THE INSTITUTION OF ENGINEERS OF IRELAND

EFFECTIVE PROJECT MANAGEMENT

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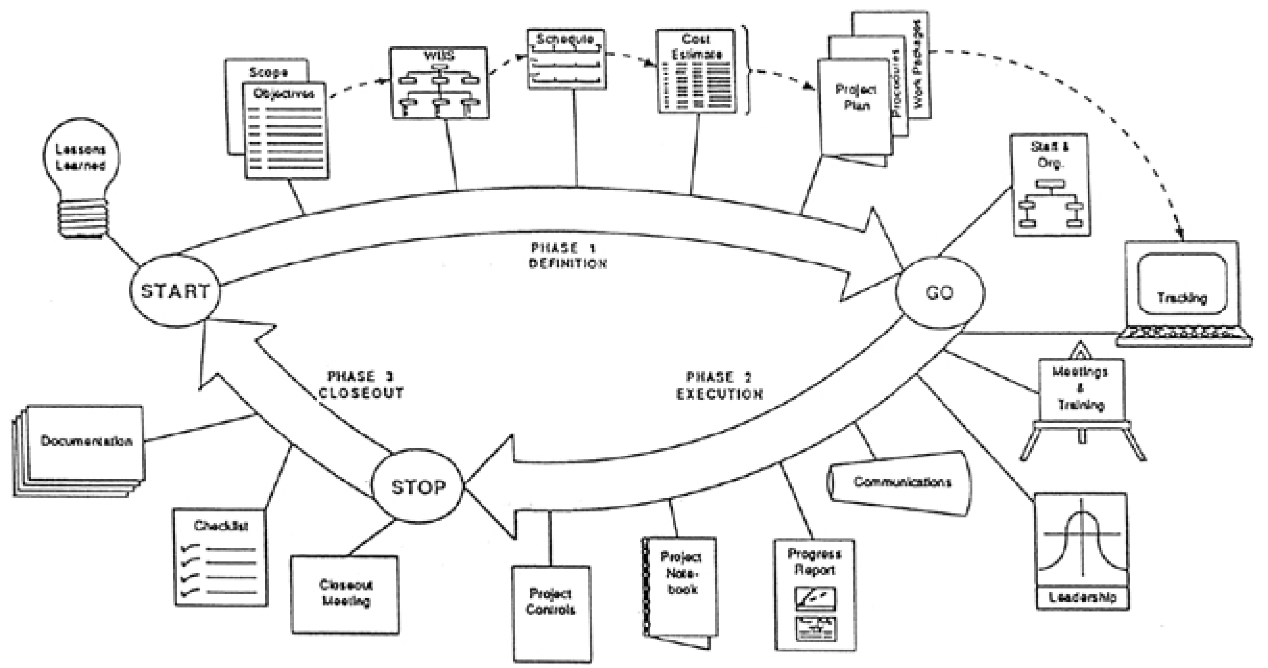


PROJECT LIFE CYCLE

SYNOPSIS

Project management as a management process is becoming of greater and greater importance to industrialised western societies. Corporations are now realising that organising their operations into project teams with the teams using the project management process is a most effective method of achieving predetermined objectives. Project management is a method for corporations to achieve profitability targets but, just as significantly, it is a culture that will assist most people to improve their personnel performance.

This paper is the authors view on the fundamental management requirements that we should be practicing to ensure that our industry achieves success for corporations and the owners of engineering projects. Success is measured in project management terms by completing a project in accordance with predetermined requirements. These requirements are measured in terms of project scope, quality, time and cost.

AN INTRODUCTION TO PROJECT MANAGEMENT AND ITS IMPLEMENTATION

The systems approach

Because project management is an outgrowth of systems management, it is fitting that the underlying principles of general systems theory be described. The aim of systems theory is to facilitate better understanding in a complex environment; that is, if the system within which managers make decisions can be provided as a more explicit framework, then such decision-making should be easier to handle.

Traditionally, management has undertaken its role through using an analytical approach, by taking apart the thing to be understood, trying to understand the behaviour of the parts taken separately, and then assembling this understanding into an understanding of the whole. This approach is referred to as **'segmentalism'**.

Many, if not most companies practice segmentalism. They see problems as narrowly as possible, independent of their connection to any other area of the problem - the actions, events and problems are compartmentalised. Segmentalism assumes that problems can only be solved when they are carved into pieces and assigned to specialists who work in isolation. Companies in which segmentalism is the dominant culture is where one finds executives who cannot innovate and handle change.

Much managerial and academic wisdom about organisational problem-solving stems from the study of segmented structures and segmented cultures. It is, therefore, no surprise that this is not very helpful in understanding innovation and change. It is for this reason that the current high interest in project management can be explained.

On the other hand, '**wholeness**' is practiced by those whose companies carry out their business by thinking about and seeing projects as an integrated whole instead of segmented from main-stream operations. The essential properties of a system taken as a whole derive from the interactions of the parts. When a system is taken apart, it loses its essential properties.

Because of this, a system is a whole that cannot be understood by analysis. In systems the focus is on synthesis, function, and, understanding why things operate as they do.

Why project management?

Projects can be classified as such when certain factors such as purpose, complexity, uniqueness, unfamiliarity, risk, impermanence and life-cycle are identifiable. Projects should have some or all of the following characteristics:

- there is a single, definable purpose, end product or result;
- there is a need to utilise skills and talents from multiple professions and organisations;
- uniqueness: the project is a one time activity, never to be exactly repeated again;
- there are significant elements of uncertainty and risk;
- the associated activities are temporary;
- there is a process of working to achieve a goal within a life-cycle of distinct phases.

The practice of project management pays attention to goal-oriented systems and environmental subsystems and relationships. It also relies on elements of the classical and behavioural approaches. It is a management philosophy and methodology that is oriented toward effective accomplishment of just one type of undertaking and that is - projects.

Effective project management calls into play certain aspects of the human relations and quantitative methods approaches. The selection of the right project manager and the right mix of team members should be based upon management skills, personality characteristics and reasoning ability. Problem solving by the team should be supported using mathematical (quantitative) modelling, including decision trees, linear programming, risk analysis and gaming theory, to mention just a few of the available techniques.

It is people who manage projects; the systems and procedures only provide the help that they need. The people-related aspect is extremely important within the project management environment. The project manager needs to be highly skilled in the following abilities: communications, organising, team building, leadership, stress-related aspects and in the specific technology of the project.

In its most simplistic form, project management can be described as a process. It is a culture, a way of thinking, and it includes particular forms of individual and organisational behaviour. The process involves the planning, organising, directing, and, controlling of resources for relatively short time periods on projects that are likely to happen once or only a relatively few times. It is a systematic, logical approach that will be helpful to project managers in reducing the risk of what they manage going wrong. It is, as we know, a management approach that can respond rapidly to changing business environments and, in that regard, it is streets ahead of the traditional approach.

ORGANISATIONAL STRUCTURES

A company, if successful, usually tends to grow, adding resources and people, developing an organisational structure. Commonly, the focus of the structure is specialisation of the human elements of the group. As long as its organisational structure is sufficient to the tasks imposed on it, the structure tends to persist. When the structure begins to inhibit the work of the firm, pressures arise to reorganise along some other line. The underlying principle will still be specialisation, but the specific nature of the specialisation will be changed.

In addition to the ever-popular functional division, firms organise by product line, by geographic location, by production process, by type of customer, by subsidiary organisation, by time, and by the elements of vertical or horizontal integration. Indeed, large firms frequently organise by several of these methods at different levels. For

$$SPI = \frac{BCWP}{BCWS}$$

Index values greater than one indicate performance either in cost or schedule terms that is better than planned, values lower than one indicate a worse position. The CPI is, perhaps, the more useful of the two, it shows the real worth that is being created by the project. Thus a CPI value of 0.85 indicates that for every pound spent, only 85 pence worth of value is being created on the basis of the original budget. The behaviour of these two indices can be plotted as the project proceeds and they give a very good indication of the real progress and what the future may hold. The Figure shows a typical situation in terms of the ACWP, BCWP and BCWS, the indices have been derived and are plotted. Using the indices gives a clearer view of the position than reading the relative ACWP, BCWP and BCWS values.

These two index numbers can be used to generate an estimate of the position of the project at completion, in terms of cost and schedule, based on the situation when the indices were calculated and assuming the indicated trends continue. For the cost at completion the formula is:

$$EAC = ACWP + \frac{BAC - BCWP}{CPI}$$

Where: EAC is the estimate at completion,

BAC is the basic or budgeted cost at completion.

For the estimated time to completion the formula is:

$$ETC = ATE + \frac{OD - (ATE \times SPI)}{SPI}$$

Where: ATE is the actual time expended

OD is the original duration.

Progress must be measured

Once the system is in operation, each responsible section manager will be required to participate in the control process through his own assessment of the degree of progress achieved. There is, inevitably, a subjective element in this, but it is necessary in order to establish the BCWP. A number of methods are possible, each has its drawbacks, but all are worthy of consideration for different circumstances:

a) at regular intervals perhaps once a fortnight, the section managers are asked to estimate the percentage completion of each of their activities that are currently authorised to be in progress;

b) at regular intervals the managers are asked to estimate the remaining number of weeks that they expect to elapse before each of their current activities is complete;

c) at each reporting point an amount of progress is credited to each current activity according to an agreed method of scoring.

Provided that the responsible managers can be trusted to make a reasoned assessment, method (a) can work well. It might seem that it would be easy to hoodwink the system and in the early stages of each activity's life this is so, but as time passes and he assessed progress is not, in fact, being made, it soon begins to show and the manager cannot disguise it

.

With method (b) one needs to assume a uniform rate of spend in each activity. This may not be a valid assumption in all cases but it is reasonably accurate if the work packages are small enough. With the estimated duration of the remaining work the BCWP is

$$BCWP = \frac{A \times BCWS}{B}$$

Where: A is budgeted duration of the work package and

B is the predicted duration of the work package.

The predicted duration is found by adding the expected remaining duration to the time elapsed since the activity first started; the BCWS is found from the current schedule as generated by the computer or by a simple calculation based on a uniform spend rate.

Method (c) requires an assessment to be made of the likely rate of spend and the identification of well defined milestones against which progress can be credited. For example, if, in the drawing office, there is a package of work that covers the output of a set of drawings for a certain item, the rule for assessing the BCWP could be: credit 10% of budgeted cost when the activity starts, give another 50% when 25% of drawings have been issued, give another 25% when 75% of drawings have been issued and give the final 15% when all work is complete.

Each of the above methods has its place: method (c) is particularly useful where milestones are easily definable but this is not always the case. For service types of activity such as quality control, milestones just don't apply, hence methods (a) or (b) are more appropriate.

Configuration management

Configuration management is the discipline of identifying the constituent elements that make up a product together with all that is necessary to define the manufacture and support of that product and then systematically controlling changes to all of these items such that the traceability and integrity of the design in terms of form, fit and functional requirements is maintained throughout its life-cycle.

We might ask ourselves if there are any special characteristics of projects that make configuration management a particularly attractive technique to apply? The answer to this is very definitely yes for it would be wasteful of both time and effort to apply it in the wrong context. In general, projects that are most suitable are ones that exhibit some or all of the following characteristics:

o there is a large and complex technical content;

o expensive and sophisticated test programmes are involved;

o support equipment, services and software are of a complexity compatible with the principal item;

o a high percentage of the work is sub-contracted;

o repeatable, volume production is anticipated;

of risk analysis. Essentially, it simply determines the effect on the whole project of changing one of its risk variables such as delays in design or the cost of materials. Its importance is that it often highlights what the effect of a single change in one risk variable can produce a marked difference in the project outcome.

- Probabilistic analysis specifies a probability distribution for each risk and then considers the effect of risks in combination. This is perhaps the most common method of performing a quantitative risk analysis and is the one most people consider, incorrectly, to be synonymous with the whole project risk analysis and management process.

The most common form of probabilistic analysis uses 'sampling techniques', usually referred to as 'monte carlo simulation'. This method relies on the random calculation of values that fall within a specified probability distribution often described by using three estimates: minimum or optimistic, mean or most likely and maximum or pessimistic. The overall outcome for the project is derived by the combination of values selected for each one of the risks. The calculation is repeated a number of times, perhaps between 100 and 1000, to obtain the probability distribution of the project outcome.

It is usual to carry out a probabilistic time analysis with the aid of a CPM network to model the project schedule. The same method can be used for probabilistic cost analysis especially when the cost estimate can be broken down into the same categories or activities as the schedule and when cost risks are related to time risks. If an independent cost analysis is undertaken then it may be appropriate to use a spreadsheet method.

Cost-performance measurement

Simply measuring cost differences, or variances, between expenditure and plan is not sufficient to define the true position of the project. Cost variances come about because activities are done either earlier or later than planned or because they cost either more or less than was originally estimated. If an accurate picture of progress is to emerge, any variance would have to be sub-divided into that element which is due to things being done at a different time and that which is due to things being done for a different cost. Furthermore, once this fundamental split has been made it is not difficult to gauge the real value of what has been achieved and from there make a projection of the likely outcome of the project as a whole in terms of both time and cost.

Three distinct measurements of cost have to be made at each reporting point, they are given the following titles:

1. BCWS - basic, or budgeted, cost of work schedule. This is the sum of all the costs in the project, or any given part of the project, up to the reporting date.

2. BCWP - basic, or budgeted, cost of work performed. This is the cost of all the progress achieved in the project, or part of the project, up to the reporting date and expressed in terms of the costs originally set out in the initial estimate; it is also termed the 'Earned Value' as it represents what has been earned, not simply what has been spent.

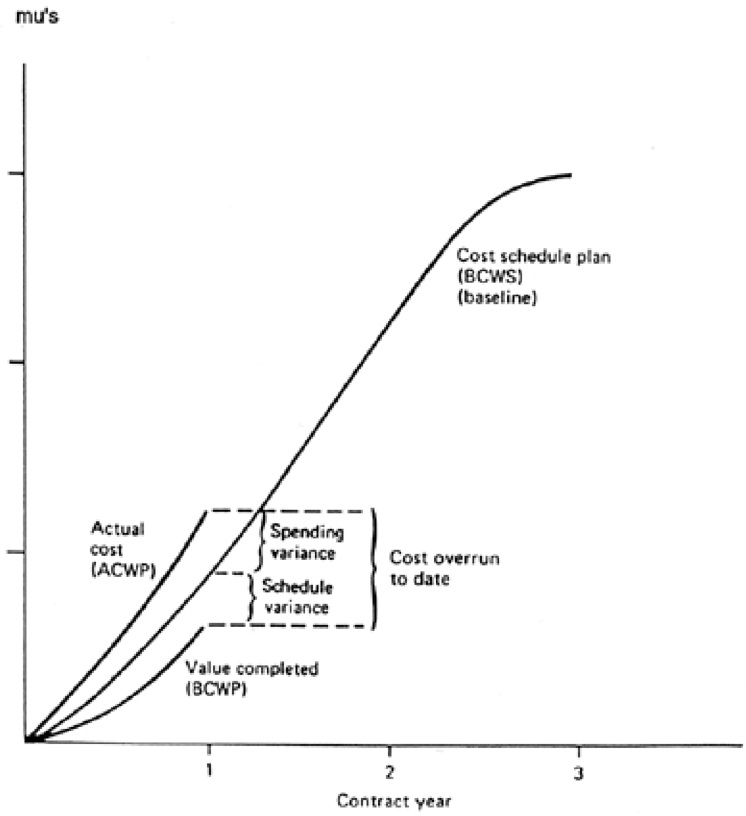
3. ACWP - actual cost of work performed. This is the total of all expenditure on the project, or part of the project, up to the reporting date.

The relationship between BCWS, BCWP, ACWP, cost variance and schedule variance is illustrated in the Figure which shows a project at the third point of its life and in which there has been a significant deviation between the budget (baseline) and the costs incurred. It will be seen that the actual cost is above the budgeted spend while the earned value, the BCWP, is below the actual spend. In this case, it can be assumed that the project is likely to finish late because of the adverse schedule variance and be overspent because of the adverse cost variance.

Two useful index numbers can be calculated that give an instant measure of performance; the cost performance index (CPI) and the schedule performance index (SPI). They are defined as:

$$CPI = \frac{BCWP}{ACWP}$$

and



details are necessary to perform this type of estimate;

- ☐ definitive: -5 to +15 percent.
  This type of estimate is developed from very defined engineering data including plot plans and elevations, piping and instrument diagrams, one-line electrical diagrams, equipment data sheets and quotations, structural sketches, soil data and sketches of major foundations, building sketches, and a complete set of specifications.

The previous figure shows guidelines that link order of magnitude of accuracy to level of information needed on the project to satisfy that level of accuracy. The specified accuracy levels in the revised AACE list reflect the general fact that estimates are more likely to be low than high due to numerous factors, including inflationary trends and incomplete data, among others.

Value engineering

Value engineering is a creative disciplined process which seeks to achieve "optimum" value for money in capital works projects. Value engineering aims to offer the owner real opportunity to achieve significant capital and life-cycle cost savings. The objective is to achieve the lowest possible cost without detriment to quality or performance, by identifying function and eliminating the unnecessary through a system of investigation; in other words, value engineering seeks to enhance value.

For a given project, the design team's task is to provide an acceptable solution which will satisfy the owner's requirements regarding project scope and performance as well as satisfying spatial, environmental and statutory requirements. This task usually involves a fairly large number of people over a relatively long period of time. Due to constraints on time and budget in the design stage, it may not always be possible for design teams to optimise the design through ensuring that the project cost will represent optimum value for money in terms of capital and life-cycle costs.

Value engineering, in contrast, is a process which provides intensive review and analysis at particular points in the life-cycle of a project. The value engineering study offers a "second look" at the design, and evaluates cost effectiveness by investigating alternative ways of satisfying function.

Ideally, value engineering should be carried out early in the design stage, at about 30% completion; and again, if appropriate, at about 70% design completion which, depending on the nature of the project, is during the early stages of the detailed design and on completion of a detailed cost plan.

The value engineering study neither displaces nor overrides any discipline; it runs parallel to the normal design process. No duplication of effort is involved. The multi-disciplinary value engineering team work together with the design team and the client's representative, and are in a position to form realistic team solutions. Each discipline is assured that its contribution will be recognised and acted upon. Because the team is working within one room and has dedicated itself to the value engineering study, communication is rapid, options are quickly assessed, and a considerable positive team spirit is generated.

The power of the technique stems from its objectivity and strictly disciplined methodolog. By understanding and applying the philosophy behind the technique, major improvements can be obtained for most projects.

Potential capital and life-cycle cost savings are frequently obtained while still satisfying the brief - with minimal or no reduction in quality. As value engineering studies are carried out in a very short time frame, costs are low and return on investment can be significant.

Typically, the total time frame for a value engineering study is about three weeks, comprising preparation, the workshop and study report, and follow-up.

Risk analysis

Project risk analysis and management is a process which enables the analysis and management of the risks associated with a project. Properly undertaken it will increase the likelihood of successful completion of a project to cost, time and performance objectives.

The major risks are the owner's, in deciding to proceed with a project and then stating or agreeing scope and specification, choosing the contract strategy, and selecting a contractor. The options in risk allocation and risk management open to a owner on each risk are to:

- ■ avoid it: by changing project design or timing, reducing dependence upon contractors and others;
- ■ transfer it: to a main contractor, vendors or design contractors;
- ■ reduce it: by a combination of any of the above and insurance cover;
- ■ absorb it: by allowing for extra costs, delay or reduced performance.

Risks for which there is ample data can be assessed statistically. However, no two projects are the same. Often things go wrong for reasons unique to a particular project, industry or working environment. Dealing with risks in projects is therefore different from situations where there is sufficient data to adopt an actuarial approach. Because projects invariably involve a strong technical, engineering, innovative or strategic content a systematic process has proven preferable to an intuitive approach. Project risk analysis and management has been developed to meet this requirement.

Once all risks have been identified, during the qualitative analysis, it may be appropriate to enter into a detailed quantitative analysis. This will enable the impacts of the risks to be quantified against the three basic project success criteria: cost, time and performance. Several techniques have been developed for analysing the effect of risks on the final cost and timescale of projects. However, such techniques do not always readily apply themselves to the analysis of performance objectives.

The main techniques currently in use are:

- ☐ Sensitivity analysis, often considered to be the simplest form design, procurement, manufacture, delivery, erection and commissioning functions into a pattern of contracts.

The arrangement of contract packages that gives the optimum combination of competitive edge with the contract price and minimum probable time for completion is the goal.

The theoretical combinations of individual items and responsibility for design, supply, manufacture, fabrication, delivery and erection and the different types of contracts are unlimited, but the practical alternatives are determined by the available resources of suppliers, manufacturers and contractors to carry out these operations and the degree to which the maximum competitive pressure can be brought to bear upon such resources.

Project master plan

The project master plan (PMP) consists of the scope of the project identified by the design concept and work definitions allocated into contract packages with key dates determined for the development of the design, procurement and construction for each contract package.

The PMP is the principal instrument of control of the project and defines how the project is to be designed and built. It established the basis for the organisation, the resources, the detailed planning and scheduling. estimating, reporting, forecasting and accounting for design and engineering services, procurement and construction.

The specifications for the PMP require that:

- ☐ the design concept has been defined;
- ☐ the scope of the work has been defined by work definitions and the code of accounts;
- ☐ the work has been divided into contract packages;
- ☐ the type of contract for each contract package has been determined;
- ☐ a stream of key dates has been established for each contract to determine collection of site information, release of design information, procurement, access to site for receipt and storage of materials, access to site areas for erection and for completion of construction, including manufacture, delivery and erection, testing and commissioning.

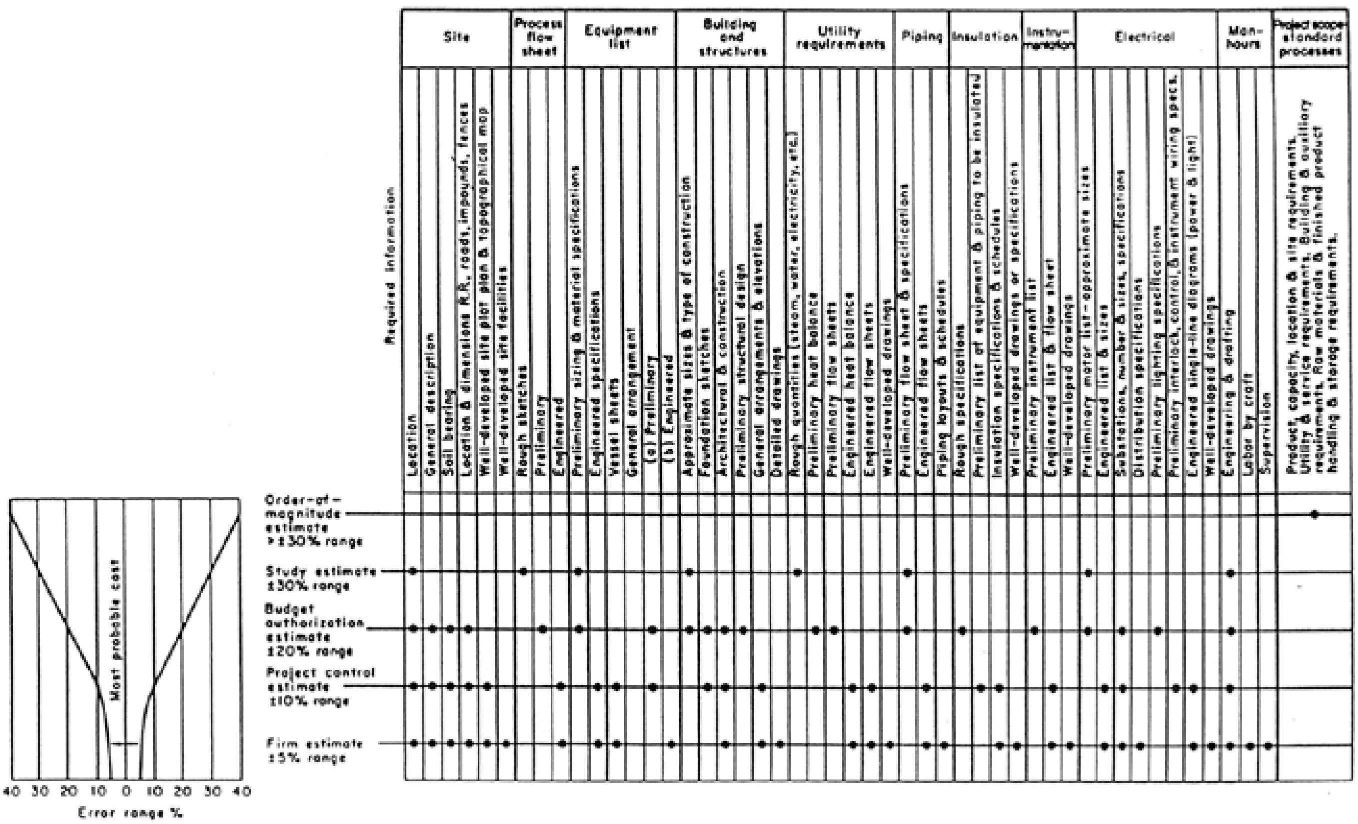
The PMP is not complete until the methods to be used for its implementation are fully documented.

Budgetary cost

Capital-cost estimating is essentially an intuitive process which attempts to predict the final outcome of a future capital expenditure program even though not all parameters and conditions concerning a project are known or are not fully defined when the cost estimate is prepared.

Estimate types vary considerably depending on the available information, time demands, and purposes of the estimate. Lists of estimate types prepared by various authors, companies, professional and industrial organisations, and government agencies are available. These lists identify the various types, or classifications, of estimates most commonly prepared. The following classification produced by the American Association of Cost Engineers (AACE) is typical:

- ☐ order of magnitude: -30 to +50 percent.
  This type of estimate is made without any detailed engineering data. The estimate is often developed using cost-capacity curves, scale-up or -down factors, or ratio estimating techniques;
- ☐ budget: -15 to +30 percent.
  This type of estimate refers to the owner's budget, not to the budget as a project control document. Flow sheets, layouts, and equipment



Plant
- o puts forward new ideas and looks for innovative approaches;
- o is individualistic, unorthodox and inclined to disregard practical details.

Resource investigator
- o maintains external contacts which may be useful to the team;
- o reports on ideas, developments and resources outside the team;
- o extroverted, enthusiastic and liable to lose interest once the initial fascinition is over.

Team worker
- o fosters team spirit, helps communications and supports other team members;
- o understands team members limitations and builds on their suggestions;
- o tends to be mild, sensitive and insensitive in moments of crisis.

Monitor-evaluator
- o ensures that everything is evaluated;
- o wants the project team to make a balanced decision;
- o tends to be sober, prudent and lacking in inspiration and ability to motivate others.

Company worker
- o is good at implementation
- o turns ideas and plans into practice and can carry out an agreed plan in a systematic and effective way;
- o is responsive to unproven ideas.

Shaper
- o shapes the way that the team effort is applied;
- o imposes some pattern to team discussions;
- o ensures that attention is directed to the setting of objectives and priorities;
- o tends to be highly strung, dynamic, impatient and prone to provocation.

Completer-finisher
- o maintains a sense of urgency and progress within the team;
- o checks every detail to ensure that nothing is omitted or done that should not be;
- o conscientious, painstaking and prone to worry over little things.

Each of these roles has negative characteristics associated with it. There should be no attempt to try to eliminate these negative characteristics, rather they should be managed. Eliminating the negative characteristics may also eliminate the positive characteristics.

The requirement for balance within the team has major implications for the project manager in terms of selection and training of team members.

PROCEDURES AND TECHNIQUES

The project plan

A plan is a description of action which is expected to take place in the future and is based upon the assumption that a certain pattern of events will occur. Planning is used as a means to fulfil objectives, and, in particular, the objectives defined in contracts, including proposals and agreements with the sponsor.

A plan defines the tasks required to be performed to fulfil objectives, and the sequence and relationship between them, the individuals or organisations who will execute the tasks, in such a manner that the required standards of time, cost and quality are achieved.

The following conditions must be satisfied for a plan to be the basis of a commitment between two or more parties to take the action required to fulfil the plan:

- ☐ the plan must cover the whole task or contract and must be prepared at a relatively uniform level of detail throughout so that the completion of the plan is as fully detailed as the commencement;
- ☐ the plan must be documented and understood by and communicated between the parties to the plan;
- ☐ the assumptions about the future and the summary of the information upon which the plan was prepared should be documented as part of the plan.

The pattern of planning must conform to the pattern of contracts. A particular plan must conform to the more general plans upon which it is dependent and must be capable of becoming the basis for more detailed plans for the contracts and tasks required for its fulfilment. The action should be described in the plan in such a way as to allow its execution to be reported and documented and compared with the plan.

The plan should provide methods for changes due to differences between assumptions made about the future and the actual events, and remedies to deal with failure to meet objectives. The quality of control of the execution of a project depends upon the quality of the preparation, documentation and communication, of and reporting of deviations from, the plan.

Development plan

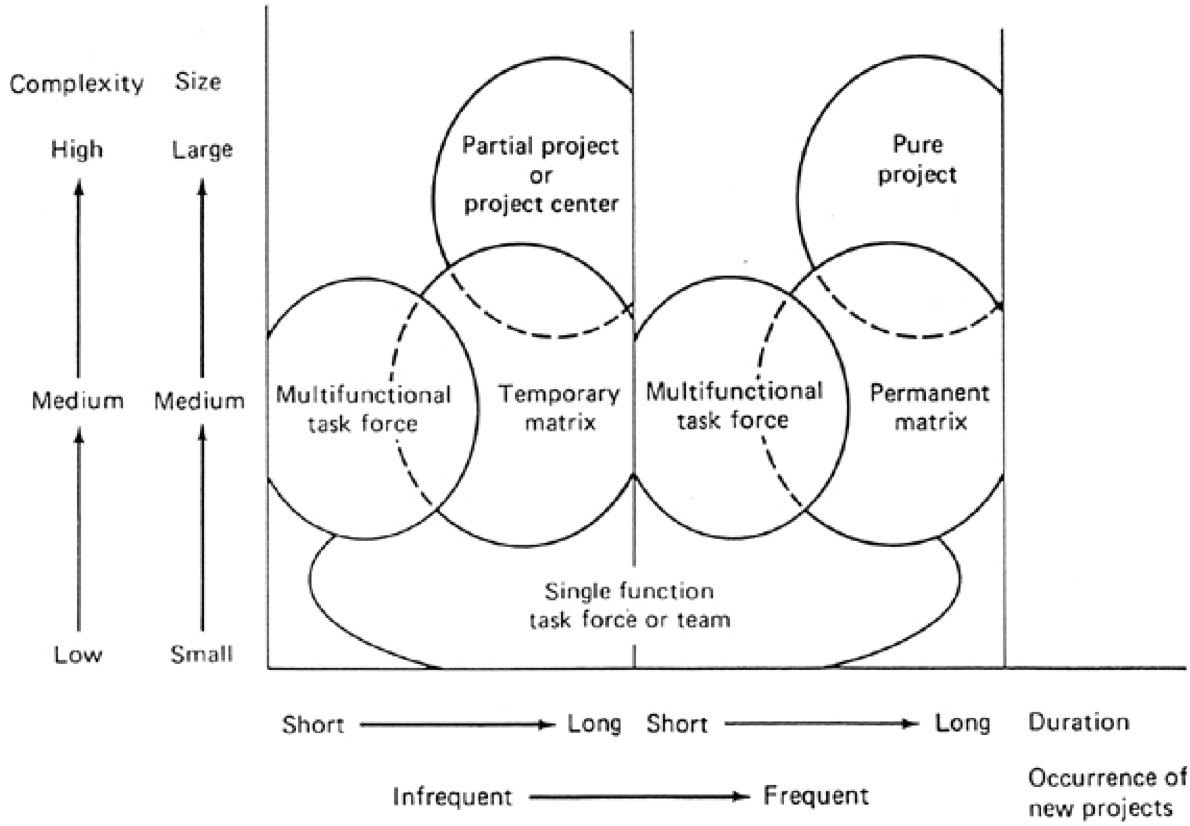
The development plan (DP) defines the development of the project through a series of phases which are:

- ☐ project scope
- ☐ project definition
- ☐ design and specification
- ☐ procurement
- ☐ construction - including
  - manufacturing
  - delivery
  - erection
  - commissioning

The DP identifies the services in relationship to each phase. It should always be included in the proposal or agreement with the sponsor to define the products of the services in each phase except when the services relate to investigations, studies or reports.

Contract packages

Contract packages consist of the division into individual contracts or tasks of the scope of the project as defined by the design concept and work definitions. The key decision which determines the pattern of the planning for the project is the decision on the pattern of contract packages, that is the division of the management,



example, a firm may organise by major subsidiaries at the top level; the subsidiaries organise by product groups; and the product groups organise into customer divisions. These, in turn, may be split into functional departments that are further broken down into production process sections, which are set up as three-shift operating units.

When projects are initiated, two issues immediately arise. First, a decision must be made about how to tie the project to the parent firm. Second, a decision must be made about how to organise the project itself.

If the project is to be included in a functional organisation, it should be placed in that unit with the greatest interest in its success or the unit that can provide the most help. Though there are advantages in this mode of organising, the disadvantages are greater. The project form of organising has its advantages and disadvantages. Though the disadvantages are not as severe as with the functional form, they are nevertheless significant. The matrix organisation combines the functional and project forms in an attempt to reap the advantages of each. While this approach has been fairly successful, it also has its own unique disadvantages. The figure shows some of the more popular options that are used; the structure is dependent upon project complexity, size, duration and frequency.

There are many variants of the pure forms of organisation, and special hybrids are commonly used to handle special projects. The best form for a particular case requires consideration of the characteristics of the project compared with the various advantages and disadvantages of each form.

PEOPLE RELATED MATTERS

Introduction

In building an effective project team the issues are largely behavioural ones. Indeed it is fair to say that the behavioural dimension is often the forgotten element; this despite the fact that often what distinguishes an effective project team from an ineffective one is its concern for the behavioural dynamics.

Behavioural roles are distinct from functional roles and have to do with processes within the team. In any project team there is a need to select the right mix of people. In designing an effective project team, project managers need to bear in mind the different qualities required and ensure that the right type of team member is selected.

Team roles

Success must be designed into the project team from the very start. The characteristics and traits of successful teams must be the primary ingredients of a model that helps us to select our team members, design our organisation, formulate our procedures and establish our style of management.

A team which has at least one of every one of the roles shown in the following Table has the potential to be very effective.

Chair

- o makes the best use of team resources;
- o recognises the teams strengths and weaknesses;
- o controls the team to achieve team objectives;
- o is calm, controlled and confident but not necessarily creative.

- o a variety of production standards is anticipated;

- o a high incidence of design or engineering change is characteristic.

Ignoring the technical complexity side, in many cases the last four factors, by themselves, make its use worthwhile. It must be said, however, that high incidences of engineering change often tend to result from technical complexity but it need not be the only cause, particularly if a large number of variants is created to specific owner requirements.

CONCLUDING SUMMARY

This paper has attempted to explain that project management is nothing less than a procedurised and scientific approach to the management of projects on behalf of owners (Clients). It has been observed by the author over the years that it is the lack of such an approach that is the principal difference between what is normally practiced and what, by right, should be provided. It is difficult, on most occasions, to define what is currently provided by European engineering consultancies for their clients as being project management. In general, it is found that engineering consultancies provide what can only be described as a liaison service that is reactive and based on a non-scientific approach.

The systems approach to projects requires that we understand the significance of the inter-relationships between the parts of the project having divided the project into pieces or packages. The system approach requires us to not only analyse the project to understand its behaviour but it also requires us to synthesis the project, that is, integrate the parts in order to ensure that non of the inter-relationships have been lost or distorted.

The project team should, where possible, be an integrated , dedicated group of personnel working together under one roof during the tenancy of the project. As part of this team there should be a client representative with the authority to make immediate decisions on technical and financial options presented by the other members of the project team.

It is generally recognised that the people factor in projects is as important as any other factor, such as, say, procedures or techniques. It has to be remembered that projects were relatively successfully carried out ever before there was any talk of project management procedures, or, before there was any sign of computers. Examples of such projects are the Great Wall (China), the Pyramids (Egypt) and the public health infrastructure of aqueducts and sewers in Italy.

In selecting the personnel for the project team what is referred to as the team role is as important as the functional or technical role of each member. Analysis of each potential team member using such techniques as psychometric testing will be helpful in ensuring that there is a correct balance in the team, or behavioural, roles. It is generally found that little, if anything, is scientifically carried out by engineering consultancies in selecting project teams.

Selection of the right personnel covering the required technical and functional roles will, in itself, not ensure project success; the other necessary ingredient is the project's organisational structure. As mentioned earlier the dedicated project team, or task force, is a recommended structure for effective project management. The other beneficial structure is the matrix. Whichever is used it is essential that the project manager is given the authority for directing the project as well as having the responsibility for managing the projects day-to-day matters. Project success is directly proportional to the authority given to the project's manager.

Within the area of project management procedures and techniques the following functions are those that are a mandatory part of the total process:

- o technical and financial feasibility analysis;
- o project funding management;
- o conceptual and detailed design management;
- o risk analysis;
- o value engineering;
- o procurement and contract management;
- o planning, scheduling and control;
- o configuration management;
- o project close-out management.

Within these functions there are such techniques as present-value evaluations, life-cycle costing, quantitative decision-making methods and many other methods that provide a meaningful scientific approach to the management of projects.

Effective project management demands that all parts of the process and their underlying techniques be provided. Anything less cannot be referred to as project management nor can we as professionals, on behalf of our clients, pretend that we are project managers unless we are providing the total process.