The planning network as a basis for resource allocation, cost planning and project profitability assessment

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INTRODUCTION
The planning network is well established as a tool for the planning of projects, and its usefulness as a catalyst for both time and cost control has been demonstrated. However, the task of management involves consideration of other factors besides merely time and cost. The overriding objectives of most commercial organisations are to make a profit, to maximise that profit and to obtain that profit from the deployment of available (or acquirable) resources. The basic planning problem is, therefore, how to decide between alternative ways of using resources such that the best profits are obtained.

These decisions are perhaps the most difficult that management have to face. It is often necessary to make decisions which will affect a significant proportion of the organisation’s money flow for many years ahead and to make those decisions at a time when there is a paucity of sound information upon which to base them. Previous experience is often used as a basis of evaluation but as technology advances new projects become more complex and previous experience has less relevance. Simultaneously, competition becomes more fierce and it is increasingly necessary to evaluate cash flows accurately so that adequate (but not uncompetitive) profit margins can be maintained.

It is particularly true of projects where the investment and revenue is spread over several years that the traditional methods of comparing average annual income with total investment are no longer sufficiently accurate to guide the present day decision taker. Project evaluation methods are required which take account of time in conjunction with investment and revenue, so that investment decisions can be made based upon a realistic appraisal of the relative economics of alternative policies.

Two developments have recently appeared upon the commercial and industrial scene in answer to the demand for more accurate financial evaluation of projects. They are the perfection of planning networks, or arrowed diagrams, as a basis for resource allocation and profit planning, and the widespread use of electronic computers capable of rapidly analysing these networks. The logicality of the planning network and the speed of computer processing enable management to test alternative plans and different degrees of planning detail before embarking on major forward planning decisions.

It is, however, unrealistic to expect a computer program to give in a single calculation, a “black box” type of solution to a large complex planning problem involving many estimates and many imponderables. The computer will predict (according to the rules it knows), but management judgement can often enhance these predictions by guiding the calculation along preferred paths. For this reason, the most effective way known so far towards accurate project profit forecasting involves a combination of managerial judgement (to specify the areas of uncertainty) and computing power (to analyse the impact of uncertainty upon factual data). In such a system the computer becomes an extension of the manager’s intellect and is used in the way that a manual worker uses a power tool.

This approach marks an important distinction from some earlier experimental systems in this field, where the

Figure 1—The planning systems pyramid

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computer program attempted to provide one single answer, the value of which entirely depended upon the relevance of the programmed decision rules to the project situation being analysed.

In this paper, an approach to profitability assessment is described through the stages of resource allocation, cost planning and profit evaluation. In the system described, the managerial decision process and risk assessment interacts with the preset programmed decision rules in such a way that solutions are reached which exploit to the full any innate managerial wisdom. This method can be considered as a step by step approach and the various stages are as shown in Figure 1. The foundation of this "planning system pyramid" is, of course, the project specification and progress towards profitability and financial risk assessment proceeds through the steps of network construction, time analysis, resource aggregation, resource allocation, and cost analysis. Many of these stages interact and in some cases the inter-action can be delegated to preset decision rules. However, it is a main premise of this paper that many of these inter-actions are managerial decisions and as such should properly be under the direct control of project management. The early steps on the pyramid have been amply described elsewhere and this paper concentrates mainly upon resource, costs and profit planning.

After setting up the planning network and time analysing it in the usual way, the next step is then to consider alternative ways in which resources can be deployed to achieve the physical completion of the project.

Planning resource requirements

The planning network will have yielded at this stage a preliminary estimate of the total project time required and the criticality of individual activities indicates ways in which improvements can be made. However, the execution of the project requires the deployment of men, machines and materials and these invariably fall into a hundred or more non-interchangeable categories. Often too, the amount of resources available is limited, or for economy reasons must be held at a steady level of utilisation.

In planning resource requirements, therefore, the following key questions have to be answered:

1. What are the total resource requirements for a project over its duration?
2. What is the minimum delay to the completion of the project when insufficient resources are available?
3. What is the most efficient utilisation of resources to carry out the project in a fixed time?

Inspection of a network time analysis will quickly indicate that, even with resource information available, finding the answers to the above questions is a formidable undertaking without the aid of a computer.

However, once resource requirements have been added to individual network activities, it is a relatively simple matter for a computer to aggregate the resources required over the time span of the project, to show the total requirement of each type. If the computer is also given a statement of the resource availability, comparative statements can be produced which indicate the resource requirement/availability situation, thus giving project management the answer to the first question.

Resource aggregation

The resources for activities on the critical path are accumulated in the time period allocated to each critical activity. For other activities having float time available, however, there is a choice between aggregating resources at the earliest time or the latest time.

Figure 2 shows the typical effect of these alternatives. In Figure 2(a) the resources required for the simple network shown have been aggregated at the earliest time which can be allocated to each activity and in Figure 2(b) resource requirements have been aggregated at the latest time each activity can be scheduled. A resource availability level is also shown and it is seen that in both cases this has been exceeded.

Assuming the extra resource requirements could be met, it would most probably be at some extra cost (i.e., overtime working, sub-contracting or engaging temporary staff). Also it will be noted that available resources are unused for some part of the time and thus further costs are incurred which are additional to the productive labour involved. Both these schedules (earliest or latest) are, therefore, likely to be high cost schedules due to the inefficient use of resources. Thus instead of merely aggregating resources against previously determined time schedules, it is necessary, if minimum costs are sought, to allocate the work to be done against the resources available.

Resource allocation

The planning network provides an ideal basis for the allocation of resources, as the network itself defines the sequence in which the work must be carried out and the time analyses show, by the amount of total float, the relative priority attached to each activity. The general method used in resource allocation is to commence at the beginning of the network and prepare a list of all the activities available for scheduling. In the first instance this will naturally be all activities starting from the first event, later in the scheduling process, however, the list of activities available for scheduling will be composed only of activities whose
Figure 2—Resource aggregation
preceding activities have already been scheduled.

The usual scheduling method is then to allocate the available resources to activities on a day by day (or time unit by time unit) basis. There will be several activities in the list, and as they can only be dealt with one at a time, the next step is to arrange them in order of priority. The sequence in which activities are scheduled is important as it is a question of ‘first come first served’, the first activities having the pick of available resources and the later ones possibly having to be delayed.

It might at first sight appear that critical activities, or activities with small amount of float, should be scheduled first. In practice however, it has been found that there is advantage in scheduling the shortest activities first and other factors also influence the choice of scheduling priority.

As resource allocation proceeds on a day by day basis from the beginning of the network to the end, the situation inevitably arises where there are insufficient resources available in a particular time period and then an activity, or part of an activity, must be carried over until the next time period which has sufficient resources available. In a resource limited situation such as this, the carrying over process will usually extend the project duration and cause the completion date to be delayed.

An example of this is shown in Figure 3(a). Here the network shown in Figure 2 has been allocated on a resource limited basis and in consequence the completion date has to be extended by 1 unit (from 6 to 7). Thus the second question “What is the minimum delay to the completion of the project when insufficient resources are available?” is answered in this particular case.

However, the third question posed above “What is the most efficient utilisation of resources to carry out the project in a fixed time?” is still to be answered. To ascertain this the allocation process is carried out with a fixed time limit and no delaying of activities is permitted beyond the amount allowed by the available float time. In doing so, it is inevitable that the level of available resources is exceeded but it is arranged that this will take place at the point where it makes the minimum increase above the preset level. The effect of the operation is shown in Figure 3(b), where the level of resource availability has been exceeded in two places but the increase nowhere exceeds one unit. Thus, the four schedules, Figure 2(a) and (b) and Figure 3(a) and (b), indicate the main alternatives available for the specimen network.

However, real projects are much more complex than this example. The network may comprise several thousand activities and involve more than a hundred different types of resource. Each network activity may require several different resources (e.g., bricklayers, labourers and cement mixers) to be considered simultaneously. Sometimes a resource may only be required for part of the activity duration, as for example in building a wall where labourers may dig and lay the foundation but bricklayers only arrive after this work has been done.

There are often special conditions to be observed when formulating work schedules. For example, some activities once started must be worked continuously without interruption (as laying concrete), others may be interrupted at any time (as building a fence), others can be interrupted only at special times (as between finishing the foundation and commencing bricklaying). Also, resources fall into different categories and require different treatment, for example manpower and equipment are wasting assets in as much that if they are not used then productive capacity is lost forever, Materials on the other hand, if not used, can be stored and used the next day without waste. Some materials (like concrete) are consumed and others (like scaffold tubes) can be reinstated as available resources after use.

Availabilities of resources too seldom follow the constant line shown in Figure 2. They are usually cyclical with five or six days of work and two or one day (weekends) of no work. Some industries have lower resource availabilities on Mondays and Fridays due to absenteeism. Thus each week comprises not one but four levels. Public and annual holidays add further complexity to the scheduling process.

Additionally, resource levels themselves are not finite and absolute. The initial prognosis may be to only work normal hours, but overtime working is an established part of the current industrial scene. Thus any practical approach to resource allocation must take account of the possibility of employing labour and equipment for a greater time than the normal working hours—overtime will probably be worked anyway!

When resource scheduling, therefore, it is usual to specify two levels, firstly, the normal level and secondly the maximum level. This second level is usually the maximum possible overtime and in the terminology of resource allocation is known as the “resource threshold.” The cost of resources within the threshold will usually be higher, a point having significance in project cost analysis, which is described later.

To complete this survey of the factors to be considered in resource scheduling, it is necessary to consider the significance of the project end date. Like resource levels, the end date is not usually fixed and unalterable, some flexibility is usually present in as much that project completion is acceptable over a range
Figure 3—Resource allocation

(a) Allocation within resource limit

(b) Allocation within time limit
of dates. This is especially true at the initial planning stage where contractual commitments have not yet been established. When it is realised that the plan eventually adopted will inevitably be a compromise between early completion dates, efficient resource utilisation and economic costs, it becomes apparent that flexibility of completion date is the only means of obtaining suitable arrangements in terms of resources and costs.

A method of expressing flexible end dates is to set a "preferred completion date" and a "maximum permissible completion date". In the jargon of the trade, the difference between these two dates is known as the "project duration threshold."

In this brief survey, the principle factors to be considered have been described sufficiently to highlight the somewhat overwhelming complexity of the resource allocation task. Fortunately considerable headway has been made in recent years in development of computer programs to undertake this calculation. It must be said, however, that the mathematics for a perfect solution does not exist and it is still necessary for management to exercise judgement in the specification of scheduling objectives, priorities, the validity of basic data (networks and time/resource estimates) and approval of computed results. Here the senior manager is fulfilling his traditional role of giving instructions to his planners and approving their work without necessarily being able to check the calculations in detail. Using a computer, however, he is assured that his instructions (inherent in the computer program) are obeyed exactly and clerical mistakes will be virtually non-existent.

A computer can very quickly calculate the best manner of allocating available resources so that particular project objectives can be met within the priorities set by management. In these complex situations, a computer will ascertain the best solution, but it often happens that the basic problem described so far is insoluble when the resource requirement exceeds the resource availability and the project duration is considered to be fixed. The adage "you cannot put a quart into a pint pot" is particularly relevant to this situation and it is necessary to exercise a deliberate choice of the manner in which the resource requirement shall overflow the resource availability. The choice is usually between delaying the completion date, using more men and machines, or working extra hours. Any of these choices will usually have maximum limits (thresholds) which it is not possible to exceed.

The alternatives are shown diagrammatically in Figure 4. Here the resources (vertical scale) are plotted against project duration (horizontal scale). Referring to Figure 4, it is seen that the resources have a normal level (i.e., the most economic rate of working) and above this the resource "threshold" representing an additional capacity which can be obtained at additional cost (i.e., overtime working, double shift working, extra plant, etc.). The threshold has, however, a finite capacity which cannot be exceeded. Also shown beyond the preferred completion date on the horizontal scale is a project duration threshold up to the maximum permissible completion date. The project duration threshold represents the tolerable delay (if any) which can be permitted under diverse resource availability situations.

Figure 4(a) shows the simple case where there are adequate resources for the completion of the project by the preferred completion date and Figures 4(b), (c) and (d) illustrate the alternatives when resource availabilities are insufficient. In Figure 4(b) the resource threshold has not been used by the project and the completion date is extended. In Figure 4(c) the completion date has been maintained but the (higher cost) resource threshold has been utilised. In Figure 4(d), both the resource threshold and the project duration have been taken up.

A further case exists, of course, where even if the resource threshold is used the project cannot be completed by the maximum permissible completion date. Usually in this event drastic action is necessary in re-specifying the project.

Consideration of the different scheduling alternatives involves an iterative analysis of the project with differing restrictions. The computer is particularly useful at this stage, as it can produce a variety of simulations of possible alternatives and print the results in a form which can be quickly assimilated by those responsible for taking decisions about the project plan.

Examples of computer analyses are shown in Figure 6 which is a resource histogram of one trade on the network Figure 5. In Figure 6(a), the computer has constructed a schedule which contains the entire work content within the normal resource level. This has delayed the completion date from 4th January 1967, to 23rd March 1967. In Figure 6(b), however the computer was instructed to schedule within the fixed time (4th January 1967) given by the original time analysis. Here it is seen that the work can be achieved but this particular resource is utilised right up to the threshold level for two weeks and within the resource threshold for five weeks.

The computer has produced clear unequivocal statements of alternative policies but it is still the prerogative of project management to decide between them. Further guidance will obviously be helpful and fortunately this can be extracted from the planning network. As the differing scheduling alternatives give different project durations and project costs, it is useful to consider the alternatives in conjunction with project cost analyses before selecting the plan to be implemented.
Project cost analysis

The next step of progress towards an acceptable project plan is to carry out a cost analysis of the network. When performing this, it is convenient to consider project costs in two elements viz.:

Direct Costs

Indirect Costs

Direct Costs are those expenses which can be attributed directly to individual activities and are usually obtained by applying the appropriate rate to the resources necessary for the activity. Hence labourers may be priced at £3 per day and bricklayers at £5 per day for normal working. Where premium (or threshold) resources are available, then the appropriate higher rate will also be specified. During resource allocation, the aim is to minimise the amount of premium resources used and hence the lowest cost schedule will be produced automatically. For cost analysis purposes, the amount of each resource used is extended by the rate which is applicable, i.e., normal or premium and the amount accumulated for each time period covered by the network.

Indirect Costs arise from the practical difficulty of apportioning some costs accurately to individual activities. Such things as administration, storekeepers, security and other overheads cannot properly be defined as relating to particular activities but rather to groups of activities or even the entire network. The network planning method of handling these costs is to introduce special activities which are for the sole purpose of spreading indirect costs. These will start and finish at the events on the network where the particular indirect costs are deemed to start and finish and the money involved is applied to these activities either as a rate per day which is then built up over the calculated duration between the two events, or as a lump sum which is spread over the duration of the activity. No time is specified for these “cost only” activities, as their duration is calculated during the analyses of the network.

A further use of “cost only” activities is to provide a means of bringing project delay costs into the calcula-
tion. Contract penalty clauses are an obvious application of this technique, but it will apply equally to the cost of lost revenue occurring through non-completion on certain dates, i.e., loss of rents of buildings, loss of production when plant is shut down for maintenance, loss of income from delayed opening of shops, etc.

To complete the build-up of project costs, the direct and indirect costs are accumulated to obtain the total expenditure over the duration of the project. It is customary to show the project cost analysis as a cumulative curve as in Figure 7, from which it is possible to see at a glance the total expenditure required and also the way in which the rate of expenditure is spread over project duration. The calculations involved in this analysis are not particularly complicated, providing the basic data is available, and if a computer is used for the analysis of the network and the allocation of resources, then cost curves (as shown in Figure 7) can be printed direct from the line printer of the computer.

It will be apparent that, with the range of factors considered in this cost analysis, both spread of cost and total cost are influenced by the work schedule produced during the resource allocation process. The direct costs will vary according to how much higher-cost, or threshold, resources have been used and some indirect costs will rise with increase in project duration.

Examples of the variation which may occur are shown in Figure 8. Here are shown alternative cumulative cost curves which could arise when differing resource allocation policies are applied. In Curve No. 1, the project was scheduled within a fixed time limit which caused high-cost threshold resources to be used and hence produced a high-cost schedule, requiring £19,600. In the case of curve No. 2, a schedule was calculated within normal resource availabilities and thus threshold costs were avoided. The project completion, however, is delayed and as the project bears some indirect costs which are proportional to time, these continue to rise during the extra project time and more than offset the saving accruing from the avoidance of resource threshold costs. The combined effect is to produce a total project cost of £21,200 which is higher than alternative No. 1.

Dependent upon the rate and time displacement of indirect costs, however, the cost analysis could well have resulted in curve No. 3. Here the indirect costs do not offset the savings in direct costs (resulting from the avoidance of threshold resource costs) and the

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**Figure 5**—A small planning network

**Diagram:**

- **A** = Design Engineers
- **B** = Draughtsmen
- **C** = Inspectors
- **D** = Assembly Engineers
- **E** = Machine Hours
- **F** = Toolroom Hours

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combined effect is to produce a lower overall cost (£17,800) for the completed project.

Using techniques of network based resource allocation and cost analysis, project management have available a convenient method of realistically evaluating planning alternatives. It will, however, be apparent that a considerable amount of calculation is involved to produce a number of alternative schedules and cost analyses upon which management can adjudicate and the computer is particularly useful as a means of alleviating this chore. The fact that the modern computer can produce such information in graphical form considerably aids communication between management and planning personnel. An example of a computer produced diagram is shown in Figure 7.

**Project profitability**

Having assessed in some detail the amount and spread of costs which the project is likely to incur, it is next necessary to make similar estimates of the income and any other cash movements which may be associated with the project before profitability can be analysed. To assess profit accurately, it is necessary that the whole of the life of the project be considered and all associated incomes and expenditures be included. Thus complete analysis will involve continuing operating costs, revenues, investment grants, taxation and tax allowances.

An important factor associated with these estimates is their displacement in time relative to the initial project expenditures. The planning network can be used to obtain these displacements merely by inserting the appropriate costs (suitably identified) into the network at the appropriate point and by extending the network (if necessary) with “cost only” activities beyond its normal completion.
A further factor in this analysis is an assessment of risk, as future profits can never be free from uncertainty. The degree of risk, however, will vary and thus the quantitative assessment of the degree of risk is a necessary adjunct to the consideration of the possible amounts of profits. Risk arises because of uncertainty inherent in the various estimates made during the analysis. Thus an objective financial assessment of a project must take account of the following main factors:

1. Amount and timing of investment
2. Amount and timing of income
3. Possible variations in both investment and income.

**Cash flows**

The amount and timing of both investment and income can conveniently be considered as cash flows, whereby an expenditure represents an outward flow (negative) and an income represents an inward flow (positive). Uncertainty about either inward or outward flows can then be represented by alternative values for these items.

The use of network planning techniques as a basis from which to build up realistic work schedules and accurate assessments of project costs have been described earlier. The cumulative cost curve of the project plan selected shows the proposed expenditure over time and thus provides the basis for one of the principle cash flows involved in profitability assessment. For a complete evaluation, however, it is necessary to consider all other expenditure and incomes which will be relevant to the project.

An example of such a study (made by computer) is illustrated in Figure 9. Here the building of a factory extension is under consideration. The plan envisages that this will be built over a period of 2 years 3 months (between 1966 period 3 and 1968 period 3) special
equipment to be installed will have a life of 4 years (between 1968 period 2 and 1972 period 1). The total cost of the factory and plant will be £270,618 and this will be depreciated over 4 years, after which it will have a scrap value of £2,000 (in 1972 period 2). There is also another small recovery of £500 (in 1971 period 1) due to the interaction of another project which will make part of the plant redundant. The initial cost and the two recoveries are shown in Figure 9 in the columns headed “CAPITAL INVESTMENT” and “OTHER CAPITAL.” As described earlier, the negative sign indicates expenditure and no sign indicates income.

Investment grants, initial and annual tax allowances are significant items in the financial evaluation of a development project, the incomes accruing from these have been calculated by the computer and are shown separately in Figure 9 in the columns marked “INVESTMENT GRANT” “INITIAL ALLOWANCE” and “ANNUAL ALLOWANCE.” These items are subject to delayed payment—this delay has been calculated and the amount entered at the date at which the cash value of the allowance will be received. The negative annual allowance figure is a refund caused by the recovery of the scrap value of the project.

In order to ascertain the income which will be ob-
Figure 8—Alternative cost plans

Figure 8—Alternative cost plans

voided from the project, estimates of the operating costs and revenue are included in the appropriate time periods. The income derived from the project is shown under the heading “REVENUE INCOME,” and the routine cost of operating the plant and using materials, labour, etc., is shown under “REVENUE COST.” The computer makes the simple subtraction to give the incomes shown under “REVENUE PROFIT.” Here it will be noted that the first operating period (1968 period 2) is expected to make a loss (-5000) during the time the plant is working but not yet producing goods.

“The tax man cometh!” In the next column on Figure 9 marked “TAX ON PROFIT” the amount of corporation tax payable on the revenue profit shown in the previous column is calculated. The cash value shown in this column is entered after the appropriate time lag at the actual date the tax payment is made. With this information, the “NET CASH FLOW” is calculated. This is the difference between the cash inflow (income) and cash outflow (expenditure) and is the arithmetic sum of the capital investment and the various allowances, the revenue profit and tax on profit. This column indicates the amount of money which is to be put in or taken out during each time period of the project.

In the next column of Figure 9 an increment has been included for “INTEREST” on the cash required to finance the project. In this example, it has been specified that cash required will attract an added interest rate of 7% per annum (amount indicated by a minus sign) and when the project accrues surplus funds, then this can be re-invested at 4% per annum. These percentages are selected as representing the borrowing and lending rates open to the company at the time. The net cash flow and interest elements are now combined to give the “CUMULATIVE CASH FLOW,” shown in the last column. This total shows the position of the investment at the end of each successive period.

Financial evaluation of project

The cumulative net cash flow for the project shows the pattern of increasing expenditure during the initial period of the project and how recovery is effected. It shows the point at which the cumulative income exceeds the cumulative expenditure (the project duration to this point is usually known as the payback period).
and also gives a general indication of the relative size of expected profits to expected expenditure.

The same information is calculated by the computer and printed on the financial analysis Figure 9, where it is seen that the net profit after meeting all tax commitments and fully depreciating all plant and equipment, is expected to be £29,812. The net profit shown here is, of course, only a guide to the general order of profit expected at the end of the project. It will be seen that the amount is heavily conditioned by the interest rates (7% and 4%) applied to the cash flows. If these rates are varied, then the net profit will also alter significantly. This net profit shown is derived from a net capital investment of £186,395 and a revenue income of £960,000. The maximum cash requirement at any one time will be £286,709 and will occur in 1968 period 3. Also calculated and shown in Figure 9 is the payback period (described above) which is here 4 years 2 periods after the commencement of the project.

Discounted cash flow yield

However, this information does not complete the analysis. The next step is to calculate the financial yield (i.e., return on investment expressed as a percentage) obtained from the project. Here it is called Discounted Cash Flow (D.C.F.) Yield and follows the 'discounted cash flow' method of calculating financial yield. Discounted cash flow is gaining increasing usage in recent years and is based upon the fact that the purpose of an investment is to obtain a series of future interest which the funds estimated to be required for the project would need to earn if, instead of being used...

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on the project, they were invested elsewhere at the same time as those estimated for the project, so as to give exactly the same returns at exactly the same time as the project predicts.

This concept of time and value can best be illustrated relative to a table of compound interest i.e., £100 invested at 5% compound interest increases each year as follows:

1st year \( \text{£}100 \times 1.05 = \text{£}105 \)

2nd year \( = \text{£}(100 \times 1.05) \times 1.05 \)

\( = \text{£}100 \times 1.05^2 \)

= \text{£}110

3rd year \( = \text{£}100 \times 1.05^3 \)

\( = \text{£}116 \)

4th year \( = \text{£}100 \times 1.05^4 \)

\( = \text{£}122 \)

Thus it can be said that the 'present value' of a profit of £122 in four years time is only £100. Similarly the 'present value' of any future profit can be obtained by dividing by a 'present value factor' which is the reciprocal of the compound interest factor e.g. again assuming 5% compound interest, £100 in four years time has a 'present value':

\( = \frac{\text{£}100}{1.05^4} = \frac{\text{£}100 \times 105^4}{\text{£}110}\)

\( = \text{£}100 \times 0.8227 \text{ i.e. present value factor} \)

\( = \text{£}82 \)

There are, therefore, three elements involved—present value, future value, and the compound interest rate which relates the two values. If the two values are considered as cash flows (as in example Figure 9) then the present value is negative (i.e., expenditure) and the future value is positive (i.e., income). The interest rate is then the rate at which discounted positive cash flows equals discounted negative cash flows.

The present value of negative £82 however, shown above, is not discounted (as it is already the present day) and the positive £100 is only discounted for one year. In the larger example Figure 9, both the negative and the positive cash flows occur over several years the present value is negative (i.e., expenditure) and the D.C.F. Yield (or D.C.F. Rate of Return) applicable to the combined cash flows of several years. The method of obtaining this involves repeated calculation of the present value using different yield rates until a rate is found for which the and it is required to calculate the interest rate (i.e., the sum of the discounted negative cash flows.

Dual rate D.C.F.

In the single rate D.C.F. method just described, the discount rate is considered to be the same when the calculation is on either positive cash flows or negative cash flows. This is not entirely realistic, as it is normal for interest rates to be different according to whether the required cash is being "lent" or "borrowed." To accommodate this distinction, the calculation can be made with different rates according to whether the project is absorbing capital or showing a profit. The two rates are termed earning rate and paying rate.

Earning rate is the rate of interest which can be obtained on the surplus funds accruing to the project. In the example Figure 9 this rate has been set at 4% but it could be set higher if the money is to be invested more profitably or it could be zero in the unlikely event of the cash not being used.

Paying rate is the rate of interest which the project must pay in order to obtain the funds necessary to finance the project. This could be the market rate (e.g., 7%) or if it is desired to calculate the yield, it could be the D.C.F. rate, i.e., the calculated rate which discounts the present value of the project to zero.

The application of different rates according to the state (i.e., positive or negative) of the investment is usually known as a dual rate analysis and where one of the rates (usually, but not necessarily, the paying rate) is the D.C.F. rate, it is termed dual rate D.C.F. analysis.

A dual rate D.C.F. analysis has been performed on the cash flows shown in Figure 9 with the earning rate set at 4% per annum and has revealed a D.C.F. yield paying rate of return of 10.96%. This indicates that if the project had not been undertaken, it would have been necessary to obtain that rate of investment in order to earn the same profit from the same amount of money invested over the same time span.

Profitability Analysis

With the information shown on the “Financial Evaluation of Project,” management have a comprehensive set of data upon which an assessment of the financial merits of the project can be deduced. Perhaps, more important, because the information has been arranged and analysed in a logical manner, it offers a standard method of making comparisons between the respective merits of different projects or different approaches to the same project.

This consistency of evaluation is invaluable in the process of communication, when several managers are required to discuss the merits of different projects. The facts presented in the analysis are unambiguous and based upon sound mathematical principles but, even if details of the method are challenged, the fact that it has been consistently applied to all projects under consideration still enables the comparative aspect to apply.

Initial evaluation is, however, usually only the starting point for a further study of alternative plans. The project may be speeded up by refining the planning network, more resources may be applied, production costs may be re-examined and alternative marketing strategies (i.e., pricing structure and sales forecasts) may be tested to ascertain the effect upon income. With each set of data, the calculated D.C.F. Yield and associated information give a sound guide to the financial merits of each particular plan.
Financial risk assessment

It will have been noted that the financial evaluation of the project in Figure 9 was based upon a number of estimates about probable expenditures and incomes in the future. Whilst the detailed cost planning will have introduced a good measure of accuracy into part of the expected cash flows, there remains much data which could be subject to wide fluctuation. Actual sales will ultimately depend upon the state of the market at the time that production is possible and this is conditioned by the general economic situation and the actions of any competitors. Similar factors such as the variability of cost of materials and labour could also influence production costs. Any variation in the information used will of course, affect the yield and hence the profitability of the project. Few investment decisions will, therefore, be settled by a single evaluation calculation and the decision taker will certainly want to investigate some of the alternatives which might arise.

Whilst it is apparent that the technique described so far can easily be repeated for the major alternatives (e.g., to build a new factory in place of a factory extension), it is not a satisfactory way of handling variability of the individual estimates used in the calculation. What is required is a method similar to that sometimes used for network time estimates, where three time estimates, (optimistic, most likely and pessimistic) are quoted when uncertainty exists.

In specifying financial uncertainty however, a more flexible method is adopted whereby each alternative estimate is given a probability rating. Here the probability rating is an expression of the chances of that particular estimate becoming a reality. It can be likened to the odds quoted for horses in a race, which are the bookmaker's assessment of the chances of each particular horse winning (or rather not winning). The number of successful bookmakers gives some weight to the odds quoted for horses in a race, which are the bookmaker's assessment of the chances of each particular horse winning (or rather not winning). The number of successful bookmakers gives some weight to the accuracy of the probability estimates.

In the case of project risk evaluation, the probability is usually expressed as a decimal or as a percentage, this showing the “weight” to be attached to that particular estimate. A series of calculations are then made to determine the profit which will result from alternative cash flow patterns. This calculation takes account of the “weight” applied to each cash flow value.

The method is to use a sequence of random numbers to guide the selection of dependent variables to be used. Each of the estimates is assigned a range of numbers the size of which is proportional to their probability. From a standard table of random numbers, the first number is taken and this is checked with the range assigned to each variable and when correspondence occurs that estimated value is taken for the calculation. The next random number selects the estimate for the next factor and so on until a full set is obtained upon which to perform the profitability calculation. When a set of data has been selected by this means, the calculation is made and the answer recorded. The calculation is repeated a number of times using figures obtained by the random number procedure described. After each calculation a count is made of the number of times that each profitability yield rate has occurred.

The distribution of the answers (i.e. number of times each particular yield rate occurred) then gives an indication of the relative probability of obtaining each answer.

The calculation is, therefore, in the nature of a simulation of alternative solutions and when repeated for a sufficient number of times gives an assessment of yield probability. A sample of 100 calculations is perhaps the smallest quantity which will give a reliable indication and it will be apparent that the use of a computer is essential for this chore.

The answer appears as the frequencies with which particular profitability percentages are likely to occur over the full range. An example of the results from this calculation on the D.C.F. Yield of the “Blackmore Extension” (Figure 9) is shown in Figure 10. Here 500 calculations have been undertaken to find the D.C.F. Yield with a variety of input data having different probabilities. The number of times each percentage was calculated is shown alongside that particular percentage. It can be seen that 10% with 168 occurrences gives the highest expectation, but there is a small chance that the yield might be as high as 12% or as low as 5%. If all figures achieved fall within forecast ranges supplied, there is no chance that the profitability will fall outside the calculated range.

In Figure 10 these frequencies have been converted to percentages and plotted graphically as a line of XXs. This chart then gives a quick guide to the range and probability of particular project outcomes.

The computer has also plotted the cumulative percentage (shown as 0—0—0 in Figure 10). This is merely the sum of the frequency distributions converted to a cumulative percentage and provides a convenient reference chart, enabling the probabilities of achieving particular yields to be read off at a glance. For example, it can be seen that there is a 90% chance of achieving 8% or better and only a 10% chance of obtaining 11% or better. Conversely, there is an even chance (50% probability) that the actual D.C.F. Yield will fall above (or below) 9.6%.

With probability frequency distributions of the main factors involved in financial evaluation of a project, management have a useful way of analysing financial uncertainty. Risk can be categorized and so a degree
Figure 10—D.C.F. Yield probability frequency distribution

of segregation is achieved between those schemes which are viable propositions and those which are either distinctly unprofitable or involve an unacceptable degree of risk.

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