completion of scheduled physical stages are generated and sorted by ACTIVITIES and construction objects.

(c) Resources involved in completed production. Consumptions of resources (materials, labor, equipment) corresponding with the percent complete of production are reported. These usage figures are compared to projections.

5.5 PLU's Implementation

It is not possible to present a detailed analysis on PLU's implementation process. PLU's implementation involved many difficulties which had to be overcome during the assimilation period. The trust (site) management must be aware of the system's advantages as well as of its implementation difficulties.

PLU does not suggest new management problems. It provides procedures to solve existing problems. Consequently, PLU has to be put into practice by those who are presently dealing with the problems of project planning, scheduling, mobilization and overall performance evaluation.

PLU implies the conscientious participation of many people from various departments. All have to know exactly what they are supposed to do, the benefits of the new way of operation and the difficulties involved in implementation.

REFERENCES

1. Preston, R. L., "Management of Construction Resources," unpublished Ph.D. Thesis, Georgia Institute of Technology, Atlanta, Georgia, 1976.

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

6.1 General Conclusions

The use of simulation techniques for the control of construction and forecasting of production requires good historical data from which to derive the needed environmental parameters that influence construction management. Due to this strong relationship, the present research phase has concentrated on establishing systems which are capable of collecting data for later use in management simulation. Further, the Romanian SICOP systems (particularly PLU) have been modified to be compatible with systems in the U.S. so that techniques presently utilized here can be readily implemented in Romania.

Certain areas of commonality between the U. S. and Romanian construction industries have been identified. In both countries, the need to handle large volumes of data during the construction process is characteristic of the management environment. This makes innovative use of computers and other high speed processing methods a necessity.

Implicit in the processing of large volumes of data for management simulation is the need for a structuring of data which allows quick retrieval and manipulation. This provides the means of accumulating organized statistical information which can be used as the basis of a management forecasting system. The most advanced method of handling information structures is the data base approach which requires random access storage devices and sophisticated hardware. This environment is,

however, keyed to the improvement of existing control systems. Both countries use computers extensively in the processing of information. There is some gap, however, in the equipment available in Romania. The IRIS 50 and PHENIX equipment used at COCC is comparable in capability to the IBM 1130 system and is second generation equipment. Although these machines are reliable for limited applications, they are not equal to the task of handling the requirements of large data base and simulation applications.

The system required for simulation support should provide an integrated source of information for project control. The information generated or collected at any site should be readily available to the central management group. From the security point of view, every user should be able to create and alter only data elements which are under his direct responsibility. Every user should have assigned passwords for retrieval of information related to his project function. Basically two types of users will be at the project: users with update and retrieval authorization, and users with retrieval authorization. The specific assignment of responsibilities for update and maintenance of data and permission to retrieve data will be identified during detailed system implementation and design. On-line inquiry capability and exceptional reporting should be established in all applicable areas. This direct contact between user and data will greatly improve credibility and accuracy of the data. The ownership of the information must be well established. Information and data must be considered as important resources in the construction effort. Most of the project data files will be available at the project for direct user retrieval and utilization in local simulations and studies. In most cases, users will enter and

collect data at the data source, eliminating or reducing the manual data manipulation and handling.

6.2 Integration Concepts

The system framework is based on the relationships among various portions of the system. Even the individual subsystems will be fully autonomous from the operational and maintenance point of view. The stress must be put on maintaining the compatibility of key data fields within individual subsystems. The unrelated and incompatible systems that result make comparison between various areas of project control difficult and lead to duplication of effort in systems development, programming, and maintenance of project data files.

The concept of integration also recognizes that a management decision in one area can quickly and seriously affect conditions in others. Therefore, the information created, collected and stored by one application area must be made available to others who need it.

6.3 Implementation

Data base concepts are implied in the implementation of large scale simulation models such as those required for construction management. A data base (1) provides a mechanism for the organization of data in large logical structures, (2) allows sharing of data by multiple applications, and (3) separates data definition from data application. A data base file is a carefully planned structure containing the basic data elements and their organization. The data base file has several implications for project control or management information systems. First, it assumes that the fundamental data have been rigorously identified. Secondly, the data files are so defined and structured so as to

assure reliability and integration of all data elements. Thirdly, the accessibility of a variety of data elements permits increased flexibility and responsiveness of the system to unique as well as recurring information requirements.

6.4 Software Requirements

A considerable expenditure of time and money is required to develop data base software which is capable of handling large simulation models. The practical approach is to select a general type of data base system and adapt it to the specific operating environment. Several systems are currently available which are potentially suitable for project simulation modeling support. Some of the better known standard systems are (1) ADABAS, (2) IDMS, (3) IMS/IV, (4) MODEL 204, (5) RAMIS, (6) SYSTEM 2000, (7) TOTAL, and (8) MARK IV. The capabilities of each package vary so that great care must be taken in selecting the most applicable system in view of the hardware available and the system update and retrieval requirements. Some of them function very efficiently when file maintenance is the dominant processing feature. Others are efficient during retrieval but less oriented toward efficient file maintenance.

6.5 Hardware Requirements

Data base systems are becoming more popular because hardware capabilities and costs now provide an acceptable data base environment. Since most of the data should be available on-line, fairly large direct access storage is required. For a large project several hundred million bytes of disk storage are normally necessary. Medium-size computers or intelligent terminals should be available at the project site level for

data acquisition and transmission. If remote processing is required, high speed terminals with several keyboard terminals are desirable and should be installed at the project. Data entry can be accomplished through cards, although key-to-disk or key-to-tape entry is more desirable. Major departments at the project site should have access to the data base through keyboard terminals or CRT display units.

6.6 Future Work

The conceptual design of the simulation modeling environment has been completed in this phase. It has become clear from results obtained to date that a data base approach to information management is needed in interfacing simulation modeling activities in both the U.S. and Romania. With the development of a unified data base approach, it will be possible to transfer detailed design of simulation modeling techniques with a common framework. For future activities, it will be necessary to extend the period of direct contact between researchers. It is felt that two months of direct contact as a minimum each year is essential.

The next phase will involve detail designing of the simulation modeling data structure. Detail design will require a team of systems analysts and programmers on the American side to provide proper interface with COCC. The sequence of development should proceed approximately as follows: (1) Detail design of the data structure; (2) Implementation of the data structure; (3) Simulation testing; and (4) Simulation program implementation. This approach allows the orderly development of the conceptual design developed in the first phase of the project.

APPENDIX A

CONTACTS BETWEEN ROMANIA AND THE U.S.

1. Preliminary Contacts

Since 1970 several contacts between the Romanian and the USA investigators who are involved in the improvement of the management systems in construction have taken place.

A. Dr. eng. D. Anastasiu (Manager of the Center for Informatics and Organization of Bucharest) attended the University of Illinois at Urbana-Champaign as a visiting scholar in 1970;

B. Eng. M. Nemteanu (Departmental Manager of the Romanian Railways Construction Trust) was in a similar situation from September 1971 to March 1972 at the University of Illinois. The program (conducted by Professor R. W. Woodhead) was in the field of the simulation methods in construction management.

C. Professors R. W. Woodhead and D. W. Halpin from the Construction Systems Group at the University of Illinois visited the Center for Organization and Cybernetics in Construction (COCC) in 1973. The discussions concerned the establishment of a common base for research in the area of simulation methods and their integration into the existing and designed management information systems.

The management of the COCC (eng. H. Manescu - Director; eng. N. Tutos - Technical Manager, chief of the Department for the Design and Application of the Systems) and many specialists from COCC (eng. J. Aurian - Technical Advisor; eng. T. Ciszar, eng. A. Ragulescu, Project-Chiefs) participated at the main phases of the discussion.

Eng. D. Anastasiu and eng. M. Nemteanu also participated at the discussions (see points 1 and 2).

The facts that objectives and management methods are essentially similar in both countries, and that a high potential for the development and application of a common management system exists, were emphasized.

The conclusions and proposals were discussed at the level of the management of the Industrial Construction Ministry - M.C.Ind. (eng. D. Arhire - General Secretary of M.C.Ind.) and at the level of the National Council for Science and Technology (Technical Advisor - eng. Matache).

D. Professors R. W. Woodhead and Dr. D. W. Halpin again traveled to Romania in June 1973 in order to visit building sites belonging to trusts from Bucharest, Constantza and Gh.Gh.Dej (Onesti) where the management systems elaborated by COCC were under development. Problems concerning the production management were discussed under the leadership of eng. H. Manescu and N. Tutos.

2. Contacts Performed Under the Common Research Program

Exchange visits which allowed direct contact between both research teams were established in the common research program approved in April 1974. The main aims established for these visits were:

- The analysis of results obtained during the previous phases and the establishment of the detailed working program;
- A program for the comprehensive study of construction management systems existing in both countries.

The following direct contacts have taken place during the research period:

A. Romanian Management level experts visited the USA in May 1974 (eng. H. Manescu - Head Manager and eng. N Tutos - Technical Manager, chief of the Systems Design and Implementation Department). Eng. Gh. Cristea from the Industrial Building Design Institute of the Industrial Construction Ministry was also a member of the delegation.

The main aim of this visit was to make a study of the organization of construction activities in the USA, as well as the management and use of computers in construction.

In order to understand the general construction environment, the Environmental Production Agency - EPA, Region Office IV, the Engineering Station and the Department of Information and Computer System of the Georgia Institute of Technology were visited.

The following institutions directly involved in construction activity were also visited:

- U.S. Corps of Engineers - South Atlantic Division
- John Portman Associates - major architectural firm
- Daniel Construction Company (headquarters in Greenville, South Carolina). On this occasion the Romanian delegation met with Mr. A. Burger - Systems Analyst for Daniel. He later became a co-worker in the common research program.
- Atlantic Building Systems (Pre-engineered Construction)
- Yancey Brothers Heavy Equipment Company

The similarity of construction problems in the USA and Romania was noted. Many areas of commonality in the development of management systems were also identified. The management systems of Daniel Construction Company are very similar conceptually to the management systems developed in Romania by the Center for Organization and Cybernetics in Construction.

B. Dr. D. W. Halpin - Principal Investigator of the common research program - came again to Romania in September 1974.

Activities under the grant were reviewed.

C. During the period of 11 November 1975 to 10 February 1976, a common working meeting was organized at the Georgia Institute of Technology in Atlanta, Georgia. Participants on the Romanian side were:

- eng. N. Tutos (11 November - 17 December 1975) as Co-Principal Investigator for the common project;
- eng. R. Sassu as Computer Analyst at COCC.

Work to date was reviewed. The control models of projects and the data base design were discussed. The Romanian investigators studied the implementation of the real time solutions being developed in the USA. Dr. D. W. Halpin and A. Burger were present at all working meetings. During this period, a number of contacts with the USA industry were made. Visits were made to:

- Daniel Construction Company
- The Construction Department of Illinois University (Urbana-Champaign) and the University of Texas (Austin)
- The Bechtel Corporation (Power Division branch in Washington)
- National Bureau of Standards (Construction Research Department).

The possibility of cooperation in the field of construction design by aid of computer was explored.

D. During the period 3 - 18 September, 1976, a final working meeting for drawing up the final report was held in Bucharest at COCC. Professor D. W. Halpin and eng. A. Burger participated from the American side. H. Manescu and eng. N. Tutos, at the level of project management,

represented the Romanian research group.