Project control – an overview*

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SYNOPSIS

The paper discusses some of the tools of management in the field of project control, especially in engineering.

Project control includes planning and cost engineering, and involves various phases: the conceptual Design and Planning Phase, the Definitive Design and Capital Budgeting Phase, and the Implementation Phase.

Each of these phases is discussed in turn, together with the use that can be made of data banks, progress reports, and computer systems.

SAMEVATTING

Die referaat bespreek 'n paar hulpmiddele vir bestuur op die gebied van projekbeheer, veral in ingenieurswese.

Projekbeheer sluit in beplanning en koste-ingenieurswese en behels verskillende fases: die voorstellingsontwerp- en beplanningsfase, die definitiewe ontwerp- en kapitaalbegrotingsfase en die uitvoerfase.

Hierdie fases word elkeen om die beurt bespreek tesame met die gebruik wat daar van databanke, vorderingsverslae en rekenaarstelsels gemaak kan word.

Introduction

During the past forty years, the engineering and construction sciences have become very complex and have grown into a large industry in this country. As a result of this complexity, and also of the rising cost structure, the responsibilities of management in the control of technical projects have become very important and, incidentally, more difficult.

New tools of management, especially in the engineering field, have been developed, and some of these tools are discussed in this paper. Today, because of the complexity of projects, it is impossible for any one person to have a complete picture of every facet of a project in all its stages of development, planning, and construction, especially as these stages often overlap.

In small or non-complex projects, techniques of control have been developed by individuals, usually with a specific object in view, these techniques being tailored to suit the particular individual's way of thinking and working. The usual shortcoming has been that these techniques have not been adaptable to large or complex projects, nor have other people been able to understand or adapt to them. Consequently, new techniques have been developed over the years, and have been grouped together into a function or discipline called project control, with qualified technical manpower trained to perform this function.

Project control is that function of the project management team that controls the performance of the elements producing the final product, viz engineering and design, procurement, and construction. This function is generally applied by the planning and cost engineering disciplines.

Project control can be defined as the process that

- forecasts and evaluates potential problem areas prior to their occurrence so that preventive action can be taken,
- reviews trends or situations so that their impact can be analysed and, if possible, an action proposed to alleviate the situation,
- provides constant surveillance of project conditions so that a 'no-surprise' situation is created effectively and economically.

There is a long-stated opinion that control is exercised only by project management, where the right of decision is vested; that a planning/cost engineer provides only information and has no exercise of control. However, a key element for effective control is timely evaluation of potential cost and planning hazards and their presentation, with recommended solutions, to project management. This means that the control engineer must be a skilled technician and must also be able to communicate effectively to management level.

The Planning Function

Planning consists of the systematic predetermination of the ends and the means necessary for the accomplishment of a project in the most economical manner. It implies the most efficient expenditure – in combination – of time, human energy, and material resources:

- WHAT work shall be done
- HOW the work shall be done
- WHERE the work shall be done
- WHEN the work shall be done.

Planning is the technique of picturing ahead every step in a long series of separate operations and of so indicating each step that routine arrangements suffice to cause it to happen in the right place at the right time.

The complexity of the planning function is due to the relative complexity of modern projects and is caused chiefly by the division of labour, or specialization, both at executive level and on site. Efficient production is rarely achieved by the voluntary cooperation of specialists acting on their own initiative. It must be brought about from above through the working out of a preconceived plan. Coordination is most effective through a definite directive agency.

There are three major facets to 'planning', as it is loosely called: planning, scheduling, and control.

In today's terms, the planning engineer provides a network planning programme covering most aspects of

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the engineering, procurement, construction, and commissioning phases. The programme contains network plans and schedules for starting and finishing dates. It is reviewed at periodic intervals, and is agreed with clients and participants.

Network analysis is a statistical technique. With time as a variable, the programme provides

- a measure of the current status against approved plans and programmes
- a forecast of future progress and problem areas, with probabilities for the meeting of schedules for planned effort
- the effects of proposed changes in plans on established schedules for the meeting of programme goals.

Planning has two basic requirements: a flow plan and elapsed-time estimates.

The programme consists of logic, network, and the plan. The logic (sequence of events) is formulated by the planning engineer in consultation with client representatives, engineers, project team leaders, and specialists so that the corporate efforts can be dovetailed into a cohesive master plan. Networks are drawn, computerized, analysed, and reported on. The crucial part of the exercise is the initial formulation of the plan called the CREATE.

After that the UPDATE part of the exercise follows at regular intervals, when progress reports are received and site visits are made to monitor progress, computerize the facts, analyse the results, and perhaps consider changing the programme. Concise reports are usually issued summarizing the latest position for use by the project management as a decision-making tool.

The Cost Engineering Function

Cost engineering is defined as the estimating, monitoring, forecasting, and analysing of project costs using technological, scientific, and other principles to facilitate the control of the final project costs within the desired parameters.

The cost engineering responsibility is to

- develop estimates and budgets
- control the costs as they occur and monitor these costs against the budget
- develop forecasts of trends in costs
- forecast the final cost of the project
- identify all changes of scope in the project and determine their cost implication.

The cost engineer's prime interest is in working with the programming and monetary activities on a project. He develops estimates and then relates them to the schedule for work accomplishment. The project management is responsible for all facets of the project, and under this umbrella is the concern for planning, costs, and productivity performance. The cost engineer supports the project management, operating as an integral part of the project team.

On a daily basis it becomes apparent that programming affects the cost, and this is even more apparent with the escalation that is occurring at present.

Project Phases

As detailed elsewhere[1], a project goes through various phases. These can be summarized as the Conceptual Design and Planning Phase, the Definitive Design and Capital Budgeting Phase, and the Implementation Phase. These phases overlap so that there is no distinct boundary between the work done in one phase and the adjacent phases. In all three phases, in both the planning and cost engineering disciplines, the functions to be performed are estimating, forecasting, and evaluating changes. All these functions concern time and cost.

During the Conceptual Design and Planning Phase of a project, the greatest amount of leverage is available to exercise control over the time and cost for the successful completion of a project.

In the planning discipline, basic programmes are prepared to give an indication of the overall duration of a project in terms of design, procurement, construction, and commissioning. In addition, time programmes coupled with study estimates can be employed.

In the cost engineering discipline, feasibility estimates, order-of-magnitude estimates, or scope estimates are generated. Study estimates and value engineering estimates can also be applied if the time allows. These estimates enable management to weigh up various alternatives and so arrive at a final decision. Obviously, no control costing is applied.

In the Definitive Design and Capital Budgeting Phase more detail is available, because the process and plant capacity have been frozen. Consequently, detailed programmes and cost estimates can be prepared, and these are up-dated as more information comes to light from the drawing boards. The equipment can be identified, and construction programmes can be prepared. These activities enable a capital budget to be prepared for both the acquisition and installation of equipment and for the general construction of the project, together with an estimate of possible escalation during the Implementation Phase. This is known as the definitive estimate.

The Implementation Phase is the stage in which orders for equipment and materials are placed, and site construction is under way. In this phase detailed programmes of material delivery and construction contractor endeavours are prepared, and effort is monitored. Detailed cost budgets for all aspects of the work are prepared, and progress against these budgets is monitored. Variations due to construction changes are evaluated and recorded. The trends of past endeavours are evaluated, and future progress is forecast from these trends.

In all the project phases, decisions can be taken only if the time and cost implications are clear, and are understood by all of those who are involved in the decision-making process. Very often managers make decisions without reference to the evaluation of time and cost, and, when the project costs increase, they blame the increase on escalation or inflation.

It is the intention of project mangement contractors that, from the Feasibility Stage to the Implementation Stage, the final cost of a project does not change, provided no change has occurred in scope, site conditions, or escalation. Changes during the life of a project are generally very costly and should be avoided where possible.

Data Banks

One of the essential tools of the control engineer is a data bank, which is, briefly, a store of all the information required for the preparation of cost estimates and master plans, as well as the statistics required for a comparison of productivity and performance. This information is gathered from past projects, and is catalogued and filed away for future use. Probably all large industrial and mining companies have data banks of their past performance, which they may use in the preparation of feasibility studies for new works or in the monitoring of progress on projects already under way.

The cataloguing and filing of information can be done in a number of different ways using manual filing methods or a digital computer. However, the two important factors are that new information must find its way into the files to either augment or up-date the existing information, and that information in the files must be easily retrievable in a form that can be used.

The Conceptual Design and Planning Phase

The Conceptual Design and Planning Phase is that stage in the life of a project when its feasibility is being investigated and the parameters of the project are being set. This may include research and development programmes, and the ultimate aim is the determination of whether the project is economically viable.

The Planning Engineer prepares basic programmes that indicate the overall duration of all the main items in the project. This shows in very broad terms the time required for the design, procurement, and construction of each module without these main activities being broken into disciplines.

For each research and development study, a programme is prepared to determine the effect of the proposal on the overall duration of the project. Sometimes time plays a greater role in determining the feasibility of a study than does cost, since the overall cost involved in the extension of a project may far outweigh the additional increase in cost brought to light by the study under view.

This phase is the one area where a data bank is of use to a planner. As the basic programme is usually built up on a modular basis, programmes of typical modules can be used in the assembly of the overall time plan. Modules can vary in size from a plant area, such as the melting shop in a foundry, to an item of equipment such as a crusher, or even the road system for a project.

The cost engineer prepares estimates of the probable cost of the project, together with estimates for any research and development study. In addition, together with the principal financial personalities, he determines the economic viability of the project, usually in the form of unit cost for final product, as well as the returns on capital investment.

The estimates of the probable cost of a project are built up in a parametric form or in a modular form from information in the data bank.

Using the parametric method, the cost engineer uses the probable cost of a selected few components within the project and then factors the balance of the project costs without identifying details. This is a method commonly used in coal-fired power stations, where, if the power output of the plant is known, the size of the boilers for a given type of fuel and the size of the generators can be determined, and from the cost of these items the total cost of the power station can be estimated. This method is reliable only if a good data bank has been built up and all the parameters have been defined.

The usual method involves a modular format. The cost engineer breaks the project into modules, and determines their cost from the cost of similar modules in the data bank. This entails some engineering, even in a simple way, in that the cost engineer has to determine more or less what the final plant will look like.

Two further functions that must be performed by the cost engineer at this stage are value engineering and life cycle costing. These functions are important because it is seldom that all the equipment to be placed in a project outlives the life of the project. Some of the items require intensive repair during their life, and may very well have to be replaced, perhaps more than once. The lifecycle of the module or item of equipment must be determined and its ultimate value to the project calculated. These costs are additional to the project costs, and, while they will ultimately probably be financed out of the profits generated by the completed project, they must be recognized because they have an effect on the overall viability of the project.

Expenditure profiles, usually erroneously referred to as cash flow curves, can also be fixed. These are tied into the acquisition and repayment of capital (as well as the cost of raw materials in the case of an industrial project) and the operating costs to graphically indicate the time and cost viability of a project.

This phase in the life of a project is very important and sets the rules for the rest of the project. The design, procurement, and construction aspects of a project overlap and, once procurement or construction is under way, the design cannot be changed because this may involve heavy costs for the work already done. Too many projects are not properly conceived and, when the costs increase because the client makes changes during the design stage, everone gets upset and blames the engineers for not controlling the cost.

The Conceptual Design and Planning Phase usually involves effort from the client, but very often the introduction of the project management team into this phase clarifies interpretation of the requirements and hence reduces costs.

The Definitive Design and Capital Budgeting Phase

The parameters of the project are finally set in this phase, which often overlaps the next phase so that, while the final time/cost budgets are being set, work in the implementation stage of the project has started and time/cost controls must be implemented. If the project management contractor appears only at this stage, a considerable amount of work may have to be undertaken before the design of the project can be defined and the time/cost implications finalized.

To facilitate the control of time and cost on a project, the project is divided into areas, which may be geographical or functional, i.e. tied to a process of the plant, a discipline, or an activity. Usually, an area is under the control of a project engineer, who becomes the mini-project-manager for this part of the project.

The planning engineer produces an overall project plan called the Project Master Plan, which shows the following:

(1) the design, procurement, construction, and commissioning for
  (i) each discipline within a project area
  (ii) each interplant service such as sewerage, electrical reticulation, roads
(2) any important milestone events, including any events that involve the client.

The Project Master Plan is not broken into details during this phase, but shows only the total periods for the design, procurement, etc. for each area or interplant service.

This Project Master Plan is usually drawn up in the form of a critical path (CPM) network, using either the arrow or precedence format. Depending on the size of the network, this can be analysed either manually or by use of a digital computer. Printouts from the computer can take many forms depending on requirements. The presentation of the plan is by means of Gantt bar charts, which shows the relationships between activities. Computer programmes and plotters can produce these bar charts mechanically. The plan forms the basis on which progress within a project area is reported.

As the design within each project area progresses, area programmes are developed. This is an expansion of the Project Master Plan, and the area programme shows the design, order, deliver, construct, and commission activities for

- all major items of mechanical equipment
- earthworks, civil works, and buildings
- structural steel
- platework
- piping
- electrical reticulation
- instrumentation.

Again CPM networks are produced for each area programme. The presentation of the programme can be in the form of listings, bar charts, tables of resources, histograms, etc., as required by project management to control the work within the area.

These are the only programmes produced up to the stage at which the design is defined.

In this phase of the project, the cost engineer produces his base estimate for the project, which is done by use of the modular format and, as for the time programmes, is based on the project area. As much physical detail as possible is listed for each discipline, as indicated in the area programme, and money is allocated to each. Each item on the list is given a cost code to enable the item to be identified and to enable later costs to be reflected against that item. Detail is usually not well enough known at this stage, and globular sums may be allocated to a particular discipline. The accuracy of the estimate is calculated, and a contingency item is added to cover estimating shortfalls and design developments. Probable escalation costs are calculated.

This estimate is improved and up-dated until the Definitive Design Stage is reached, when the estimate for each area is frozen and becomes the project control budget.

The process of preparing and up-dating an estimate is manual and partly computerized. Because estimating is an art and the estimator must have a feel for a project, mechanical estimating systems are not usually satisfactory. A data bank is an essential tool at this stage. Life-cycle costs and value engineering techniques may also be employed.

Implementation Phase

As stated before, the Implementation Phase can overlap the previous phase so that the transition from one to the other is not a definite point in time.

As this phase entails the production of the working drawings, the purchasing and expediting of equipment and materials, and the site construction, controls must be placed on all aspects of the project to ensure the best and most economical time/cost results.

The planning engineer produces detailed work lists for each major activity on the area programme, which are incorporated in the detailed design, procurement, and construction programmes.

Drawing Register Programme

The drawing register programme consists of a detailed list of drawings required to be produced on the project. The issue dates of required drawings are calculated from the area programmes and are included in the drawing register programme. The drawing register is used as a detailed work list for the scheduling of drawings through the drawing office.

Manhour and drawing production S curves are produced from the drawing register programme. The information for the subsequent monitoring of progress is obtained from this register.

Materials Control Programme

The materials control programme consists of a detailed list of equipment to be purchased by the project. The required site delivery dates are calculated from the area programmes and are passed on to the computerized material control programme, which is used for the monitoring of procurement progress on the project. Information like forecast delivery dates is passed back to the area programmes so that any problem areas can be identified.

Control Budgets

The cost engineer can now prepare control estimates or budgets, which are based on manhours and on money. These budgets are detailed, covering all probable cost heads against which expenditure will occur. The cost heads are given codes to identify them.

In addition to the budget, which is a listing, a profile or budget curve can be produced. Against this profile, both historical costs and future predictions can be depicted graphically.

The control of expenditure must now be put in hand. All orders for equipment and materials, as well as all labour contracts, must be examined by the cost engineer to see that the budget money is available and the costs are within the budget, value is being achieved for the cost expended, and the total expenditure over the life of the equipment is reasonable. The expenditure can then be approved. Predictions of the outstanding costs must be made and compared with the definitive estimate. All variations to the project that occur after the definitive design has been frozen must be recorded, and the cost of these changes estimated by the cost engineer.

Progress Reports

Both the planning engineer and the cost engineer keep progress records of the project against the base estimates. They measure the productivity as well as the progress, and report these figures, together with all variations, on a regular basis to the project manager, who in turn reports to the client. The reports are tailored to the client's requirements, which can be as simple or as detailed as he thinks fit.

Computer Systems

A number of computerized systems are available today to deal with planning and scheduling, the preparation of estimates, the control of costs, and the preparation of reports. Most of these systems have been designed with a particular purpose in view, and very few cover all aspects of project control. Those that do have shortcomings.

Before investing in a computerized system, a potential user should design a manual system based on his requirements, in regard to both what he wants out of the system and when he wants it, and make certain that it works. Only then should a computerized system be investigated.

Conclusion

In these inflationary times, the forecasting and identification of cost escalation are of paramount importance. Of equal importance is the planning of a project so that the planned completion dates can be achieved. Any delays and late changes can have drastic effects on the viability of a project. These effects are not only more noticeable, but also more difficult to predict in long-term projects (taking more than two years). For this reason, thorough conceptual design and planning are vital to a successful project.

To make project control really effective, it must be properly conceived, professionally produced, and timeously executed. The results achieved are well worth the effort required in terms of a project produced on time and within the budget.

Reference

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Hydraulic transport of solids

The 8th International Conference on the Hydraulic Transport of Solids in Pipes to be organized by BHRA Fluid Engineering will be held in Johannesburg from 25th to 27th August, 1982. The meeting will be held in conjunction with the South African Institutions of Civil Engineers, Mechanical Engineers, and Mining and Metallurgy, and the Council for Scientific and Industrial Research.

In many countries hydraulic pipelines are now being used commercially for moving solids over long distances. The Queensland Cement and Lime Company found, after detailed cost studies, that the cheapest method of transporting limestone from a new quarry and grinding plant to a cement clinker works was by slurry pipeline. A paper will describe the design and initial operating experiences with the high-pressure steel pipeline system that transports the limestone, clay, sand, and iron slurry for 24 km. Other papers will deal with the handling and pumping of seasand, fly ash, phosphate, and gold slimes. Four papers will be presented on the Hansa Hydromine, probably the most advanced hydraulic mining system in Western Europe. High-pressure water jets are used to cut the coal, which is then moved in open channels to a central sump. The slurry moves through vertical and horizontal pipelines before being hoisted 850 m to the surface.

An important factor affecting the economy of long-distance hydraulic transport is pipe wear, caused by a combination of friction and corrosion. A paper from BHRA Fluid Engineering will discuss the measurement of wear rates in pipes carrying abrasive slurries. Other papers cover fluid mechanics, rheology, pumps and pumping systems, and instrumentation.

Further details are available from the Conference Organiser, Hydrotransport 8, BHRA Fluid Engineering, Cranfield, Bedford MK43 OAJ, England; telephone Bedford (0234) 750422, telex 825059.

Underwater mining

The 13th Underwater Mining Institute will be held in Madison, Wisconsin, from 26th to 28th October, 1982. The topics to be covered include sulphide deposits at spreading centre, geological framework of deep sea rifts, mineralogy of rift sulphides, continental shelf minerals exploration, assessment of OCS hard mineral deposits, new exploration techniques, engineering constraints in coastal mining operations, reports on new discoveries, up-date on new offshore mining rules and regulations, and other subjects related to marine mining, including robotics. The keynote address will be given by Dr John Byrne, Administrator of the National Oceanic and Atmospheric Administration. A programme brochure and registration details are available on request.

For further information, contact Dr Gregory Hedden, Sea Grant-Advisory Service, University of Wisconsin, 1815 University Avenue, Madison, Wisconsin 53706, U.S.A.