PROJECT MANAGEMENT CONTROL UTILISING INNOVATIVE FORECASTING AND COMPUTERISED DATA BASES

by

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Abstract

The prime objective of this thesis is to research and develop a new system of project budgeting, monitoring and forecasting to meet the needs of the Construction Industry. It is intended that this work will facilitate the means for more efficient control of projects from inception to final completion, utilising where possible the latest developments in computer technology.

The initial stage of the work involves an investigation and appraisal of existing methods of formulating project budgets. In particular attention is paid to previous work in the development of mathematical 's' curve models, together with their limitations in use and application. Potential for future development is also identified.

The thesis then focuses on the evolution of an improved modelling philosophy for project budgets and forecasts which overcomes previously known problems. In parallel with this work is the development of a computerised system intended to enable the testing of the model against live project data.

The model finally selected is then tested against the extensive research work previously undertaken by the DHSS and the data collected from sixteen construction projects.

To facilitate the development of a suitable control system to act as a vehicle for the application of the principles developed, a contextual survey is included. This survey is intended to provide an update of previous survey work undertaken by the author in 1977 and to further investigate factors orientated specifically to the objectives of the thesis.

The research then concentrates on the development of an integrated set of sub-systems which contribute to the budgeting, monitoring and prediction of project expenditure. These systems are developed in accordance with the need to establish the financial status of projects both before, during and after they are completed. The overall system is based on the latest computer technology available and is designed to be flexible in its application. Tests documented in the text prove that the system operates both in principle and in practice. A further extension of the research is the use of the various project data bases to provide information for a corporate control system which has been developed in principle.

This thesis provides a significant step forward in computerised project budgeting and control utilisng 's' curve philosophy and provides a basis for further development. Potential exists for future development of the prediction and corporate control systems, together with software developments to improve general application over a wide range of industries and disciplines where project work is undertaken.

Contents

Chapter 1

1. INTRODUCTION

1.1 General

The ability to accurately forecast and budget project expenditure is of paramount importance to the efficiency of management control. Further, the need to accurately monitor project expenditure and to value work completed to date is vital to provide a basis from which the project can be efficiently administered. The total activity of a construction company is represented by an analysis of projects; hence there is a need to accumulate project control data in order to produce corporate control information for the top management of an organisation.

1.2 Existing Project Financial Control

1.2.1 The production of financial information relating to projects often requires considerable effort on the part of the company staff, particularly in cases where a high degree of accuracy is required. Traditionally expenditure budgets have been determined by utilising the project programme to distribute budgeted costs on an activity basis; this has proved to be a time consuming process, the accuracy of which is highly dependent on the translation of "bill of quantities item" costs into "activity costs". The quality and dependability of the project programme schedule plays an important role in the determination of a budget. Another difficulty exists where activities cannot be clearly identified or quantified because relevant information is not available.

It can therefore be seen that a comprehensive budgeting system can be expensive and time consuming to produce.

1.2.2 Monitoring systems are highly dependent on accurate information being produced from site in a form which can be equated with the budget. Very often site information is inaccurately allocated to centres of cost, thereby reducing the effectiveness of the control information produced. In order to establish profitability it is necessary to prepare accurate valuations of the work completed to date from which income can be determined. The comparison of total income with expenditure must be equated to a given point in time to ensure that parity exists.

1.2.3 Project forecasting normally takes the form of intuitively projecting known current value of work completed to a final completion time and cost. Little use is made of statistical extrapolation of the performance to date. However it is considered essential that this process is conducted to realise the full benefit of financial control in general.

1.2.4 A major problem associated with producing corporate financial control information is the shear volume of data which needs to be processed. Useful information for top management would include project summary reports and projections in terms of future turnover and profitability. Without doubt this is the most difficult area to produce accurate report information since project inaccuracies are magnified and it is therefore essential that the project systems must produce data in a form which is both accurate and compatible.

1.2.5 The operation of a financial control system involves the expenditure of staff time which will add to the overhead cost of the company. Conversely, without an adequate means of control a company will be less efficient. A balance must be struck between the cost of the system and the amount of extra profit it produces. Obviously, there is no benefit in operating a system at a loss. Some companies have been observed to cut their overhead to a minimum by using the exception principle. For example, if a project appears to be progressing well it is left alone; only the problem projects are financially analysed in detail. The disadvantage with this philosophy is that there is always the danger of not taking corrective action early enough. In extreme cases the situation might already be irretrievable since the fundamental damage would have already occurred.

1.3 The Need

Ideally a system should be available which produces accurate and comprehensive project control information, both accurately and with the minimum of staff input. To meet these requirements it is considered essential that maximum use is made of the latest developments in computer technology. In particular micro computers which are powerful and relatively inexpensive to purchase should be investigated as potential work horses for such a system.

New methods of formulating project budgets should be evolved which enable the user to model budgets quickly and accurately. These proposals must incorporate provision for reliable monitoring and forecasting systems to be integrated using compatible interfaces.

The project systems should have the capability to produce a data base which can be utilised for overall corporate control of the organisation.

1.4 Previous Research on Project Budgeting and Forecasting

It has been observed that the majority of cumulative project cost expenditure patterns produce 's' curve profiles called sigmoids, the extremes of which produce either wholly convex or concave shapes. Mathematical theory defines that within set parameters certain cubic polynomial equations produce 's' curve profiles which can be varied by introducing appropriate constants and may be used to simulate known expenditure patterns.

In the mid 1970's the Department of Health and Social Security (DHSS) undertook an extensive study to establish typical expenditure curves for hospital projects graded into categories related to project cost.(1) Resulting from this research a cubic equation was developed which could be used to manipulate 's' curves by assigning values to two constants. Work has also progressed in other parts of the world, one notable example being the research of Dr. Shlomo Peer(2) of the Israel Institute of Technology who has utilised a similar philosphy to the DHSS.

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(1) DHSS Publication Expenditure Forecasting Method: Surveying Division 1977.

(1) Hudson, K.W. 1978 DHSS Expenditure Forecasting Method Chartered Quantity Surveyor 5(3) p.42

(2) Shlomo Peer 1976 A model for forecasting construction cash flow. Israel Haifa Institute of Technology

Research conducted by Bromilow in Australia(3) has shown that certain project expenditure patterns can be simulated by using exponential equations. This study was made by collecting a considerable amount of data from actual projects which could then be simulated by a specially formulated simple exponential equations.

Both of these methods suffer from serious shortcomings. Polynomial equations are only practical within certain limits and exponential equations suffer from inflexibility particularly when attempting to simulate costs during the middle portion of the project time span.

1.5 The Context

1.5.1 The need to efficiently manage projects of all types has been brought into prominence during recent years due to economic factors and developments in technology. This has been particularly so in the Construction Industry where outdated methods of construction and antiquated administrative procedures have been exposed by rapid changes in other fields, principally electronics and energy conservation. There have also been marked changes in the demands made by clients requiring the services of the Construction Industry. Economic pressures and a more sophisticated attitude towards business investment have caused commercial clients to look very closely into the financial viability of committing funds to the construction

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(3) Bromilow, F.J. 1973 A model for forecasting construction cash flow, Melbourne, Australia CSIRO, Division of Building Research.

of new building facilities. This situation has been complicated by increasingly stringent Building Regulations and the requirements of the Town and Country planning laws which can slow the project design process considerably due to social, democratic and in some cases bureaucratic procedures. The domestic home buyer who represents a large proportion of the Industry's business now expects higher standards relating to the function, performance and design of dwellings. In recent years restrictions on personal incomes coupled with high interest rates have restricted the sums people can borrow resulting in mounting pressure on contractors to keep their prices within the limits set by the market.

1.5.2 The Current Situation of the Construction Industry

Increasing demands on the architect to produce buildings which are aesthetically pleasing, economic to build and appropriate to the functional needs of the client. In addition, buildings must reach higher performance standards and be economic to run and maintain.

The construction project process traditionally consists of two prime stages namely, design and construction which in turn can be further subdivided into:

(a) Feasibility

(b) Design

(c) Production

(d) Commissioning and Finalisation

Attempts have been made by certain bodies[1] to categorise the design and construct process into detailed stages which can be easily identified for the purpose of management and control. Although much effort has been expended in this direction it would appear that little attempt has been made to capitalise on this work by developing management and control systems geared to a logical step by step progression of the project process. Generally the documentation produced seems to have been largely ignored. For example, the RIBA has produced a detailed plan of work together with other publications which are seldom referred to.[1] On inspection these appeared to contain a considerable amount of useful information which has not been developed to a stage where it can be practicably applied.

The structure of the Industry brought about by a socio economic structure which evolved between 50 and 100 years ago largely exists unchanged today. The architect in general still operates on the basis of a special gentlemans business relationship with his client which is geared to designing and managing the whole project process. This arrangement would appear to work for the majority of small and simple projects, but where larger and more complex buildings are required the management of both the design and construction process has been found in many cases to be highly inefficient.[2]

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(1) NEDO The public client and the construction industries 1975

(1) NEDO The professions in the construction industries 1976

(2) Thompson, N. Alternative method of management. Building 1978 January 27, pp.67, 69-70

The education of an architect is considered by most schools of architecture to be primarily concerned with the principles and practice of design. Few curriculums pay sufficient attention to management and control. In addition the architects knowledge of structural design, services engineering and contract economic are in the main rudimentary resulting in the need to employ specialists on all but the simplest of projects.

Since a significant proportion of large complex contracts have experienced difficulty when using the architect in his traditional role as designer/manager new methods of project administration have already been evolved. Before proceeding further it must be made quite clear that there is no reason why the architect should not manage the project as well as undertaking the design provided that the whole process is conducted in an efficient manner. However, according to documentation produced it would seem to indicate that as buildings become larger and more complex there is an increasing case for restricting the architects role to designing the structure and co-ordinating the design team.(1) It has already been demonstrated that the overall management and administration of the project including design, construction and commissioning can be advantageously put under the direct control of a project manager acting on behalf of the Client.(2)

(1) Chartered Institute of Building. Project Management in Building Occasional Paper No.20 1919

(2) Graves, F.C. Managing the National Exhibition Centre compared with health building projects. Hospital Engineering 1977 31 November, pp.6-8, 11-12

Alternative methods have been tried to improve co-ordination and control of the project including management contracting where a construction company provides a team to administer the construction work on a fee basis with the Client paying direct for project costs. An important advantage claimed for this method is that the construction management team can be involved during the early stages to improve the efficiency of the design.

The growth in design and build contracting has provided an additional dimension to the possibility of solving the problem. However, although tangible advantages can be gained by a client adopting this option, there would appear to be obvious pitfalls in terms of limited aesthetic design potential and a lack of competition resulting in the Client paying too much for the building he requires. Only a very limited number of design and build companies have succeeded in overcoming these difficulties.

Other possiblities and variations to the above, for example, design and build tendering, provide under certain circumstances viable alternatives to the traditional method of appointing an architect to design the building and administer the whole construction process.

Whatever methods of contract administration are adopted the project must be controlled in accordance with good basic management principles. Ample evidence exists which proves decisively that building contractors, in addition to architects, lack management expertise[1] and have fallen far behind their counterparts in other industries particularly in the successful adoption of modern management techniques.[2]

The above implies that a pre-requisite of using control systems is the education of managerial and supervisory staff in the principles and practice of management based on the latest developments in information technology. This situation is being helped by a steady flow of graduates into the Construction Industry from Polytechnics and Universities and it is anticipated that a steady improvement in appropriate management expertise will occur as time progresses.

1.6.1 Objective

The prime objective of this thesis is to research and develop a new system of project budgeting, monitoring and forecasting to meet the needs of the Construction Industry. It is intended that this work will facilitate the means for more efficient control of projects from their inception to final completion, utilising where possible the latest developments in computer technology.

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(1) Moxley, R. Alternative Method of Management. Building Jan. 1978

(1) Bowley, M. The British Construction Industry. Cambridge University Press, 1976

(2) Franks, J. Project Management. Building Trades Journal 1977

(2) Chartered Institute of Building. Construction Management in Building: Present and Future 1965

(2) Graves, F.C. Management of a construction project. Paper to RICS Annual Conference 1976

1.6.2 Research Programme and Sub Objectives

The initial stage of the research will be to establish a sound mathematic basis which will facilitate the efficient production of reliable and accurate project budgets. Part of this work will be concerned with the establishment of curve shaping constants which can be related to construction projects. The published curve fit constants produced by the DHSS will be used as in the initial development stage since these figures were evolved from a large sample of actual hospital building schemes. The intention is to produce an entirely new curve fit equation which will have easier practical interpretation and will not suffer from the impractical constraints imposed by the cubic equation.

Once a suitable curve shaping method has been found a series of tests will be carried out to determine the applicability of the equation related to a wide range of construction activity. Since the proposal is to cover design and construction, studies will be made in each area. At least fifteen projects will be covered to give a reliable indication that the equation will be applicable in most circumstances.

Associated with the curve fit development will be an investigation to establish whether or not it is possible to produce a reliable forecasting system utilising the curve shaping method. If successful further work will be undertaken to establish the statistical accuracy of the results achieved based on data collected from the fifteen projects previously mentioned.

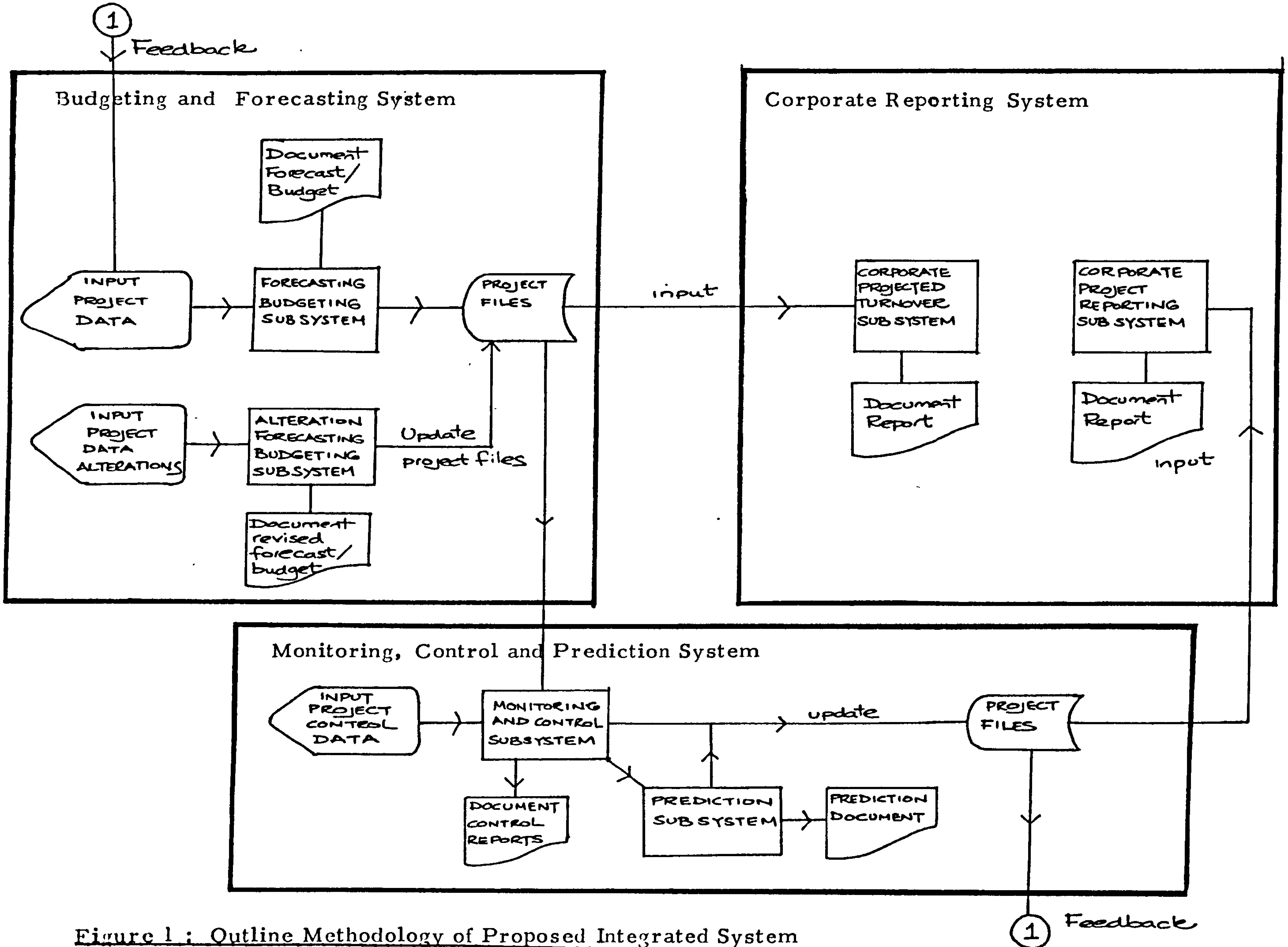


Figure 1 : Outline Methodology of Proposed Integrated System

Assuming that the research will proceed successfully to this stage, the next step will involve a number of carefully selected case studies to identify clearly the needs of construction practice in terms of project budgeting, monitoring and forecasting. This process is considered to be essential if the curve shaping proposals are to be properly interfaced to the practical situation.

The initial intention is to produce a number of integrated sub-systems which will utilise a common data base to produce a complete project management control system. The structure of this system is shown in Figure 1 which illustrates the links between budgeting, monitoring, forecasting and corporate control reports. Provision for versatility in the application of the system proposals will be made to widen the potential market and hence increase its use. The whole of the research will be conducted using a computer to test and develop the mathematics, together with the validation of the equations developed. In the later stages the systems proposed will be computerised to facilitate complex file handling and substantial data manipulation actuated by simple commands given interactively through a terminal.

Chapter 2

2. EXISTING METHODS OF PROJECT BUDGETING AND FORECASTING

2.1 Introduction

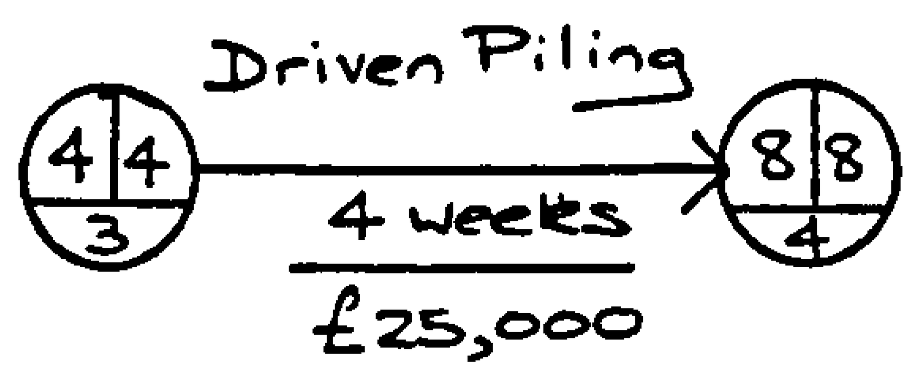
My research into existing methods of budgeting project expenditure has shown that three categories exist. The most common method involves the bills of quantities and the project programme. The items in the bill are converted into activity costs which are then allocated to the project programme to produce a project cash flow. Where the final project sum is known, but it is not easy to identify activity costs, then an intuitive judgement might be made of project expenditure. The final method involves the use of mathematically derived 's' curves which can be made to simulate project expenditure given an historic base of project expenditure profiles which ensure statistical accuracy.

2.2 The Allocation of Estimated Cost to the Project Programme

This method normally involves a large amount of work to translate the estimate into activity costs. Unfortunately bills of quantities produced using the 6th Edition of the Standard Method of Measurement for Building Works do not use work items which can be directly related to site activities. Hence it is necessary to group, split or apportion bill items in order that they conform to the project activity breakdown. This process is normally time consuming, and by its nature, can create inaccuracies in the allocation of cost. The use of an operational bill of quantities which relates directly to site processes would considerably help the situation.[1] Once the allocation of budgeted expenditure to activities has taken place, the

(1) Skoyles, B.R.E.

next stage is to establish the pattern of expenditure relative to each activity. Considerable experience in both the technical and managerial sense will be required to make accurate and meaningful allocations, particularly where large activities covering a long time period are concerned. This aspect highlights a major problem with network activity budgets since no provision is normally made to spread the expenditure in any other manner except on the basis of even distribution. The use of a bar chart format does give the opportunity to vary the expenditure pattern as required. See Figure 2.



CPA Network Application

Activity Desc	1	2	3	4	5	6	7	8	
Driven Piling					12 500	20 000	22 500	25000	← Cumulative
				7500	5000	7500	2500	2500	← Period Costs

Figure 2 Programme Budget Applications

The accumulation of budgeted activity expenditure will produce a cumulative project budget to which can be added to the indirect costs in order to give an overall project budget. Inaccuracies in the spread of activity expenditure will reflect on the quality of the project budget and its use as a means of assessing performance.

It is relevant to pay attention to the monitoring and control processes to be conducted in conjunction with the budget since the two stages must be compatible for comparison purposes. Attention should be paid to the need for activities to be grouped into cost centres which can be used to permit meaningful decision making and control by management. This method of budget preparation requires considerable understanding of the construction process and experience in the way estimates are prepared. The process is labour intensive and time consuming on all but the simplest of projects, and the incidence of variations to the project exposes the inflexibility of this means of modelling project expenditure. Where this method is applied to the design process or the overall project programme from inception to completion the disadvantages directly associated with the SMM disappear, however the difficulty of relating expenditure in this manner to a timescale remain.

Forecasting the final project cost and time using this method is normally based on an intuitive projection of the cost to date relative to the valuation of work completed and the original budget. One method of achieving this is to project revised budgeted expenditure parallel to the original budget thereby leaving management to assess the potential effect of future variances e.g.

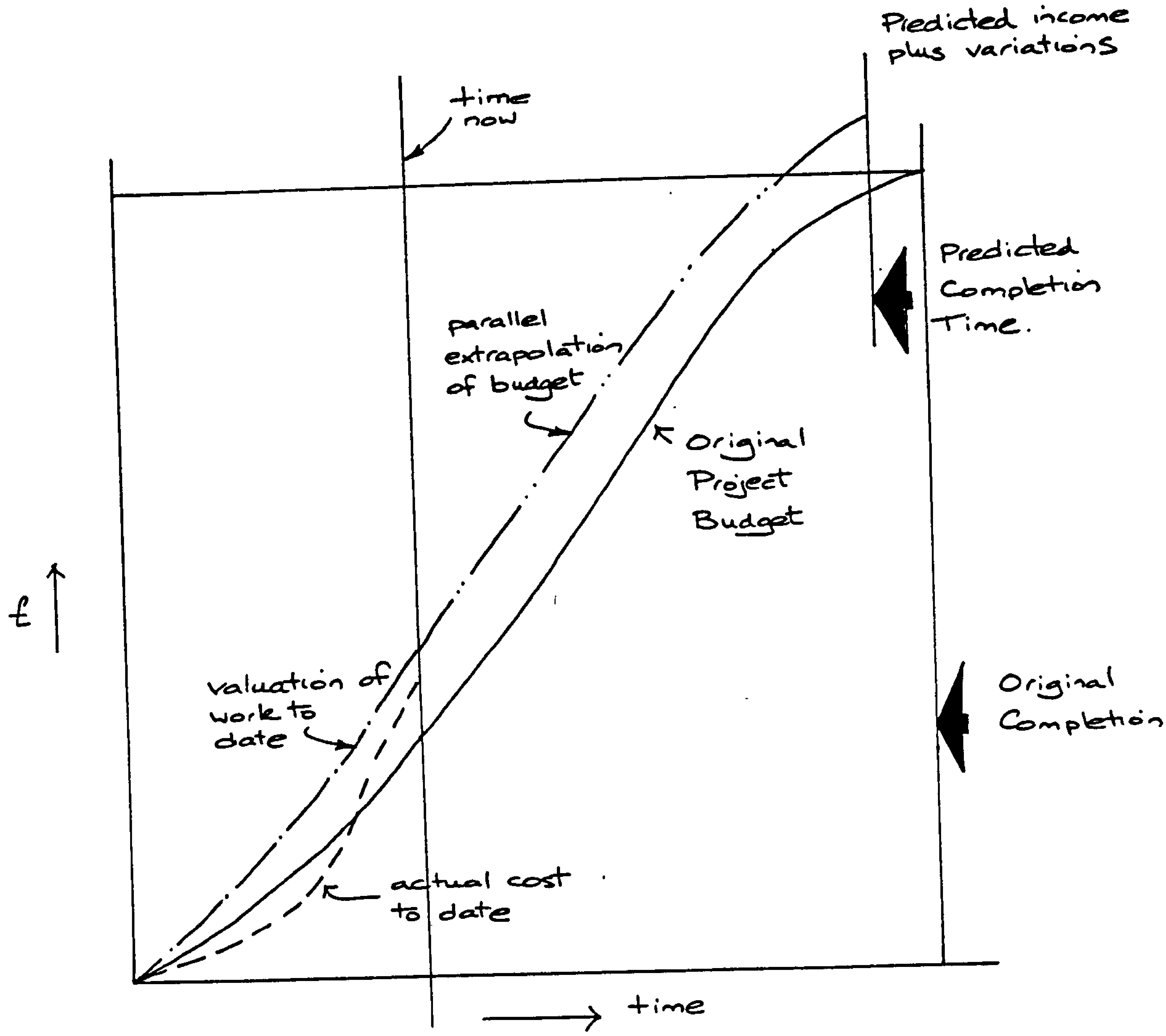


Figure 3

2.3 Intuitive Assessment of Project Expenditure Budgets

Where the total project cost has been agreed the quickest and simplest way to prepare a budget is to draw a straight line from the origin to the completion. This method is, of course crude, but it does indicate the general direction to the overall objective. Intermediate assesssments of project progress could be relevant where expenditure is fairly even throughout the project time span and degree of accuracy required is not particularly sensitive. A more sophisticated approach would be to distort the straight line according to an assessment of project activity, particularly where it is known that certain significant items of expenditure occur.

For example:

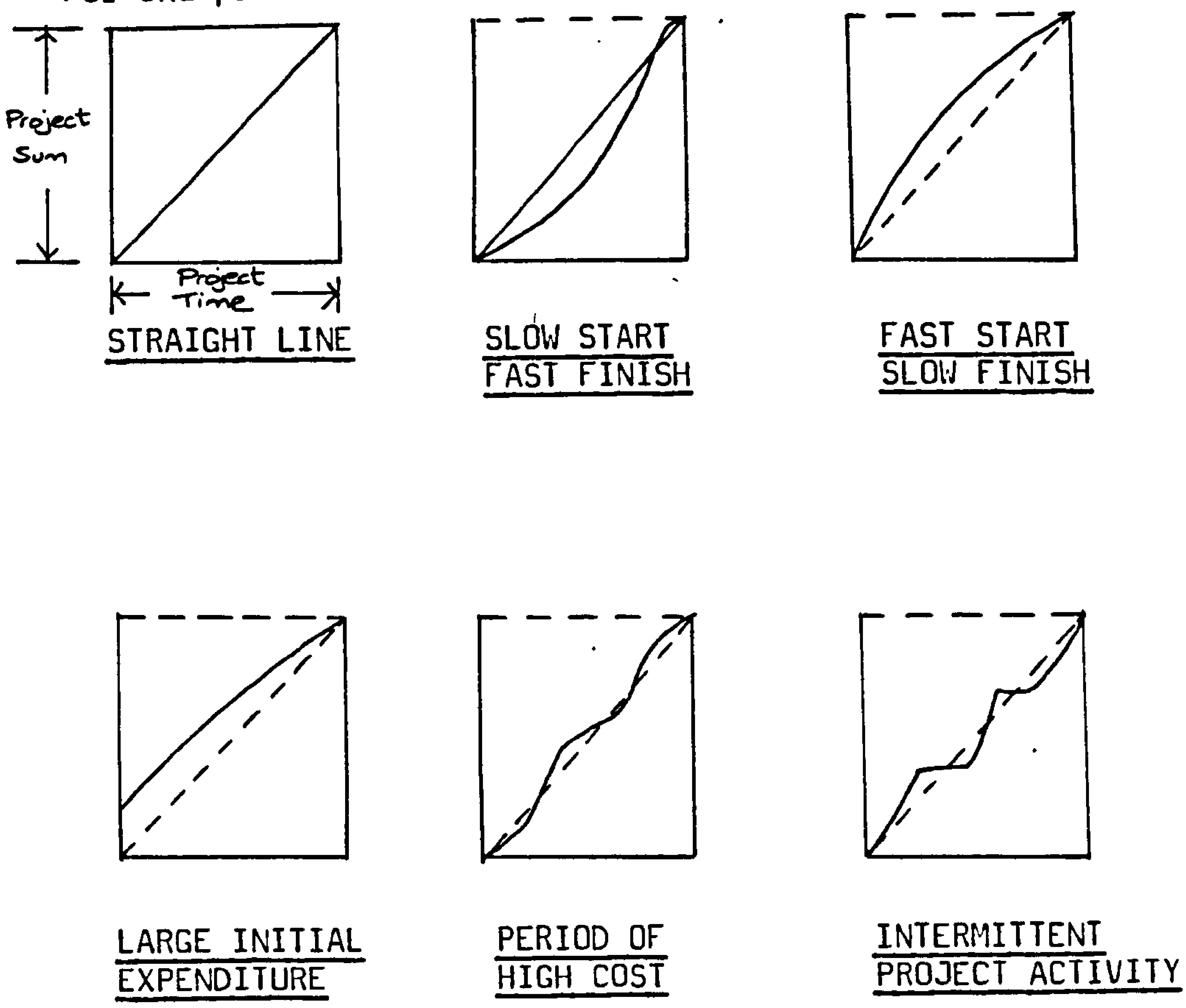


Figure 4

This method, athough rough and ready, involves limited time to prepare and is ultimately flexible in the sense that it can be changed with little effort. Importance is attached to the intuitive judgement and the experience of the individual preparing the budget. In general this method can only, in most cases, be used as a guide when assessing project performance.

Attempts to forecasting project cost and completion, can at best, only be equivalent to the method described in 2.2.

2.4 Mathematically Based 's' Curve Forecasting

There have been a number of attempts in the past 20 years to budget and forecast project expenditure utilising 's' curves. Without exception the researchers in this field have either investigated the use of polynomial or exponential expressions. The most notable international research has been conducted by the following authors:

(1) The Department of Health and Social Security
Surveying Division U.K. 1977

(2) Shlomo Peer
Haifa Institute of Technology, Israel 1976.

(3) F.J. Bromilow
CSIRO Division of Building Research
Melbourne, Australia 1973.

(4) L.H. Putnam
Quantitative Software Management Inc. USA, 1979

An appraisal of each of the above areas of research has been made together with comments on the practicability of applying this work to construction projects.

2.4.1 DHSS Expenditure Forecasting Method

Research was initiated by the introduction in 1967 of an improved system of control of capital investment by the DHSS.[1] Details of a large number of actual schemes were

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(1) Hudson, K.W. FRICS DHSS Expenditure Forecasting Method
Chartered Surveyor B and QS Quarterly
Volume 5 No.3 Spring 1978

submitted by the Regional Hospital Boards. From a statistical study of this information, guidance was produced for the likely contract duration of schemes in different cost categories. An analysis of the expenditure patterns of schemes was also performed. It should be noted at this stage that land costs together with consultant fees and equipment costs were not included, thereby restricting the data to building and/or engineering costs.

The cumulative monthly values of work executed, before the deduction of any retention monies or addition of fluctuations, were expressed as a percentage of the contract sum and plotted against percentage of contract period. In each cost category a line of best fit was drawn and the resulting s-curve graphs were issued as guidance. It will be appreciated that as the curves produced are lines of best fit, no one job in each cost category will necessarily fit the curve exactly. However, when all jobs in a cost category are taken cumulatively the forecast produces a close approximation to the actual value of work executed for schemes in that category.

Data was then extended to include projects up to £12m.

The next stage was to find the equation which closely approximated to the 's' curves, hence the formulation:

$$y = s\left[x + Cx^2 - Cx - \frac{1}{K}\left(6x^3 - 9x^2 + 3x\right)\right]$$

where

y = cumulative monthly value of work executed before deduction of retention monies or addition of fluctuations.

$$x = \frac{\text{month(m) in which expenditure y occurs}}{\text{contract period (p)}}$$

i.e. proportion of contract completed.

s = Contract sum

C and K parameters derived by utilising simultaneous equations relative to the cordinates of the curve fit.

The formula can be used in two ways, namely:

(a) knowing C, K, contract sum and contract period, the cumulative value of work executed after any number of months can be calculated;

(b) knowing C, K, contract sum and cumulative expenditure in any month, the likely work duration can be calculated.

A table of C and K parameter values has been published by the DHSS which equates to the chosen curve fit of each hospital cost category. See Table 1.

Table 1

Standard C & K Parameters

Cost Category	Standard Parameters	
	C	K
£10,000 to £30,000	- 0.409	7.018
£30,000 to £75,000	- 0.360	5.000
£75,000 to £120,000	- 0.240	4.932
£120,000 to £300,000	- 0.200	4.058
£300,000 to £1,200,000	- 0.074	3.200
£2m	0.010	4.000
£3m	0.110	3.980
£4m	0.159	3.780
£5m	0.056	3.323
£6m	0.192	3.458
£6.5m	0.154	3.401
£7.0m	0.172	3.557
£7.5m	0.131	3.445
£8.0m	0.142	3.538
£8.5m	0.099	3.404
£9.0m	0.104	3.456
£9.5m	0.061	3.317
£10.00m	0.063	3.344
£10.50m	0.019	3.207
£11.00m	0.018	3.218
£11.5m	- 0.025	2.089
£12.0m	- 0.028	3.090

In general it has been found that the gradient of the 's' curve central portion is limited where a polynomial equation is used. When the more pronounced 's' shape curve reaches a frequency which causes the peaks to occur within the proportional project line span negative values will occur at the beginning and end of the curve. In this event the curve looses its ability to perform a viable curve fit. My tests have indicated that some of the DHSS C and K parameters are on the limits of viability.

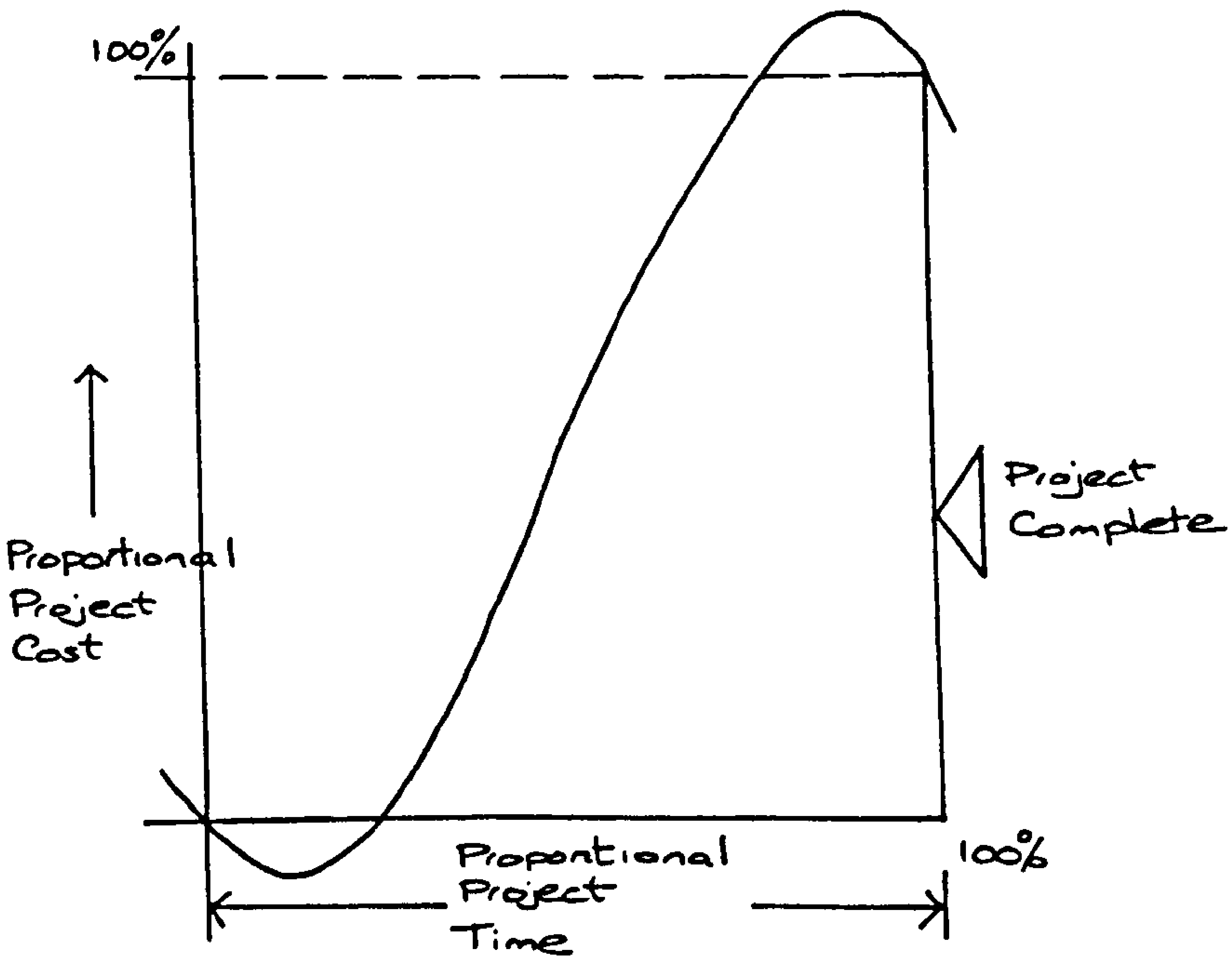

Figure 5

Another restricting factor is the presence in the equation of numeric constant values which specifically related the interpretation of the curves to hospital projects. Hence, there would appear to be limited scope for applying this equation to other types of construction projects.

Forecasting using the DHSS Curve

When commencing a new scheme the constants C and K shown in Table 1 are used to determine the project budgeted expenditure. After the scheme has been in progress for a few months, it is possible to determine the C and K parameters of that particular scheme, as distinct from the standard parameters of the cost category in which the scheme falls. This is achieved substituting two actual values and cumulative monthly expenditure into the forecasting formula, together with the months in which the expenditures occurred, and solving the pair of simultaneous equations obtained.

The two most recent observations of monthly expenditure are used, but first they are smoothed in conjunction with the previous three or five observations by means of a polynomial regression to iron out individual curve irregularities.

If a project deviates from the original standard forecast then C and K parameters for the scheme can be calculated and a new forecast made on the basis of observed expenditure to date. The new forecast can also make allowance for any revisions of the authorised sum or work duration by substituting new values of S and P in the formula.

When the actual expenditure begins to be consistently above or below the standard curve it is necessary to revise the estimate of project duration. This can be done by transposing the equation in terms of (P)

Hence $\frac{KyP^3}{S} + (CK - K + 3)m.P^2 - (CK + 9)m^2.P + 6m^3 = 0$

This method of forecasting is subject to the limitations of the polynomial equation, therefore forecasts can only be made with certain C and K limits. Where the project expenditure exceeds these the system is of little value.

2.4.2 A Model for Forecasting Construction Cost Flow Shlomo Peer

In an attempt to develop a cash flow forecasting system a preliminary study was undertaken as a feasibility test for a typical cost model relating to housing projects. Detailed construction schedules were prepared for four typical projects of different size and variable rate of progress. Construction costs were compiled and itemised for each cost component. The cumulative curves for one of these projects is shown in Figure 6. The cumulative cost-curves for all projects were brought to a common denominator by relating cost to time in percentage terms, as shown in Figure 7. The predicted curve fit of the project shown in Figure 6 was obtained by polynomial regression of the 4th degree. Similar curves were obtained with the aid of tanh and error functions with three parameters - two representing the slope of the function in x and y, and the third the location of the origin on the graph.

The relevant formulas are as follows:

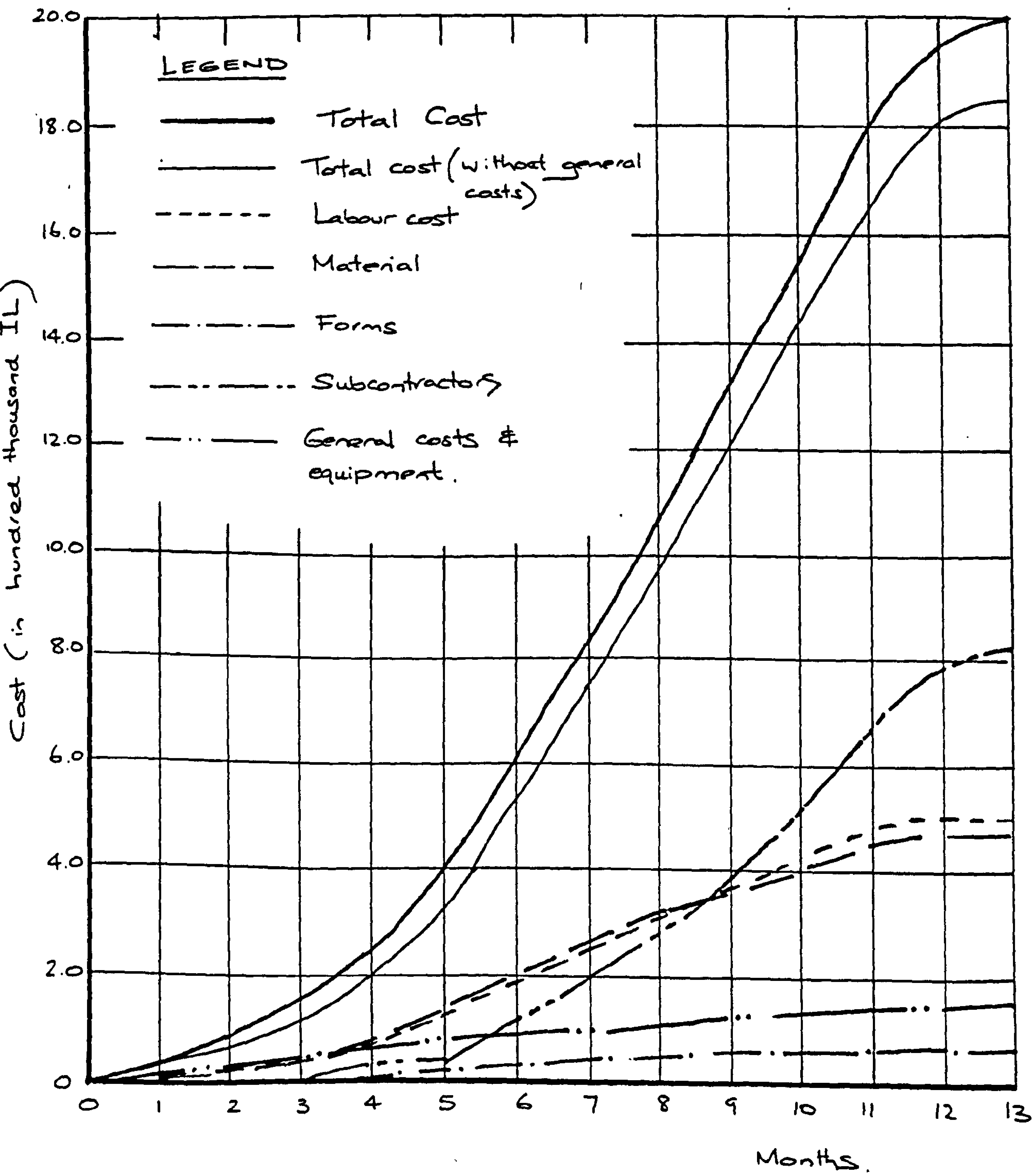

Figure 6 Erection cost-flow for project of 96 units

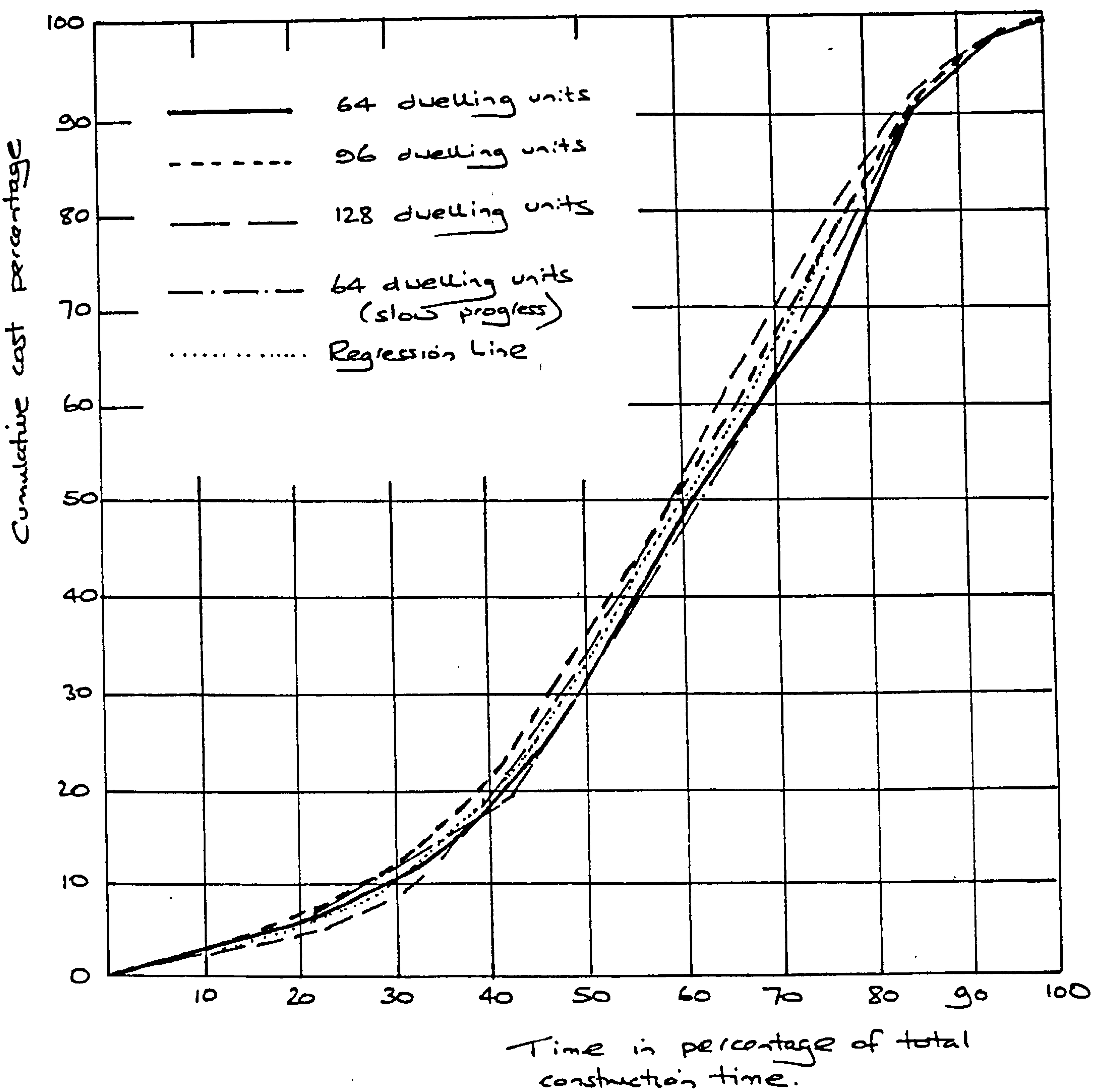

Figure 7 Cumulative cost vs construction time (in percentage)

$$y = \left[0.0009 + 0.2731(W/T) - 1.0584(W/T)^2 + 5.4643(W/T)^3 - 3.6778(W/T)^4\right] C$$

$$y = 0.567 \left\{\tanh (3.2495(W/T) - 2.038) + 0.963\right\} C$$

$$y = 0.5487 \left\{ \mathrm{erf} (2.8822(W/T) - 1.7972) + 0.986\right\} C$$

where y = cumulative cost

C = total cost

W = partial time
(W = 0,1,2, ...T)

T = Total contract time

(W/T) = relative fraction of total time

The standard deviations between the predicted and actual cost curves, as obtained by the different curve-fitting methods applied, are listed in the following table.

Project			Standard deviation for curve-fitting functions		
No.	Total cost (in 1000 1L)	Total Constr. Time (mths.)	Polynomial	Tanh function	Error function
1	1349	10.5	0.338	0.382	0.387
2	1400	16.0	0.398	-	-
3	1994	13.0	0.395	0.485	0.483
4	2618	13.0	0.525	0.559	0.501

The polynomial curve yielded a more accurate estimate, while the others were easier for manual calculation, the independent variable being of the first degree and the values of the functions available in the tables.

Peer claimed that knowing the total cost of a project and its construction time, these formulas enabled him to estimate the cumulative cost curve at any time. The deviations involved were insignificant in practical use, especially when considering that management is concerned with the overall cash flow of the company rather than that of a single project.

This work can only be described as preliminary research, however it does signify important factors for consideration.

The polynomial equation used is unnecessarily complicated and inflexible due to the number of constant values built into the expression. Greater care has been taken to fit a particular set of results, but there is no evidence to suggest that these have general applicability. The use of only four examples gives no basis on which to prove the viability of the equations. Naturally a more extensive programme of research is required. There is also the possibility that the equation will suffer from the same negative results displayed by the polynomial expression used by the DHSS. It can therefore be deduced that this work is of limited value and in many ways duplicates that undertaken by DHSS.

2.4.3 Measurement and Scheduling of Construction Time and Cost Performance in the Building Industry(1)

This work was concerned with defining quantitative standards of performance actually achieved by the building industry in Australia in relation to the time occupied in planning and construction, cost performance, and the number and value of variations to contracts. The effectiveness of procedures that were in use, the nature of costs and weaknesses, and the potential for improvement were measured. Further easily comprehensible decision rules were devised.

Data was collected from some 370 plus building projects undertaken by large governmental, private client organisations and design firms during the late 1960's.

Analysis revealed that the values of the main performance characteristics were highly significantly related to one single independent variable, viz. the size of the project as measured by its final cost.

Thus	(PC)	=	f(c)
where	(PC)		denotes the performance characteristic
and	(C)		denotes the final cost of the project at constant labour and material prices.

That such relationships could be found at all had been doubted by the industry. It was therefore surprising to find that with only a few exceptions the interactions with otherwise important variables (such as type of building) were not significant. In all cases the relationships could most readily be expressed as exponential functions.

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(1) Bromilow, F.J. Measurement and Scheduling of Construction Time and Test Performance in the Building Industry. Division of Building Research. CSIRO, Melbourne 1972

$(PC)i = KiC^{Bi}$

where i = specific performance characteristic (e.g. construction time)

K = a constant characteristic of the general level of performance and characteristic i in Australia

B = a constant indicative of the sensitivity of performance characteristic i to size of Project.

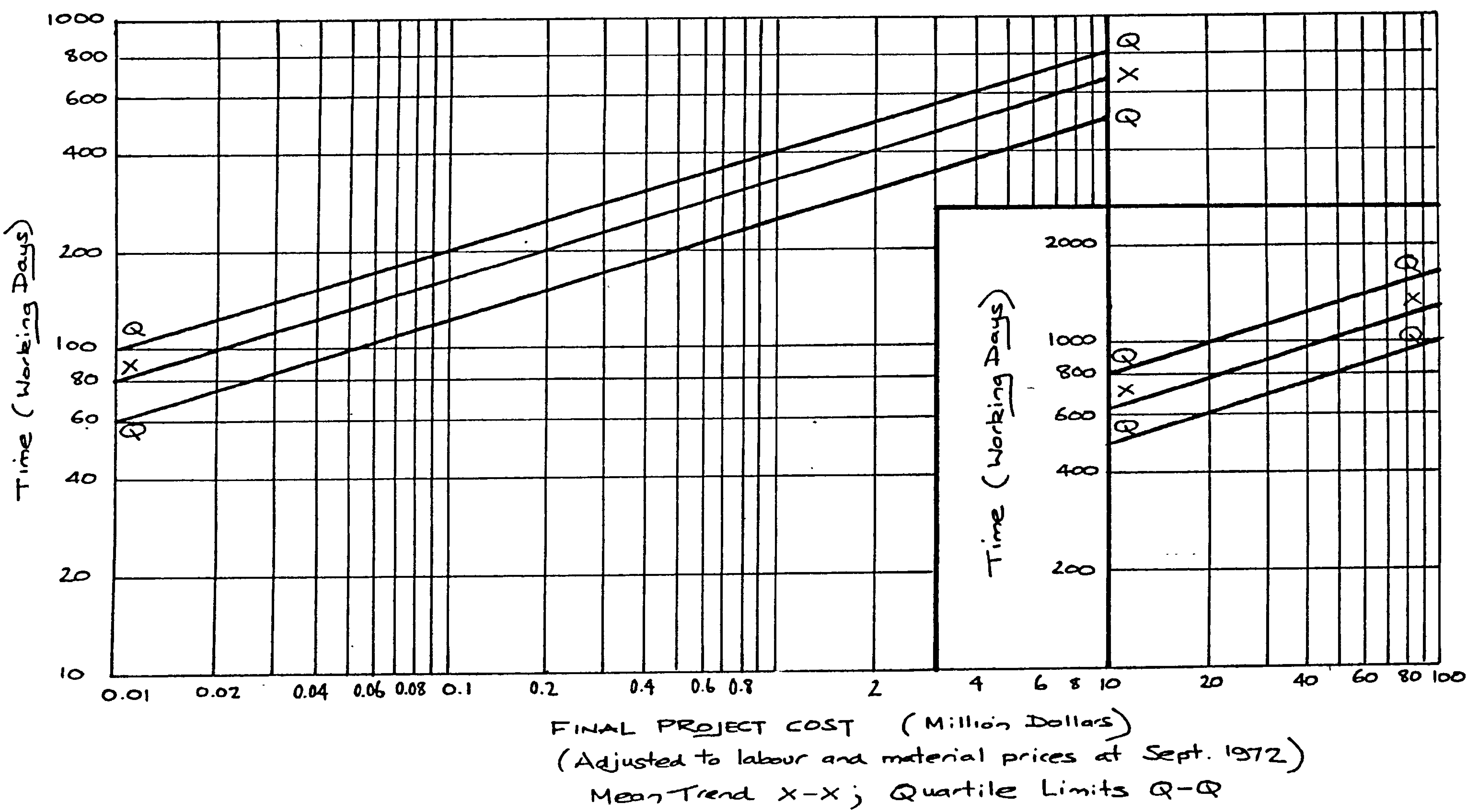
<u>Construction Time Performance</u>

The research conducted found that the times allowed for construction projects overrun on average by 47% and only 12% of projects were completed by the completion dates written into contracts. These proportions varied widely according to the type of building and contractual procedure adopted. On investigation the period time T (working days) which actually elapsed during the construction was a well defined function of the building cost C.

$$T = 313C^{0.30}$$

and a plot of the actual construction time against final cost is shown in Figure 7a, with the trend line Measures of variability are shown by the quartile limits (a quarter of the projects took more than 30% longer than normal and a quarter took more than 20% less time than normal); these are marked by Q-Q in Figure 7a.
Hence a yardstick for construction time performance in Australia had been established.

Figure 7a Time taken for Construction of Buildings, as a function of Project Cost



Other performance standards were set by Bromilow in a similar manner in terms of cost.

Experiments conducted by myself and Mr. J. Berny at the Polytechnic of the South Bank indicated that exponential curves similar to those developed and used by Bromilow might be applicable to budgeting and forecasting project costs. A major advantage observed was that the exponential curves did not suffer from the limitations associated with negative values produced by polynomial equations. However because of the relative simplicity of the Bromilow exponential equations they did not possess sufficient flexibility to simulate a wide range of construction project expenditures. This was particularly apparent during the mid portion of the project time span. In order to achieve good fits at the beginning and end of the project it was found, in certain instances, that large curve fit errors occurred during the mid span.

2.4.4 Software Costing and Life Cycle Control

In the course of the search to discover other work using exponential equations to simulate project expenditure a number of growth curves were investigated,[1] the most appropriate was the research into "software costing and life cycle costs" by Laurence H. Putnam. This work involved the development of an effective, time-varying macroscopic model of the Rayleigh diffusion equation.

Putnam maintained that the characteristic (average) behaviour of software development over time is well described by the

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(1) Putnam, L.H. Software Costing and Life Cycle Control Software Inc. 1979

Rayleigh equation because it is a good model of a large number of gaussion variables whose phases are random.

The Rayleigh equation parameters yield the management parameters that directly answer management questions. The Rayleigh/Norden overall manpower equation for large systems is

$$y = (K/t_d^2)\cdot t\cdot \exp(-t^2/2t_d^2) \text{ people}$$

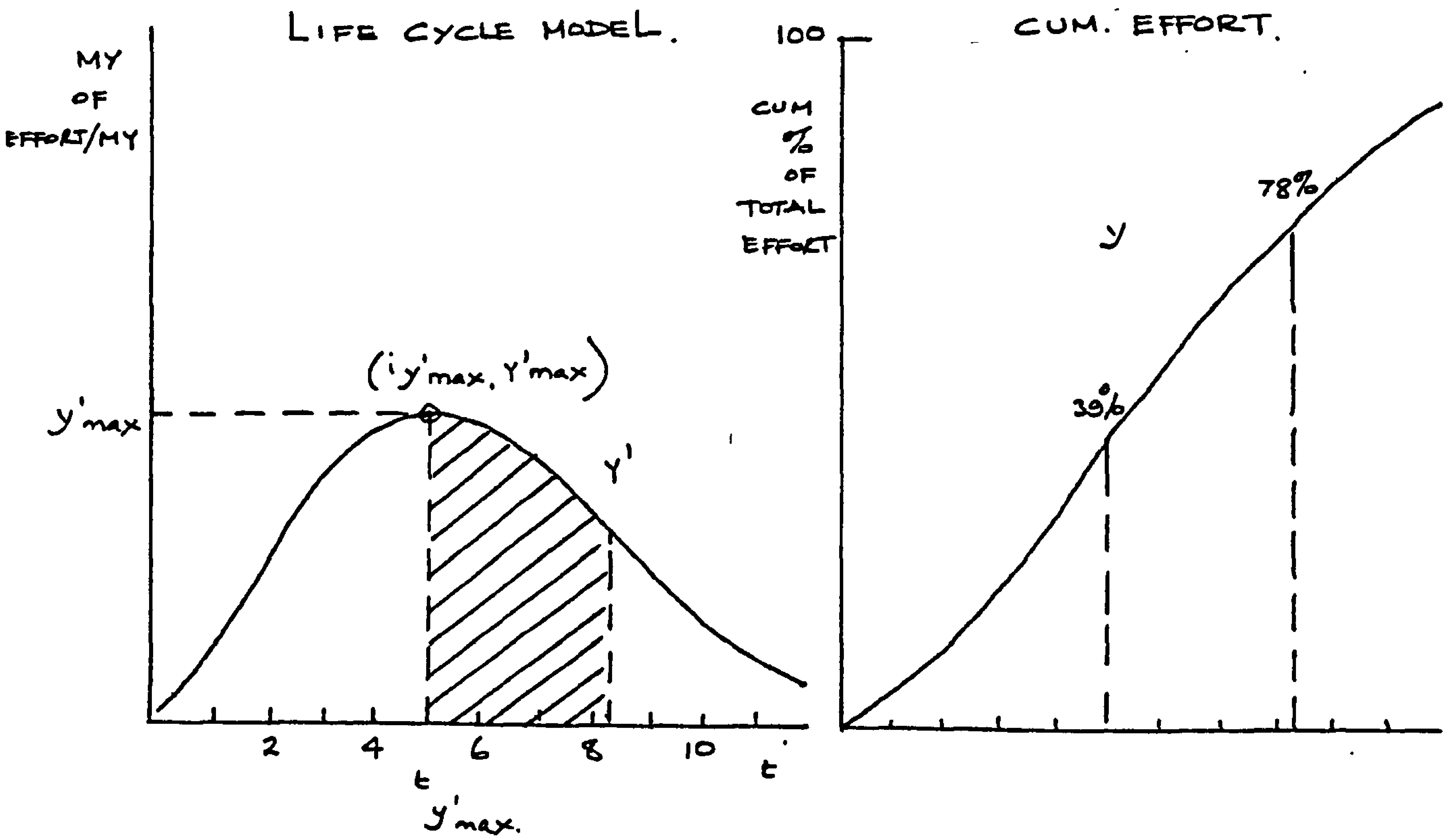
where:

K is the life cycle effort in man years, or man months,

td is elapsed time in years, or months, from the beginning of detailed logic design and coding, and

$\bar{y}$ is manpower in man years/year, or man months/ month or countable people at any instant in time.

Multiplying this equation with the labour rate turns it into a cost function. Integrating over time yields cumulative effort and cost at any time, hence development effort and cost is an easily extractable subset of life cycle numbers. See Figure 8.



$y' = 2Kat\,e^{-at^2}$

$Y = K(1 - e^{-at^2})$

Important Parameters

K = TOTAL MY FOR ENTIRE PROJECT

$K = e^{1/2} \cdot Y'_{max} \cdot t_{y'max} = \sqrt{e} \cdot y'_{max} \cdot t_{y'max}$

$a = 1/2\, t^2_{y'max} = (1.65)\, y'_{max} \cdot t_{y'max}.$

Fig 8

Although this equation was specifically used to budget/forecast the cost of developing computer software it appeared that there might be scope for applying this to the costs involved in designing buildings. The curves described by the Rayleigh equation might also provide a basis for simulating construction expenditure.

Having established the basis of existing work I considered the next stage was to search for an equation which would overcome the difficulties already described in this chapter. The natural starting point was the DHSS work since this research was supported by a comprehensive study of actual hospital building projects. Hence the initial work involved finding a possible alternative polynomial equation which could be tested against the DHSS findings.

Chapter 3

3. THE PROPOSED 's' CURVE MODEL

3.1 Development of the Cubic Equation

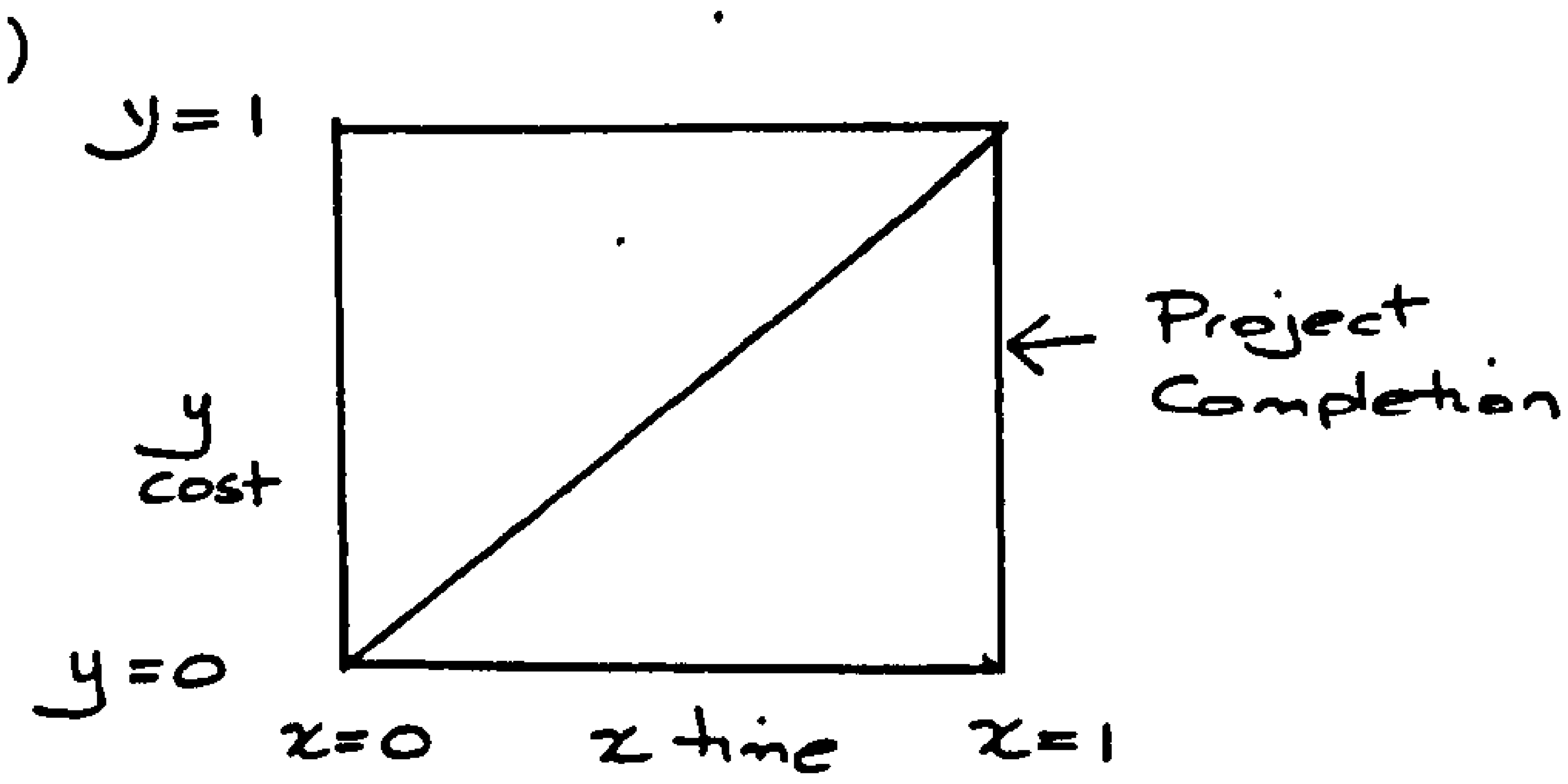
The initial step was to relate the shape of the curve required to a simple and easily recognisable condition set within the total project cost and time span.

It was therefore necessary to define the following terms of reference:

(a) Every project must start at zero cost and time.

(b) The total project costs and time culminates at unity.

(a) and (b)



N.B. The straight line between y = o, x = o and x = 1, y = 1 represents the vector where the "proportionate value of y" = "the proportionate value of x"

It was then established that an 's' shaped curve will have one point when the proportion of the total project cost will equal the proportion of the expected project duration. In other words the 's' curve will cross the proportionate line y = x

This point was termed as the "equiproportion point" and was given the symbol β beta.

It could therefore be said that at the equiproportion point $y = x = \beta$

The next task was to introduce a constant value to enable the profile of the curve to be simulated. This was termed as alpha. α

After investigation it was found that the following transformed cubic equation produced a satisfactory simulation:

$$y = {}^{Cm}/_{S} = x\ (1 + a(1 + a\ (1 - x)(x - b)$$

where Cm = cumulative Cost (value, budgeted cost or monies spent)

S = Contract sum

y = $^{Cm}/_{S}$ = Proportion of the contract sum spent for the first m periods

P = contract duration

m = current period - the period in which latest expenditure occurred (e.g. in months)

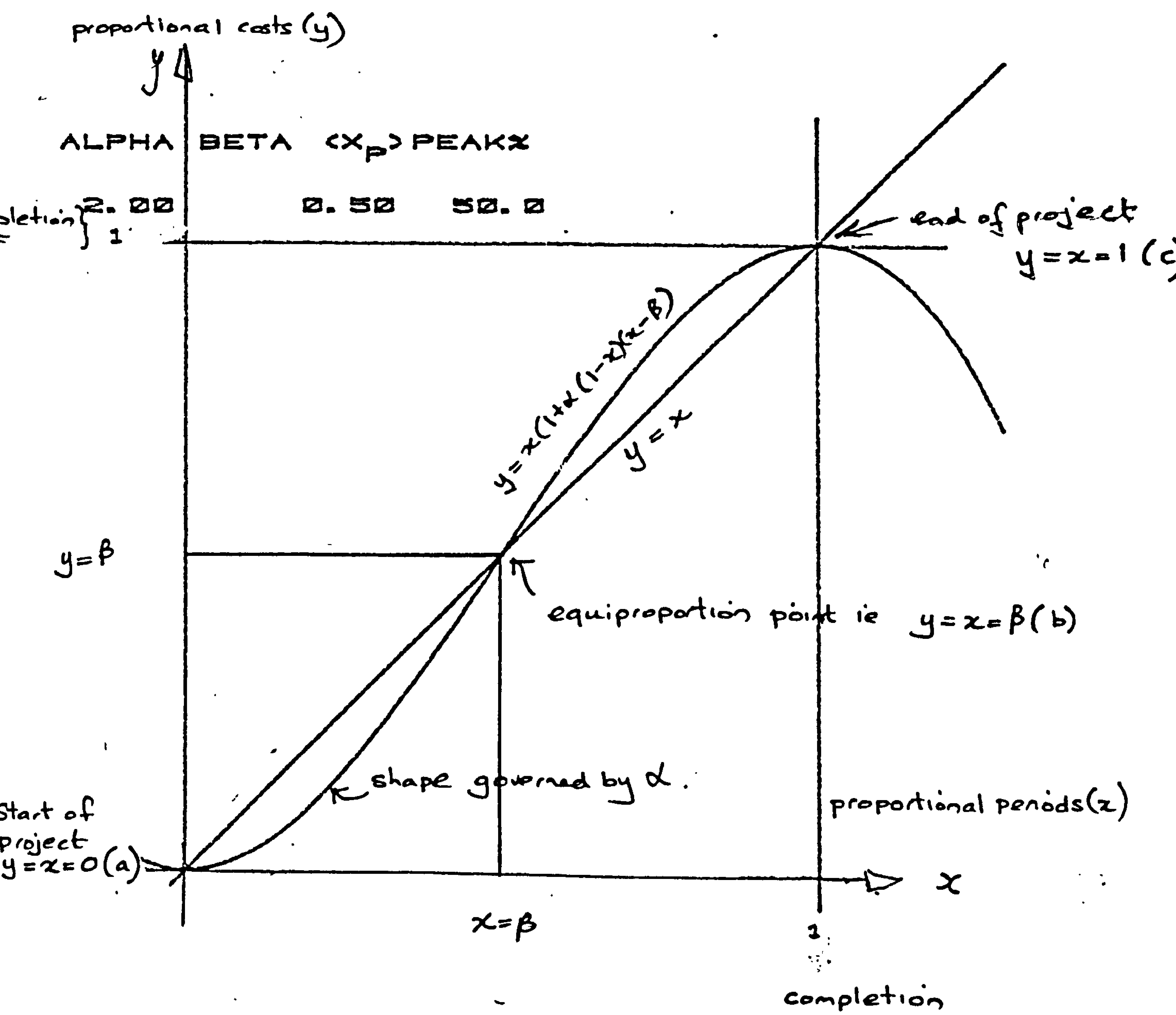
$x = {}^{m}/_{P}$ = Proportion of contract duration and date i.e. to period m.

b = beta constant (equiproportion constant)

a = alpha constant (determine the shape of the curve)

Graph 1

Conditions in brackets.



Graph (1) shows the symetrical case of alpha = 2 and beta = 0.5. It will be seen that the straight line (proportionality line y = z) cuts the curve at y = x = 0.5. In this case half the project is completed at the halfway cost point and the shape is controlled by alpha.

If the simplest polynomial equation is produced to give an 's' shaped curve, one is forced to use a cubic equation and the above conditions generate the alpha-beta cubic equation shown above. The alpha beta equation developed does not suffer from the infexibility created by constants C and K used in the DHSS case, since the values of the constants alpha and beta can be deduced from practical considerations.

3.1.1 Reference to Appendices

Before proceeding further reference should be made to Appendix 1 which contains a definition of the terms and symbols used in this text of the mathematical properties.

A summary of the mathematical properties of the "alpha-beta" equation is given in Appendix 2.

3.2 The Analysis and Evaluation of the Alpha and Beta Constants

If one uses the cubic equation on its own to depict the 's' curve then parameter properties are as described below. The mathematical development of this section is given in Appendix 2.

3.2.2 Properties of the Alpha Constant

1. Alpha = 0

   If alpha = 0 the curve becomes a straight line y = x which is the line proportionality.

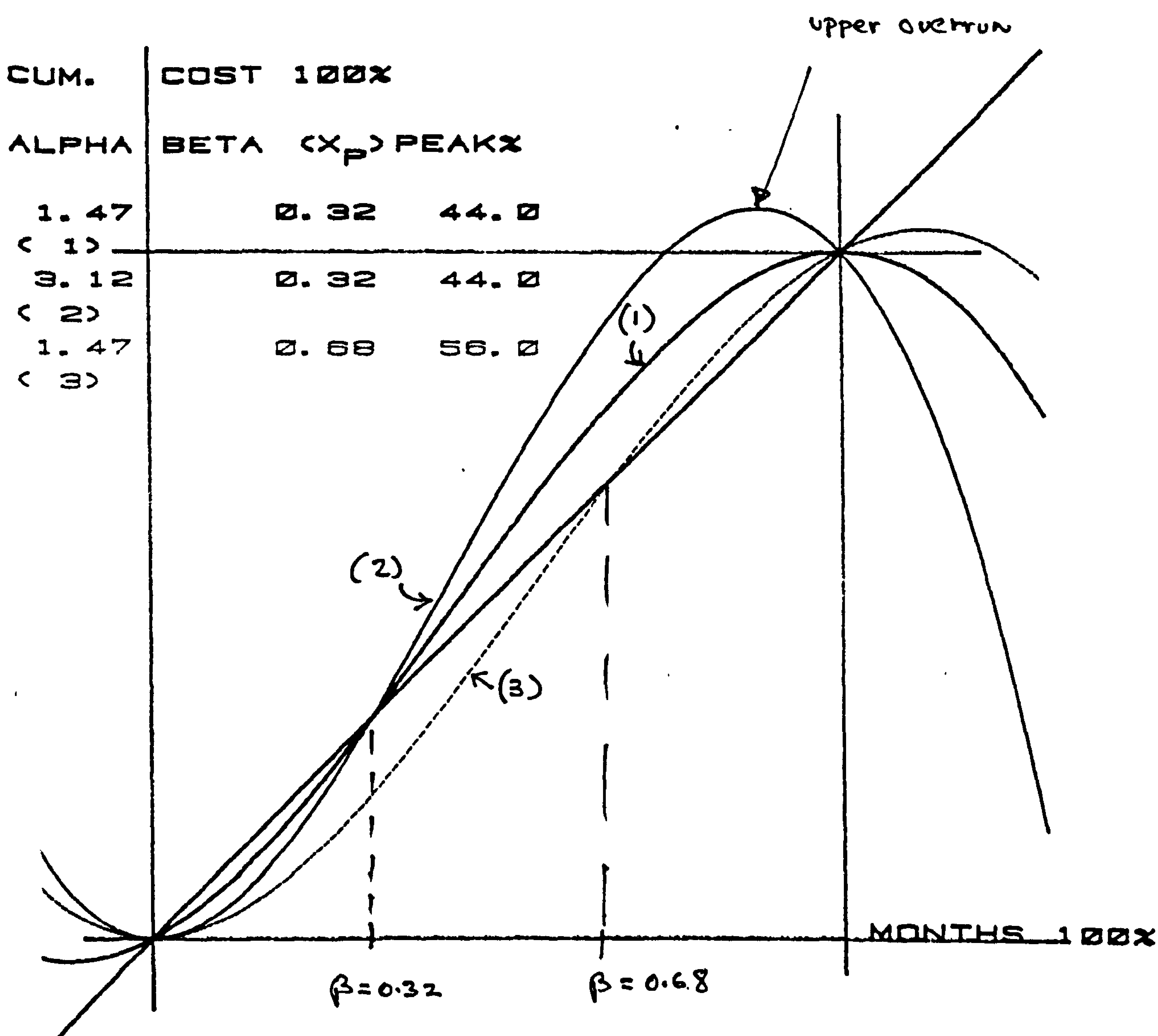
2. Alpha

   If alpha is less than 0 the 's' curve would take on a practically unrealistic form having, at best, an initial 'convex' or 'hill' form showing an initial rapid drop in costs from a high cost start. Additionally it does not mathematically allow a peak period cost (e.g. highest monthly project cost) to exist.

3. Alpha

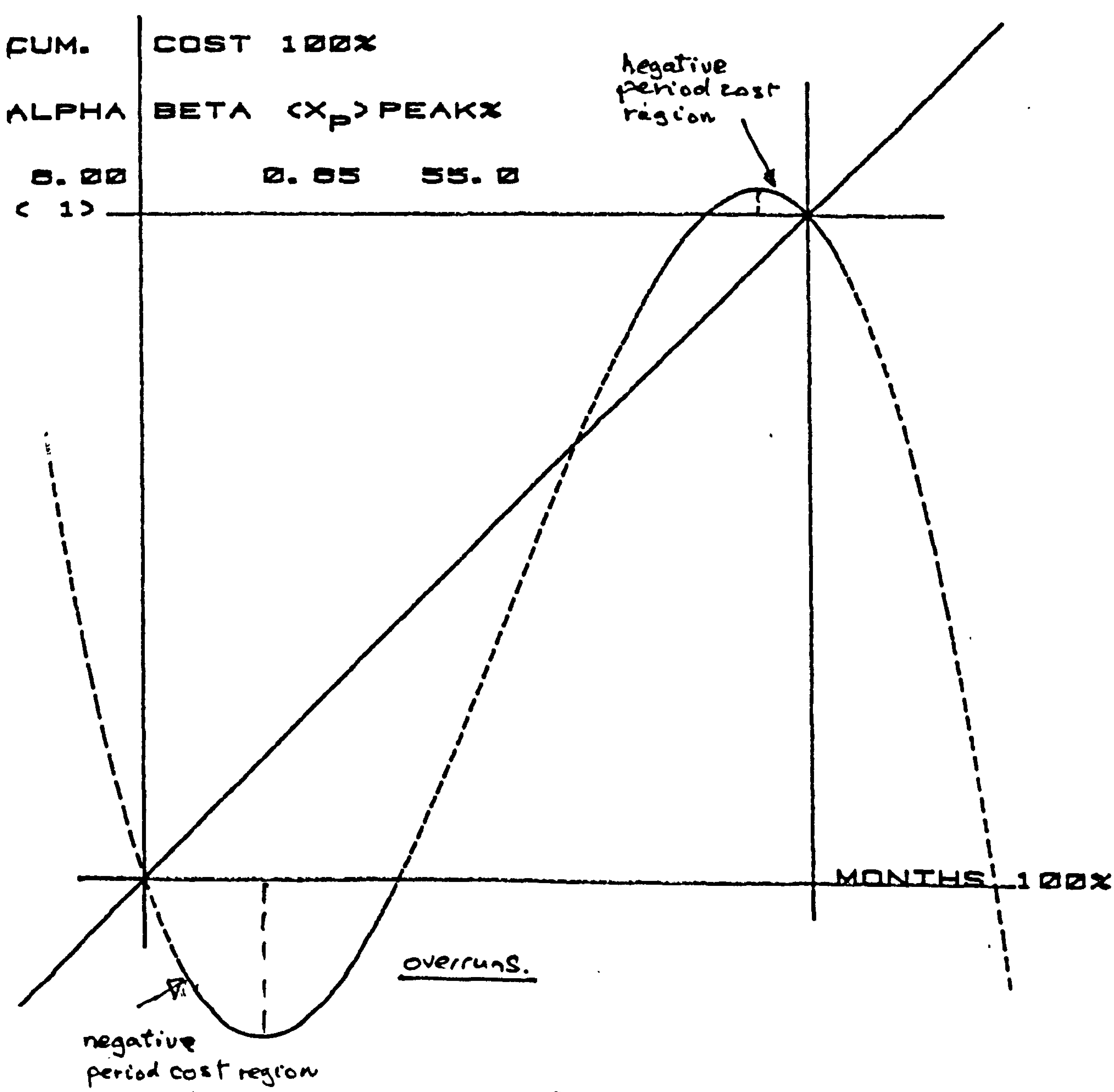
   If alpha is greater than zero the project costs increase gradually having a 'concave' ('U' shaped) form initially (see graph (2) curve (1)). As the value of alpha increases for the same value of Beta (see graph (2) and curve (2)) the initial costs rise more slowly. Beyond a given value of alpha which can be deduced by solving the first differential of the alpha-beta cubic equation set to zero slope (dy/dx = 0) the overrun situation arises. Curve (2) graph (2) also shows an overrun situation before the project ends (from x = 0.75 to x = 1) creating negative period costs after the maximum cost is reached prior to project completion.

Graph 2



α - shaping constant properties

Graph 2a



CUM. COST 100%
ALPHA BETA <X_P> PEAK%
8.00 0.85 55.0
< 1>
negative period cost region
MONTHS 100%
overruns.
negative period cost region

The overrun situation can be shown to arise if:

alpha   min (1/b,1/(1-b))

and visa versa overrun does not arise if:

alpha = min (1/b,1/(1-b))   ....(3)

Finally curve (3) of graph (2) shows an exaggerated case of the effect of increasing the value of beta for the same alpha as in curve (1). In this instance it will be seen that the expenditure at the start is deccelerated and the peak occurs later, resulting in accelerated expenditure towards the end of the project.

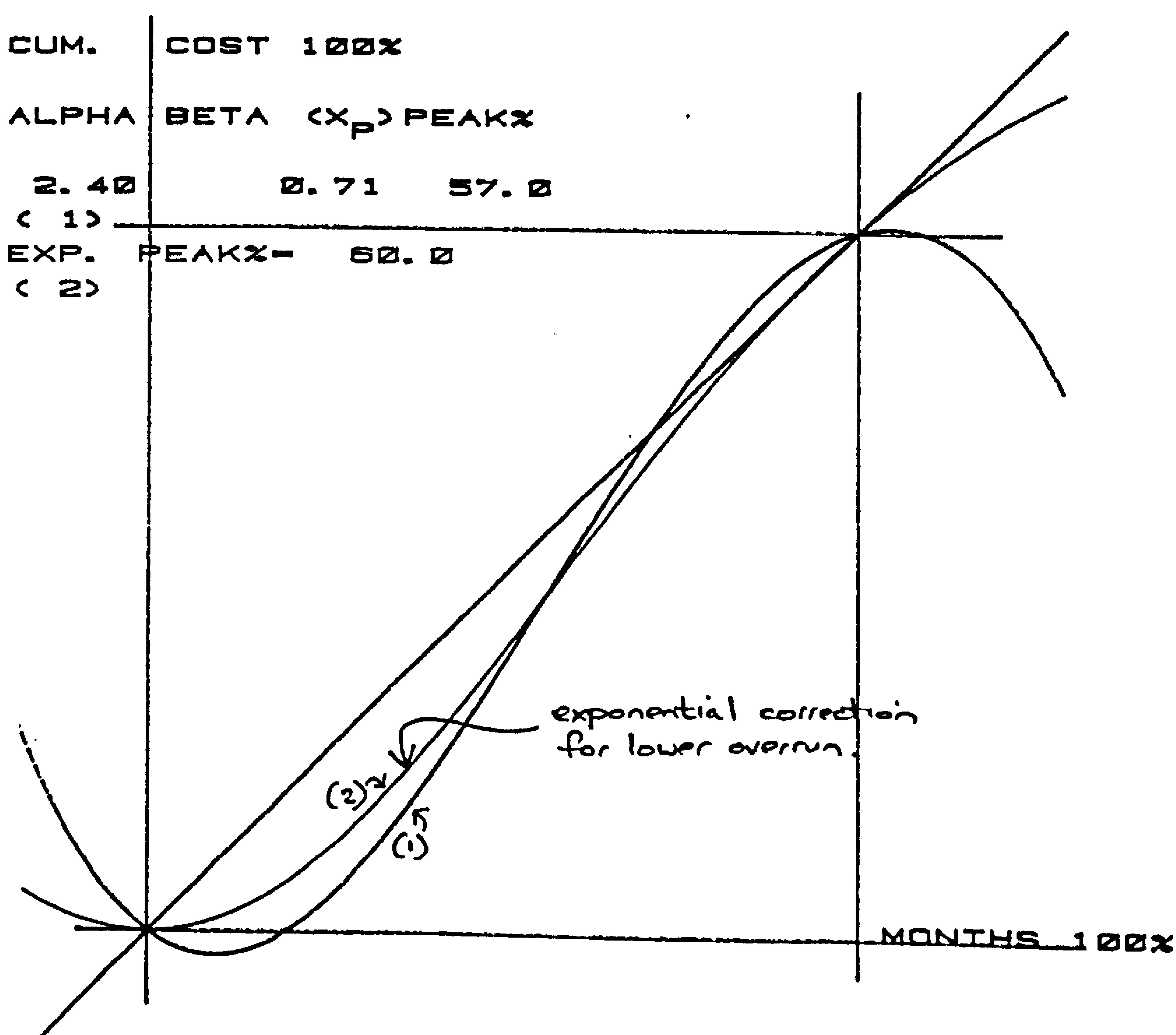
In practice it is possible to frequently avoid the above variations, since symmetric curves are more likely to occur. Such curves ensure the rate of cost increase and decrease at the start and finish are roughly similar. The exponential curve has the useful property that, used in combination with the curves created by the cubic equation, the generated 's' curves retain this symmetric property which neither curve on its own can maintain for more extreme values of the curve parameters.

Graph (3) demonstrates the effect of combined use of the two equations and the similarity of shape at the ends. The curve fit SDY was only 3% when compared to 9% using the best fitting cubic equation.

3.2.3 Properties of the Beta Constant

The properties of beta are only considered for the case of a positive alpha i.e. under the condition that a peak period cost exists (alpha > 0).

Graph 3


CUM. COST 100%
ALPHA BETA (Xp) PEAK%
2.40 0.71 57.0
(1)
EXP. PEAK%= 60.0
(2)
exponential correction for lower overrun.
(2)
(1)
MONTHS 100%

1. Beta = 0

If beta = 0 and alpha greater than 0 the resulting curve is convex 'hill shaped' i.e. non feasible as in the case of alpha < 0.

2. Beta < 0

The same applies as in (1) above.

3. Beta > 0

This is the only practical condition for the constant beta but requires further analysis of the alpha-beta cubic equation in order to show the relationship with peak period costs (Zp) and the peak period cost point in time (Xp).

4. Details of beta > 0 case

The period in time when the peak period cost (Zp) occurs may be shown to be related to beta as follows:

$$x_p = (b+1)/3 \qquad \ldots\ldots(4)$$

The above equation has several practical implications.

a. If $0 < b < 1$

In this case the "equiproportion" point beta is where the 's' curve crosses the proportionality line y = x during the project. Using equation (4) the above values of b show that Xp must lie in the middle third of the project duration, implying the peak period cost Zp occurs in this time span.

This result appears to be well supported in practice and hence enhances the validity of using a cubic equation as a model for management control, in particular for the centre portion of the project.

b. $0<Xp<1$

If the peak period cost exists it must occur during a project which implies that:

$0<Xp<1$ and hence $-1<B<2$

This sets practical limits on the values of b which can only be exceeded $(b>=2)$ if the period costs do not have a peak. This situation arises in the case of high inflation, but may be corrected by the use of present values (day 1 costing basis) and it occurs when forecasting at an early stage in a project before the point Xp has been reached.

5. Evaluation of Beta

To find the value of b it is easier to evaluate Xp first. For practical purposes the value of x_p is given by:

$$x_p = (PZ_p/2S)\ (1+(1-4S/3PZ_p)^{.5}) \qquad \ldots\ldots (5)$$

reformulation of equation (4) gives:

$$\text{Beta} = 3x_p - 1$$

Equation (5) implies that for a real solution it is necessary that:

$$Zp \quad 4S/3P \;=\; 1.33 \text{ average period cost} \quad \ldots. (6)$$

The results above (equations 4 and 5) show the alternative practical premises for determining the value of constant Beta i.e. to preferably find the point at which peak period costs occur (Xp) or the peak period cost (Zp) itself (see graph 1c).

The implication of the inequality equation (6) is that the peak period cost is usually in excess of 33% over the average cost period providing the minimum of the curve is at the origin.

The value of the peak period cost may be shown to be well approximated by:

$$Zp = Yp' .S/P$$

where $Yp' = dy/dx$ at $x=Xp$ (see graph 3a)

i.e. Yp' is the gradient of the 's' curve. The maximum gradient has been shown to be critical for the forecast and budget simulations i.e. Y'p maximum must be found. This is approximated by finding the maximum period cost. e.g. the month in which the maximum expenditure occurs.

After differentiating and appropriate transformation (see appendix 2) it can be shown that:

$$Yp' = PZ_p/S = 1 + a(3x_p(x_p - 1) + 1) \quad \ldots\ldots (7)$$

This expression may be used to determine alpha from Yp' or Zp and beta (see graph 1d), in which $Yp' = 1+a/4$ when $x_p = 0$.

The practical validity of the above results is upheld by the analysis of published DHSS data.

The supportive evidence of the methodology resulted from reformulating the constants given by DHSS for their projects (see table (1)) and showed that there was little variation from the calculated average value of Yp' = 1.4 and only one value was 1.32 which was just below the above restricted theoretical requirement of 1.33.

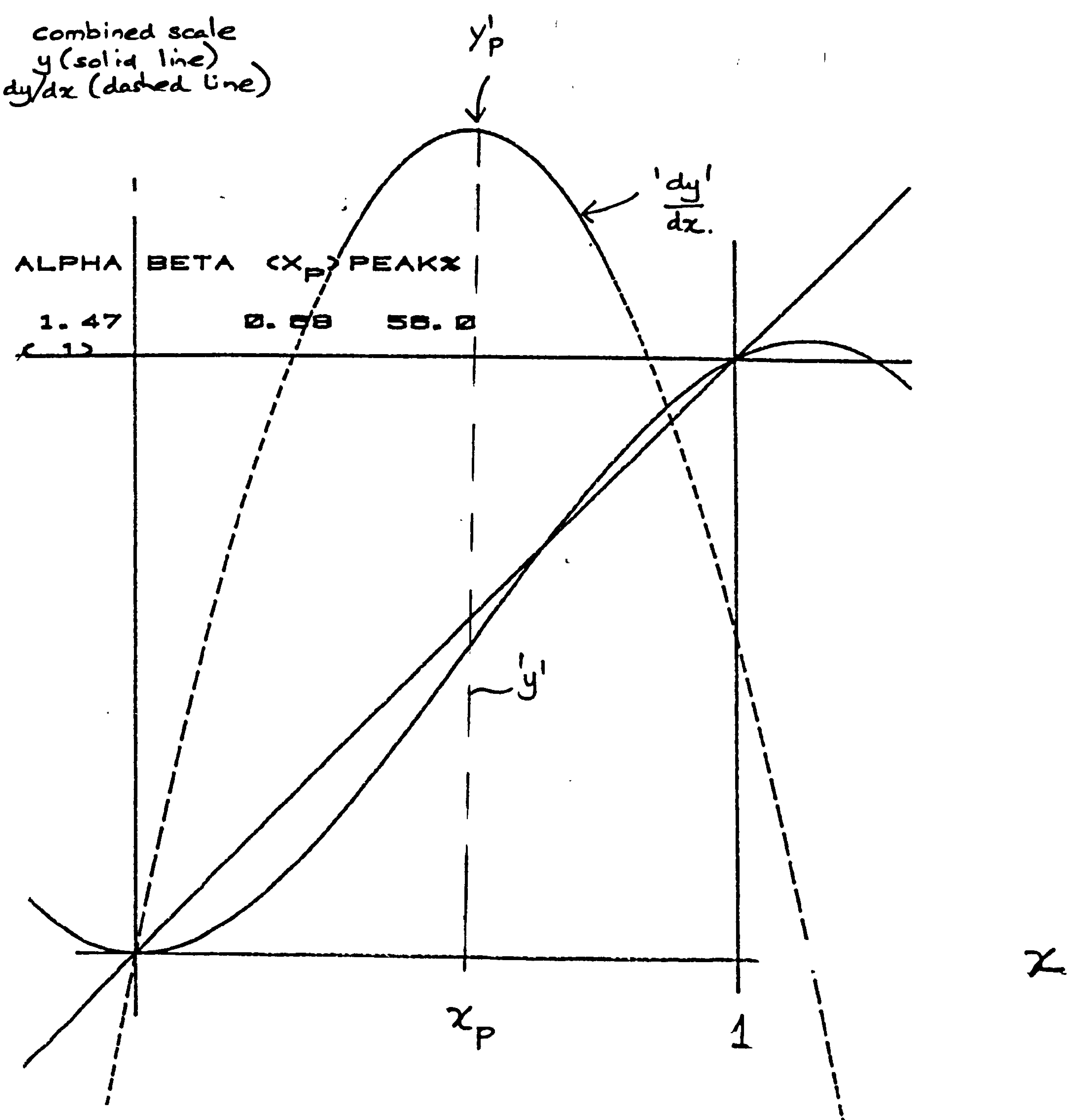
3.3 Practical Determination of Alpha and Beta values

The basis of the whole analysis in this thesis requires the user to select a value of alpha and beta for a given expenditure curve. The forecast evaluation is improved as the user becomes better acquainted with the constants selected, either for the whole project or on an individual cost centre basis.

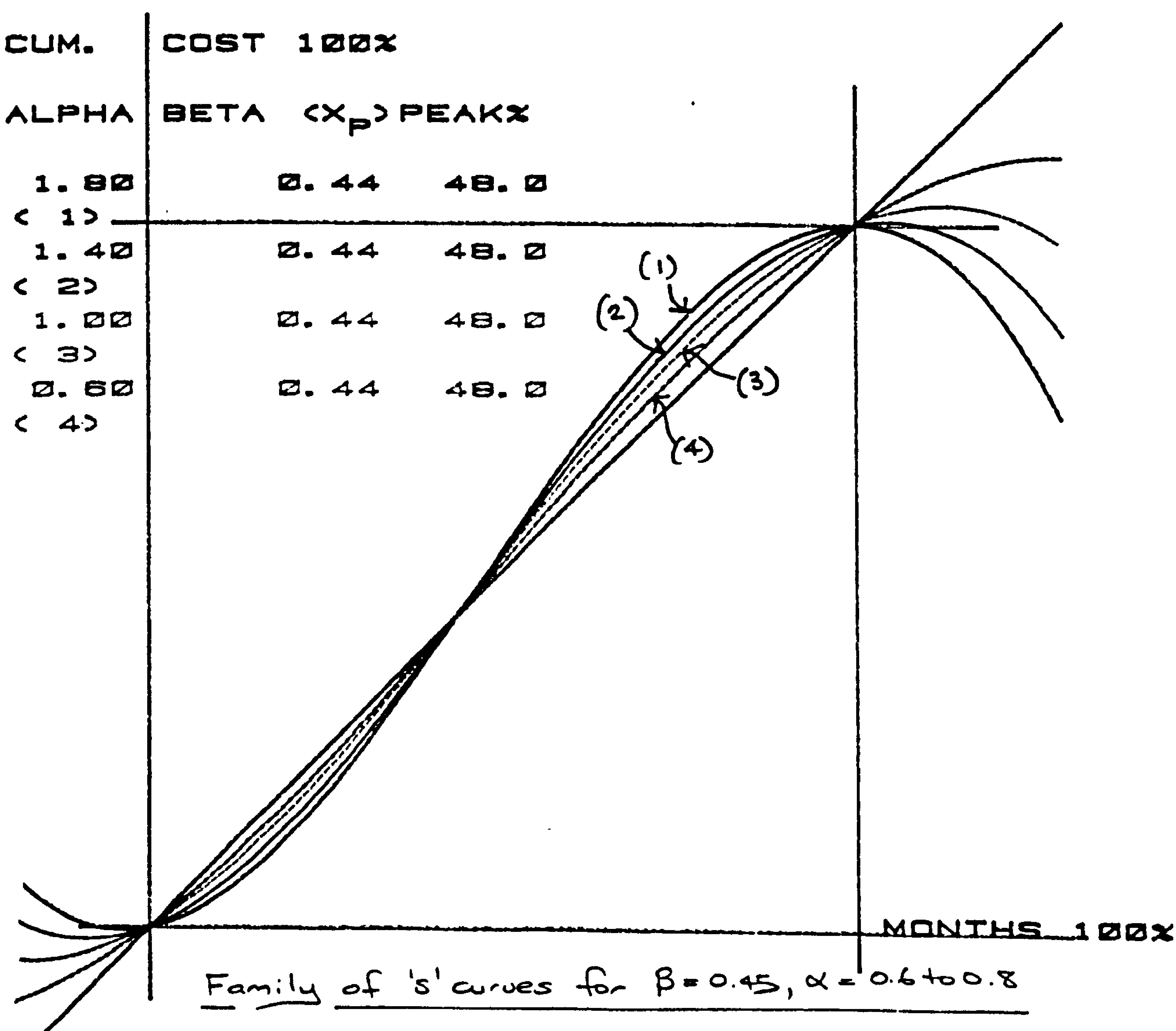
For the initial guidance of the user I have produced an alpha-beta form of DHSS constants which incorporates amendments in order that overrun does not occur (see Table (2)). It is not until a case history of previously used constants is built up that the user will be able to be more discerning about the constants he should use. In the meantime the DHSS constants form a valuable check.

The first stage, which will enable the user to utilise the freedom achieved by the formulation of the cubic equation, is to estimate the point of time at which the peak period cost is likely to arise (x_p) which will evaluate beta.

Graph 3a


combined scale
y (solid line)
dy/dx (dashed line)
y'_p
'dy'
dx.
ALPHA BETA (Xp) PEAK%
1.47 0.88 58.0
(1)
'y'
x_p
1
x

Graph 4



Family of 's' curves for $\beta = 0.45$, $\alpha = 0.6$ to 0.8

In practice the selection of an appropriate method to determine the constants will largely depend upon the circumstances of the application and the users familiarity with the system.

The forecasting system utilises the alpha-beta equation to determine the 's' curve expenditure forecast for each cost centre. In practice it is possible that some anticipated expenditure will be outside the bounds of the curve described by the alpha-beta equation. This situation has been overcome by the provision of a computer program which overlays cost variations outside those given by the initial 's' curve.

The accumulation of the individual cost centre budgets set to a programmed timescale gives an overall budget for the project. From my research I have found that in the majority of cases it has been impossible to avoid the overrun situation for the accumulated budget. To overcome this problem I have found it necessary to iteratively find the best combination of the alpha-beta and exponential equations, see example graph (3).

Due to the users initial lack of familiarity with these concepts, I consider that the cost centre analysis, as described above, is adequate to determine viable budgets. With more experience it is anticipated that the user will be able to recognise the point of time at which the peak period cost will occur and he should be able to quantify its value. This is a more precise approach which is supported by my practical experience. However, I have frequently found that this creates overrun and my solution to this problem is to incorporate the exponential equation in the computer program. This has the advantage of reducing curve errors from a maximum of 15% to below 5% based on the results of the simulations of industrial data, both at the design and construction stages.

3.4 Other properties relating to the use of 's' curves

3.4.1 a. Redundant Periods

Another difficulty encountered was the project expenditure pattern with redundant or near redundant periods resulting in extreme curve irregularities. The method adopted to mitigate these circumstances was to input a percentage cost which would set the low cost time period to zero and the data points were thus eliminated temporarily from consideration hence, allowing a more accurate curve fit, after which the redundant/low cost periods were re-introduced into the final profile giving a noticably better curve fit.

3.4.2 b. Inflation

The effect of inflation on a budget or forecast with present value (day one costs) can be accounted for by normal compounding as shown below:

For period m:

$$Y \text{ (actual)} = Y \text{ (present value) } (1+i)^m$$

where i = inflation rate/period

When consideration of inflation has been taken into account this leads to an important practical outcome about the constants of alpha and beta which show in response to inflation a decrease in alpha and an increase in beta. See graph 5.

The above results in making the 's' curve in the case of high inflation appear concave (u shaped) only i.e. the top part on the 's' is missing. This type of curve may furthermore have no peak cost period i.e. beta 2.

3.4.3 c. Sensitivity Analysis

This may take several forms, both at the budgeting and work in progress stages. The simplest form is based on a number of computer runs which will simulate the variations in expenditure related to changes in alpha and beta, and/or changes in the final time and cost.

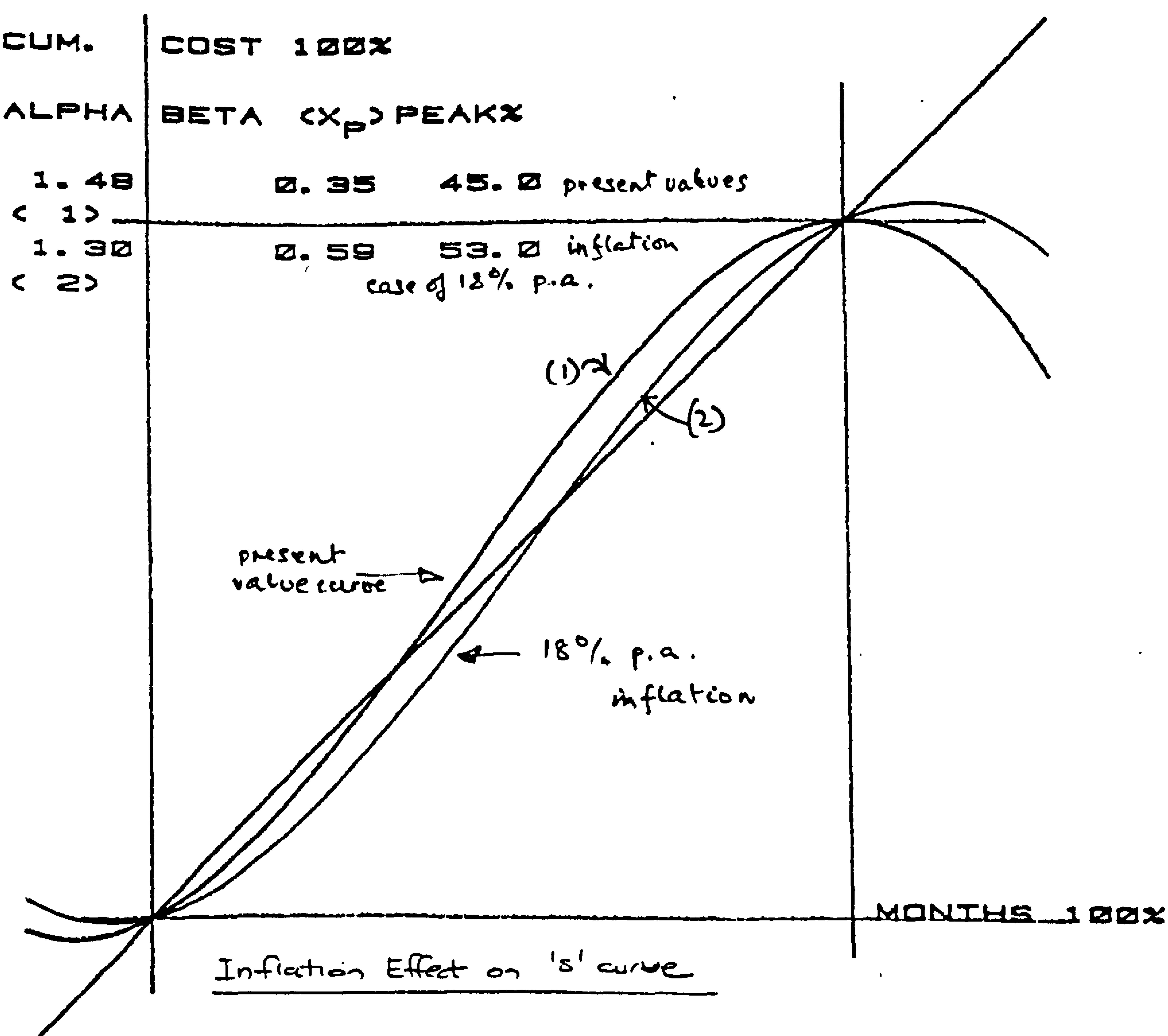
3.5 Comparison of the DHSS and alpha-beta equations

The transformation of the DHSS equation into the alpha-beta form shows the constants are related as follows:

$$a = 6K \text{ and } b = .5 + CK/6$$

$$K = 6/a \text{ and } C = ab - a/2$$

The analysis from basic principles utilising the above has made it possible to transpose the data given in the DHSS



Inflation Effect on 's' curve

table of typical project expenditure patterns in terms of alpha and beta constants.

The results are given in table (2) which includes minor corrections, shown by an *, of the constants that where found to give overrun.

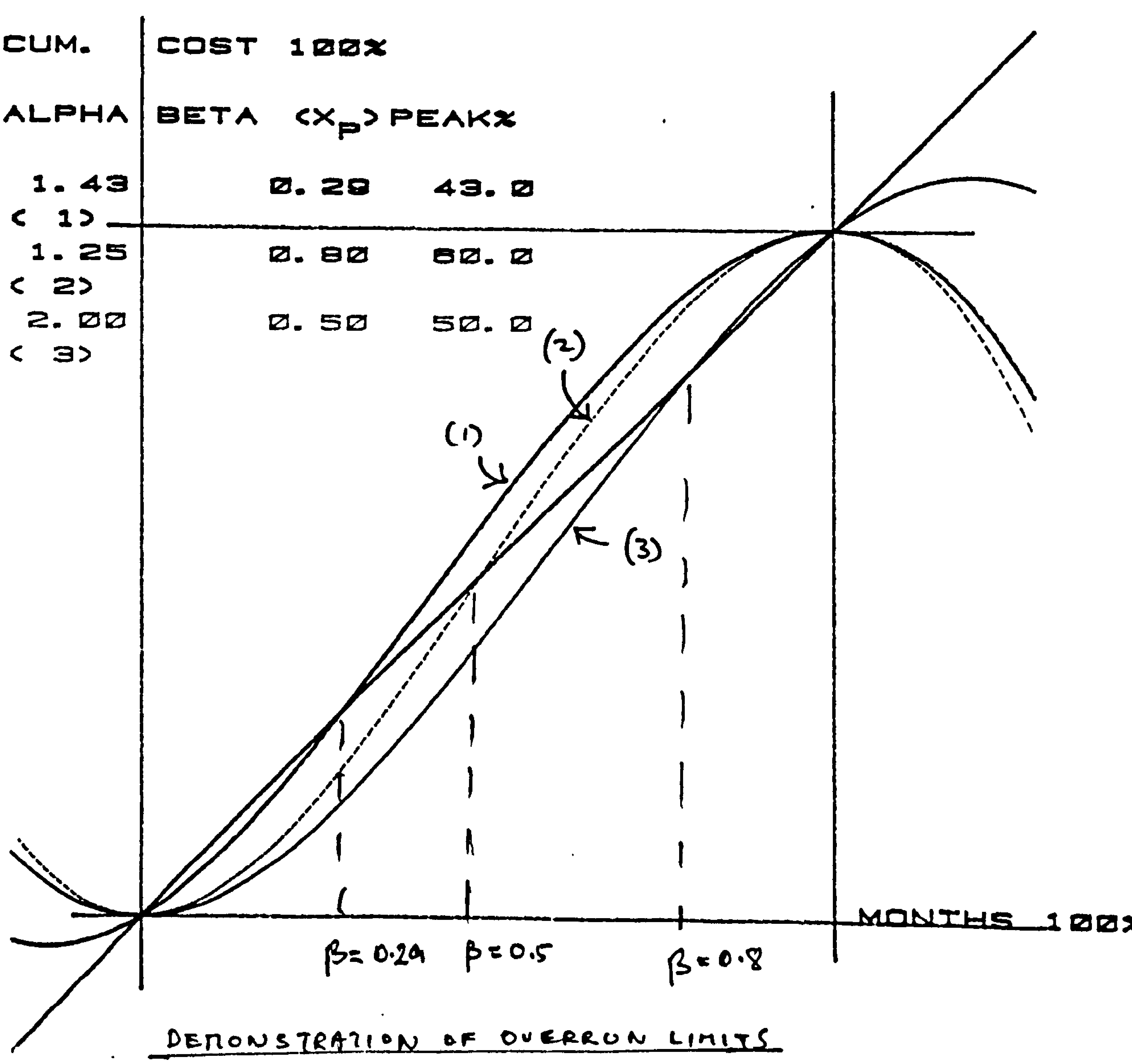
The primary reason why the previously described analysis was not possible using the DHSS equation is that the constant C contains a product of alpha and beta which has an approximate value of 1 (range .8 to 1.2). This fact renders the crucial peak cost properties intractable.
It was because of the formulation from basic principles that the full significance of the constituent parts of constant C was realised and hence the advance that has been made was facilitated.

Table 2

Cost Category DHSS Hospital costs based on 1976	Standard Parameters		Equivalent	
	C	K		
£10,000 - £30,000	-0.409	7.018	0.8549	0.0216
£30,000 - £75,000	-0.360	5.000	1.2	0.2
£75,000 - £120,000	-0.240	4.932	1.21655	0.30272
£120,000 - £300,000	-0.200	4.058	1.47856	0.364733
£300,000 -£1,200,000	-0.073* -0.074	3.234* 3.200	1.854* 1.875	0.460533
£2m	0.010	4.000	1.5	0.506667
£3m	0.110	3.980	1.50754	0.572967
£4m	0.159	3.780	1.5873	0.60017
£5m	0.056	3.323	1.8056	0.531015
£6m	0.181* 0.192	3.664* 3.458	1.6376* 1.73511	0.610656
£6.5m	0.149* 0.154	3.524* 3.401	1,70273* 1.76419	0.587292
£7.0m	0.169* 0.172	3.612* 3.557	1,66121* 1.68681	0.601967
£7.5m	0.131	3.445	1.74165	0.575216
£8.0m	0.142	3.538	1.69587	0.583733
£8.5m	0.099	3.404	1.76263	0.556196
£9.0m	0.104	3.456	1.73611	0.559904
£9.5m	0.061	3.317	1.80886	0.533723
£10.0m	0.063	3.344	1.79426	0.535112
£10.5m	0.019	3.207	1.87091	0.510165
£11.0m	0.018	3.218	1.86451	0.509654
£11.5m	-0.025	3.089	1.94238	0.487129
£12.0m	-0.028	3.090	1.94175	0.48558

* Asterisk refers to corrected values in order to avoid overrun

Graph 6


CUM. COST 100%
ALPHA BETA <Xp> PEAK%
1.43 0.29 43.0
< 1>
1.25 0.80 80.0
< 2>
2.00 0.50 50.0
< 3>
(1)
(2)
(3)
MONTHS 100%
β= 0.29
β=0.5
β=0.8
DEMONSTRATION OF OVERRUN LIMITS

3.6 Overrun situation

3.6.1 a. Limitation of cubic equation

The values of beta govern the values that the constant alpha may have in order that overrun does not occur. Analysis of equation (3) shows that three major cases of overrun arise, this data is depicted in graph (6) and summarised in the table below.

Given equation (3):

$$\text{alpha} <= \min (1/b, 1/(1-b)) \quad \ldots\ldots (3)$$

the overrun cases are:

curves in graph 6	curve (1)	curve (2) symmetrical case	curve (3)
x_p and b values	$0<b<x_p<.5$	$b=x=0.5$	$1>b\ x_p>.5$
a inequality equn.	$a<=1/(1-b)$	$a=2$	$a<=1/b$
limiting cases:			
minimum period	$x<0$	$x=0$	$x=0$
maximum period	$x=1$	$x=1$	$x>1$

The above table sets the practical limits on alpha and beta for the use of the cubic equation as the sole budget model.

In the forecasting situation the value of beta can be well in excess of unity. In such a case I have found that it is initially necessary to ensure the minimum passes through the origin. This can be shown to give a maximum for the cubic curve at 2Xp i.e. peak period cost occurs halfway through the project. However, it is important to note that this does not generally coincide with the project end, but it does allow for a more flexible limit to the cubic equation forecasting model.

3.6.2 b. Overrun Solution

Further analysis shows that two overruns may occur if:

$$alpha > max\ (1/b, 1/(1-b))$$

If the value of alpha lies between 1/b and 1/(1-b) then only one overrun occurs. This situation is ensured by the condition that the peak period cost exists, implying that $0 < Xp < 1$.

As mentioned earlier providing present values are taken the cubic equation may, in all cases envisaged, be constrained to uphold the latter condition. It is for the above reason that one need only employ one exponential type curve to overcome the overrun drawback of the cubic equation. A test data example is shown in graph (3).

3.7 Solving the Overrun Problem

The main alternative to using the cubic equation is the utilisation of an exponential equation which also simulates an 's' curve. By its nature the exponential does not develop overrun, however it does not possess the cubic equation's flexibility in the middle range of the time span. It was therefore concluded that potential exists for the use of both curves to simulate project expenditure.

Data was collected from a number of construction projects relating to both design and construction with the object of developing a suitable combination of equations. It was noted from a number of data sets that costs tended to deccelerate at a decreasing rate of increase towards the end of the project time span which ideally suited the application of the exponential curve.

After investigating a number of exponential expressions it seemed that one based on the Rayleigh diffusion in normalised form had the potential to simulate the cost of construction projects. (See appendix for mathematical development)

namely:

$$y = \frac{(1- e^{-\gamma x^2})}{(1-e^{-\gamma})}$$

where $x = \frac{\text{current time period}}{\text{total time}}$

The value of gamma $\gamma = \frac{4.5}{(1+\beta)^2}$

In order to test the curve fit ability of both the polynomial and exponential equations a computer programme was written which facilitated a curve fit test based on the root mean squared deviates of the actual and predicted (fitted) proportional cumulative costs abbreviated as SDY

$$SDY = \left(\frac{1}{P} \sum (Ya-Yp)^2 \right)^{0.5}$$

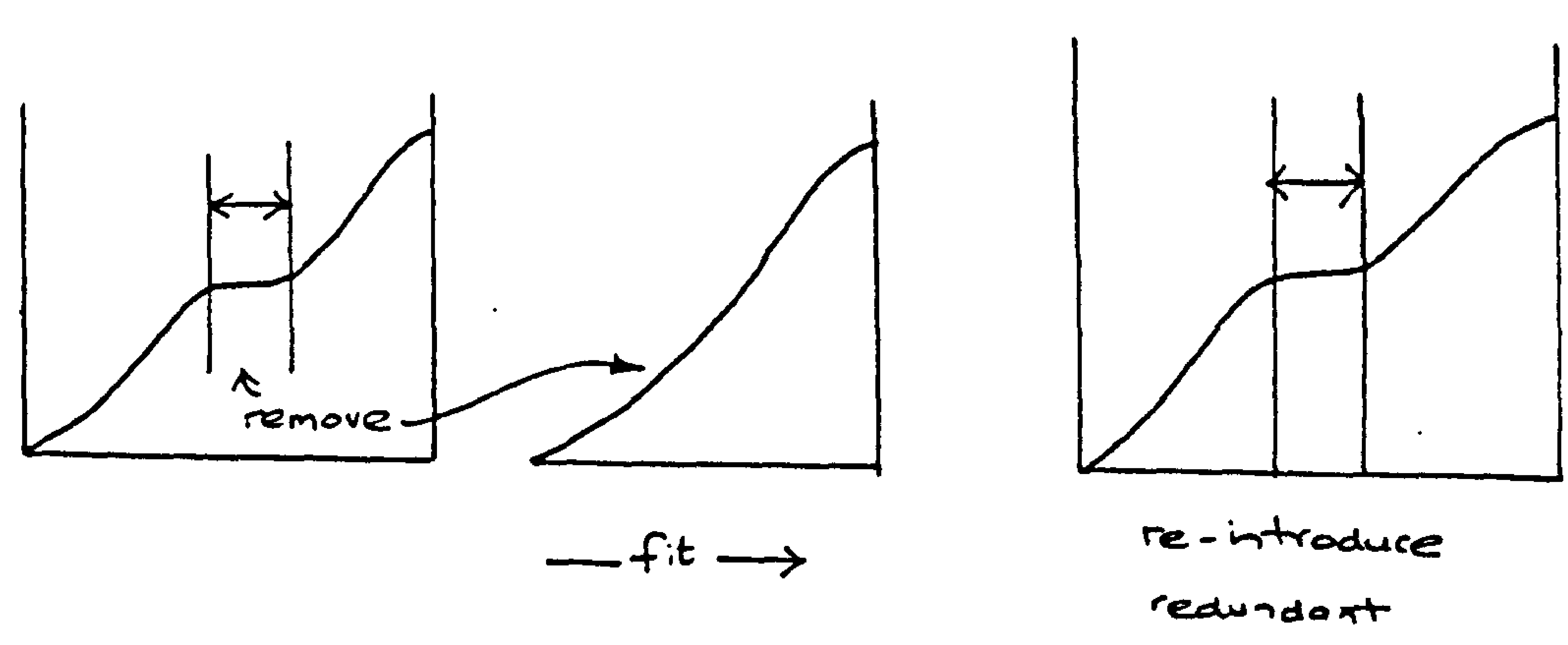
where Ya is actual cumulative cost proportion (y)

Yp is predicted cumulative cost proportion

A comparison is made between the SDY of both equations and the equation with the lowest percentage error for each respective time period is selected. A switch is made where one set of results consistently produced smaller deviations than the other. The whole process entirely avoids the overrun situation at the beginning and end of the project Subsequent tests have proved that expenditure curves can be fitted in most cases to within an accuracy of 3% total project cost.

In one of the test examples extreme curve irregularities were apparent because of periods during the time span when little or no work was carried out. This situation has been overcome by eliminating the redundant or near redundant periods from the curve fit procedure.

After a curve fit has been achieved the redundant periods can be reintroduced to give the actual profile, i.e.



At this stage of the development it appears that a basis has been established for simulating project expenditure. By utilising a combination of polynomial and exponential equations, the overrun problem has been solved and the indications are that accurate curve fits can be made. This process has been further sophisticated by the afore described procedure to cope with redundant or near redundant periods during the project time span. To validate the findings a test programme of live data must be established, both for design and production situations.

Chapter 4

4. DATA ANALYSIS AND CURVE FITTING

4.1 Introduction

It has already been demonstrated that the alpha-beta polynomial equation can successfully simulate C and K produced by the DHSS based on the analysis of over 700 hospital projects. Hence the alpha-beta equation can be used as an alternative to the DHSS polynomial equation. However, to overcome the difficulties created by overrun (negative results) and to improve curve fit potential the previously described combined use of the polynomial and exponential equations has been developed. This chapter is concerned with the testing of this philosophy against known actual project expenditure.

The two principal components of project cost are design expenditure and production costs. I therefore decided that these two areas should comprise the main areas of investigation and testing.

With regard to design expenditure simulation, this could be approached at the simplest level by collecting data from a single profession practice, or alternatively at a more comprehensive level by the analysis of project information from a multi-disciplinary practice. In order to test the methodology under the most rigorous conditions the co-operation of a multi-disciplinary design practice was sought. Subsequently facilities were kindly provided by a leading multi-disciplinary design partnership which enabled professional cost data to be collected in respect of seven major building projects which had been previously constructed in the United Kingdom. The projects were selected to represent a wide range of projects in terms of size, type and duration. Further expenditure patterns were chosen which displayed irregularities, thereby placing great demands on the curve fitting system.

Comprehensive data regarding construction projects were collected from eight construction projects involving schemes ranging from a small development of residential flats, contract value £750,000, to a power station scheme in the Middle East contract value £37,000,000. Seven of the projects were constructed in the United Kingdom and a profile of work was selected to be representative of construction work in general. The range of work between £750,000 and £3,000,000 accords with 50 percent of total building work carried out in the United Kingdom in 1980.(1) The projects consisted of five commercial schemes and two residential developments, one involving refurbishment. The types of construction involved ranged from steelframe buildings to reinforced concrete and masonry structures. Project times in general varied between ten and twenty-six months.(1) Data has been provided by an international contractor relating to a major power station scheme being constructed in Dubai over a period of twenty-four months. This scheme

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(1) DoE Housing and Construction Statistics HMSO 1982
New orders obtained by contractors:
by value range

provides a completely different aspect to the United Kingdom contracts and the design projects previously mentioned, thereby contributing to the variety of work tested and the general applicability of the philosophy proposed.

Overall the fifteen curve fit tests will give reasonable grounds to establish the ability to accurately curve fit a wide range of projects and together with simulation tests on synthetic project data the results will be reinforced.

4.2.1 Study of Project Design Expenditure

The data was collected from the seven projects listed below by referring to records of expenditure relating to the hours spent by the various professions involved at the design stage.

1. Shell: Oil Refinery Works
2. British Gas: General Building Works
3. Leeds
4. Midland Bank
5. Bank of England
6. Southend
7. Middlesbrough

Fortunately the partnership providing the information had operated a comprehensive computerised costing system based on professional cost centres. Hence, it was a relatively straightforward task to identify these costs from computer printouts provided. Figure 9 illustrates a typical analysis sheet which was used to summarise the cost data ready for

Figure 9 Typical Data Collection Sheet of Design Hours and Costs

LS340 PERIOD	MECH H	MECH C	ARCH H	ARCH C	C&S H	C&S C	ELECT H	ELECT C	PRO H	PRO C	OS H	OS C	MEQ H	MEQ C	TOT. H	TOT. C	CUM TOT. H	CUM TOT. C
12/77	CON (SOUTH DAT) [illegible]	[illegible]	7	63	83	855	–	–	23	196	13	125	–	–	125	1239	125	1239
1/78	–	–	–	–	110	1102	–	–	36	328	21	240	–	–	166	1670	291	2909
2/78	–	–	–	–	149	1160	–	–	5	42	35	382	–	–	188	1584	478	4494
3/78	–	–	2	16	6	29	–	–	–	–	14	155	–	–	22	199	500	4693
4/78	–	–	24	242	48	500	–	–	–	–	4	44	–	–	76	786	576	5478
5/78			126	1112	16	150	–	–	–	–	–	–	–	–	141	1262	716	6740
6/78	–	–	15	113	24	278	–	–	–	–	4	42	–	–	42	433	758	7173
7/78	–	–	31	334	–	–	–	–	–	–	6	66	–	–	36	400	794	7572
8/78	–	–	93	934	–	–	–	–	–	–	–	–	–	–	93	934	887	8506
9/78	–	–	26	284	–	–	–	–	–	–	1	12	–	–	27	296	922	8889
10/78	–	–	45	427	18	171	–	–	–	–	2	17	–	–	64	615	986	9503
11/78	–	–	162	1570	45	464	–	–	–	–	4	49	–	–	210	2083	1196	11587
12/78	–	–	210	1947	18	147	–	–	–	–	–	–	–	–	228	2095	1423	13681
1/79	2	25	239	2144	48	557			–	–	17	115			305	2840	1728	16522
2/79	–	–	225	2271	8	100	–	–	–	–	6	52	–	–	239	2323	1966	18845
3/79	13	140	164	1587	12	145	4	42	–	–					192	1882	2158	20728
4/79	7	77	120	1254	–	–	–	–			–	–			126	1330	2284	22058
5/79			26	301							2	27			28	[illegible]	2312	[illegible]
6/79	4	50	65	754	–	–	–	–	–	–	–	–	–	–	69	804	2380	23190
7/79	–	–	11	129	–	–	–	–	–	–	–	–	–	–	11	129	2391	23318
8/79	–	–	88	801	–	–	–	–	–	–	–	–	–	–	88	801	2482	24146
9/79	–	–	108	1134	1	13	–	–	–	–	16	168	–	–	125	1316	2606	25462
10/79	–	–	152	1380	–	–	–	–	–	–	–	–	–	–	152	1380	2768	26842
11/79	11	131	143	1294	–	–	–	–	–	–	–	–	–	–	154	1425	[illegible]	[illegible]
12/79	2	23	147	1325	–	–	–	–			22	121			170	1469	3082	29736
1/80	4	43	116	1113	3	35	–	–	3	25	45	616	–	–	169	1832	3250	31568
2/80	–	–	116	1548	2	28	–	–	–	–	28	282	–	–	195	1858	3445	33426
3/80	2	18	203	1846	26	360	–	–			16	221			246	2465	3703	36049
4/80	12	95	192	1778	9	125	–	–	–	–	–	–	–	–	213	1998	3916	38045
5/80	1	11	151	1570	12	188	–	–	1	12	8	129	–	–	173	1910	4089	39954
6/80			179	1990	19	311			1	12	39	621			238	2933	4326	[illegible]
7/80	4	36	436	3974	13	213	–	–	1	6	33	532	–	–	487	4760	4839	47938
8/80			322	3149							12	184			334	3333	5173	51271
9/80	6	70	312	3087	4	57	2	44	4	46	40	646			367	3950	5540	55220
10/80	45	577	205	2095	18	294	1	13	–	–	106	1382	–	–	374	4362	5914	59583
11/80	29	361	360	4459	65	908	–	–	4	52	139	2161	–	–	596	7880	6509	67463
12/80	8	100	224	2705	53	843	–	–	38	371	45	775	–	–	367	4801	6876	72264
1/81	8	109	196	2328	200	2527	–	–	29	258	23	388			455	5679	7331	77943
2/81	5	60	244	3211	41	671	–	–			66	870			355	4813	[illegible]	82936

keying into computer disc files set within the main frame computer at the Polytechnic of the South Bank.

4.2 Computer Analysis of Data

To enable the curve fitting process to take place utilising both the cubic and exponential equations with appropriate switching parameters previously described, the computer programme entitled RAMNI.BAS was written. The programme was designed to cumulate the data collected prior to projecting curve fits for both the overall project expenditure and the expenditure of the individual professions. Appendix 3 contains the output of results and the programme listing.

A summary of the results obtained in respect of all the projects mentioned above is given in Figure 10.

Project	Duration months	Total project error %	Cubic equation used bet periods	α alpha	β beta	γ gamma	Project Cost (£)
Shell	58	2.5	2 and 16	4.8	0.2349	7.62	173,465
British Gas	31	1.5	7 and 30	2.44	0.715	1.386	154,193
Leeds	26	2.5	3 and 9	0.7235	1.258	3.374	17,799
Bank of England	11	3.5	2 and 10	0.632	0.472	2.7	52,171
Southend	39	2.4	2 and 37	-1.635	-0.115	-0.1	82,197
Middlesbrough	48	4.2	2 and 36	-1.538	0.2322	1.398	376,169
Midland Bank	20	2.6	3 and 10	1.082	0.436	3.512	24,328

Figure 10

It will be noted that the projects varied in value and duration, hence giving variety to the analysis. The results obtained were most encouraging particularly as the worst total projection error did not exceed 4.2% and the average was only 2.74%. The most significant factor was the fact that both the cubic and exponential equations were used in every case to improve the curve fitting process. In all cases the switch was made to the exponential equation at both the beginning and end of the project to improve the curve fit.

The alpha, beta and gamma constants determined by the curve fit procedure indicated that the diversity of project expenditure patterns contained within the test data. Only Midland Bank and Bank of England had similar expenditure curves.

A further ten tests were conducted on synthetically derived project data designed to disprove the validity of the curve fit theory and in every case similar results were obtained compared with the above. It was therefore concluded that reasonable grounds for optimisum had been established regarding the practical viability of the theory proposed.

It is worth noting that an analysis of the design project data indicated that the prime design profession, i.e. the profession leading the design team from start to finish, normally the architect, tended to influence the shape of the other professional design inputs where they occurred over the whole of the project time span.

Figure 10(a)
Shell Data

Start Work	Finish Work	Category	α	β	G	β Peak	Maximum Duration	Gamma Peak
1	58	O/A	4.76449	0.2349	7.62	24	48	19
1	54	Mech	4.66568	0.24819	5.826	25	47	19
1	58	Arch	2.96581	0.280185	4.17	25	51	24
1	37	C&S	3.61177	0.311782	4.084	26	50	22
1	42	Elect	4.02955	0.269512	4.766	25	48	21
1	32	Pro	3.47939	0.3029	3.674	26	49	22
1	56	QS	-0.642981	1.35004	4.374	46	80	52
1		MEQ						

Figure 11

Midddlesbrough Data

Start Work	Finish Work	Category	α	β	G	β Peak	Gamma Peak
1	48	O/A	-1.538	0.232	1.398	20	29
1	48	Arch	-0.866	0.679	2.802	27	21
1	48	Mech.	-0.7314	3.178E-2	1.546	17	28
1	48	Q.S.	-1.507	-7.640E-2	0.678	15	42

Figure 12

British Gas

Start Work	Finish Work	Category	α	β	G	β Peak	Maximum Duration	Gamma Peak
1	31	O/A	0.156	6.35	1.386	76	38	19
1	31	Mech	-0.373	-2.47	1.866	-15	- 3	36
1	31	Arch	0.164	5.819	0.684	71	142	35
1	30	C&S	-0.32	-2.455	1.81	-15	-11	39
1	31	Elect	2.195	0.5177	3.344	16	30	15
10	23	Pro	2.066	0.4168	4.41	15	29	16
2	31	QS	0.532	1.7735	1.418	29	58	31
9	31	MEQ	0.806	1.0867	1.994	22	45	25

This situation can be seen by reference to the curve fit results of Shell and Middlesbrough shown in Figures 10(a) and 11.

These results tend to support the conclusions mentioned in the post grade research undertaken by N. Kotani at University College in 1976.(1)

Those professional design inputs which only occurred over part of the total project time span did not necessarily follow the lead of the prime professions. This situation is clearly shown by the profession curve expenditure of the British Gas project shown in Figure 12.

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(1) Kotani, N.B. Consultants Fees related to variance of Project Design Costs. Paper School of Environmental Studies, University College London, 1974.

4.3 Study of Project Construction Expenditure

4.3.1 The Method of Data Collection

To enable direct comparisons to be made between construction projects and to facilitate the identification of actual cost it was decided to break the project down into seven cost centres which represent the major areas of expenditure. Costs were collected from project records and allocated to the cost centres. To simplify the figures used, the established total costs of each centre were rounded to the nearest £500.

By the examination of cost records it was possible to determine the start and completion times of each cost centre. A cumulative expenditure curve was then established for each cost centre and a best curve fit was made using the alpha beta equation. It was anticipated that actual cost centre expenditure would in some cases be outside the range of the alpha beta curve fit, in which case these would have been made using an alteration programme written specially for this purpose. In the cases studied this facility proved to be unnecessary and was therefore not used.

A further breakdown was then made for five of the cost centres relating to labour, plant and materials.

Figure 13 summarises the data collected for seven of the projects studied.

Fig. 13 Construction Project Costs

Data Input Breakdown.

	PROJECTS					
	Warehouse	Refurb.	Office 1	Factory	Flats	Office 2.
Value	1,050,000	1876,000	2,452,000	3,270,000	750,000	3,050,000
Time (months)	10	15	18	17	9	18
Cost Centre Breakdown						
Substruct. 1	200,000	50,000	550,000	838,500	98,000	585,000
Superstruct. 2	400,000	600,000	887,000	1200,000	250,000	1375,000
Finishes 3	60,000	400,000	350,000	150,000	120,000	378,000
Ext WKs. 4	12,000	15,000	15,000	38,000	12,000	35,000
Drainage 5	8,000	20,000	10,000	12,000	8,000	18,000
Subcontractors 6	314,000	699,000	500,000	868,500	227,000	509,000
Site O/H. 7	56,000	92,000	140,000	163,000	35,000	150,000
Construction Programme ('start'/finish times)						
1	1-3	1-3	1-4	1-5	1-2	1-6
2	3-7	2-13	4-13	4-14	3-7	4-12
3	7-10	4-15	11-18	12-17	7-9	11-18
4	8-10	4-15	16-18	14-17	7-9	12-18
5	2-4	3-13	3-5	2-5	2-3	4-7
6	6-10	3-15	10-18	6-17	5-9	10-18
7	1-10	1-15	1-18	1-17	1-9	1-18

Curve Profile of Cost Centres (alpha/beta)

	α	β	α	β	α	β	α	β	α	β	α	β
1	1.43	.29	1.90	.52	1.85	.53	2.01	.51	1.25	.80	1.48	.30
2	2	.5	1.85	.48	1.48	.30	2	.5	1.43	.29	2	.5
3	1.80	.48	1.90	.49	2.15	.475	1.34	.65	2.05	.49	1.62	.58
4	1.60	0.70	1.32	.75	1.95	.53	1.80	.46	1.35	.70	2.10	.5
5	1.25	.80	1.10	.78	1.92	.54	2.03	.54	2	.5	1.30	.7
6	1.45	.30	2	.5	2.10	.43	1.74	.58	2	.48	1.30	.75
7	2	.50	1.80	.6	2.25	.478	1.50	.62	2.1	.5	1.43	.29

% Allocations on prime cost (labour, plant materials)

	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M
1	15	40	45	40	15	45	12	42	46	15	35	50	30	24	46	25	20	55
2	27	25	48	47	10	43	25	27	48	28	20	52	37	15	48	30	12	58
3	45	5	50	43	9	48	40	10	50	37	15	48	38	6	56	48	6	46
4	15	40	45	12	39	49	18	38	44	17	38	45	42	10	48	42	18	40
5	20	48	35	30	30	40	22	44	34	30	31	49	40	11	49	45	20	35
6	N/A →																	
7	N/A →																	

Fig 13 Construction Project Costs
Data Input Breakdown.

		PROJECT	
		Rye	
Value		3090000	
Time (Months)		26	
Cost Centre Breakdown			
Substruct	1	500000	
Superstruct	2	1000000	
Finishes	3	750000	
Ext. Wks	4	150000	
Drainage	5	100000	
Subcontractors	6	450000	
Site O/H	7	140000	
Construction Programme			
	1	1–8	
	2	7–15	
	3	14–26	
	4	10–24	
	5	9–20	
	6	12–22	
	7	1–26	
Curve Profile of Cost Centres			
		α	β
	1	1.87	·52
	2	2.1	·5
	3	2.15	·48
	4	1.97	·515
	5	2.25	·478
	6	1.32	·76
	7	1.41	·30
% Allocations on prime cost labour, plant, materials			
	1	13 42 45	
	2	40 26 34	
	3	18 37 45	
	4	22 43 35	
	5	32 30 38	
	6	N/A →	
	7	N/A →	

Figure 14

Tabulation of Curve Fit Results from Construction Projects

Project	Duration months	Total project error %	Cubic Equations used bet periods	α	β	γ	Project Cost (£)
1 (warehouse)	10	1.2	0 and 4	0.90	0.498	2.432	1,050,000
2 (refurbishment)	15	1.0	3 and 14	2.66	0.568	2.164	1,876,000
3 (office 1)	18	1.7	0 and 15	0.151	-0.134	2.826	2,452,000
4 (factory)	17	1.6	0 and 16	1.047	0.3574	2.874	3,270,000
5 (flats)	9	1.9	0 and 3	0.926	0.73	1.368	750,000
6 (office 2)	18	1.4	0 and 17	1.05	0.324	2.958	3,050,000
7 (Rye)	26	1.6	0 and 24	0.601	0.727	2.058	3,090,000
8 (Power Station)	24	2.1	0 and 16	0.77	0.92	1.976	37,043,000

The overall project expenditure was then accumulated by the computer and an overall curve fit was then made in the same manner as that described for the design projects.

The results from the computer runs are tabulated in Figure 14.

It is significant that a combination of both equations again produces the best curve fit. However, the construction results show themselves to be far more applicable to the cubic equation, since the span of best fit is far greater and all but one project uses the cubic from the start. It appears that the exponential has general application at the end of the project. It is worth noting that one of the projects switches to the exponential from month 3.

It would appear that the construction project curves are far more consistent than those tested at the design stage, which would seem to indicate that prediction is easier when the basis for the project has been determined. For example, the design is extremely intangible, whereas the construction of the project will be undertaken within a previously determined design. Hence, it therefore follows that under normal circumstances the construction should be easier to predict utilising the curve fit parameters. A number of simulated project tests were undertaken with similar results to the above.

4.4 The Effect of Inflation

Utilising the alteration programme "ALTI" it was decided to test the effect of inflation on one of the construction projects investigated. The total value of the uninflated project amounted to £3,090,000 expended over twenty-six months. The profile of the curve required the following constants:

$$\alpha = 2.05446$$
$$\beta = 0.511701$$
$$\gamma = 2.498$$

Figure 15 illustrates the effect on the curve by increasing the inflation rate initially in stages of 5% per annum and later by larger increments up to 100% per annum.

It will be seen that the α shaping constant remains virtually unchanged, however the beta constant becomes proportionately closer to unity as the inflation rate increases. The gamma constant progressively reduces in value from 2.498 to 1.676. This clearly indicates that the peak period expenditure is delayed thereby clearly demonstrating that inflation causes accelerated expenditure, particularly in the later stages of the project.

It therefore follows that projects which include the effects of inflation will have faster expenditure than those unaffected by inflation. Further the higher the inflation rate the faster the rate of expenditure towards the end of the project.

Other tests on data have substantiated these claims and it certainly explains high increases in costs of projects spanning over long periods of time.

Figure 15

Inflation	Total Project Value	Duration	α	β	Gamma γ	Cubic Period
0	3,090,000	26	2.05446	0.511701	2.498	2 - 25
5	3,264,080	26	1.99272	0.528826	2.408	2 - 25
10	3,438,150	26	1.97585	0.541156	2.33	3 - 25
15	3,612,240	26	2.0614	0.542275	2.26	5 - 25
20	3,786,310	26	1.9814	0.565765	2.196	
25	3,960,390	26	2.00936	0.578365	2.14	
35	4,308,550	26	1.98	0.594556	2.042	
50	4,830,790	26	2.1189	0.624	1.924	
100	6,571,580	26	2.112	0.6705	1.676	

4.5 Summary

The conclusion drawn from the above results is that even in cases where the cubic is applicable, the combination of cubic and exponential equations produces a better overall curve fit. In most of the studies undertaken the actual expenditure can be shown to be outside the parameter limits of the cubic,hence negative results will occur causing the curve to be impractical as a forecasting device.

In the light of the above results a means has been established to determine the nature of expenditure curves which permits almost any curve to be modelled with a reasonable degree of curve fit accuracy.

Appendix 3 contains the software programme written to produce these results (namely RAMFI.BAS). Examples of the computer runs used to compile the results in this section are also included.

This development creates a number of important advantages which make the proposed model ideal for universal application not only in the Construction Industry,but across other industries as well. Further possibilities open up with regard to curve determination and the subsequent understanding of the nature of the curve in terms of the constants already described.

4.5.2 Future Applications

A basis has now been established for the determination of project expenditure curves to within 5% of the total project cost, which in turn has increased the potential applicability of this theory. By understanding the precise nature of the project expenditure curve in terms of alpha, beta and gamma constants, together with the switch points, it is possible to measure the effect of management policies and decisions relative to the project. It is also possible to observe the difference in expenditure patterns between groups or categories of project.

As more experience is gathered by utilising this philosophy it will be possible to measure the effect of management decision making more precisely. Alternatively, management policies, decisions and plans can be expressed in the form of a cost centre based expenditure model related directly to the construction programme. Hence, a reciprocal relationship has been established which permits the validation of the decision making hypothesis from two points of view.

Three computer programmes have been written to accommodate these procedures. The programme entitled "SIM1.BAS" (contained in Appendix 7) simulates project expenditure curves by requesting the manager to input non-cumulative period values which are then fitted in accordance with the procedure previously described. The reciprocal programme is "GRF3.ALG" (see Appendix 8) which permits the manager to observe the effect of changes made in the alpha, beta and gamma constants relative to his notion of anticipated project expenditure. At the tendering stage the full implications of project decision making in terms of method determination, resource allocation, risk and profit distribution can be more fully appreciated utilising these programmes. The computer programme "ALT2.BAS" allows the project to be modelled using the theory of cost centres as previously described. Another function of this programme is to permit the project budget to be updated at any time during the actual project duration. This facility has two prime advantages, namely, the ability to amend the budget in order to accommodate changing circumstances, and secondly, the provision of an updated curve fit analysis which establishes the changes relating to the curve fit constants. With experience these constants can be interpreted in terms of cause and effect resulting from management decisions. Reference should be made to Chapter 8 for a detailed explanation of this programme.

It is possible that the curve fit software could be interfaced with the light pen video terminal where the manager can physically draw the curve of project expenditure according to his concept of the project expenditure pattern. The computer programme will then fit the curve and present the user with the relevant constant values and the switch points selected between the polynomial and exponential equations. This process can be repeated in order to iterate a suitable solution.

Another development would be to interface the software with a network based project management package. It is normal practice for these packages to provide activity costs which can be grouped into costs centres according to the requirements of the user. The cost centre expenditure related to a timescale will give an overall project expenditure which can be subject to the curve fit process previously described. Further potential exists at the monitoring stage relating to profitability reports and curve predictions.

Chapter 5

5.1 Forecasting

The term forecasting used in this thesis related to:

a. Budgeting project expenditure prior to commencement.

b. Forecasting predicated completion costs and durations, based on value of work completed to date without or with the addition of user determined final project completion time or cost. The latter form is that used by DHSS and is much easier to handle.

5.2 DHSS and Allied Methods

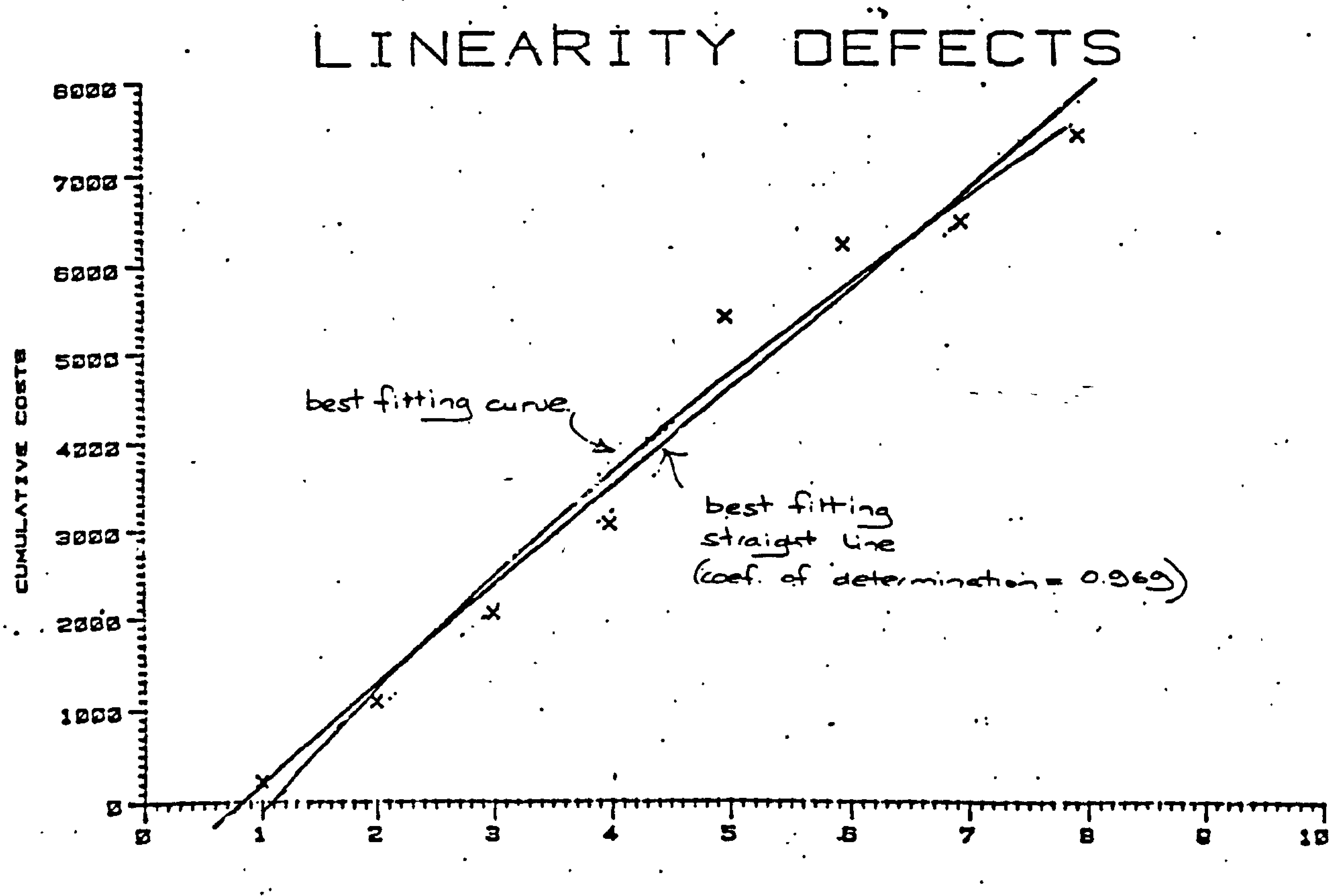
Forecasting is an important and natural development of 's' curve analysis. The DHSS have used their cubic equation as a model for prediction purposes. The stated method was to make estimates of the C and K constants based on the most recently available data in a project (they recommend the last 5 to 7 periods). In order to obtain these constants they smoothed the most recent data by polynomial regression and obtained values of C and K using the last two smoothed data points. DHSS do not quote the accuracy of their forecasts, nor indicate the period from which forecasting may commence, however I regard these points of information as an essential part of forecasting.

In the first attempt at forecasting, the DHSS routine was followed and tests were conducted on the industrial data. The findings were that prediction by this procedure gave unacceptable variable results. The next step was to try other smoothing routines; in particular variants of exponential smoothing. Tests were also carried out incorporating a variety of weighting factors for the data. All these methods failed to give reliable results.

The major reasons for the lack of success of the above approaches was primarily found to be due to two properties of the data, particularly near the commencement of the project.

Inspection showed that the cumulative costs could increase in a nearly linear manner over several periods. The linearity effect was particularly prevalent near the start of a project. Graph (7) typically illustrates this point for the cumulative costs of the first eight weeks of one of our industrial projects. It is important to overcome the linearity problem near the start of a project as it affects the possibility of early forecasts. It is furthermore clear from this condition why the selection of an appropriate smoothed curve is not possible under these circumstances and hence forecasting routines relying on the use of such a curve generated over a few periods cannot give a reliable basis for extrapolation into the future.

The linearity problem lead to the investigation of the possibility of finding constants by variously weighted polynomial regression routines. As these approaches were equally unsuccessful the curve fitting errors (SDY) were investigated over the data points used in the earlier tests for a range of alpha and beta values typically for alpha values between -0.5 and 0.5 and beta values between -7 and 11.


LINEARITY DEFECTS
CUMULATIVE COSTS
PERIODS (BR. DAS MONTHS)
best fitting curve
best fitting straight line (coef. of determination = 0.969)

Graph 7

FAMILY OF ALFA CVS :-BETA VS SDY%

Figure 16

Xp	α -.50	-.45	-.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	β
-2	.	.	.	.	.	/	7	(1.1)	7	/	.	.	.	.	.	.	.	.	.	.	.	-7
-1.75	.	.	.	.	/	/	4.3	2.3	8.5	/	.	.	.	.	.	.	.	.	.	.	.	-6.25
-1.5	.	.	.	/	/	7	1.8	4.2	9.5	/	.	.	.	.	.	.	.	.	.	.	.	-5.5
-1.25	.	.	/	/	8.5	3.7	1.8	5	/	/	.	.	.	.	.	.	.	.	.	.	.	-4.75
-1	.	/	/	8.5	4.4	(1.3)	4.3	3.5	/	/	.	.	.	.	.	.	.	.	.	.	.	-4
-0.75	/	/	7	3.8	(1.5)	3.7	7	/	/	/	.	.	.	.	.	.	.	.	.	.	.	-3.25
-0.5	7	4.5	2.2	2.1	4.3	7	9.5	/	/	/	.	.	.	.	.	.	.	.	.	.	.	-2.5
-0.25	2.1	2.8	4.5	6.5	8.5	/	/	/	/	/	.	.	.	.	.	.	.	.	.	.	.	-1.75
0	7	8.5	9.5	/	/	/	/	/	/	/	.	.	.	.	.	.	.	.	.	.	.	-1
0.25	/	/	/	/	/	/	/	/	/	/	.	.	.	.	.	.	.	.	.	.	.	-0.25
0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.5
0.75	.	.	.	.	.	.	.	.	.	.	.	/	/	/	/	/	/	/	/	/	/	1.25
1	.	.	.	.	.	.	.	.	.	.	.	/	/	/	/	/	/	/	9.5	8.5	7	2
1.25	.	.	.	.	.	.	.	.	.	.	.	/	/	/	/	/	8.5	6.5	4.3	2.6	1.7	2.75
1.5	.	.	.	.	.	.	.	.	.	.	.	/	/	/	9.5	7	4.3	1.9	2	4.4	7	3.5
1.75	.	.	.	.	.	.	.	.	.	.	.	/	/	/	7	3.6	(1.1)	3.7	7	/	/	4.25
2	.	.	.	.	.	.	.	.	.	.	.	/	/	8	4.2	(1)	4.3	8.5	/	/	.	5
2.25	.	.	.	.	.	.	.	.	.	.	.	/	/	6	1.6	3.6	8.5	/	/	.	.	5.75
2.5	.	.	.	.	.	.	.	.	.	.	.	/	9.5	4.2	1.7	7	/	/	.	.	.	6.5
2.75	.	.	.	.	.	.	.	.	.	.	.	/	8	2.2	4.2	/	/	.	.	.	.	7.25
3	.	.	.	.	.	.	.	.	.	.	.	/	7	(0.9)	7	/	.	.	.	.	.	8
3.25	.	.	.	.	.	.	.	.	.	.	.	/	5.5	2.2	9.5	/	.	.	.	.	.	8.75
3.5	.	.	.	.	.	.	.	.	.	.	.	/	4.2	4.2	/	.	.	.	.	.	.	9.5
3.75	.	.	.	.	.	.	.	.	.	.	.	/	2.8	6	/	.	.	.	.	.	.	10.25
4	.	.	.	.	.	.	.	.	.	.	.	/	1.6	8.5	/	.	.	.	.	.	.	11

← negative area non-feasible solutions —— * —— positive area feasible solutions →

NB (1.5) Indicates area of low error.

/ 10% error or more.

. errors exceeding 20%.

A table of these results was formed in which high value errors were suppressed shown in the form of an error map (see a typical case Figure 16) as can be seen from the error map large "islands" of low errors occur which explained the high variablility in forecasting accuracy.

The forecasting procedure aims to minimise the effects of 'linearity' and restrict the region of the 'error map' in which a search is made for appropriate forecasting constants.

5.3 Alpha-Beta Cubic Equation Forecasting

Research into the underlying problem of obtaining viable values for the constants alpha and beta and determining the earliest period from which forecasts can be made is still in progress. However, tests on the most recent routines are proving successful. Present indications are that it should be possible to forecast from about the end of the first quarter of the project with an initial forecasting error of + 15% which is well within the corresponding statistical estimations of + 25% for 90% confidence limits. This error has been found to drop rapidly as the project progresses, which would be expected on statistical grounds. Typically the errors may drop below 10% in the first half of the project providing no extreme changes occur such as policy alterations causing extreme cost fluctuations. Such vagaries would, it should be stressed, totally invalidate predications until sufficient new data is available.

The major feature of the forecasting procedure is to initially find the peak period cost (Zp) as this can be shown to be the least sensitive datum which may be extracted from the known cost information. The earliest point during the project at which the peak period valuation may be determined is the period from which forecasting may commence. Using the peak period valuation, initial values of the constants may be found, these in turn are used to set search limits based on the curve fitting errors they create. The values of alpha and beta which have a minimum SDY error are determined inside the above limits.

The above methodology overcomes the earlier stated objections in that this procedure does allow determination of a period for forecasting commencement, avoids the problem of linearity and reduces the region of the error map in which a search is made for the best values of the alpha-beta equation parameters.

5.4 Predictions Utilising the Exponential Equation

In addition it has been found that extremely good results can be achieved in a number of cases by projecting the predicted expenditure curve from the current known valuation point. This has been achieved by transposing the exponential equation.

See Appendix 2.

To demonstrate the actual performance of the predicted forecast utilising the exponential projection it was decided to utilise the known expenditure patterns of the design and construction projects used to validate the curve fit process.

Since the results obtained early in the project are less significant and produce highly variable results the first analysis was set at third the way through the project time span or alternatively at the fifth month position. The prediction programme "PREDI" was feed with the appropriate valuations corresponding to the original curve together with the expected final valuation on completion. The exponential curve was then projected and the point in time at which the final valuation was achieved denoted the predicted project completion time.

The table shown in Figure 17 shows the relevant data and results together with the variance between the actual and predicated completions.

The construction projects on average were predicted more accurately than the design projects, the two worst cases being - 20% of the actual completion. Three of the seven design projects had highly variable results ranging from -41% to + 64, whilst the remaining four results ranged from -4.16% to + 10%.

A comparison of the percentage of elapsed time to the percentage of total project valuation achieved to date clearly indicated that where these figures were similar the project completion time was accurately predicted. However, large discrepancies resulted in high over or under estimates of the project time.

PROJECT	Known Final Valuation £	Prediction Data		Predicted Completion (Months)	Actual Duration (Months)	VARIANCE as % of actual Duration	% time elapsed to date	% of Total Current Valuation
		Current Valuation	Current Month					
OFF1	2.452,000	867,399	6	17	18	−5.55	33	35.37
FACTORY	3,270,000	1,127,240	6	17	17	0	35	34.47
FLATS	750,000	328,111	5	9	9	0	55	43.70
OFF2	3,050,000	1,008,819	6	18	18	0	33	33.00
WAREHOUSE	1,050,000	495,198	5	12	10	+20	50	47.00
POWER STAT.	37,043,000	9,177,000	8	27	24	+12.5	33	25.00
REFURBISH	1,876,000	365,332	5	20	15	+25	33	19.5
RYE	3,090,000	889,589	9	28	26	+7.7	35	28.8
DESIGN PROJECT								
SHELL	173,465	124,048	20	33	58	−43	34	71.5
B of E	152,171	27,679	5	11	11	0	45	53
SOUTH	82,197	13,596	13	55	39	+41	33	16.5
MIDB	376,169	123,521	16	46	48	−4.16	33	33.8
BRIGAS	154,193	18,496	10	51	31	+64	32	12
LEEDS	76298	22,296	9	28	26	+7.7	35	29
MIDBANK	24,328	7,187	7	22	20	+10	35	29.5

Figure 17 Prediction of Project Duration at 33% Completion or at Month 5

PROJECT	Known Final Valuation £	Prediction Data		Predicted Completion (Months)	Actual Duration (Months)	VARIANCE as % of actual Duration	% time elapsed to date	% of Total Current Valuation
		Current Valuation	Current Month					
OFF1	2.452,000	1,735,595	12	20	18	+11	66	70.8
FACTORY	3,270,000	2,584,691	12	18	17	+5.8	70	79
FLATS	750,000	443,310	6	10	9	+11	66	59
OFF2	3,050,000	2,262,861	12	19	18	+5.5	66	74
WAREHOUSE	1,050,000	658,203	6	11	10	+10	60	62.7
POWER STAT.	37,043,000	24948000	16	27	24	+12.5	66	67.3
REFURBISH	1,876,000	1,360,221	10	17	15	+6	63	72.5
RYE	3,090,000	2,136,491	18	28	26	+7.7	69	69
DESIGN PROJECT								
SHELL	173,465	166,485	40	45	58	-22	69	96*
B of E	152,171	35,273	7	12	11	+9	64	67.6
SOUTH	82,197	31,455	26	68	39	+74	66	38.3*
MIDB	376,169	173,376	32	74	48	+54	66	46*
BRIGAS	154,193		20	38	31	+22	65	51.8*
LEEDS	76298	61,255	17	25	26	+4	55	80.2
MIDBANK	24,328	21,526	14	18	20	-10	70	88

*

Figure 18 Prediction of Project Duration at 66% Completion

The next step was to test the project duration prediction at two-thirds of the project time span and the results obtained are shown in Figure 18.

It can be seen that the construction project results are now considerably better than the design projects having a duration prediction accuracy of between +5.5 and 16%.

Conversely four of the design projects still showed large variations ranging from -22 to +74% which in some cases were worse than previously obtained earlier in the project.

Since eleven out of the fifteen projects under investigation had produced good results at this stage it was decided to analyse in more detail the remaining four projects. Figure 19 summaries the results of the individual design and project analysis.

The Shell project has a protracted completion where small amounts of cash are expended from month thirty-five onwards. The exponential curve is incapable of predicting such a small tale-off of expenditure and hence the predicted project time is below actual project completion, even at 99% completion.

The South project expenditure was slow at the beginning and in the mid span consequently the predictions made during these periods indicated completion times well in excess of the actual completion time. Expenditure was high during the last five months of the project and the last

Figure 19

Predicted Completions of Projects at Months Indicated

Project	Final Valuation	Current		Predicted Completion	Actual Completion
		Valuation	Month		
British Gas	154,193	18,496	10	51	31
		95,319	20	38	
		132,344	25	34	
Shell	173,465	124,048	20	33	58
		166,485	40	45	
		169,571	45	48	
		172,022	50	52	
Middlesbrough	376,169	123,521	16	46	48
		173,376	32	74	
		324,206	40	54	
South	82,197	13,596	13	55	39
		31,455	26	74	
		50,712	33	62	
		77,384	38	45	

months expenditure was particularly high. Hence, the predictions up until the very last month were indicating project completion much later than the actual completion.

Both British Gas and Middlesbrough had slow expenditure at the beginning followed by rapid spending near to the completion. Further, the general trend of expenditure was interspersed with limited periods of slow and rapid spending. The duration predictions during the early stages indicated much longer periods to completion than actually occurred. This assessment was considered to be quite reasonable, since if the expenditure rate did not increase, then the completion would be protracted. The rapid expenditure at the very end of the projects had precisely the converse effect to that observed in respect of the Shell project. In other words, the predicted completions became more accurate with the imminent completion of the projects, but the degree of accuracy did not improve to minimal proportions until the very last month.

The mathematical development of the prediction system is shown on page 4 of Appendix 2.

Summary

It is concluded that the exponential projection of existing project expenditure from the current date can produce reliable predictions given the following circumstances. The predicted completion time for the construction projects at 66% of elapsed project time, as depicted by Figure 18, showed a mean error of 8.69% when compared with the eventually known completions. The projections have been made on the basis of the known peak period cost to date, which enables the transposed equation shown below to calculate the curve projection, period by period, until the final anticipated expenditure is reached:

$$Cm = Sk\ (1 - e^{-m^2/2M^2p})$$

When the final expenditure is reached the predicted project completion date is established. The percentage error achieved represents a significant development, since the projection is made solely on the analysis of the actual valuation of work completed to date and does not rely on intuitive judgements normally made by management staff.

The predicted completion error associated with the design projects was considerably worse than the construction projects. After further investigation this situation was explained by a number of relevant factors, the most significant being the value of k used in the Rayleigh Diffusion equation.

The value used in both the construction and the design cases was 1.05. This was derived from the data produced by the DHSS during their survey of 700 plus hospital projects. Indications are that a lower value of k will improve the design project predictions. Further, the design projects by their nature displayed larger expenditure curve irregularities which naturally increased the variability of the results.

It is intended to use this work to form the basis of a prediction sub-system which will use the stored cost data base. This information combined with a management input of end costs and durations, will give the user alternative project predictions. This sub-system feature will permit the manager to select the minimum amount of necessary information to enable him to model viable future project time and cost to within known statistical accuracy. There is also scope for predicting tender sums, particularly where projections can be made knowing the nature of the project curves in terms of the constants described. By anticipating the duration, the cost of the project can be predicted within known limits of accuracy. Visa versa, knowing the project cost, the completion date can be determined. Other applications relate to risk analysis and bidding strategy.

It is concluded that a viable means has been achieved in order to produce curves which can be applied to a wide range of project expenditure patterns far in excess of those possible by the utilisation of a transposed cubic equation. It is foreseen that the application of the curve fit and prediction philosophy proposed can be relevant to both the tendering and construction stages. Further potential exists in terms of the design and the total project process. The proof and means of successfully utilising these principles will be dealt with in the following chapters.

Chapter 6

6. CASE STUDIES

6.1. Introduction

Before considering the development of the applications systems necessary to implement the research previously described, I considered it essential to undertake a fact finding study of the Construction Industry in order to appreciate more fully the problems and needs of designers and contractors in general terms. More specifically, the study was also intended to indicate the design and constructors attitude towards financial matters and their awareness of the importance of financial control procedures.

Any investigation related to the Construction Industry must contend with its diverse nature, both in terms of professional structure and type of work; a further difficulty relates to ideal circumstances observed in one situation which was likely to be completely inappropriate in another. The first step was to identify the contracting methods and their various main characteristics in order that a valid selection of in depth case studies could be made. After a careful analysis involving statistics and publications produced by the government and professional institutions the matrix shown in Figure 20 was produced. Traditional procedures involving total contract tenders and nominations represented 90% of the total with specialist procedures, i.e. joint ventures, package deals being in the minority. However, two significant aspects became apparent during the study which related to the growth of the less conventional methods of contracting. The first was the apparent realisation by some clients that the traditional system did not, in many cases, offer the most efficient way of designing and constructing buildings, and secondly, the improving professional status of the contractor which appeared to support the contractors role as developer and producer.

6.2 Number and Range of Studies

It was decided that a limited number of in depth case studies of construction design and production would be undertaken to establish current modes of operation and to determine the needs in each instance relative to the objectives of the research. The selection of studies was intended to give a reasonable cross section of all the main alteratives and methods existing in the contracting sphere. The two categories under scrutiny (traditional and non-traditional) appeared to breakdown into types of organisations relative to the size and nature of the built structures involved and the design/build procedures utilised.

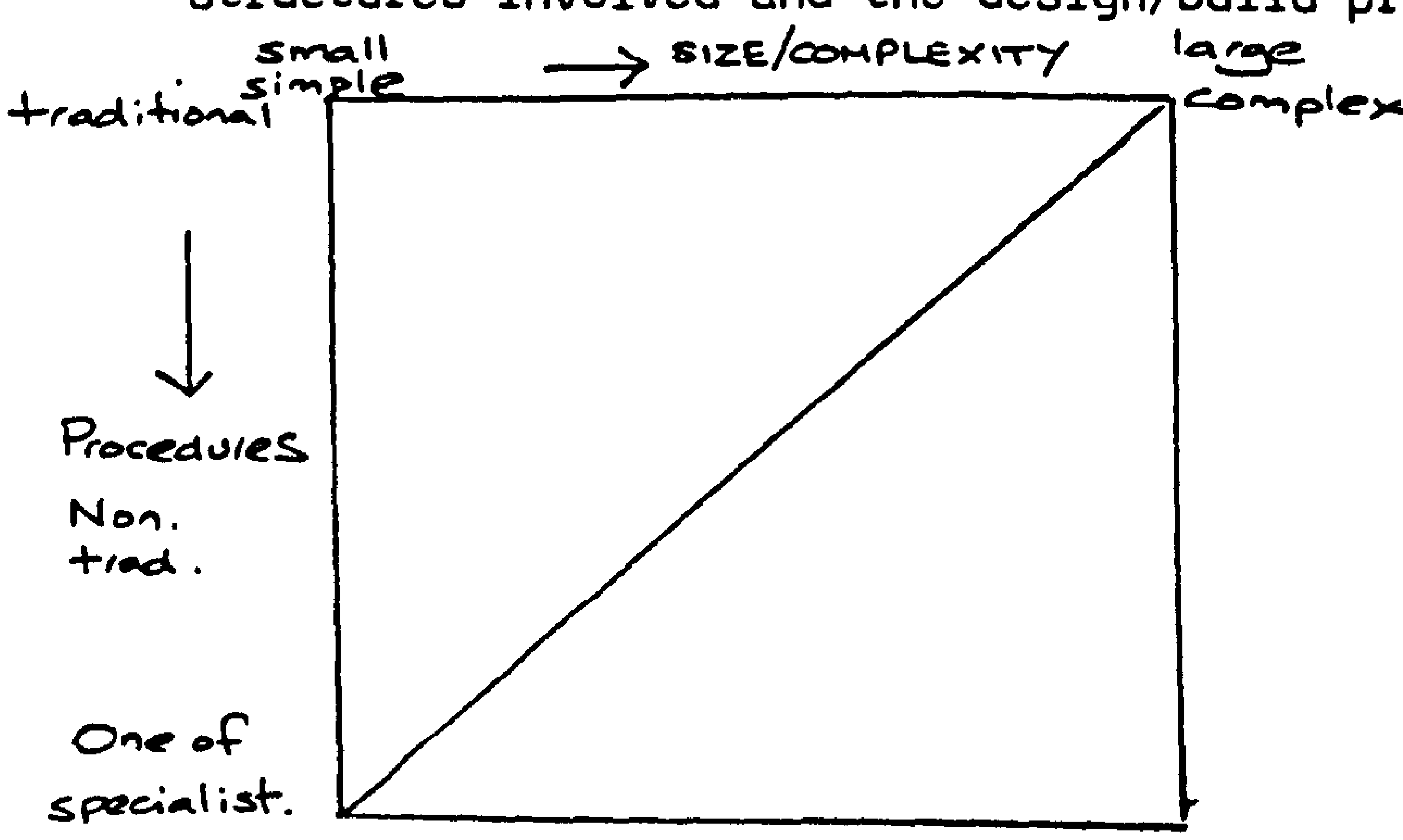


Figure 20

Project Procedure/Size Complexity of Project

A total of ten projects were considered necessary to update my knowledge and experience in order to give a broad spectrum of needs. Unfortunately one project was withdrawn due to managerial difficulties unrelated to the investigation which occurred prior to the termination of the study. The remaining nine projects were selected to fit as near as possible to the cross section line shown in Figure 20 in order to give as representative a spread as possible. Since a true statistical representation of the industry would have involved a whole major research programme in itself, it was decided to base the survey on a qualitative nature moderated by the experience of the author and his advisors. The reasoning in this case being that broad areas of need could be established beyond any reasonable doubt and that support would be given to the viability of the research and development to be implemented in the area selected. Further, the main energy of the research could be devoted to the development of an appropriate system of project monitoring and forecasting.

In addition to the sites studied due regard was given to the organisations involved with the design and construction of the projects. It was generally deduced that the larger and more complex the project, the more likely that non traditional methods would be used to manage and adminster the project. The smaller projects were almost entirely run on a completely traditional basis using private architectural practices and small building contractors.

6.3 In order to report the findings of the case studies the projects and organisations have been grouped under the following headings:

(1) Large Complex Projects

(2) Medium

(3) Small Simple Projects

(4) Organisations

6.4 (1) <u>Large Complex Schemes</u>

Three studies were made in this area and the projects selected were intended to contrast in building type and style of management. The table below sets out the main characteristics of each case:

Case	Type	Construction	Organisation	Size values 1979 prices
A	Public Health Lab.	traditional	Project Manager based	£10m +
B	Scientific Lab. Oxford Univ.	traditional	traditional private practice professions Tendering Contractors	£3.2m
C	Commercial Warehouse Factory and Offices	traditional/ system	Design and Build Contractor	£7.5m

The basic system of design and build was evident in each case and it can therefore be stated that no evidence was found to suggest that the procedure of work as laid down by the RIBA plan of work is theoretically incorrect although it is recognised that a single plan cannot represent precisely all types and sizes of project.

6.4.1 Case A

By far the largest project was the new public health laboratory and this building by virtue of its complexity required a high standard of management and control to achieve acceptable efficiency. The study was conducted at the design stage and it was very evident that the co-ordination of the design team and the user groups were of paramount importance. A project manager had been appointed well after the design had commenced, due primarily to failure of the previous management control system. A new control system had been devised and was implemented approximately one third the way through the design process. An equally important aspect was that of financial control of the design process and the design itself. Detailed analysis of design costing was left almost entirely to the professional quantity surveyor, although the project manager retained executive control of the decision making process. There was a noticeable lack of scientific management control and most of the policy making and co-ordination took place through ad hoc meetings between all concerned.

The DHSS had produced an extremely comprehensive management procedure known as the "CAPRI CODE" which was referred to in essence, but was not used in detail due to inflexibility of some procedures stated. A project programme had been produced but this was of poor quality and did not reflect the true nature of the work. An attempt was being made to budget design cost on the part of the project manager using cash constraint imposed by the client and to some degree this was proving successful; two major savings had been made by altering the design to eliminate unnecessary and costly architectural features. The afore aspect clearly illustrated the advantage of having a project manager capable of catering for the client's interests without being involved aesthetically with the design and its detailed problems.

The new organisation structure shown in Figure 21 was logical and appeared to have a clear constitution and strong lines of communication. The prime disadvantage with the structure seemed to be the number of meetings which were necessary to make the system work effectively. In essence, this problem was unavoidable due to the number of separate bodies, practices and individuals involved.

The latter stages of the design were much better organised and greater efficiency was apparent in almost every respect. Although much depends on the individual, the importance of a central co-ordinating executive is of paramount importance to a project of this nature. It was genuinely felt that a greater employment of scientific forecasting and management procedures could have significantly contributed to the efficiency of the processes used.

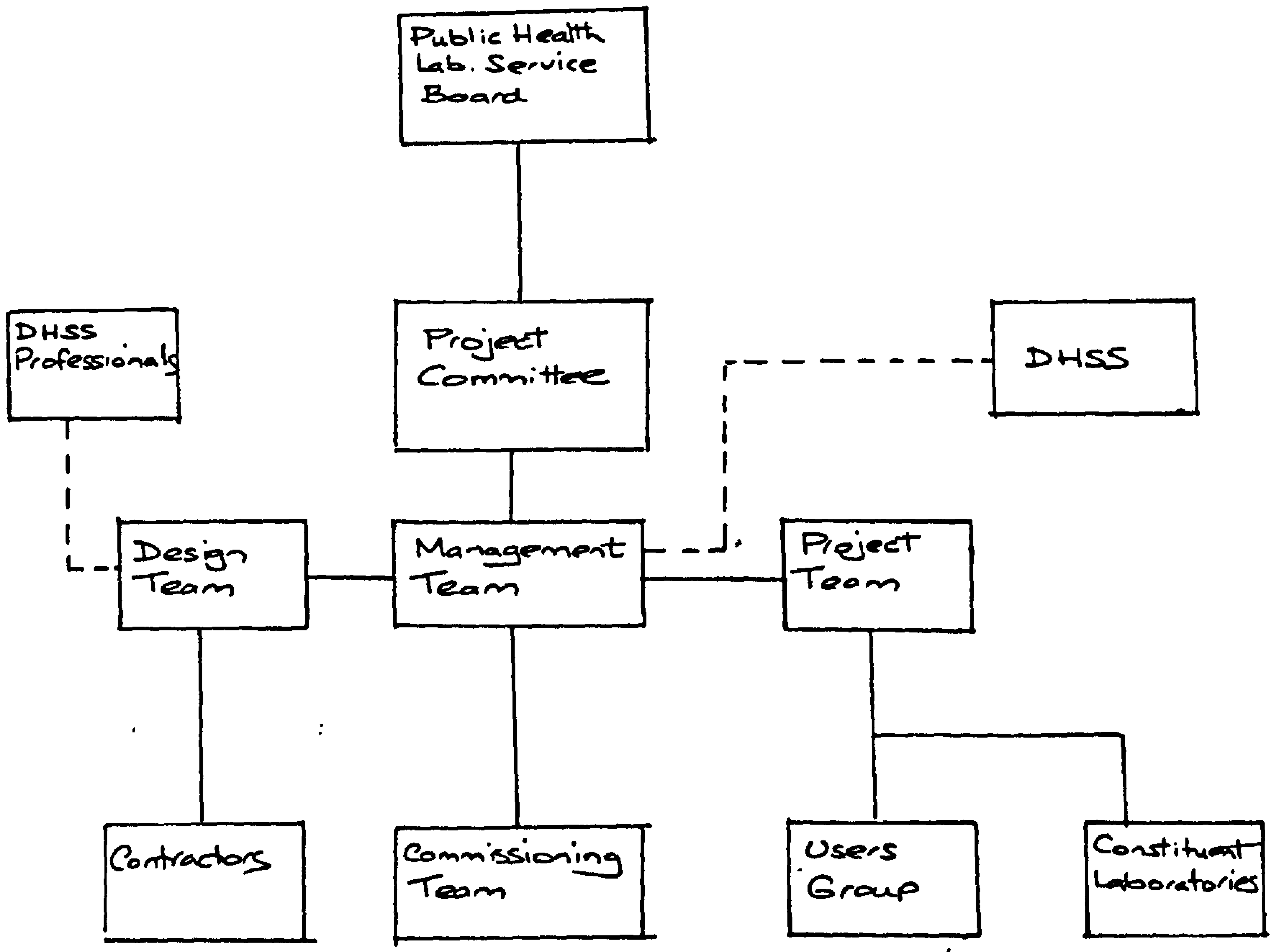


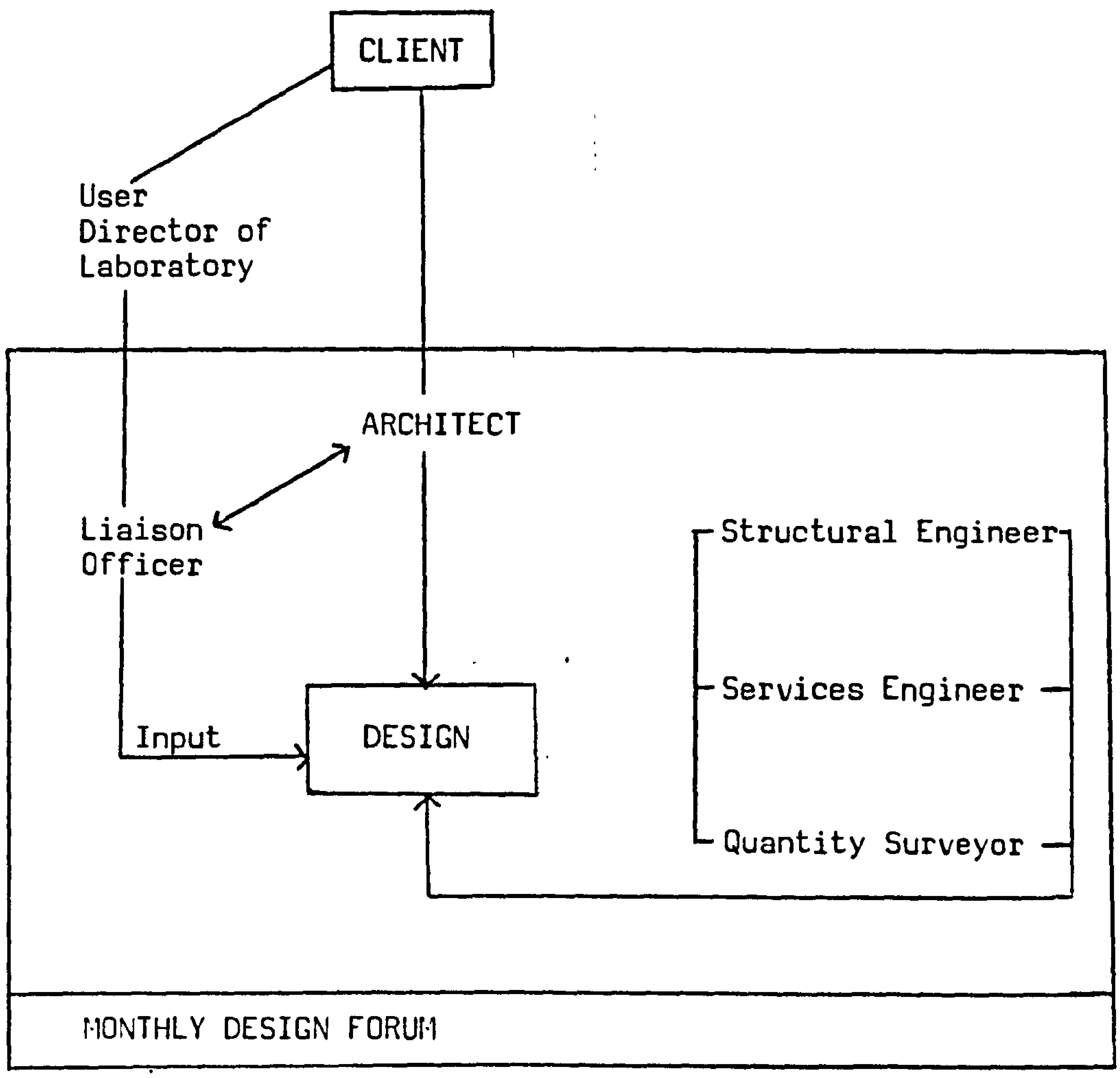
Figure 21 Project Structure Case A

6.4.2 Case B

The scientific laboratory at Oxford University was a traditional building of exceptional aesthetic quality due to its location and the design ability of the Architect. This building was observed at both the design and construction stages. Complete control of the project was being exercised by a small private architectural practice on behalf of the client. The design was evolved and controlled by a team, lead by the architect, consisting of a number of independent design practices and a firm of pressional quantity surveyors. (See Figure 22a Design Organisation Structure)

Co-ordination between the design team proved to be difficult due to the geographical location of the practices which in one case meant a journey of thirty miles to attend a meeting. However, periodic meetings were arranged and these were supplemented by the telephone. A tremendous help to the co-ordination was the use of plan data sheets. Each specialist designer produced a prior build up of his individual requirements which were then overlaid to produce a final integrated result. The architect admitted that this system was slow, but it did work well and achieved the objective of good integration. The design had progressed much slower than anticipated and the project was several months behind programme. Ultimately it was hoped that major benefits would be derived from a reduced number of queries and anomolies resulting from the drawings and documentation produced.

Figure 22a


CLIENT
User
Director of
Laboratory
ARCHITECT
Liaison
Officer
Structural Engineer
Services Engineer
Input
DESIGN
Quantity Surveyor
MONTHLY DESIGN FORUM

The obvious conclusion to be drawn was that the design of this project had been very professionally undertaken, but difficulties of a geographic nature had slowed the work considerably. The alternative would have been to progress the work at a faster rate, but this would inevitably have forced the design team into errors. There was no evidence of procedures to budget the costs involved in producing the design and apart from an outline bar chart no formal planning and monitoring processes were evident.

The tendering process was completed efficiently and the successful builder was selected from a total of nine contractors. It is worth noting that there was a very close spread of tender prices which could be attributed to the fullness of information provided,thereby reducing the number of contractor risk items to be priced.

The subcontractor works were completed during the period of study and it was significant that the works progressed relatively smoothly without problems occurring through design anomolies. The contractor appointed conducted his work on a national basis and was well known to all in the industry.

Control of the project was taking place through regular production meetings and the progress of the project was being marked up on a bar chart. There was no other method of planning in existance which indicated how much reliance was being placed on the experience and personal ability of the site manager to fill in the gaps and make the correct decisions. On detailed inspection of the contract programme it revealed that the rate of production envisaged was relatively slow and there were many instances where services subcontractors could have been programmed to start earlier. For example, carcussing work could have began in the basement once the formwork to the ground floor slab had been cured and struck.

There was no evidence that the contractor had produced a budget for the construction work and apart from the normal monthly reconciliations there appeared to be no other financial data to assist management control. Work on site was being executed through a work force consisting of mainly labour only subcontractors who were dependent on the main contractor for instructions, co-ordinating and the supply of materials.

At the termination of the study the project had only suffered minor delays and in general work was progressing satisfactorily. No information was available regarding the profitability of the construction work.

This case study indicated that given a capable architectural practice a professional approach to the design process was possible but the speed with which it could take place was severely restricted unless special arrangements were made. Another factor was that correct and full design documentation contributed to the smooth running of the construction process.

6.4.3 Case C

The third project in this category was an office factory and warehouse complex for a major book publishing company in Cambridge. The contract was worth £7.5m and the project was scheduled for completion in 2½ years. The period of investigation covered three months during the middle of the construction time span.

Unlike the previous case studies this project was based on a design and build contract where the contractor undertook full responsibility for all matters from inception including the complete design of the building and its ancillary services.

An investigation of past records indicated that the design had progressed smoothly and to programme. This was achieved by utilising a design group employed directly by the contractor. The group consisted of architects, engineers and surveyors who worked under the same roof to produce a fully integrated design.

The most impressive aspect of this study was the speed with which the design was carried out. By eliminating the time consuming tendering process the client gained approximately 2½ months on the overall project time. However, it must be stated that this building was less complex than the buildings in the two previous studies and it would have been significant to study a laboratory utilising design and build contractural procedures. Unfortunately no projects of this nature could be found which must be considered as

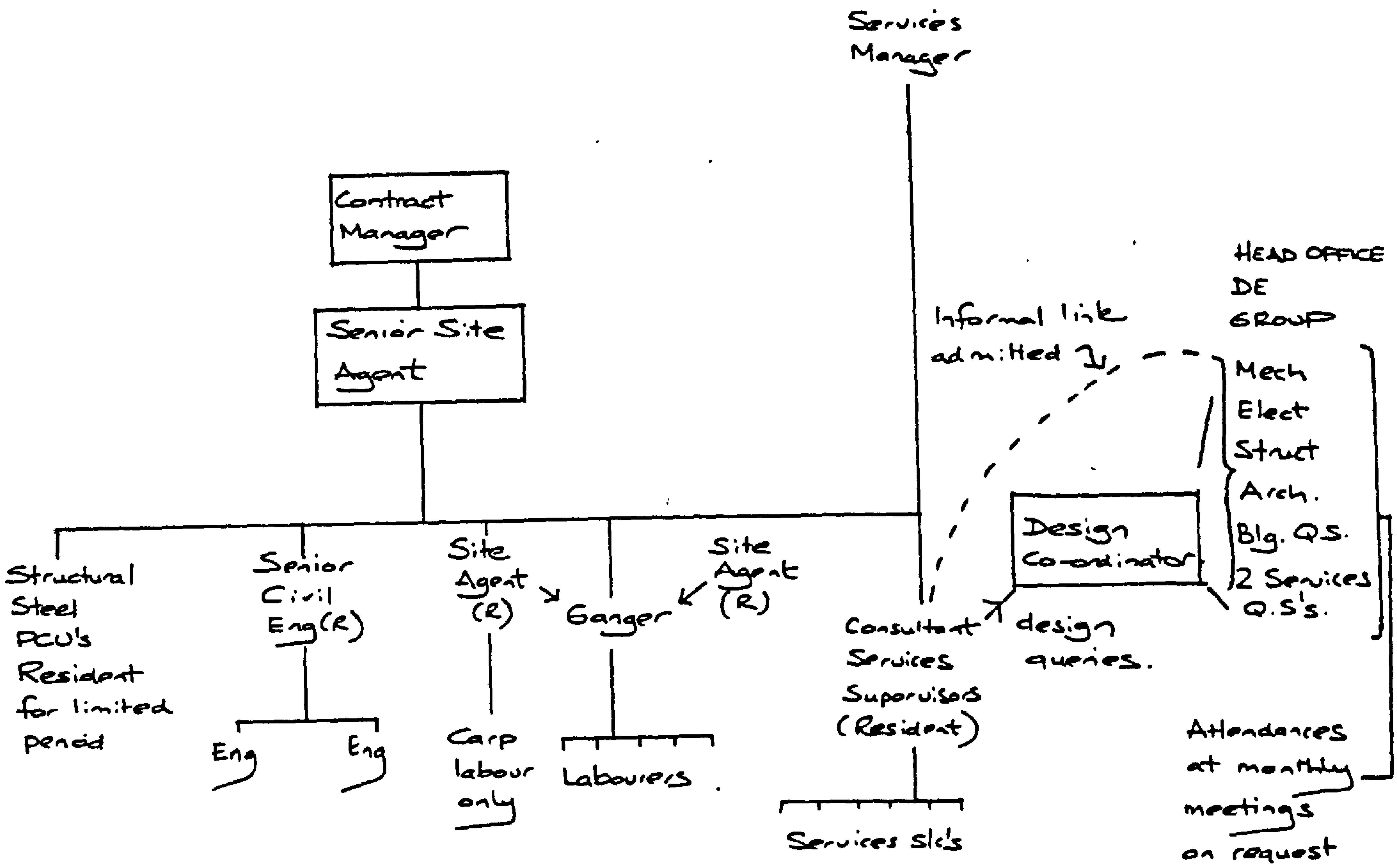

Services Manager
Contract Manager
Senior Site Agent
HEAD OFFICE DE GROUP
Informal link admitted
Mech
Elect
Struct
Arch.
Blg. Q.S.
2 Services Q.S's.
Design Co-ordinator
Structural Steel PCU's Resident for limited period
Senior Civil Eng (R)
Eng
Eng
Site Agent (R)
Carp labour only
Ganger
Labourers
Site Agent (R)
Consultant Services Supervisors (Resident)
Services S/c's
design queries.
Attendances at monthly meetings on request

Figure 22c

highly significant regarding viability and the particular expertise necessary.

The management structure adopted for this project was specifically geared to take advantage of the design and build situation and a high degree of importance was attached to co-ordination and liaison between the construction management team and the design group back at head office. See Figure 22c. Particular importance was attached to the co-ordination of services design and subcontractors. The general administration and control of the site was achieved through monthly production meetings interspersed with ad hoc meetings to solve particular problems and situations as necessary. There was clear evidence that planning was being used as a central theme for management control. The overall bar chart for the contract was produced from a network programme which had been processed manually. The more detailed stage programmes used for project control covered a period of 2½ months and were updated monthly. Both the senior agent and the consultant services supervisor kept a detailed update of weekly progress.

Strict financial control was kept manually utilising a valuation system based on the project estimate, together with information from the project costing system. Normally a reconciliation was carried out once per month on a manual basis. Cost centre breakdown was available but the manual process required considerably more effort. It was surprising that no effort had been made to introduce computerised control procedures. This project was by far the most efficiently run of all those observed, however scope for improvement of financial and management control was very evident.

6.5 (2) Medium Sized Schemes

Three case studies were undertaken in this category in order that a dual comparison can be made between similar and differing sized projects. The table below sets out the main characteristics of each study:

Case	Type	Construction	Organisation	Size values 1979 prices
D	Office and Commercial Centre. Multi-story car park	traditional	traditional private practice professions Tendering contractors Non-executive co-ordinating Project Manager	£2.45m
E	New Inspection and Testing Building and Warehouse	traditional/ system framework	Design and Build	£2m
F	Rehabilitation of Existing Offices	traditional	Design and Build	£1.88m

6.5.1 Case D

The Office and Commercial Centre was the result of a joint venture between a private client and the local Borough Council. The design was seriously protracted due to Town and Country Planning objections which required several alterations to the basic structure. The traditional tendering procedure was not instituted until 2½ years after the inception of the project and construction work did not commence for a further nine months. The design was based on cost targets set by the quantity surveyor incorporating an allowance for inflation. Throughout the design period month by month meetings were held between the members of the design team in an attempt to ensure adequate co-ordination and communication.

No formal project programme was produced to monitor and control the design process and there appeared to have been a general lack in establishing firm target milestone achievement dates. A verbal agreement to establish tentative target dates took place at the monthly planning meetings. It appeared from records inspected that co-ordination and communication between the design professions deteriorated as the project design progressed. Weak control by the architect only added to this problem.

Control on site by the main contractor was observed to be very poor. Virtually no planning was evident on site apart from an outline bar chart which defined the main activities within the constraints of the start and completion dates. The project progress became extremely slow and this situation was aggreviated by numerous design problems which had not been properly thought out, or alternatively, insufficient co-ordination had taken place. There appeared to be no costing or financial control outside of the normal monthly valuations.

Approximately six months after the commencement of the project a member of the professional quantity surveyor's staff realised that a co-ordination problem existed concerning the project and volunteered his services as a project co-ordinator. His prime function was said to be that of integrating the design team and developing proper liaison and co-operation from the contracting side. A principal objective was to avoid disparity caused by lack of communication. After just one month the project co-ordinator was given the title of project manager even though he was to have no executive responsibility. Numerous changes were made by the client resulting in the issue of variation orders.

The main contractors inability to cope with design problems and changes, together with the failure of the site staff to cope with the management and administration of the project caused even further disruption and delay. There was clear evidence that the design professions involved were not acting as a team and it was apparent in a number of instances that attempts were being made to apportion blame for mistakes from one to the other. In certain instances "trench warfare" was the order of the day.

Unfortunately this project, in the author's experience, had the symptoms displayed by so many projects in the United Kingdom that go seriously wrong. The amalgamation of events which took place were caused by numerous problems and simply bad luck. However, there can be little doubt that the project lacked strong professional leadership which could have overcome many of the problems encountered. There appeared to be a stage where the project had reeled and staggered for so long that the way had been lost and to all intends and purposes it was beyond recovery.

No evidence was apparent of a serious attempt to programme and control the design progress and cost at both the design and construction stages. This was further aggravated by the contractors inability to manage the project efficiently in the light of the circumstances encountered.

6.5.2 Cases E and F

The new train inspection and testing building at Birmingham and the rehabilitation project in London, although completely different in construction, were managed in a very similar manner by the same company, and therefore these will be dealt with together.

In both instances, the client had approached the contractor direct regarding the design and construction of the buildings on a package deal basis. In the United Kingdom the client normally turns to the architect first and it is significant that the goodwill and reputation of the contractor to provide a complete service had broken this tradition. It is worth noting that the two sites under consideration were of a completely different nature, requiring an entirely different design and site management situation. The rehabilitation project involved the complete refurbishment of a three storey masonry building including restructing of openings, insertion of new division walls and installation of new services. In contrast, the inspection and testing building was traditionally

PAGE

NUMBERING

AS ORIGINAL

The contrast apparent between this section and the previous sections relates to the degree of sophistication both in design and construction management.

Details of the design were contained on relatively few drawings and in the case of the supermarket and the oast house no bills of quantity were produced by the client. The tendering contractors were required to take off their own quantities for estimating purposes, using the specification and drawings provided. In all three projects design details were provided, but these did not cover every part of the project and a great deal of reliance was placed on the resolution of these on site with the contractor once the work had reached that stage.

In a significant number of cases changes in the detailed design resulted in variation orders being issued by the architect, thereby incurring extra costs. No evidence was apparent of any formal planning of the design effort apart from the determination of tentative completion dates for the various sections.

In all cases the management on site consisted of a general foreman/agent being supported by a contract manager and surveyor based at head office who visited the site on average twice a week.

All the labour on site was subcontracted. The traditional building trades were sublet to labour only gangs known to provide a satisfactory service and more specialist subcontractors provided a complete service. In general the services and roofing contractors were nominated by the architect.

No formal planning took place on any of the projects and apart from contracted completion dates no other time targets were set. The progress of the projects were largely determined by the availability of resources and the construction sequence. Ample evidence was observed of delays caused by the late or incorrect ordering of materials, and a lack of co-ordination with subcontractors was also evident. Mistakes requiring work to be pulled down was seen on all the projects and these could almost entirely be attributed to poor site management.

Monthly valuations were carried out, but no attempt was made in any of the projects to establish budgets against which costs could be measured. The profitability of the projects could only be checked by historical accounting procedures after the contract completion dates. Hence no financial control existed on these sites whatsoever apart from informal assessments made by the surveyor and general foreman.

The site supervision by the architect was spasmodic and generally occurred on an ad hoc basis as the situation of the contracts demanded problems or queries to be solved.

All these projects were behind programme ranging from two to three months, primarily due to avoidable mistakes and errors.

In conclusion it can be stated that these projects represent an area of the construction industry where vast gains in efficiency could be achieved through improved design and management control. It is surprising that this scale of building work has not been priced out of the market, since it is clear that with more efficient methods and procedures vast improvements could be made in productivity. There seemed to be a general lack of management ability on the part of all contractors observed to implement anything more complicated than basic day to day administration. This state of affairs had resulted in a lack of forward planning which anticipated future pitfalls and problems.

6.7 Organisations

The studies so far have identified the traditional method of designing buildings using independent practices who collaborate with each other to achieve individual project designs. In contrast it was considered beneficial to cover the structure and operation of a large multi-disciplinary design partnership to establish current procedures and the potential for the application of the research proposals. In addition it was decided to investigate the operational characteristics of a company offering a complete design and build service which could be compared with the traditional contracting companies contained in the survey.

6.8 CASE STUDY - DESIGN PARTNERSHIP

The "design partnership" investigated was one of the largest organisations of its type in the United Kingdom employing a total of 650 professional, technical and clerical staff. The "partnership's" operations were conducted through six regional offices both at national and international level. Overall management of the enterprise was achieved through thirty-four partners who met regularly every three months to discuss the overall policy and strategy of the business. The more detailed running and control was achieved through Management Groups whose prime areas of concern were strategic planning in terms of:

Development
Communication
Professional and Technical Activities
Welfare
Central Services, i.e. legal, property, personal cost

The six offices were divided into two resource groups formed to achieve the best utilisation of professional and technical staff. The management of the organisation at this level was achieved by a committee of senior staff who reported back to the Management Group. Each project had appointed a team leader based at one of the regional offices, whose prime responsibility was the control and co-ordination of professional and technical staff, together with the management of the contractor and liaison with the client. A sub partner was also appointed to oversee the whole operation including links with the contractor and client at a higher level.

Under each team leader was a multi-disciplinary design team consisting of architect civil/structural engineers, HVAC engineers and quantity surveyors.

It could be seen that line relationships existed through to the management group in respect of each discipline, but at the same time relationships also existed within the project design teams, thus establishing a matrix organisation structure.

Comment

Clearly the advantages of co-ordination and communication created by multi-disciplinary design group work were highly significant in terms of the quality and efficiency of the design. A further advantage appeared to be the fact that everybody worked for the same organisation and was therefore influenced by the overall policy and objectives set by the enterprise. Although the "partnership" totalled 650 staff, all specialisms were not covered and in some cases it was necessary to seek outside assistance from consultants. This factor clearly illustrated the prime disadvantage of design partnerships which lies in the span of expertise available. Because of its size, the "partnership" was able to cover a considerable range of design expertise. It was recognised that the smaller design partnership could find it prudent to call on outside expert assistance, alternatively it would make do with the internal design staff available. The prime danger with this latter course of action was the possibility of poor or inefficient design in all aspects. A senior member of the "partnership" considered in this study, suggested that thirty professional design staff from the various disciplines should be considered as an absolute minimum.

Contractual Aspects

The "design partnership" operated precisely the same contractual arrangements between the client and contractors as those used for traditional design groups. The use of nominations, or alternatively, the award of the whole project to a main contractor were quite normal. Where required the partnership might consider it in the clients' interest that a management contractor be appointed to supervise the whole execution of the work.

In accordance with modern trends in construction management the "partnership" had completed a limited number of large projects using a project manager to co-ordinate the design and construction aspects.

The Co-ordination and Integration of M & E Services in the Building Design Process

The "partnership" clearly defined the fact that the responsibility for ensuring that services were properly related to each other and to the fabric and structure of a building lay firmly with the architect and with no one else. (This statement clearly demonstrates that the role of the "project manager" is that of a co-ordinator without any executive responsibility).

The "design partnership" further maintained that under normal circumstances the architect alone was paid to perform the co-ordination role and he should therefore discharge this responsibility to the full. It was felt that engineers in individual disciplines, no matter how brilliant, could not achieve this on their own and it is in their interest, economically and technically, that the architect should fully discharge the co-ordination role and no part should be usurped by choice or default.

Notwithstanding the previous comments it was possible that where heavily serviced and complex projects were commenced it was conceivable that the architect could be overwhelmed by the scale of the problem.

Complex arrangements of ducts, piping and trunking represented an engineers world into which the average architect will not venture, and the average engineer would only be concerned with his own part of the services. The partnership did not change its ground because of the above situation and maintained that the architect should not pass on the responsibility because the problem had become bigger.

The recommendations of the "partnership" were categorised as follows:

1. On all large projects, an architect should be nominated as being responsible for all matters concerning the co-ordination of services in the building. He would chair regular meetings of the job engineers and be a liaison for all engineers and other members of the

architectural team. In a small job this role would inevitably be performed by the job architect but in the large complex projects, it must be someone else because for certain periods of time it required a full-time commitment. It also requires continuity of thinking as embodied in a systematic checking procedure. On the large complex project, the job architect could never give the matter adequate attention.

2. On really complex projects, a co-ordination engineer should be appointed in addition to assist the 'services co-ordination architect' in arbitrating on the rival claims of the individual engineers and on the technical issues arising from the relationship between services and questions of sequence of installation. An engineer in such a role was helping the architect to do his job more professionally and in the partnership this should be paid for out of the architect's fee.

   The "partnership" emphasised that irrespective of the engineering nature of a component, the nature, appearance and positioning of any services terminal point was a part of the total architecture of a room and therefore should be recognised as being in the domain of the architect.

Co-ordination Drawings

It appeared that the "partnership" did not generally use services co-ordination drawings, and some doubt was expressed regarding the inability of their future use. However, it was recommended that co-ordination drawings should only be used where the situation warranted their utilisation. Conceivably this might have only occurred at one location in a whole project. Where critical situations such as this occurred they should be highlighted, investigated and recorded by a sketch detail.

In accordance with the afore philosophy the architect was responsible for the tasks performed by the engineers assisting in these investigations. The consulting engineers laid the specific responsibility for ensuring that subcontractors with design responsibility were made aware of critical co-ordination situations and of the assumptions made by the architect and engineer at earlier design stages.

The final stage in the design process was to ensure, in checking the nominated subcontractors drawings, that these critical situations had been properly taken care of and that nothing had changed elsewhere which could alter these circumstances.

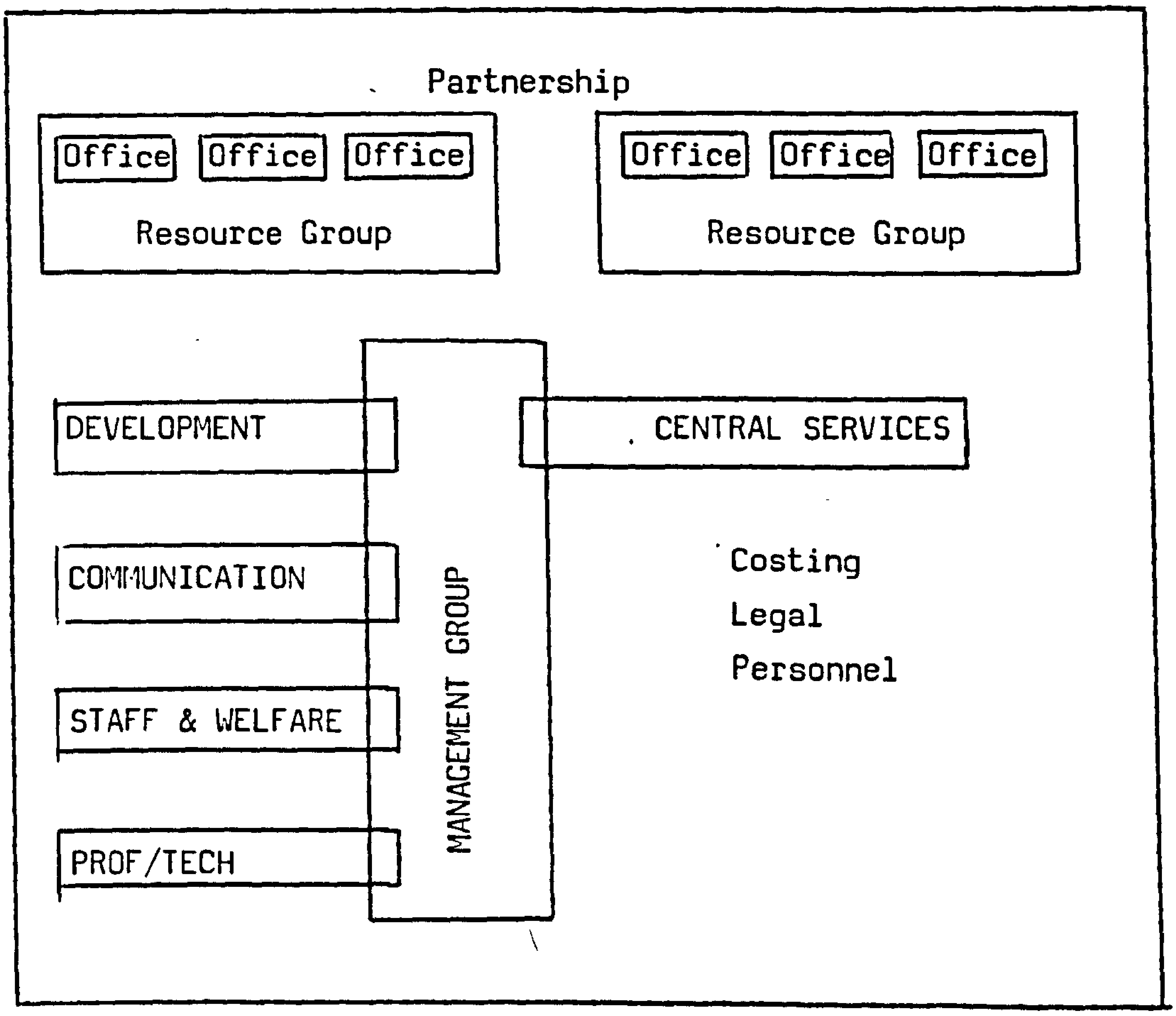
Figure 23

650 staff 34 partners

No Head Office

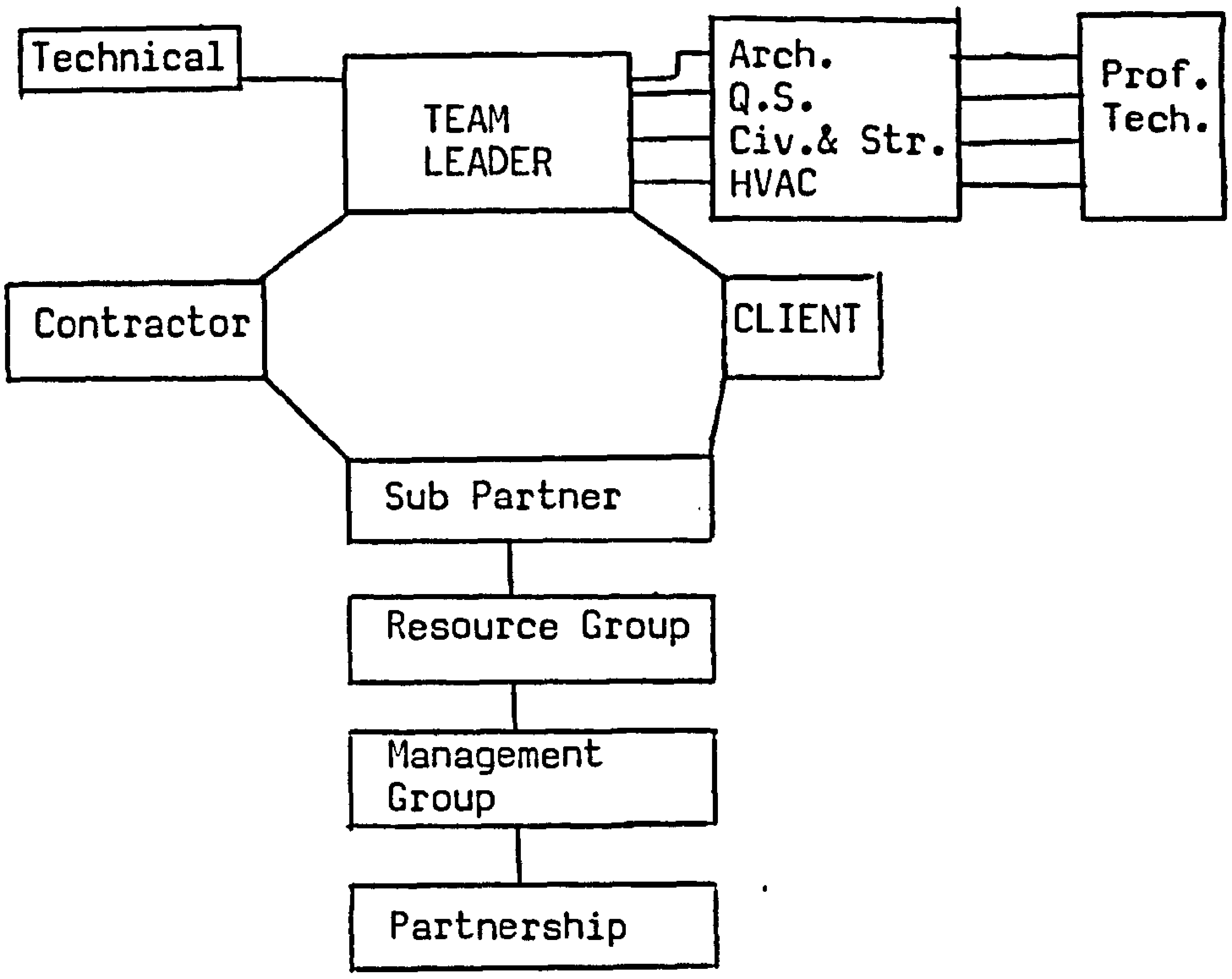
Each branch office has federal autonomy

Elected management group and partners responsible for the running of the practice.



Minimum 30 designers practical for design partnership

Figure 24



Partners meet once every three months
(34 partners)

Prod. Job margin summary
History Future
Professional Hours Summary

Forecast monthly to check target variations and trend programmes.

Costs

Totalled

Financial Control

The "partnership" had developed a comprehensive design costing system based on hours utilised by each profession. The data collected from time sheets was keyed into a computer terminal and monthly costs were given relative to each project and profession. This system enabled the management of the partnership to assess expenditure in relation to anticipated fee income. Unfortunately no means existed whereby a reasonably accurate budget was produced against which could be measured progress to date and the associated cost involved. This facility was recognised as important but at that time no means had been developed whereby a reliable budget assessment could be made.

No evidence was seen relating to advanced project control. This was particularly surprising since the partnership owned and operated a computer which was capable of running a computerised networking system. One can only assume that the necessary expertise required to operate such a system did not exist.

In conclusion it can be stated that the degree of co-ordination and integration between the design professions was first class and that some of the shortfalls identified earlier in the document had been overcome. However, the gap between design and construction still existed and little or no attempt was made to bring the contractor in at the design stage to improve the buildability of the design. Another important factor related to the inability of the partnership to forecast its own costs relative to the projects which it undertook.

6.9 COMPANY CASE STUDY

The Company was formed in the United Kingdom over twenty years ago. It was a unique organisation when it was formed due to the service provided to clients which fully integrated the disciplines of design and construction and accepted total contractual and financial responsibility at every stage. Over the years the process had been constantly updated to keep pace with modern day technology and meet the continually changing needs of industry and commerce. At the time of the study the company consisted of a combination of a highly professional consultancy group and an effective contracting organisation, providing from its own resources all the skills necessary to produce efficient engineering and building products. The Company was based in central England which provided an ideal headquarters for undertaking contracts all over the country. The Group turnover in 1978 amounted to £35.5 million.

Work on every new project was divided into six main stages of activity requiring a great deal of co-ordination and integration to achieve full efficiency, e.g.

1. Advanced Studies
2. Plant and Process Design
3. Building Design
4. Services Design
5. Construction
6. Commissioning

1. Advances Studies

Following the briefing by the client advanced studies were undertaken by the Company to define the project and its objectives, dictate the overall design criteria, assess costs and determine its commercial, social or other viability. Where viability was already established, design studies might have been necessary to compare alternatives and define the most effective design. Further detailed studies may have been deemed necessary into specific aspects of the development including manufacturing processes, resource availability, site evaluation, project expenditure limits and construction feasibility.

The results of these investigations were carefully appraised and a study team was usually formed to match the client's needs and resources. Members of the study team formed the core of the design team when work progressed through to detailed design and construction. This involvement ensured that consultants were engaged to deal with the problem as a whole. In addition the client was at liberty to involve his own independent consultants to keep a watching brief on the process.

2. Plant and Process Design

The staff of the Company included a team of mechanical engineers who specialised in a whole range of areas, e.g. warehousing, production process, instrumentation and control, etc. Every project was handled by a team throughout all stages from inception to final commissioning.

This specialist service was not limited to new developments but was available when clients wished to refurbish or develop existing plants and other facilities.

3. Building Design

This stage was executed by fully integrated multi-discipline groups. Each group contained designers qualified in architecture and in civil, structural, environmental mechanical and electrical engineering. The groups were supported by building economists, construction and planning engineers and would call on the resources of the plant and process and interior design groups when required.

Every project was controlled by a design team under the supervision of a leader qualified in the discipline appropriate to the particular undertaking. The prime function of the design leader was to co-ordinate the work of the team and dictate policy to ensure that the overall design met the criteria established at the advanced studies stage. During the construction stage members of the design team visited the site regularly to ensure quality control and liaise, as necessary, with the Project Manager and Site Manager.

4. Services Design

To achieve full integration, mechanical and electrical engineers formed part of the plant and process and the building design groups. The staff contributed to the overall activities of the groups at the advanced study and design stages, and also provided technical supervision during the installation and commissioning stages. Their involvement in the early stages was intended to ensure that the plant and buildings were designed to provide the best solution for environmental and process needs with optimum energy and management control. Mechanical engineers were responsible for all environmental engineering, together with water services, public health engineering, steam, gas, compressed air and vacuum systems, etc.

Electrical engineers undertook the analysis of power supply and distribution, control and instrumentation, electrical protection systems, emergency installations, illumination engineering and communication systems.

5. Conservation

The Company had its own regionalised construction organisation with the necessary management expertise, labour and other resources capable of implementing major construction projects. Site managers, who answered on technical matters directly to a regional construction director, were appointed for each contract to manage and control every aspect of the construction including the work of subcontractors. They had their own team of key personnel supplemented as necessary by local labour.

Qualified electrical and mechanical supervisors oversaw all installations.

In addition, when process plants or warehouse projects were being developed, specialists from the appropriate engineering disciplines were located on the site. Resident site teams were further reinforced by quantity surveyors, planning engineers and steel erection supervisors.

The Company's experience of construction management, planning and procurement and of the integration of the design and construction functions was aimed at ensuring efficient completion of the project within the agreed time and cost schedules.

6. Commissioning

Once the construction was completed and the various essential items of plant and equipment had been installed, the project had to be made to work as a complete and efficient entity to ensure that it fully met the Client's requirements and the engineering and environmental evaluations laid down at the advance study stage. The Company's engineers were claimed to be expert in commissioning procedures of all types of engineering and manufacturing installations. In all cases, they ensured that the correct commissioning procedures were established and carried out, also that operation and maintenance manuals for the complete installation were provided.

The Company also offered the Client its expertise concerning the occupation of a new project, or the transfer of an industrial or other process from one building to another.

In addition to the above described integrated design and construct service the Company provided a consultancy only service to any client incorporating one or more of the specialisms previously mentioned.

Planning and Project Management

The Company recognised the importance of efficient management and forward planning of the design and construction to ensure that every development was successfully completed on time and within the required cost levels. Initially the planning engineers and the project managers determined a management strategy and prepared a strategic programme to suit each individual project. Normally the strategic programme was in precedence diagram form indicating the relationships and sequence of activities. Further programmes were developed progressively in line with the formulation of the design, procurement construction and plant installation stages of a project.

The outline project programme covered the whole project process from feasibility to commissioning. Clear relationships were shown between the various aspects of the design process and the construction. Further this programme provided the basis for the development of a procurement schedule to ensure that materials, components and equipment were ordered/acquired to meet the resource requirements of the project.

The outline project programme was further developed into stage and subcontractors programmes, which are periodically updated and used for management control purposes. Normally each trade was progressed in terms of work completed and labour on site to achieve a production rate in accordance with the parameters laid down by the original outline programme.

The project programme provided a basis for contract management utilising the concepts of co-ordination, communication, budgetary control and progress targets.

Organisation

Great significance was attached to the formal structure which the Company utilised to conduct its affairs. In this case the enterprise consisted of two separate limited liability companies as shown in Figure 25.

The commercial company could not identify as undertaking four functions which are specifically defined as follows:

Figure 25 Organisation Structure

1. Marketing
2. Buying
3. Quantity Surveying
4. Estimating

Clearly these functions had strong financial ties which tended to bind them together into an integrated unit with functional responsibility to the construction company. The construction company had two main divisions with a director in charge of each. Namely, these were consultancy and construction. The consultancy division subdivided into three design groups comprising of the following:

Group Manager	Architects
Planners	Civil and Structural Engineers
Project Managers	Mechanical and Electrical Engineers
Quantity Surveyors	
Project Economists	

Although the line management responsibility was through the group manager there was also functional responsibility to the professional heads.

Other design departments included steelwork, operational engineering and research and development.

The construction company upper and middle management consisted or regional/area construction managers, together with managers of steel erection, concrete erection and service supervision. The next level of management was represented by senior site staff. Within the organisation structure the company operated a number of inter-related systems and procedures which contributed to the overall efficiency of the business.

Area of Operation

Principally the Company worked on a nationwise basis although much of the smaller work occurred in the Midlands area. This placed a great deal of dependence on the willingness of key staff to move periodically to where work had been obtained. Generally labour was subcontracted to local firms or specialists able to operate in current areas of work.

Due to the fact that by far the majority of construction work was still obtained by the traditional competitive tender, the Company naturally diversified its operations over a wide area in order to attain the desired turnover. This in turn placed a greater demand on efficient communication and co-ordination to achieve the desired operating conditions.

Because of the past shortage of work in the United Kingdom the Company had looked abroad to expand its interests. At that time the two principal overseas expansion areas are the Netherlands and the Middle East.

General

In many ways this company was remarkable in the sense that over the past twenty years it had broken across all traditional modes of operation in the British Construction Industry, and yet, it had not only managed to survive, but had grown from strength to strength. Much of this success appeared to be directly attributable to the enthusiasm and capability of top management, however, this should not detract from the efforts and expertise of the permanent company staff. The Company was unique in the United Kingdom because if its ability to provide a comprehensive and wide ranging truly professional service to the client, who could rest assured that he was obtaining security and good value for capital invested. The afore described operations did not stop the company from operating in a traditional manner, but this activity had always been in the minority.

6.10 Summary

The information gathered from the case studies indicates that it is practical to design and construct buildings utilising a number of different methods. The degree of success achieved depends mainly on the systems and organisations utilised, together with the motivation of the people involved. The size and complexity of the project plays a major part in selecting appropriate methods of management and control from inception to final completion. Therefore it is appropriate that each of the case study categories are summarised as follows:

6.10.1 Large Complex Schemes

To cope with the management of large complex projects,plans of work have been devised to introduce logical guidelines for the developing of project programmes. Unfortunately universal plans of work cannot precisely represent all individual project requirements and consequently they can only be used as a guide. The large public health laboratory studied at the design stage clearly needed a high degree of management control,including the use of financial control systems to assist the decision making process. In each of the laboratory schemes insufficient attention was paid to financial considerations,particularly at the design stage. In contrast,the Factory and Offices described in Case C were controlled financially utilising both the accountancy and control facilities within the design and build organisation. However, little attempt had been made to computerise the project financial control process to give useful and up-to-date reports.

All the projects clearly illustrated the need for good positive project management which emphased the need for adequate communication, co-ordination, control and forward planning.

6.10.2 Medium Sized Schemes

Case D (Commercial Development) displayed organisation and managerial weakness throughout the design and build period. Poor management by the architect, together with a client who could not make up his mind and an incompetent contractor combined to make this project an example of how a project should not be administered. A half hearted attempt to introduce better management control by the appointment of a non executive project manager was a complete failure. No evidence was observed of management decisions being taken with regard to the financial state of the project. The project appeared to stumble from one crisis to another requiring ad hoc decisions to be taken.

Both Cases E and F were generally managed well with good co-ordination and control, both at the design and construction stages. The involvement of the design team at the production stage was an obvious advantage. Although the budgeting and control systems were adequate and the sites were well managed, there appeared to be scope for improved efficiency. In general this related to the availability of up-to-date information in terms of progress and cost.

It is worth noting that Case D was based on a traditional competitive tender contract and Cases E and F were design and build schemes.

6.10.3 Small Simple Schemes (Schemes G, H and K)

Although these projects required less management sophistication it was highly significant that little or no attempt was made to budget and financially control these schemes. Inefficiencies in terms of resource utilisation, design and construction method were observed which could have been avoided by better management of design and construction. More awareness of project expenditure, together with adequate budgeting and forecasting would have provided useful tools to the management of these projects to improve their control and effectiveness. The information gained from these sites was completely in line with my experience of this type of project and I therefore conclude that this is a general problem which must be solved.

6.10.4 Nontraditional Organisation Structures

The multi-disciplinary design partnership displayed tangible advantages in design management and co-ordination which clearly indicated its suitability to take on large complex schemes on a nationwide basis. In general management control was well structured and effective, however, budgeting and forecasting of project expenditure in terms of resources utilised was virtually non existent. Discussions with the financial director revealed that such developments would be highly beneficial to the organisation in an appropriate form.

The Design and Build Organisation investigated displayed a greater degree of co-ordination and efficiency than would normally be expected where a project was undertaken on a traditional basis. In general management was good, but improvements could be forthcoming if managers were provided with up-to-date financial information in an appropriate form, thereby contributing towards the decision making process.

6.10.5 Conclusion

This investigation has clearly indicated a need to improve the efficiency of management in the construction industry at all levels of involvement. A major weakness would seem to be a general lack of control information, together with poor co-ordination and communication. The need for adequate procedures to budget, monitor and control the construction process has been firmly reinforced. By its nature the construction process can be broken down into cost centres, both at the design and construction stages; this was clearly seen during the studies. It was also apparent that managers required reports containing the information they need to make decisions relevant to current project problems. Little evidence was found of network analysis being used to manage projects and it was therefore concluded that the cost centre approach could provide a viable alternative on which to base project budgeting. A major reason for not preparing project budgets was the time taken to initially produce them and subsequently incorporate revisions as variations occur.

Considering the results of the study, together with the references quoted, I am convinced that there is a need for an easy to use computerised budgeting, monitoring and forecasting system which can have general application to the construction industry. The following chapters will therefore concentrate on producing a model which could be applied in practice utilising the principles previously described.

Chapter 7

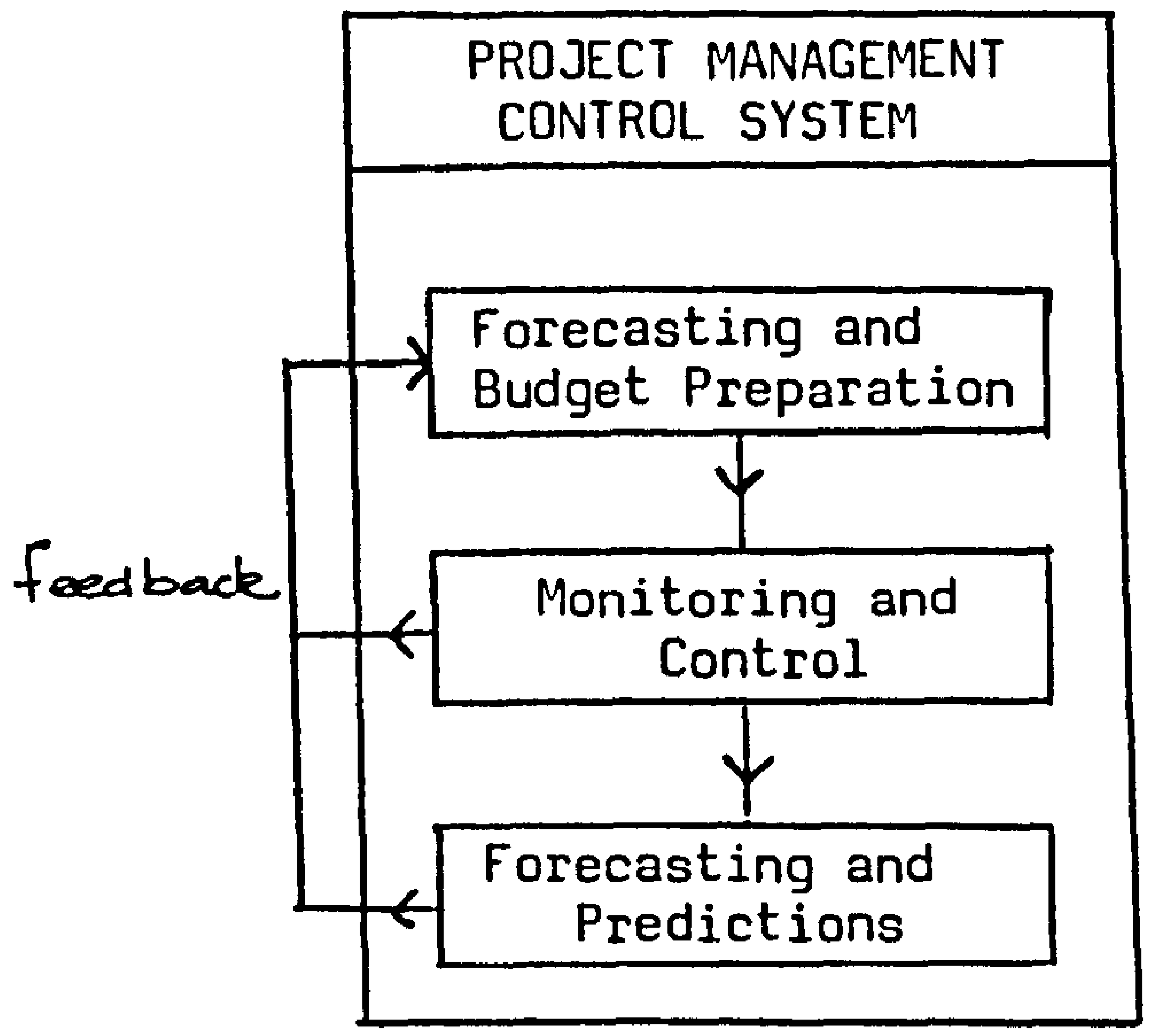
7. Project Management Control System

Having established a sound basis for simulating project expenditure the next stage involves the development of means to enable the theory to be effectively utilised in the practical environment. This work has the additional advantage of providing a test bed for evaluating project data and applicability of the system. It is intended to build a project management control system which will demonstrate the full potential of the theory previously described and will provide a basis for future development.

Organisations concerned with project management will each have their own particular requirements and it is therefore anticipated that the model proposed will not meet the needs of individual firms without revision. However, the basic concepts of management budgeting, monitoring, control and predictions will be built into the model and will be applicable to the majority of applications.

The three distinct stages in the project management process are shown in Figure 26 which further reinforces the vital need for strong inter-relationships between the stages and the importance of a reliable feedback system.

Figure 26



7.1 Forecasting and Data Preparation

A comprehensive sub-system will be developed which is both easy and economic to use, as well as being quick and reliable. The forecasting system will pass data direct to the monitoring and control sub-system. Because of the volume of data preparation involved, it is considered essential that the system proposals should be based on the latest computer technology currently available. The principal task of the forecasting sub-system will be the modelling of project expenditure based on interactive software programmes written in high level computer language. The object is to create a project forecast data base which can be used at the monitoring and control stages. Further the precise nature of the expenditure curves modelled can be identified in terms of the afore mentioned alpha, beta, gamma philosophy, thereby enabling knowledge to be accumulated on project expenditure which can be used to determine other project forecasts at some future date. The forecasting system will be designed as free standing in order that it can be used in its own right without the control and prediction sub-systems; hence it can be utilised to observe changes to the project expenditure given variations to the nature or extent of the work.

7.2 Monitoring and Control

This sub-system will be developed to give the manager a basis on which to make decisions regarding the project. It is intended that adverse trends in expenditure will be quickly identified thereby giving early warning of likely losses if corrective action is not taken.

The sub-system will also assess actual progress relative to the budget proposals previously determined, hence gains or shortfalls in performance will be periodically brought to the manager's attention.

The resultant information will give management clear indications relating to cost, valuation, progress, profitability and past trend patterns.

7.3 Forecasting and Predictions

Given past performance the sub-system will be designed to enable predictions relating to future project expenditure and project completion. In essence a revised project cost and duration will be determined using the theory already described in Chapters 4 and 5. Observations will also be possible of the future curve prediction in terms of alpha, beta and gamma.

The system to be proposed will form the basis for adaption to individual commercial applications and will provide scope for further development. It is also intended to act as an aid for future experimentation and research.

7.4 The Forecasting System using Alpha Beta Philosophy

The object of this section is to facilitate the marriage of the alpha-beta philosophy to a practical means of creating project forecasts in a quick and efficient manner which, where necessary, permits an iteractive solution. Obviously this type of exercise requires a large amount of data handling and therefore the use of a computer is imperative to achieve the aims envisaged.

Ideally the sub-systems should be applicable to a micro computer which would bring the use of the system within the range of a vast number of small/medium sized firms. However, it was judged that considerable advantages existed in undertaking the development work on a main frame, particularly with the convenience of an advanced operating system and graphics facilities. In order to enable the subsequent transfer of programmes from the main frame to a suitable range of micro computers, it was decided to adopt basic language programming for software development. An important factor already identified relates to data transmission between the forecasting, monitoring and prediction sub-systems. It is therefore essential that the computer programmes are designed to provide suitable interfaces for the transfer of mutually useful data.

Provision must also be made for utilising the forecasting module on a free standing basis where project budgets only are required. As a matter of general development policy it is vital that the systems proposed are easy to use requiring little initial computer knowledge. It is envisaged that the file handling requirement will be extensive since each project will need a number of data files both permanent and temporary. A system is to be developed whereby file handling will be fully automated to facilitate the amendment, updating and processing of the data input.

The essential data required by the forecasting system needs to be precisely formulated in the following terms:

1. Total estimate of project cost.
2. Envisaged project duration.
3. Peak expenditure: the time at which it occurs.
4. The curve profile which is obtained by the shaping constants in alpha and beta previously described.

   The curve profile which is defined by the shaping constants alpha, beta and gamma, which relate to the combination of cubic and exponential equations utilised to solve the overrun problem.

The philosophy stated earlier in the thesis clearly identified the alpha-beta cubic equation constants, together with an exponential equation constant, which provide the terms of reference for points (iii), (iv) and (v) above.

```
PROJECT CASH FLOW ANALYSIS AND FORECAST
------------------------------------------

INPUT PROJECT NAME(MAX FIVE CHARACTERS)
 ?RYE1

INPUT BUDGET FOR EACH COST CENTRE
SUBSTRUCTURE ?500000
SUPERSTRUCTURE ?1050000
FINISHINGS ?700000
EXT WORKS ?150000
DRAINAGE ?100000
NOMINATED S/C'S ?400000
SITE O/H'S ?190000

INPUT DURATION OF PROJECT IN WEEKS
 ?26


STATE THE START WEEK FOR EACH COST CENTRE I.E.
SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H
 ?1,6,15,22,2,15,1
STATE FINISH WEEK FOR EACH COST CENTRE I.E.
SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H
 ?6,18,26,26
 ?6
 ?26
 ?26
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
SUBSTRUCTURE
 ?12,46,42
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
SUPERSTRUCTURE
 ?35,25,40
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
FINISHES
 ?40,10,50
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
EXT WKS
 ?12,39,49
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
DRAINAGE
 ?15,45,40
INPUT ALPHA, BETA SUBSTRUCTURE
 ?1.8,    .5

INPUT A,B SUPERSTRUCTURE
 ?2,.5
INPUT A,B FINISHES
 ?2.1,.43
INPUT A,B EXT WKS
 ?1.3,.7
INPUT A,B DRAINAGE
 ?2,.5
INPUT A,B S/C'S
 ?1    .45,.3
INPUT A,B SITE O/H'S
 ?2,.5
```

Figure 26a Conversational Mode Computer Input

An important aspect of the forecasting system design is the potential to produce concise and reliable project budgets quickly and easily. In addition,the user should be able to operate the system procedure without a high degree of computer expertise,and the handling of project data should be fully automated to support this ideal. With these requirements in mind it was decided to develop an appropriate method of conversational mode input, to guide an individual step by step through the data input process. An example of this procedure is shown in Figure 26a.

Where users are completely familiar with the system there is no reason why data input should not be achieved through specially prepared files.

7.5 Automatic File Handling Procedure

When the user keys the project name three files are created using a facility in DEC10 basic which permits an extension to the file name. For example the programme statements are as follows:

```
550  PRINT "INPUT PROJECT NAME (MAX FIVE CHARACTERS)"
650  INPUT YS
750  X1$ = LEFT S (Y$,5) + "G.DAT"
800  X3$ = LEFT S (Y$,5) + "P.DAT"
850  X4$ = LEFT S (Y$,5) + "A.DAT"
```

Assuming the project name to be "RYE" the names of the files created will be:

(1) RYEG.DAT

(2) RYE .DAT

(3) RYEA.DAT

The files are used to store the following information:

(1) Non-cumulative values.

(2) Cumulative values.

(3) Percentage cost centre breakdowns in terms of labour, plant and materials.

These files are subsequently used by the project forecasting amendment; monitoring and control systems, together with the proposed corporate control procedures.

7.6 Development of the Forecast Curve

Previous work in this field, particularly that carried out by the DHSS, relied entirely on establishing a statistical basis on the past project performance and this then formed the yardstick for assessing future projects. The problem with this approach alone raises the question as to how relevant past results are in present circumstances and how adaptable to change are the constants thereby produced. The advantage with the alpha-beta approach is that the user can start to use the system for forecasting immediately by adopting the following procedures.

1. In the absence of past experience and data available, the user can intuitively select a curve shape which he feels will represent the project. The software developed

will enable the curve to be represented in terms of alpha, beta and gamma by the curve fitting process already described. This approach has the advantage that the nature of the curve can be quantified and compared with actual performance. Subsequently the results can be stored for future reference when preparing budgets.

2. The forecast can be modelled on a cost centre basis utilising a project time scale to alleviate costs. The cost centre period costs can be determined by allocation. Alternatively the expenditure curve can be established by the application of the constants alpha, beta and gamma to the total expenditure envisaged for the cost centres.

   This approach is extremely fast and easy to prepare. For example, a large multi million pound project budget can be produced in less than half an hour. Fine tuning of the forecast can be made by the use of the alteration programme which facilitates changes of a minor nature.

   The traditional method of allocating detailed bill of quantities costs over a contract programme is thereby unnecessarily slow and outdated.

   The number of cost centres utilised can be selected according to the requirements of the user. For normal construction projects it is not envisaged that these could exceed twenty in number.

3. With increasing familiarity the user will be able to integrate the project cost centre expenditure in terms of alpha, beta and gamma. Consequently by utilising past experience in the form of records kept and his own intuition, he can select an appropriate curve to forecast the expenditure envisaged.

7.7 The Philosophy of Cost Centres

Over the past few years it has been a matter of accepted principle to break a project down into a number of financial packages in order to more readily identify costs and to exert greater financial control. The number of cost centres selected for a project will range according to size, complexity, value of work and the requirements of the Client.

An important factor relates to the appropriate level of control necessary compared with the cost of implementation and the likely benefits to be achieved. The actual breakdown into cost centres must of course be consistent with natural breaks in the work representing clearly identifiable boundaries which effectively isolate one package of cost from another.

The potential accuracy of forecasting expenditure budgets is increased with the level of breakdown* and hence the cost centre approach can be particularly useful where little previous known data exists regarding project costs. From experimentation project 's' curves have been produced by taking straight line cost centre expenditure set to a

* Brian Fine   Fine & Curtiss & Gross Computing Mathematical Consultant

timescale; looking at the situation from another viewpoint, the reliance on statistically contrived data is considerably reduced and the emphasis is moved to the nature of the project in hand. Hence, the observed physical requirements are taken directly into account and have a direct bearing on the project time span. Another factor which tends to question the entire reliance on a statistically derived 's' curve for a project is the host of individual clients' requirements which can considerably affect the total project. For example, the construction time required and special phasing arrangements necessary to satisfy specific project needs. It will no doubt be fully appreciated that a hospital project of a certain value to be completed in five years will have a completely different expenditure pattern to one to be completed in two and a half years.

By incorporating cost centres set to a timescale a direct relationship can be achieved between the contract programme and the expenditure envisaged.

Before adopting a range of cost centres it will be necessary to prepare a contract programme which clearly and accurately represents the construction operations. The overall construction programme can either be scheduled as a bar chart or a network programme. The construction activities shown on the programme will need to be grouped together under cost centre headings and the expenditure associated with each cost centre must be determined from the estimated cost of the work. The amount of work and difficulty experienced in accurately allocating estimated costs in this manner will largely depend on the way in which the quantities have been prepared. A bill of quantities produced in accordance with the Standard Method of Measurement of Building Works does present some difficulty in this respect since not all items contained therein can be directly related to the project activities. In general,the more operationally based bill enables the afore said relationship to be directly established in an easier and more accurate manner. The introduction of the 6th edition of the Standard Method of Measurement has helped this situation and it is anticipated that the 7th edition will make still further improvements.

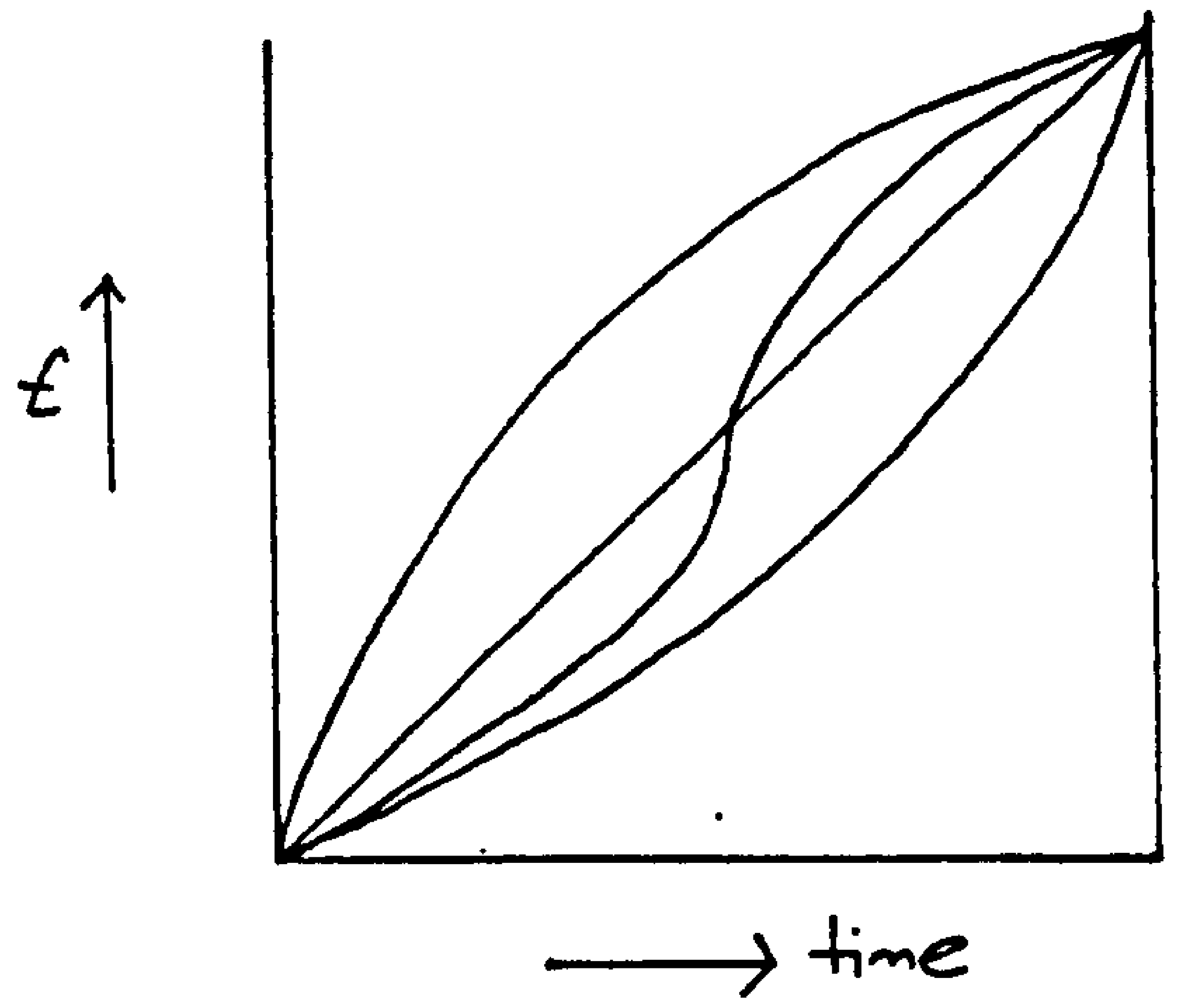
It is worth noting at this stage that some of the most advanced computer based network programming packages, particulary those evolved in the USA*, have comprehensive facilities for establishing cost centres comprising of activity costs. A natural development would be to interface the alpha beta forecasting and prediction sub-systems with these programmes to increase their versatility.

Once the cost centre has been quantified financially its anticipated cash flow relative to time are determined. The nature of the expenditure may take one of the following forms:

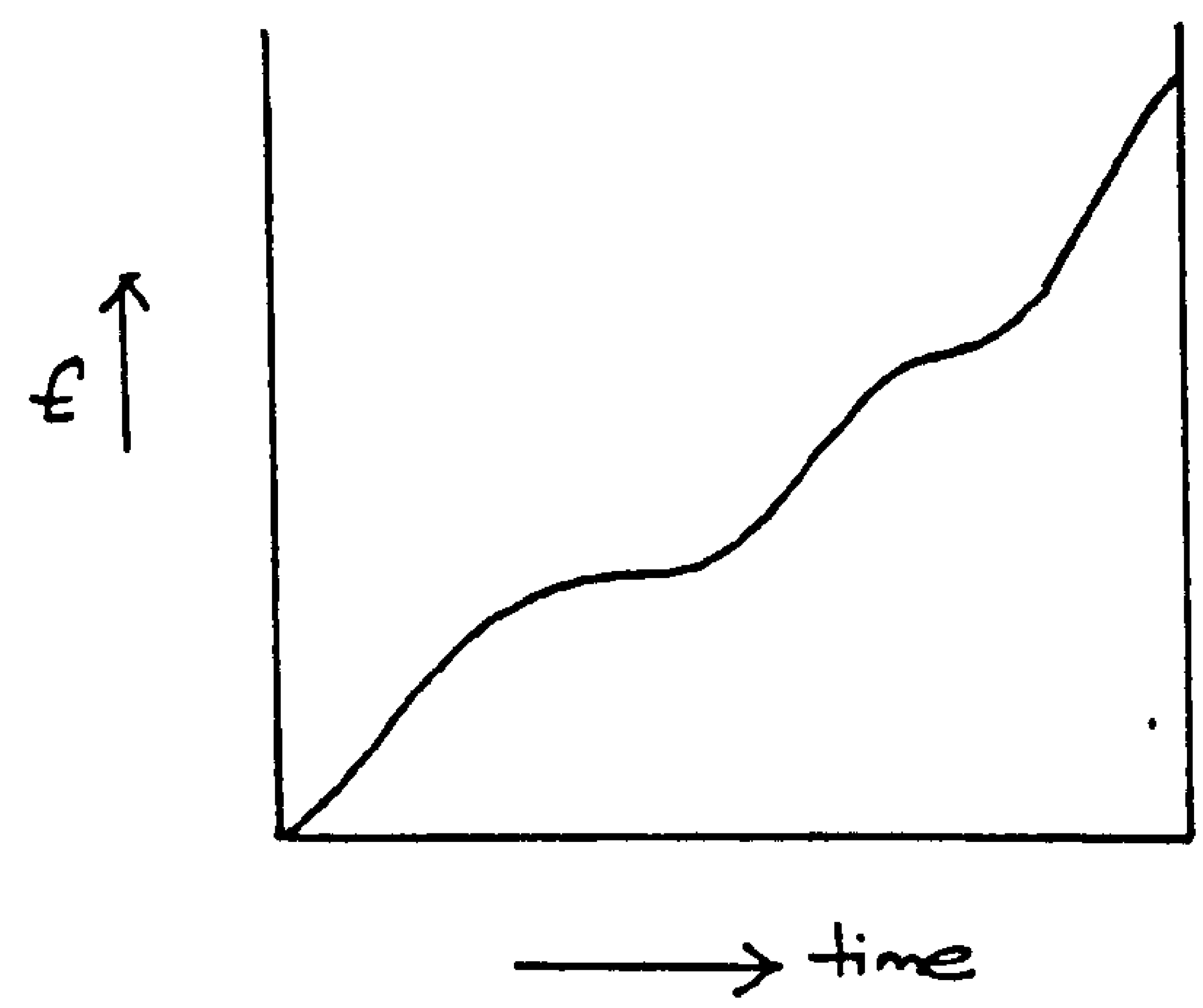
1. Straight line.
2. A regular shallow 's' curve
3. A pronounced regular curve, i.e.

---

* PCS	Digital Corporation	
Digital Corpn.	Project Control Systems (PCS)	PMS, IBM 1979
IBM	Project Management Systems (PMS)	1976



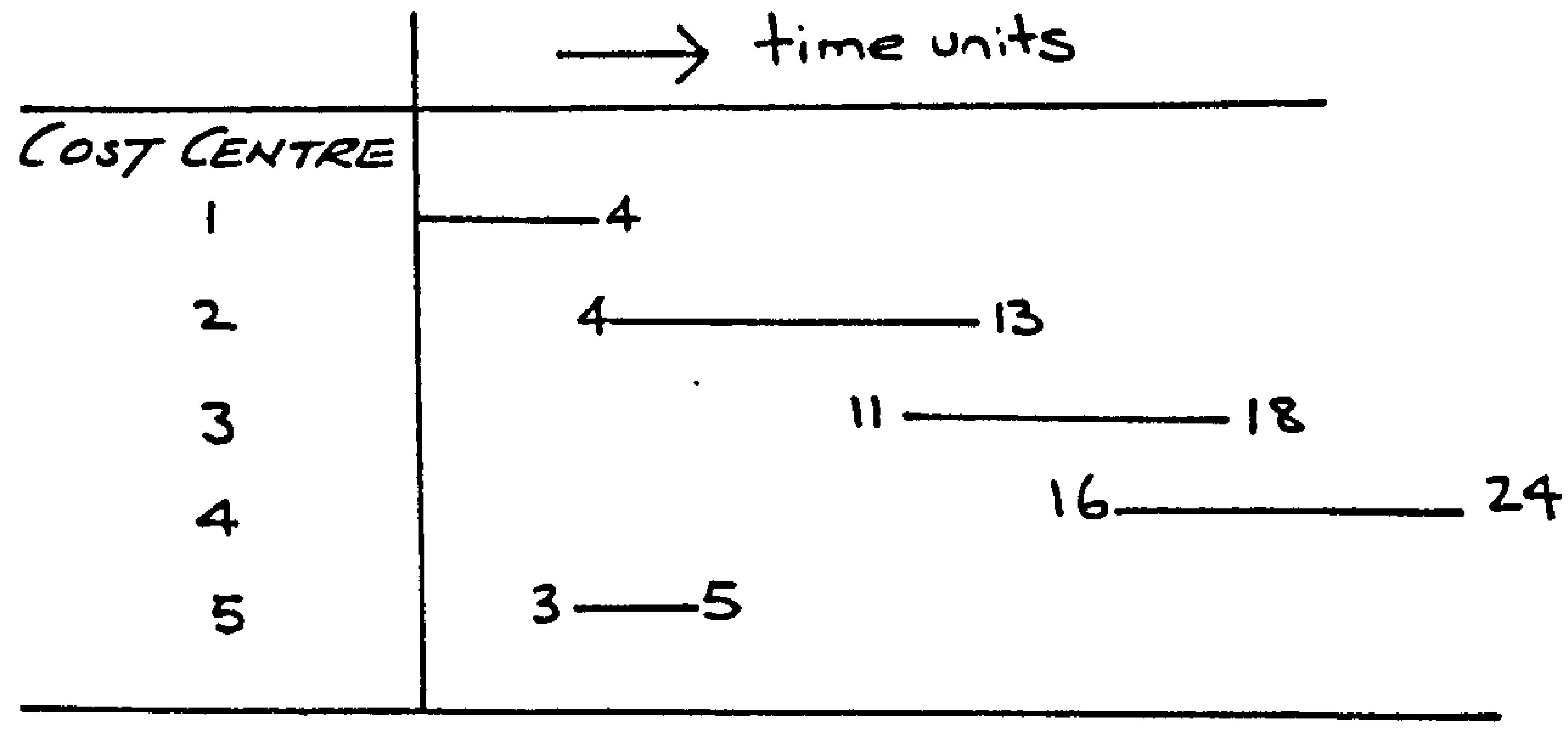
4. An irregular curve.



5. A non continuous set of expenditure with or without a regular pattern.

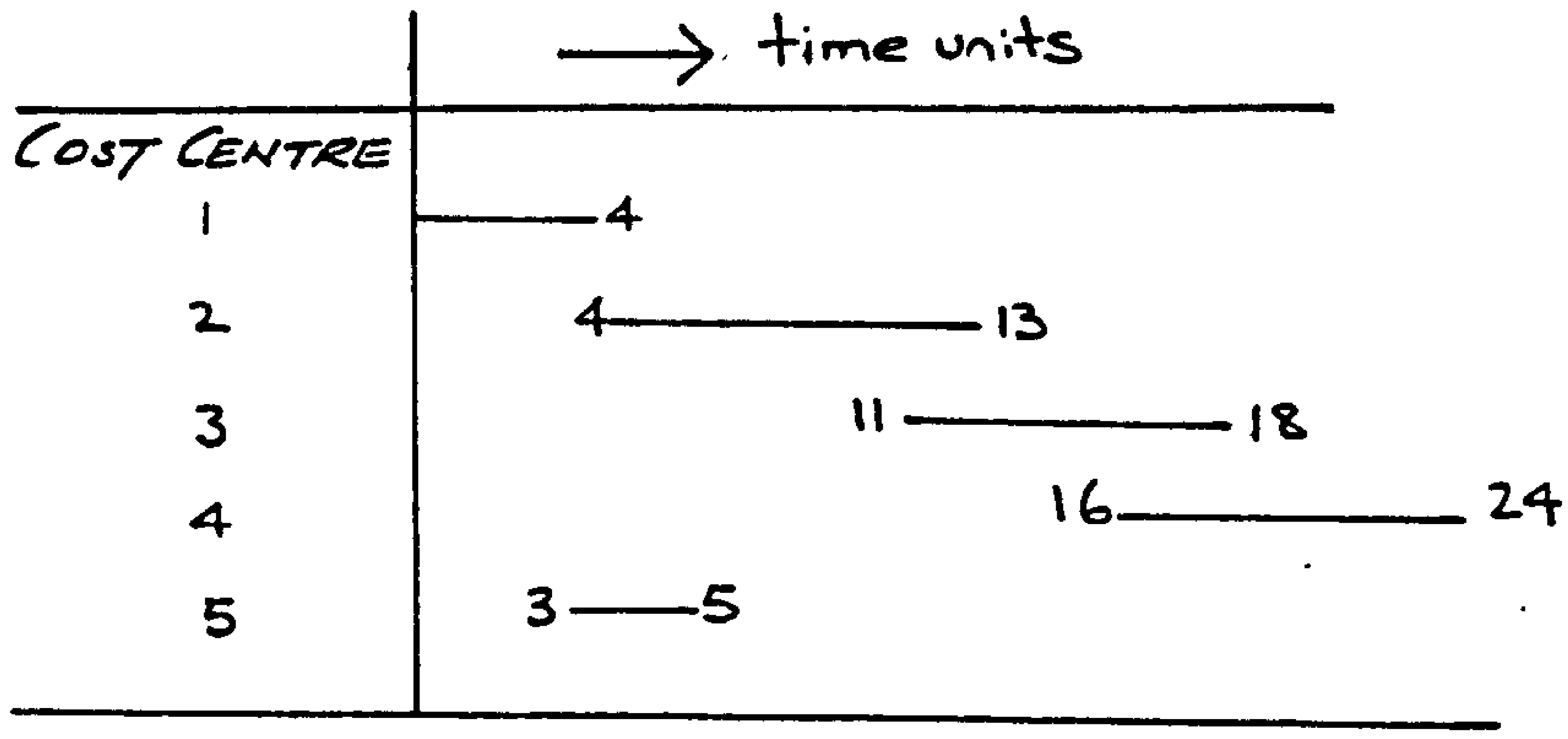
Normally the continuous regular curves can be simulated by alpha, beta and gamma. However, the completely irregular patterns can be accommodated by the programmes software which allows alterations to be made.

The time limits set for regular cost centre curves are initially specified as start and finish times representing the elapsed weeks or months into the project. This process is carried out interactively by the user as follows:



The data input is stored in a two dimensional matrix (cost centre x time) and the programme procedure shown in Appendix 4 determines the expenditure programme.

It is generally considered that the adoption of cost centres offers the best possible means of modelling project expenditure. This process can be carried out quickly and efficiently in accordance with individual project requirements.



The data input is stored in a two dimensional matrix (cost centre x time) and the programme procedure shown in Appendix 4 determines the expenditure programme.

It is generally considered that the adoption of cost centres offers the least possible means of modelling project expenditure. This process can be carried out quickly and efficiently in accordance with individual project requirements.

Figure 27

```
FEST3          16:22          27-SEP-82


PROJECT CASH FLOW ANALYSIS AND FORECAST
---------------------------------------


INPUT PROJECT NAME(MAX FIVE CHARACTERS)
 ?OFF1

INPUT BUDGET FOR EACH COST CENTRE
SUBSTRUCTURE ?550000
SUPERSTRUCTURE ?887000
FINISHINGS ?350000
EXT WORKS ?15000
DRAINAGE ?10000
NOMINATED S/C'S ?500000
SITE O/H'S ?140000

INPUT DURATION OF PROJECT IN WEEKS
 ?18


STATE THE START WEEK FOR EACH COST CENTRE I.E.
SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H
 ?1,4,11,16,3,10,1
STATE FINISH WEEK FOR EACH COST CENTRE I.E.
SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H
 ?4,13,18,18,5,18,18
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
SUBSTRUCTURE
 ?12,42,46
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
SUPERSTRUCTURE
 ?25,27,48,\,\
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
FINISHES
 ?40,10,50
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
EXT WKS
 ?18,38,44
INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL
DRAINAGE
 ?22,44,34
INPUT ALPHA, BETA SUBSTRUCTURE
 ?1.85,.52

INPUT A,B SUPERSTRUCTURE
 ?1.48,.3
INPUT A,B FINISHES
 ?2.15,.475
INPUT A,B EXT WKS
 ?1.95,.53
INPUT A,B DRAINAGE
 ?1.92,.54
INPUT A,B S/C'S
 ?2.1,.43
INPUT A,B SITE O/H'S
 ?2.25,.41
---------------------------------------------------------
```

Figure 27

PROJECT ESTIMATE AND PROGRAMME OF PRIME COST EXPENDITURE

COST CENTRE ANALYSIS

SUBS	SUPER STR	FIN	EXT WKS	DRAIN -AGE	NOM S/C'S	SITE O/H'S	TOT	WKS
85989.06	0.00	0.00	0.00	0.00	0.00	1919.60	87908.66	1.00
183923.44	0.00	0.00	0.00	0.00	0.00	4337.19	188260.63	2.00
186467.19	0.00	0.00	0.00	2451.56	0.00	6430.71	195349.45	3.00
93620.31	65070.32	0.00	0.00	4755.56	0.00	8200.15	171646.34	4.00
0.00	91325.52	0.00	0.00	2792.89	0.00	9645.52	103763.93	5.00
0.00	109704.16	0.00	0.00	0.00	0.00	10766.82	120470.98	6.00
0.00	120206.24	0.00	0.00	0.00	0.00	11564.04	131770.28	7.00
0.00	122831.76	0.00	0.00	0.00	0.00	12037.19	134868.95	8.00
0.00	117580.72	0.00	0.00	0.00	0.00	12186.27	129766.99	9.00
0.00	104453.12	0.00	0.00	0.00	22485.60	12011.26	138949.98	10.00
0.00	83448.97	14943.36	0.00	0.00	50917.70	11512.19	160822.22	11.00
0.00	54568.23	40810.55	0.00	0.00	70707.82	10689.04	176775.64	12.00
0.00	17810.96	57859.38	0.00	0.00	81855.97	9541.82	167068.13	13.00
0.00	0.00	66089.84	0.00	0.00	84362.14	8070.53	158522.51	14.00
0.00	0.00	65501.95	0.00	0.00	78226.34	6275.15	150003.44	15.00
0.00	0.00	56095.70	3721.67	0.00	63448.56	4155.71	127421.64	16.00
0.00	0.00	37871.09	7166.67	0.00	40028.81	1712.19	86778.77	17.00
0.00	0.00	10828.13	4111.67	0.00	7967.07	-1055.40	21851.46	18.00
550000.01	887000.00	350000.01	15000.00	10000.00	500000.00	140000.00	&2452000.04	

END OF RUN

FILES SAVED
OFF1G.DAT OFF1P.DAT OFF1A.DAT

Chapter 8

8. Computer Applications

8.1 General Project Forecasting and Budgeting Software

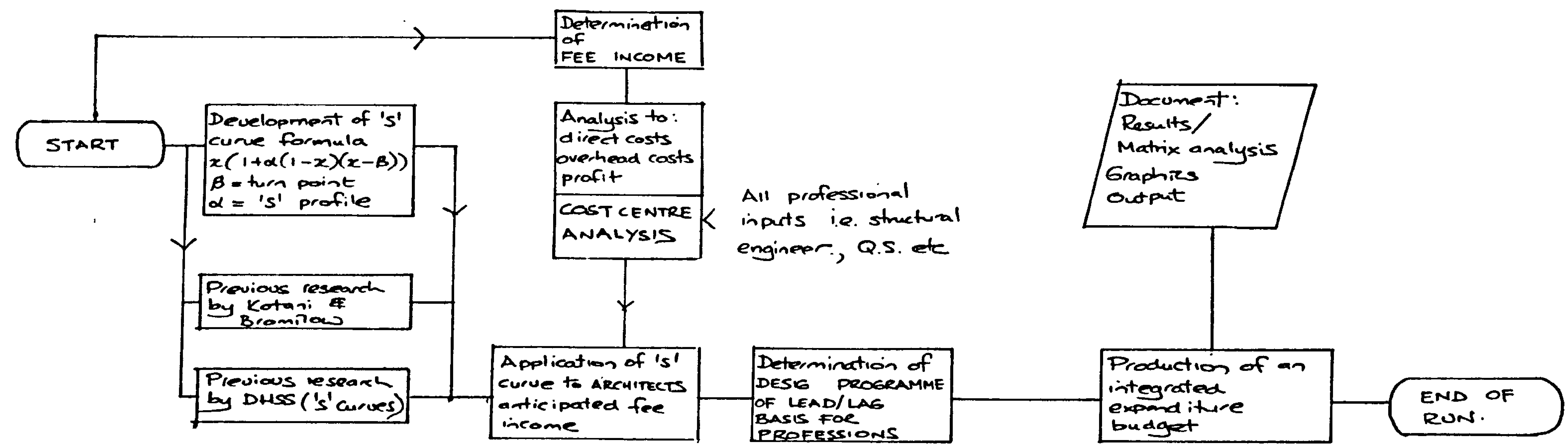
The computer programmes written to process the forecast data are included in Appendix 4.

The flowcharts for the processing of the overall budget and costs centres are shown in Figures 28, 29 and 30 respectively.

Figure 29 illustrates the procedure based on the overall project forecast. This option would be appropriate where the user is completely familiar and experienced with the project in hand and can select the overall curve fitting constants with a reasonable degree of confidence. The selection of this level of forecasting subsequently restricts the user to monitoring and control of the project on an overall basis only. The process depicted in Figure 30 allows the user much more scope to model the project forecast. This is particularly helpful where knowledge of the overall nature of the curve (alpha/beta) is restricted. In addition the cost centre breakdown facilities give considerably more scope for monitoring and control of the project.

The project forecasts are intended to be based on direct costs expended on the project. General overhead costs and profit should not be included since they have no direct relationship to the project. The indication of loss or gain on prime cost will be used to assess the efficiency and productivity of the contract.

Figure 28 Forecasting Sub-System Methodology Flow Chart



Forecasting Alteration and Adjustment Program

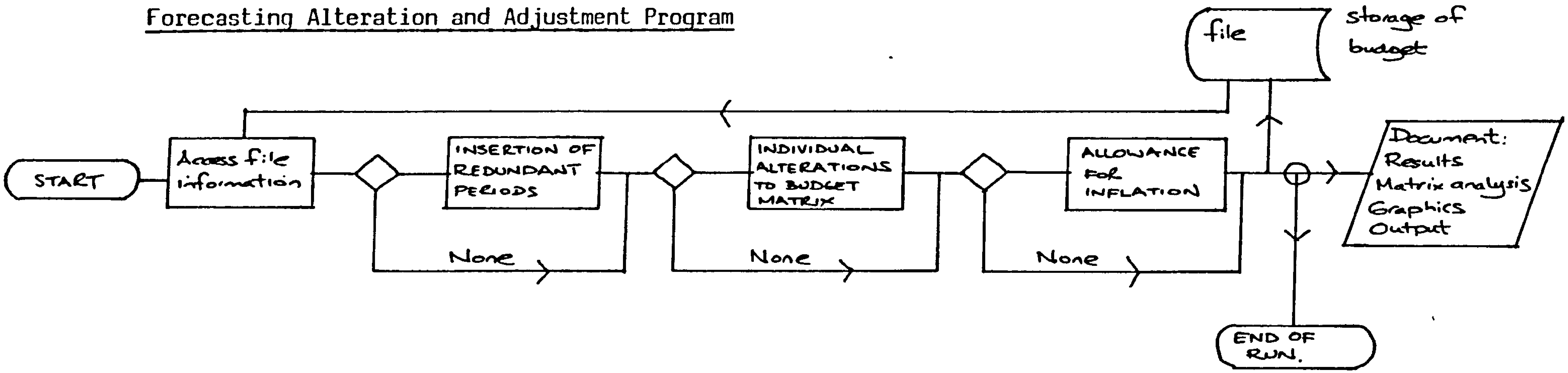


Figure 29 Project Forecasting Overall Expenditure Forecast

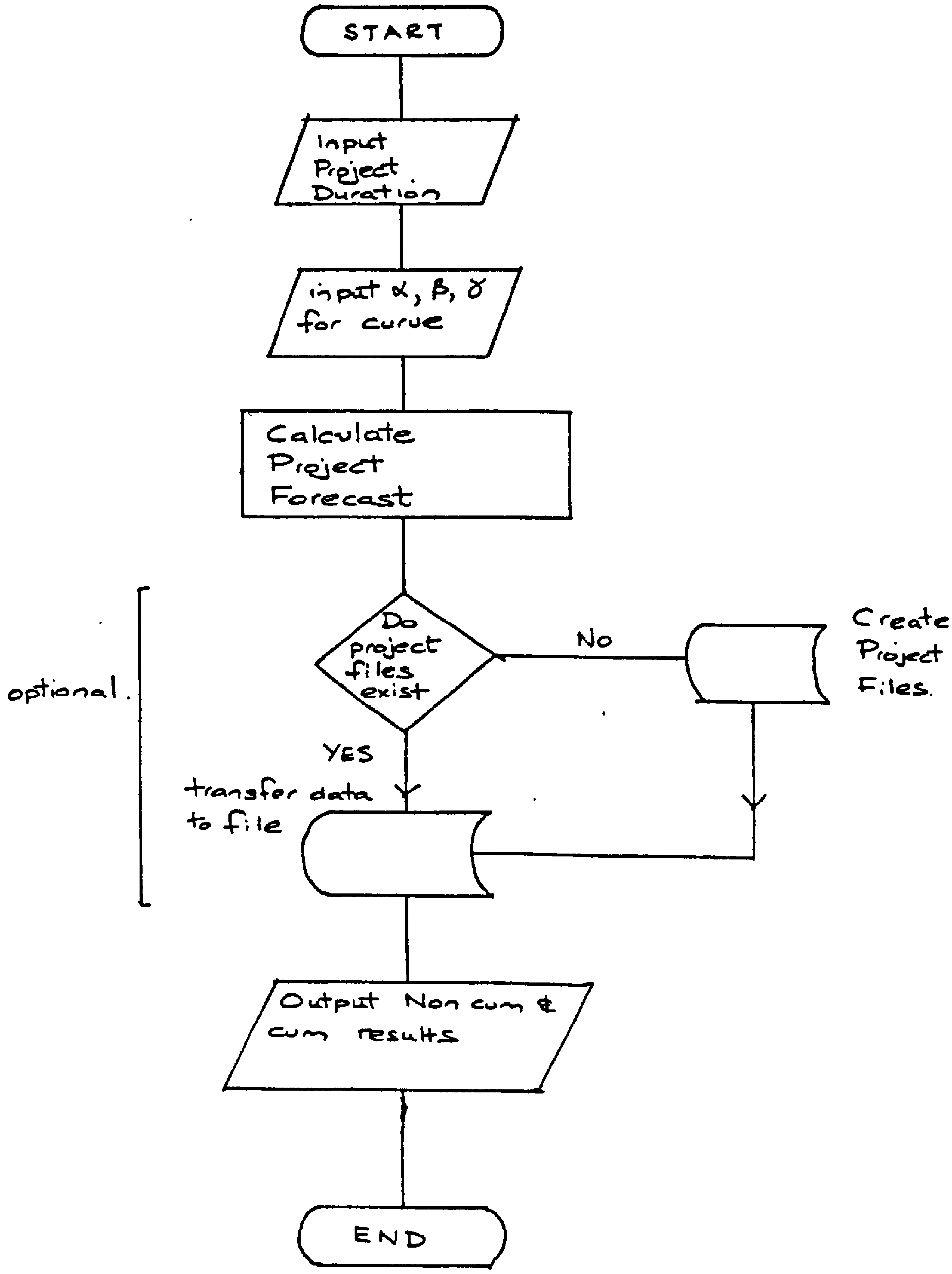


Figure 30

Forecasting System Flowchart

Site overheads can be included as a cost centre since they are significant to the overall control and efficiency of the project; this can only be specifically included.

8.1.1 Breakdown into Labour, Plant and Materials

Having assessed the total forecast expenditure for each cost centre it may be necessary to breakdown the amount into labour, plant and materials to facilitate detailed control at the monitoring stage. In the software development this is achieved by asking the user for a simple percentage allocation to each category. These percentages are stored in a file in order that budget/forecast allocations can be made during the monitoring process. An alternative procedure would be to input the specific values in terms of labour, plant and materials at the forecasting stage. These values could be accumulated during the forecasting stage to establish cost centre expenditure curves.

The input procedure and the output of results are shown in Figure 27.

The time scale budgets are stored on file in both cumulative and non-cumulative form and will be utilised by the continuing monitoring process. At this stage the forecast is complete, however, an important final stage remains where the overall curve is made up of individual cost centre assessments. The user at this point in time has little idea of the precise nature of the overall curve in terms of alpha, beta and gamma.

Therefore software has been chained to the main forecasting programme which carries out an analysis of the final curve. From a number of test runs virtually all the curves fitted utilised both the cubic and exponential equations. Examples of switching points from exponential to cubic and visa versa resulting from cost centre based forecasting are shown by the complete runs in Figure 31.

The underlying implication is that the combination of the cubic and exponential produces a much improved curve fit, compared with the cubic equation alone. Further, the usefulness of previous attempts of curve fitting are only feasible under strictly controlled circumstances.

8.1.2 Operation

The programmes developed operate in conversational mode and have been designed to prompt the user. It is foreseen that safeguards would be built into the programme to eliminate the possibility of data errors and to prevent crashing during a run.

Figure 27 illustrates the form of conversational mode utilised.

An important feature of the programme is the declaration of cost centre start and finish dates which are then used to model the cost centre expenditure according to the constants and the time scale.

Figure 31

MONITORING CONSTANTS

ALPHA= 0.150739   BETA=-0.130396   GAMMA= 2.826

THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 6
MAXIMUM DURATION 33
(GAMMA) PEAK PERIOD 8
(GAMMA) ALPHA EQUIVALENT 0.320063   ERROR 1.91528 %
(GAMMA) MAX DURATION ESTIMATE 27

CUBIC BETWEEN PERIODS 0 AND 15

TOTAL PROJECTION ERROR= 1.7 %

GRAPH OF PROJECT EVALUATION

DURATION 18 WEEKS AT COST 2.45200E+6 'POUNDS'

```
COST (1000'S)   ! 490     ! 980     ! 1471    ! 1961    ! 2451
COST% X----X----X----X----X----X----X----X----X----X----X----X----X
           10   20   30   40   50   60   70   80   90   100  110  12
 0 % 0 -G-S
     I  AP
     I      AP
     I         PA
     I            PA
 28 % 5               PA
     I          *      PA
     I           *        S
     I           *           AP
     I           *              AP
 56 % 10         *                 AP
     I             *                  S
     I              *                    PA
     I              *                      P A
     I             *                          P A
 83 % 15 -G-      *                                AP
     I          *                                    PA
     I       *                                          PA
100 % 18 *                                               PA
      X----X----X----X----X----X----X----X----X----X----X----X----X
COST%      10   20   30   40   50   60   70   80   90   100  110  12
```

A=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENTS 4*NON-CUMULATIVE EXPENDITURE

Figure 31

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	87908.7	87908.7	139828	-2.1
2	188260.	276169.	281261	-0.2
3	195349.	471518.	423916	1.9
4	171646.	643164.	567415	3.1
5	103764.	746928.	711377	1.4
6	120471.	867399.	855422	0.5
7	131770	999169.	999169	0
8	134869.	1.13404E+6	1142239	-0.3
9	129767.	1.26381E+6	1284250	-0.8
10	138950.	1.40276E+6	1424823	-0.9
11	160822.	1.56358E+6	1563578	0
12	176776.	1.74035E+6	1700134	1.6
13	167068.	1.90742E+6	1834110	3
14	158522.	2.06594E+6	1965128	4.1
15	150003.	2.21595E+6	2240208	-1
16	127422.	2.34337E+6	2326972	0.7
17	86778.8	2.43015E+6	2396868	1.4
18	21851.4	2.45200E+6	2451999	0

N.B. An experiment involving straight line expenditure on all of the cost centres produced an overall 's' curve, which indicates that the amalgam of project cost centre expenditure is naturally quite different from that of its constituents, thereby vindicating the final curve fit analysis procedure.

8.2 The Forecasting Alteration Programme

This programme module has been developed to enable the user to modify the forecast according to circumstances which cannot be accommodated by the normal alpha, beta, gamma curve fit process. The programme procedure can be used to fine tune the forecast after the initial computer run. Another use can be during the actual project time when variations, increased costs and other amendments require the original forecast to be amended to enable realistic comparisons to be made.

Figure 32 illustrates the basic methodology of the sub-system.

8.2.1 The Amendment Process

The computer programme operating in conversational mode asks the user to specify whether he would like to make any changes to the forecast. If the reply is affirmative the user is asked to specify the cost centres and the work number he wishes to alter, after which he will be requested to input the relevant expenditure data. This process is repeated until all the necessary alterations have been made.

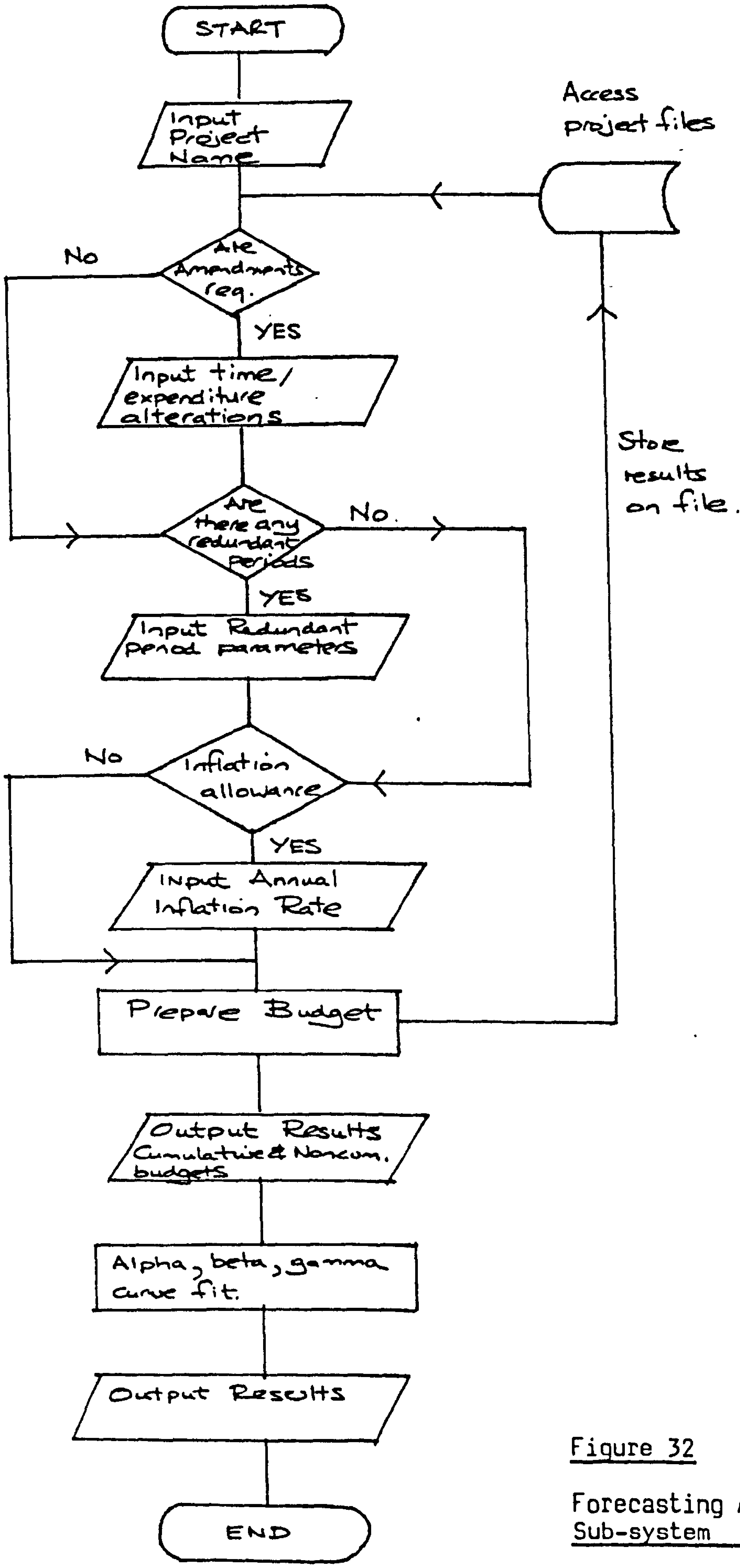


Figure 32

Forecasting Alteration Sub-system

The amendments will facilitate the following conditions:

1. Unusual costs which occur outside the scope of the 's' curve patterns utilised.

2. To build in redundant periods appertaining only to the cost centre under consideration.

3. The 's' curve produces one continuous process only. However, it is quite possible that the expenditure is spent intermittently or in quite separate stages in which case it can be modelled accordingly.

Taking this process to its ultimate conclusion the whole forecast could be formulated in this manner from the beginning.

It is foreseen that the majority of projects will only require amendments of a more minor nature, but from experience, a proportion of projects will need to be amended carefully to simulate the project expenditure effectively.

:.2.2 Insertion of Redundant Periods

This facility has been built into the programme to allow for the whole project work to be wholly suspended for a period of time. Any number of redundant periods can be inserted and all that is necessary is the specification of the start/stop parameters.

The user would find this procedure useful to allow for protracted annual holidays, i.e. Christmas or firms annual holidays, together with the suspension of work to meet client's requirements.

The insertion of redundant periods dramatically alters the shape of the 's' curve into a series of plateaus. As mentioned previously the redundant or near redundant periods are eliminated from the curve fitting process and therefore the alpha, beta, gamma determination must be subsequently modified to allow for the actual curve profile.

8.2.3 Inflation

Assuming that the forecast has been produced on present costs it is possible to build in an allowance for inflation to cover increased costs. This is particularly relevant with projects that have contract clauses which allow for increased costs to be added to the contract sum, or alternatively, projects which span over a considerable period of time and are subject to the influence of inflation.

The computer programme has been written to accumulate inflation on a month by month basis given an average annual inflation rate.

The affect of inflation on the 's' curve constants is an important factor in the determination of any format using this method. Reference should be made to Figure 15 which demonstrates the affect of applying a range of inflation allowances.

Figure 33 illustrates a complete run of the alteration programme together with output results.

Figure 33

```
FORECAST ALTERATION AND ADJUSTMENT PROGRAM


INPUT PROJECT NAME ?TARMC


ARE THERE ANY REDUNDANT PERIODS TO BE ALLOWED FOR IN TIME SPAN
ANSWER YES OR NO
 ?NO

TOTAL REVISED PROJECT DURATION IN WEEKS 24

DO YOU WISH TO MAKE ANY ALTERATIONS
INPUT YES OR NO
 ?NO
NO

DO YOU WISH TO MAKE AN ALLOWANCE FOR INFLATION
ANSWER YES OR NO
 ?
```

Figure 33

PROJECT FORECAST AND PROGRAMME OF PRIME COST EXPENDITURE
ANALYSIS ON A WEEKLY BASIS

SUB	SUPER STR	FIN	EXT WKS	DRAIN -AGE	NOM S/C'S	SITE O/H'S	TOTAL	WEEK
240.06	0.00	0.00	0.00	0.00	0.00	5.06	245.12	1.00
643.35	0.00	0.00	0.00	0.00	0.00	14.61	657.96	2.00
931.41	0.00	0.00	0.00	34.29	0.00	23.29	989.00	3.00
1104.25	0.00	0.00	0.00	91.91	0.00	31.11	1227.26	4.00
1161.87	0.00	0.00	0.00	133.06	0.00	38.05	1332.98	5.00
1104.25	174.93	0.00	0.00	157.75	0.00	44.13	1481.05	6.00
931.41	489.80	0.00	0.00	165.98	0.00	49.33	1636.52	7.00
643.35	752.19	0.00	0.00	157.75	0.00	53.67	1606.96	8.00
240.06	962.10	0.00	0.00	133.06	0.00	57.15	1392.36	9.00
0.00	1119.53	101.93	0.00	91.91	0.00	59.75	1373.11	10.00
0.00	1224.49	286.82	0.00	34.29	0.00	61.49	1607.09	11.00
0.00	1276.97	443.26	0.00	0.00	0.00	62.36	1782.58	12.00
0.00	1276.97	571.26	0.00	0.00	140.75	62.36	2051.33	13.00
0.00	1224.49	670.82	0.00	0.00	385.92	61.49	2342.71	14.00
0.00	1119.53	741.93	56.00	0.00	576.61	59.75	2553.81	15.00
0.00	962.10	784.59	152.00	0.00	712.81	57.15	2668.65	16.00
0.00	752.19	798.82	224.00	0.00	794.53	53.67	2623.21	17.00
0.00	489.80	784.59	272.00	0.00	821.78	49.33	2417.50	18.00
0.00	174.93	741.93	296.00	0.00	794.53	44.13	2051.51	19.00
0.00	0.00	670.82	296.00	0.00	712.81	38.05	1717.68	20.00
0.00	0.00	571.26	272.00	0.00	576.61	31.11	1450.97	21.00
0.00	0.00	443.26	224.00	0.00	385.92	23.29	1076.47	22.00
0.00	0.00	286.82	152.00	0.00	140.75	14.61	594.17	23.00
0.00	0.00	101.93	56.00	0.00	0.00	5.06	162.99	24.00
$7000.00	$12000.00	$8000.00	$2000.00	$1000.00	$6043.00	$1000.00	$37043.00	

Figure 33

PROJECT FORECAST AND PROGRAMME OF PRIME COST EXPENDITURE
ANALYSIS ON AN ACCUMULATIVE BASIS

SUB	SUPER STR	FIN	EXT WKS	DRAIN -AGE	NOM S/C'S	SITE O/H'S	TOTAL	WEEK
240.06	0.00	0.00	0.00	0.00	0.00	5.06	245.12	1.00
883.40	0.00	0.00	0.00	0.00	0.00	19.68	903.08	2.00
1814.82	0.00	0.00	0.00	34.29	0.00	42.97	1892.08	3.00
2919.07	0.00	0.00	0.00	126.20	0.00	74.07	3119.34	4.00
4080.94	0.00	0.00	0.00	259.26	0.00	112.12	4452.32	5.00
5185.19	174.93	0.00	0.00	417.01	0.00	156.25	5933.37	6.00
6116.60	664.72	0.00	0.00	582.99	0.00	205.58	7569.90	7.00
6759.95	1416.91	0.00	0.00	740.74	0.00	259.26	9176.85	8.00
7000.00	2379.01	0.00	0.00	873.80	0.00	316.41	10569.21	9.00
7000.00	3498.54	101.93	0.00	965.71	0.00	376.16	11942.33	10.00
7000.00	4723.03	388.74	0.00	1000.00	0.00	437.64	13549.41	11.00
7000.00	6000.00	832.00	0.00	1000.00	0.00	500.00	15332.00	12.00
7000.00	7276.97	1403.26	0.00	1000.00	140.75	562.36	17383.33	13.00
7000.00	8501.46	2074.07	0.00	1000.00	526.66	623.84	19726.04	14.00
7000.00	9620.99	2816.00	56.00	1000.00	1103.27	683.59	22279.85	15.00
7000.00	10583.09	3600.59	208.00	1000.00	1816.08	740.74	24948.50	16.00
7000.00	11335.28	4399.41	432.00	1000.00	2610.61	794.42	27571.71	17.00
7000.00	11825.07	5184.00	704.00	1000.00	3432.39	843.75	29989.21	18.00
7000.00	12000.00	5925.93	1000.00	1000.00	4226.92	887.88	32040.72	19.00
7000.00	12000.00	6596.74	1296.00	1000.00	4939.73	925.93	33758.40	20.00
7000.00	12000.00	7168.00	1568.00	1000.00	5516.34	957.03	35209.37	21.00
7000.00	12000.00	7611.26	1792.00	1000.00	5902.26	980.32	36285.84	22.00
7000.00	12000.00	7898.08	1944.00	1000.00	6043.00	994.94	36880.01	23.00
7000.00	12000.00	8000.00	2000.00	1000.00	6043.00	1000.00	37043.00	24.00

Figure 33

MONITORING CONSTANTS

ALPHA= 0.770263   BETA= 0.920231   GAMMA= 1.976

THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 16
MAXIMUM DURATION 33
(GAMMA) PEAK PERIOD 13
(GAMMA) ALPHA EQUIVALENT 1.81272   ERROR 8.60285E-2 %
(GAMMA) MAX DURATION ESTIMATE 25

CUBIC BETWEEN PERIODS 0 AND 16

TOTAL PROJECTION ERROR= 2.1 %

GRAPH OF PROJECT EVALUATION

DURATION 24 WEEKS AT COST 37043. 'POUNDS'

```
COST (1000'S)    ! 7       ! 14       ! 22       ! 29       ! 37
COST% X----X----X----X----X----X----X----X----X----X----X----X----X
           10   20   30   40   50   60   70   80   90   100  110  12
 0 % 0 -G-S
     IAP
     I AP
     I   AP
     I    AP
 21 % 5     PA
     I        *PA
     I         *PA
     I         *  PA
     I        *     PA
 42 % 10     *        S
     I         *        AP
     I          *          AP
     I           *           S
     I             *            PA
 63 % 15            *              PA
     I-G-           *                   AP
     I              *                      PA
     I             *                         PA
     I           *                             P A
 83 % 20       *                                 P  A
     I        *                                    P  A
     I      *                                        P A
     I   *                                             PA
 100 % 24 *                                             PA
      X----X----X----X----X----X----X----X----X----X----X----X----X
COST%      10   20   30   40   50   60   70   80   90   100  110  12
```

A=ACTUAL   P=FORECAST   S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
 * REPRESENTS 4*NON-CUMULATIVE EXPENDITURE

Figure 33

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	245.119	245.119	542	-0.8
2	657.959	903.078	1263	-1
3	988.999	1892.08	2149	-0.7
4	1227.26	3119.34	3188	-0.2
5	1332.98	4452.32	4367	0.2
6	1481.05	5933.37	5675	0.7
7	1636.52	7569.9	7099	1.3
8	1606.96	9176.85	8626	1.5
9	1392.36	10569.2	10245	0.9
10	1373.11	11942.3	11942	0
11	1607.09	13549.4	13706	-0.4
12	1782.58	15332.	15524	-0.5
13	2051.33	17383.3	17383	0
14	2342.71	19726.	19272	1.2
15	2553.81	22279.9	21178	3
16	2668.65	24948.5	25135	-0.5
17	2623.21	27571.7	27048	1.4
18	2417.5	29989.2	28853	3.1
19	2051.51	32040.7	30540	4.1
20	1717.68	33758.4	32101	4.5
21	1450.97	35209.4	33532	4.5
22	1076.47	36285.8	34831	3.9
23	594.173	36880.	36000	2.4
24	162.99	37043.	37043	0

The use of the alteration programme in conjunction with the forecasting programme gives the system more versatility and greater flexibility, thereby making its application that much more viable in the practical environment. The modelling process is entirely flexible within the constraints set by the number and type of cost centres selected and therefore due attention should be paid to this aspect prior to utilising the programmes.

8.3 Application

The Forecasting/Alteration sub-system can be utilised to provide an overall budget, alternatively an individual cost centre analysis can be implemented which provides the basis for a more detailed budget if required. The budget is normally expressed in financial terms, however, there is no reason why it should not be represented in man hours or any other units which quantify the project appropriately.

With regard to the Building Industry three major areas of application have been identified, namely:

1. Design management
2. Production management
3. Project Management of the whole construction process.

8.3.1 Design Management

The contextual survey paid particular attention to the way in which the design expenditure was managed, since it was already suspected that the level of management and integration at this stage was very low. In effect the cases subsequently investigated tended to confirm this notion, although there were exceptions. Nevertheless, the fact that no evidence was found of serious attempts to budget design costs is considered to be highly significant.

The argument used by designers to support their non action in this respect was based on the concept that every project was different and consequently it was impossible to assess accurately the likely design costs given a particular "client's brief". It appeared at the time of the survey that the real truth of the matter reflected the unwillingness of designers to be put in a straight jacket with regard to budgeted targets. Hence nobody wished to attempt and/or understand forecasting.

In essence the designer is a resource in much the same way as an engineer or a bricklayer since they all cost money to employ. The designer will argue that he is stepping into the unknown and therefore the time spent is impossible to quantify. With the trend towards more componentisation, simplyfied construction and prefabrication in factories, it would appear that this argument will be difficult to sustain as a general rule. It therefore follows that designers should be subject to budgets and with experience it should be possible to forecast design costs.*

There is no reason why the cost centre approach should not be used to represent the design professions commonly associated

---

* In the U.S.A. it is now common practice to forecast the cost of producing computer software which is at least, if not more, intangible to assess the building design costs.

with construction design, i.e.

Architect
Mechanical Engineer
Electrical Engineer
Civil Engineer
Quantity Surveyor
Structural Engineer

The forecasting system proposed would accommodate this application with only minor alterations. The assessment of 's' curve constants could be based on each profession in turn. Alternatively, the prime profession i.e. the profession covering the whole time span and involving the most work could be used as the normal 's' curve to which all the others would conform.

Development

As part of this research programme, design forecasting software has been developed to enable the manager of a multi disciplinary design process to relate his budget/ forecast to the level of fee income likely to be earned. This development work has been undertaken to demonstrate how easy it is to produce budgets using the "alpha/beta" method forecasting.

The programme entitled FESTI.BAS requires the user to input data relating to professional fee incomes, after which the overhead and profit charges are deducted to give the prime cost budget. An additional breakdown of the budget to the users requirements may be made at this stage.

A maximum of seven professions are catered for by the programme, however, more can be provided by simple alterations to the software. Where less than seven cost centres are required zero budgets will need to be inserted.

A programme of work is then formulated based on its relationship with the prime profession, i.e. the architect in the case illustrated. It is considered viable in some cases to relate all professional start and completion times to appropriate specific points in the completion of the architects work. This premise is made based on the research undertaken by N. Kotani* and the data obtained from the projects previously mentioned in this thesis. However, there would appear to be instances where some professions, because of the time span or nature of the work do not conform in this respect and therefore need to be assessed separately.

The peak month cost is then required and the computer will then produce a budget for each individual profession together with an accumulated overall budget which is then further analysed in terms of alpha, beta and gamma using the curve fit procedure already described.
See Figure 34 Complete Design Computer run.

8.3.2 Production Management

In contrast to the almost total lack of forecasting in the design area, contractors seemed more aware of the need to predict budgeted expenditure and some attempt was being made to achieve this objective. One of the main problems observed

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* Kotani, N.B. Consultants Fees related to variance of Project Design Costs. Paper School of Environmental Studies, University College London, 1974.

Figure 34

```
DESIGN FEE ESTIMATION PROGRAM
-----------------------------

INPUT PROJECT NAME(MAX FIVE CHARACTERS)
 ?DES2

INPUT ESTIMATED FEE INCOME FOR THE FOLLOWING:-
ARCHITECTURE ?25000
STRUCTURAL ENGINEERING ?12234
MECHANICAL ENGINEER ?11456
ELECTRICAL ENGINEER ?9876
QUANTITY SURVEYING ?6000
EXTERNAL CONSULTANTS ?1000
ALLOCATABLE OVERHEADS ?670

INPUT % OF ARCHITECTS FEES ALLOCATED TO SUB/S & SUP/S
 ?45,55
INPUT % OF STRUCTURAL ENGINEERS FEES ALLOCATED TO SUB/S
 ?35

INPUT % TO COVER OVERALL O/H CHARGE AND % PROFIT EXPECTED
 ?15,10
INPUT DURATION OF PROJECT IN MONTHS ?12

ANALYSIS OF ESTIMATE
--------------------
```

	ARCHITECT SUB/S	ARCHITECT SUP/S	FIN	STRUCTURAL ENG SUB/S	STRUCTURAL ENG SUP/S	MECH ENG	ELECT ENG	Q.S.	EXT CT'S	DIR O/H'S
PRIME COST	8437.50	10312.50	0.00	3211.43	5964.07	8592.00	7407.00	4500.00	750.00	502.5
OVERHEAD	1687.50	2062.50	0.00	642.29	1192.82	1718.40	1481.40	900.00	150.00	100.5
PROFIT	1125.00	1375.00	0.00	428.19	795.21	1145.60	987.60	600.00	100.00	67.0
TOTAL	11250.00	13750.00	0.00	4281.90	7952.10	11456.00	9876.00	6000.00	1000.00	670.0

Figure 34

```
INPUT STANDARD/AVERAGE COST PER MAN HOUR ?12.50

STANDARD MAN HOURS AVAILABLE TO EACH PROFESSION
-----------------------------------------------
ARCHITECTURE           2000
STRUCT ENGINEERING     978.72
MECHANICAL ENG         916.48
ELECT ENG              790.08
QUANTITY SURVEYING     480


STATE % OF ARCHITECTS WORK COMPLETE BEFORE FOLLOWING OTHER PROF. START
INPUT VALUES FOR S.E.,MECH,ELECT.,Q.S.,EXT. CT'S.,DIR O/H'S RESPECTIVELY
 ?7,8,7,1,10,1
STATE % OF ARCHITECTS WORK TO COMPLETE AFTER FOLLOWING HAVE FINISHED
INPUT VALUES FOR S.E.,MECH,ELECT.,Q.S.,EXT CT'S., DIR O/H'S RESPECTIVELY
 ?30,15,14,5,$0,.05

? INPUT DATA NOT IN CORRECT FORM--PLEASE RETYPE
 ?30\0\0,15,14,5,10,.05
```

Figure 34

LIKELY % DURATION EXCESS ?5
INPUT PEAK COST MONTH ?7
ALPHA= 1.595 BETA= 0.528

PROJECT ESTIMATE AND PROGRAMME OF PRIME COST EXPENDITURE

ARCH	STRU/ ENG	MECH/ ENG	ELECT ENG	Q.S.	EXT CT'S	DIR O/H'S	TOTAL	MONTH
546.66	0.00	0.00	0.00	173.52	0.00	16.73	736.91	1.00
1077.49	794.79	469.94	405.13	349.80	0.00	33.36	3130.52	2.00
1504.49	1630.61	963.72	830.81	483.02	50.73	46.38	5509.75	3.00
1827.64	2059.90	1296.91	1118.04	573.17	104.41	55.78	7035.84	4.00
2046.95	2082.67	1469.50	1266.82	620.25	137.16	61.57	7684.92	5.00
2162.42	1698.91	1481.49	1277.16	624.27	148.99	63.75	7456.99	6.00
2174.06	908.62	1332.88	1149.05	585.22	139.90	62.31	6352.04	7.00
2081.84	0.00	1023.68	882.50	503.11	109.88	57.26	4658.27	8.00
1885.79	0.00	553.88	477.49	377.94	58.93	48.60	3402.63	9.00
1585.90	0.00	0.00	0.00	209.70	0.00	36.33	1831.92	10.00
1182.16	0.00	0.00	0.00	0.00	0.00	20.44	1202.60	11.00
674.59	0.00	0.00	0.00	0.00	0.00	0.00	674.59	12.00
18749.99	9175.51	8592.01	7406.99	4500.00	750.00	502.50	49676.99	

was that the preparation of forecasts was ponderous and time consuming because of the need to relate to expenditure in the bill of quantities to the contract programme.

In cases where forecasts were prepared these were not updated as the jobs progressed thereby variations to the original budget were not incorporated. As projects proceeded a greater reliance seemed to be placed on the comparison of work valuations with actual cost to establish profitability. No attempt was observed to predict final cost and time once the project was underway.

The application in the production area will be based on cost centres, but significantly different requirements need to be incorporated. The cost centres will be directly related to the contract programme and precise start and completion dates will be required in order to formulate the project budget. Each cost centre will be subdivided as appropriate into constituent costs, e.g. labour, plant and materials, thereby permitting a more detailed assessment to be made for control purposes at the monitoring stage. The cost centre budgets will be allocated to the project time-scale using curve shaping constants to distribute anticipated expenditure.

Alternatively, the overall project budget could be determined without the use of cost centres. This application would only be appropriate where the user possessed a reliable basis for determining an accurate budget and where a detailed breakdown is not required for project control purposes.

Further developments in the computer software will make it possible to allow the user greater modelling flexibility. This can be achieved by facilitating the selection of an appropriate number of cost centres to suit the project in hand and each cost centre can be given a title to comply with the requirements of every individual project.

Armed with the knowledge of likely cost centre expenditure curve profiles the user will then select the appropriate alpha/beta curves. If this is not possible then the "ALTERATION" programme can be used to cope with all other cases.

Where users require a more detailed breakdown of a project the computer software could be rewritten to provide for project elemental costs which in principle could be treated in the same manner as cost centres.

The complete conversational process for the production application is shown in Figures 27, 31 and 33 which utilises both the forecasting and alteration programmes.

8.3.3 Project Management of the Whole Construction Process

The basic philosophy previously described does provide a means for developing systems which enable projects to be managed and administered from inception to final completion. It is foreseen that this type of application will be extremely valuable to the project manager in his role as the client's executive controller.

The cost centres will be required to represent expenditure on the feasibility, design, construction and commissioning of the project. It therefore follows that budgets must be established for each of the cost centres selected and these must be precisely modelled to represent the anticipated expenditure involved. The number of cost centres required will be determined by the nature and size of projects in hand, however, it is considered at this stage that between twelve and twenty centres of cost will need to be identified for most sizeable projects. The titles selected for the projects will again depend on the type of project and the manner in which the expenditure is to be distributed.

Where the complete design and build process is carried out by one company then the formulation of budgets and the monitoring of the system will be much easier than in the cases where several separate organisations combine to build the project. At this point in time it would appear from the survey already conducted and from other sources that the multi-disciplinary company is more ideally suited to this type of application. Where the project management and administration is undertaken by more than one individual or organisation, problems of communication, integration and co-ordination occur which make it far more difficult for the project manager to implement the system. Of course, this is not an impossible situation but the effectiveness of the control system could suffer, unless a conscious effort is made by all concerned to work in accordance with the principles of the system laid down.

The monitoring and control process will be geared to accurate data input relating actual periodic expenditure and the percentage of the work completed to date. Failure to meet the above requirement will seriously reduce the effectiveness of the system as a means for management control and decision making. It is therefore considered essential that the standards of data input are properly determined and that the mode of operation is clearly established. Requirements of this nature must be properly communicated to all concerned.

The proposed output of reports relating to profitability and predictions by the system is considered to be extremely useful and relevant to the project managers role as the project chief executive.

After the revised budget has been finalised it is stored on the project files. Under normal circumstances the original budget will be overwritten and lost. However, large main frame systems have tape back-up facilities which permit the retrieval of old project tapes when required. This provision could be useful during the project itself when budget revisions are necessary.

8.4 Summary

The research and development into the forecasting system has without doubt provided a means hitherto unequalled in the production of project forecasts. The ability to model projects accurately and to understand the nature of the expenditure in specific terms such as alpha, beta and gamma represents a major step forward in the ability to model a wide range of projects with differing expenditure patterns. In addition the speed at which budgets can be produced far exceeds traditional procedures which if required allows the user to iterate a solution to his problem. This in turn will lead to a greater understanding of the forecasting process and its implications. The applications software clearly demonstrates how these proposals can be implemented. Whilst this development is intended to demonstrate how the principles can be applied, the final manner in which the applications programmes are written will be to the choice of the eventual user. However, the systems proposed represent a number of novel programming procedures, particularly the file handling sub-system and the approach to cost centres applied to a common timescale. The Alteration Programme provides for a considerable amount of flexibility and permits precise modelling of the project.

The development of the forecast is only a means to an end. Without management utilisation the whole process is of very little practical value. The forecast must therefore be used as a yardstick for assessing performance which results in decision making and control. Further it is necessary to up-date the forecast regularly with a view to predicting the eventual outcome of the project.

The following chapter is concerned with the development of a monitoring and control system which fully integrates with the forecasting proposals already made.

Chapter 9

9. Project Monitoring and Control System

9.1 General

The development of the system must meet the general requirements of the forecasting system described with regard to simplicity and ease of use. It must also provide periodic reports which enables the manager to check the current status of the project and where possible provide him with predictions relating to the eventual project outcome.

The data already stored in the computer by the forecasting system will be utilised to give budgeted information in order to provide the yardstick for control.

It is proposed that the same cost centre philosophy is utilised and that this will form the basis for more detailed control by the manager. The system illustrated allows for seven cost centres but this can be increased according to the needs of the user. Normally the number of cost centres selected for the forecasting system will be reflected at the monitoring and control stage. Software has also been written for the assessing of project expenditure only.

The conclusions from the contextual survey indicated that manual financial control systems were in operation on most sizeable projects and that these were tied in closely to the contract surveyors reconciliations on site. Unfortunately most of these systems were slow and time consuming. Because of this factor much of the information when finally produced was of a rather historic nature thereby limiting its use in terms of management decision making. The same principle applied to the large design partnership studies. Unfortunately the other design practices did not operate any monitoring and control system whatsoever.

9.2 Monitoring System Methodology

The operation of this system is envisaged as being in three distinct stages, namely:

1. Establishment of the actual project cost to date.
2. Determination of project profitability to date.
3. Prediction of eventual project cost and time.

The flow chart showing a more detailed appraisal of the philosophy is shown in Figure 35. A detailed explanation of the system is given under the following headings:

Basic Information

Valuation of Work

Profitability Analysis

Predictions

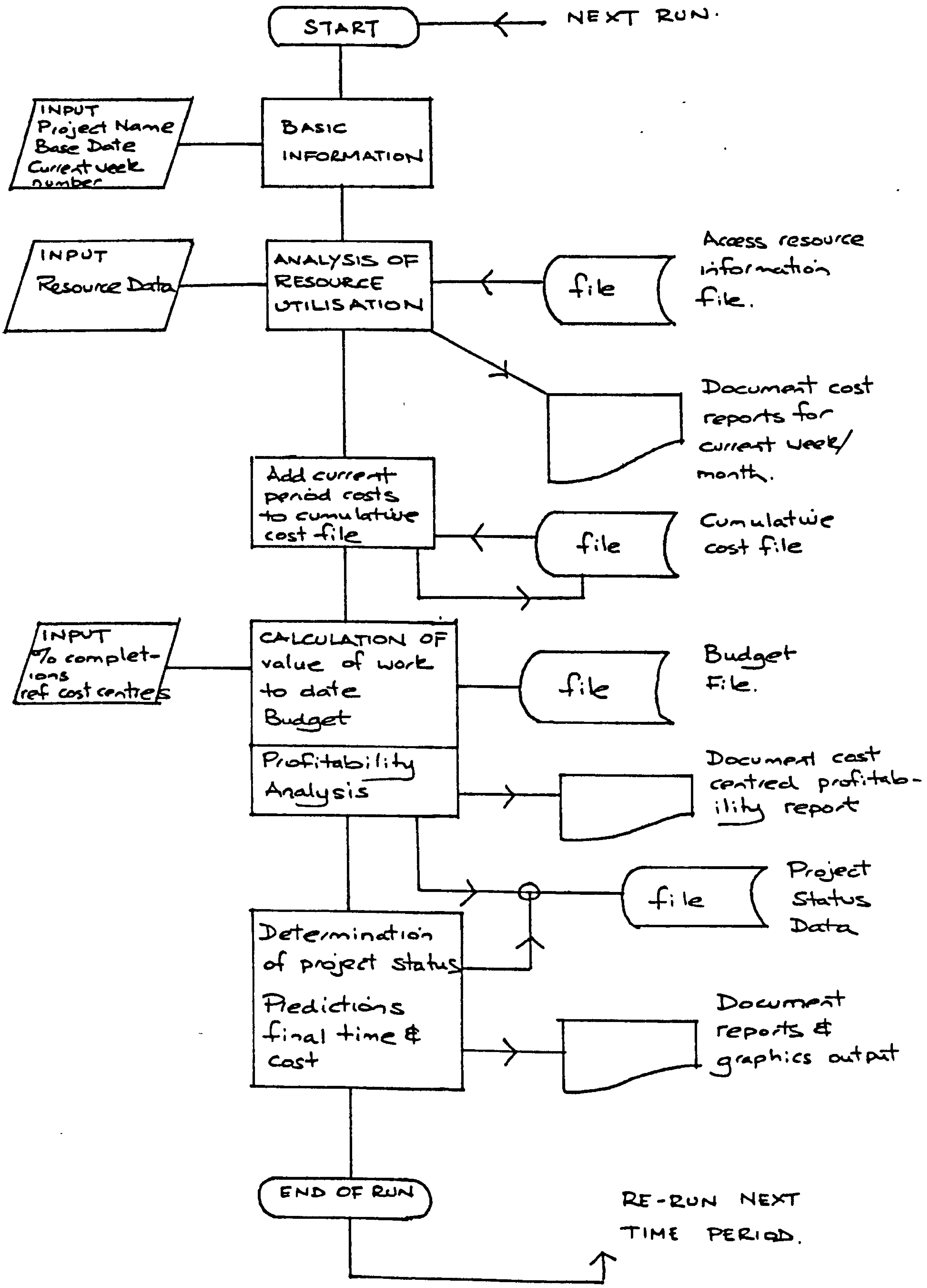


Figure 35 Monitoring Sub-System Methodology Flowchart

9.3 Basic Information

The user will be required to input the project name together with the current week/month number. This process will be undertaken interactively with the computer, as will all the inputs from a terminal. In the case of the first monitoring run the project base date will also need to be stated.

The files already stored by the forecasting system will be accessed and read sequentially by the monitoring system programme in order to provide the necessary budgeting information.

A file will also be created to store cumulative project actual cost information.

The user will be required to input the actual costs associated with each particular cost centre for the week under consideration; these are added to the accumulated costs to date and a report is produced. See Figure 36.

Valuation of Work

The valuation of work to date must be associated with the cost centres already selected. The form of the valuation may be in financial terms or alternatively as a percentage completion to date. The illustration shown is based on the percentage completion option.

Accurate valuation of the work completed is, of course, crucial to the whole system and therefore sufficient attention should be paid to this particular aspect.

Figure 36

```
PROJECT CONTROL PROGRAM MODULE
==============================

CONVERSATIONAL MODE DATA INPUT PROCEDURE
========================================

INPUT PROJECT NAME(MAX 5 CHARACTERS) ?TARMC
 INPUT PROJECT WEEK NUMBER
 ?11

COST CENTRE NO.  1
INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY
 ?0,0,0
COST CENTRE NO.  2
INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY
 ?400,435,587
COST CENTRE NO.  3
INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY
 ?0,0,0\0,0,0\72,75,87
COST CENTRE NO.  4
INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY
 ?0,0,0
COST CENTRE NO.  5
INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY
 ?13,12,11
CC6 NOM/S-C'S
 ?0
CC7 SITE O/H'S
 ?60
***********************************************************************************************
```

Figure 36

MONTHLY EXPENDITURE TO DATE

COST CENTRES

MONTH	SUBSTRUCTURE LABOUR	PLANT	MAT	SUPERSTRUCTURE LABOUR	PLANT	MAT	FINISHINGS LABOUR	PLANT	MATERIAL
1	300.00	200.00	300.00	0.00	0.00	0.00	0.00	0.00	0.00
2	300.00	350.00	300.00	0.00	0.00	0.00	0.00	0.00	0.00
3	300.00	340.00	200.00	0.00	0.00	0.00	0.00	0.00	0.00
4	350.00	340.00	400.00	0.00	0.00	0.00	0.00	0.00	0.00
5	340.00	350.00	300.00	0.00	0.00	0.00	0.00	0.00	0.00
6	275.00	300.00	250.00	200.00	0.00	0.00	0.00	0.00	0.00
7	300.00	300.00	300.00	89.00	120.00	78.00	0.00	0.00	0.00
8	250.00	200.00	200.00	300.00	200.00	200.00	0.00	0.00	0.00
9	80.00	70.00	70.00	250.00	300.00	350.00	0.00	0.00	0.00
10	0.00	0.00	0.00	350.00	250.00	400.00	40.00	35.00	40.00
11	0.00	0.00	0.00	400.00	435.00	587.00	72.00	75.00	87.00
TOT	2495.00	2450.00	2320.00	1589.00	1305.00	1615.00	112.00	110.00	127.00

	EXTERNAL WORKS LAB	PLANT	MATERIAL	DRAINAGE LAB	PLANT	MATERIAL	NOM S/C'S	SITE O/H'S	TOTALS
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.00	821.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00	985.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.00	885.00
4	0.00	0.00	0.00	30.00	30.00	30.00	0.00	30.00	1210.00
5	0.00	0.00	0.00	140.00	0.00	0.00	0.00	35.00	1165.00
6	0.00	0.00	0.00	60.00	60.00	60.00	0.00	40.00	1245.00
7	0.00	0.00	0.00	50.00	50.00	50.00	0.00	45.00	1382.00
8	0.00	0.00	0.00	50.00	50.00	50.00	0.00	50.00	1550.00
9	0.00	0.00	0.00	40.00	45.00	40.00	0.00	55.00	1300.00
10	0.00	0.00	0.00	35.00	36.00	45.00	0.00	50.00	1281.00
11	0.00	0.00	0.00	13.00	12.00	11.00	0.00	60.00	1752.00
TOT	0.00	0.00	0.00	418.00	283.00	286.00	0.00	466.00	13576.00

Naturally it would be an advantage if the project was originally priced on the basis of the cost centres utilised in the system. The valuation of the work would be undertaken by physical measurement on site and these could be related back to the total amount of work hence achieving a percentage completion figure. Where the project was not originally priced using the monitoring system cost centres then it will be necessary to reform the estimate in appropriate cost centre budgets before the system can be used. Failure to undertake this process properly will result in inaccuracies which could considerably reduce the value of using the monitoring and control process in the manner proposed.

The only measure of assessing percentage cost centres completion is in terms of money. Where several resources are involved in comprising a cost centre these must be converted and accumulated in financial terms. The whole process is a function of the accuracy of the valuation visa vee the time spent on formulating it.

Where the work is tangible and can be measured there would appear to be few problems, however in the case of assessing the percentage completion of the design process then difficulties do exist. One could base the percentage completion on the number of drawings produced to date relative to the total required. The problem with this approach is that a proportion of the work, for example innovative thought, cannot be quantified and hence to some degree an intuitive assessment needs to be made. This situation can to some extent be mitigated by experience gained in adopting this style of approach.

Other difficulties need to be appreciated and guarded against, particularly where vested interests are concerned thereby causing the figures to be manipulated in order to produce a good impression. In essence there is no general solution to this process. It is a function of the application and determination of the user to come up with realistic valuations of work completed to date.

9.4 Profitability Analysis

The original forecast to date is accessed by the computer programme and is broken down where appropriate into resource budgets in terms of labour, plant and materials. The equivalent valuations will be displayed against the budgets as shown in Figure 36 thus giving an indication of progress to date. The costs generated to date can be compared with the valuation and hence a measure of profitability can be established for each cost centre and its relevant sub-division as appropriate. A summary of the project status to date is then prepared in order to give the manager a complete picture of the situation.

The analysis produced in this manner is seen as a basis from which the manager will be able to make his decisions. The form and amount of output can be varied according to individual needs and circumstances. By comparing the current and previous reports of this type, past performance trend patterns can be established which will inform the manager about how effective his decision making has been.

Figure 36 Profitability and Progress Analysis

```
ENTER ESTIMATED % COMPLETED TO DATE FOR WORK CATEGORIES 1 TO 7
INPUT WORK CATEGORY 1
 ?100
INPUT WORK CATEGORY 2
 ?36
INPUT WORK CATEGORY 3
 ?4
INPUT WORK CATEGORY 4
 ?0
INPUT WORK CATEGORY 5
 ?100
INPUT WORK CATEGORY 6
 ?0
INPUT WORK CATEGORY 7
 ?47
*******************************************************************
```

Figure 36

PROFITABILITY ANALYSIS REPORT

PROJECT TARMC

WEEK NUMBER 11

COST CENTRES

	SUBSTRUCTURE			SUPERSTRUCTURE			FINISHES		
	LAB	PLANT	MAT	LAB	PLANT	MAT	LAB	PLANT	MAT
BUDGET	2100.00	1400.00	3500.00	1416.91	944.61	2361.52	116.62	77.75	194.37
ESTIMATED VALUE OF WORK TO DATE	2100.00	1400.00	3500.00	1296.00	864.00	2160.00	140.00	140.00	140.00
ACTUAL COST TO DATE	2495.00	2450.00	2320.00	1589.00	1305.00	1615.00	112.00	110.00	127.00
PROFIT/ LOSS	-395.00	-1050.00	1180.00	-293.00	-441.00	545.00	28.00	30.00	13.00

Figure 36

	EXTERNAL WORKS LAB	PLANT	MAT	DRAINAGE LAB	PLANT	MAT	NOM S/C	SITE O/H	TOTALS
BUDGET	0.00	0.00	0.00	300.00	200.00	500.00	0.00	437.65	13549.42
ESTIMATED VALUE OF WORK TO DATE	0.00	0.00	0.00	300.00	200.00	500.00	0.00	470.00	13210.00
ACTUAL COST TO DATE	0.00	0.00	0.00	418.00	283.00	286.00	0.00	466.00	13576.00
PROFIT/ LOSS	0.00	0.00	0.00	-118.00	-83.00	214.00	0.00	4.00	-366.00

****

Figure 36

GENERAL ANALYSIS OF PROJECT STATUS TO DATE

RESOURCES UTILISED TO DATE

POUNDS STERLING 13576

RESOURCES REMAINING

POUNDS STERLING 23467

OVERALL PERCENTAGE OF WORK COMPLETE TO DATE 35.6613

ESTIMATED FINAL PROJECT PRIME COST $ 37409

SHORTFALL/GAIN ON ANTICIPATED FORECAST PROFIT/COST -366

END OF REPORTING PROCEDURE

Figure 37 Project Status and Predictions

GENERAL ANALYSIS OF PROJECT STATUS TO DATE

RESOURCES UTILISED TO DATE

POUNDS STERLING 13576

RESOURCES REMAINING

POUNDS STERLING 23467

OVERALL PERCENTAGE OF WORK COMPLETE TO DATE 35.6613

ESTIMATED FINAL PROJECT PRIME COST $ 37409

SHORTFALL/GAIN ON ANTICIPATED FORECAST PROFIT/COST -366

END OF REPORTING PROCEDURE

INPUT DATA :-
PRESENT DURATION 11 MONTHS AT VALUE 13210
EXPECTED PROJECT COST 37409

PRESENT EXPECTED COST OCCURS AT PERIOD 30

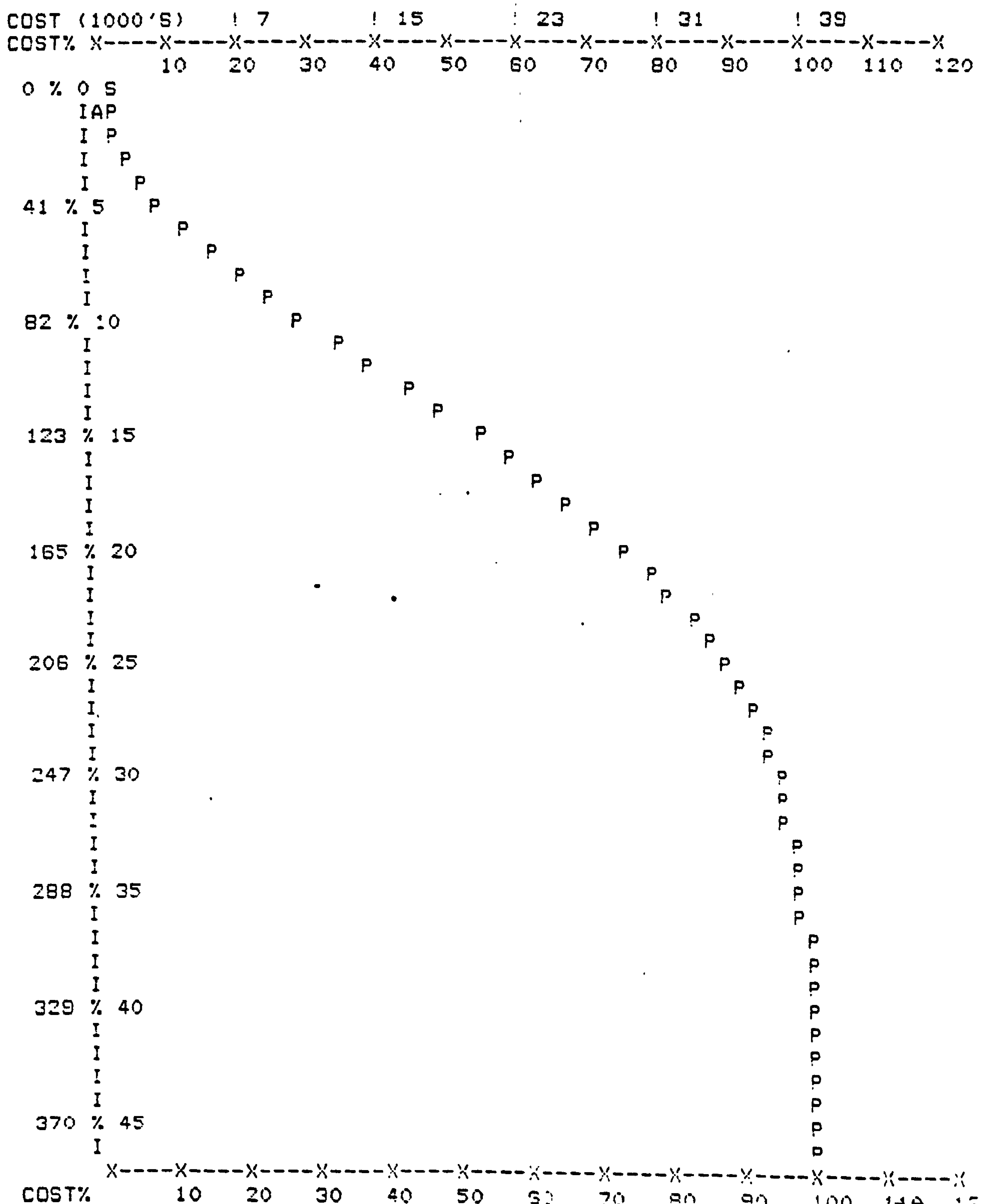
MAX PREDICTED COST IS 39278.1

PRD	CUM. COST	PREDICTED (CUM. COST)
11	13210	13210
12	X	15160
13	X	17120
14	X	19060
15	X	20950
16	X	22780
17	X	24520
18	X	26170
19	X	27720
20	X	29150
21	X	30460
22	X	31660
23	X	32740
24	X	33700
25	X	34550
26	X	35300
27	X	35960
28	X	36520
29	X	37010
30	X	37420
31	X	37770
32	X	38060
33	X	38300
34	X	

Figure 37

GRAPH OF PROJECT EVALUATION

DURATION 46 WEEKS AT COST 39279.4 'POUNDS'




```
RESPECIFY PROJECT NAME YES OR NO
 ?YES
RESPECIFY PROJECT NAME FOR CORPORATE PROG REFERENCE
 ?TARMC
```

9.5 Predictions

The programme software then facilitates the prediction of total project cost and time. This is achieved as previously described in section Chapter 5 and the results are output in the form shown in Figure 37. Because of the statistical inaccuracy of the predictions made early in the project, the programme will not activate the sub-system until a minimum of five project time periods have elapsed.

Case Study

The figures detailed below represent the monthly valuation to date in £1,000 units of a power station being constructed in the Middle East.

Month	Valuation (£1,000 units)
4	1,397
5	2,491
6	4,797
7	7,659
8	9,899
9	11,915
10	14,328
11	16,304
12	18,293
13	20,362

The anticipated final value is 37,043 and the project completion time is intended to be twentyfour months.

By running the program software PREDI (see Appendix 7 a prediction of final completion duration can be made utilising the exponential transposition method.

Figure 38 Prediction Case Study

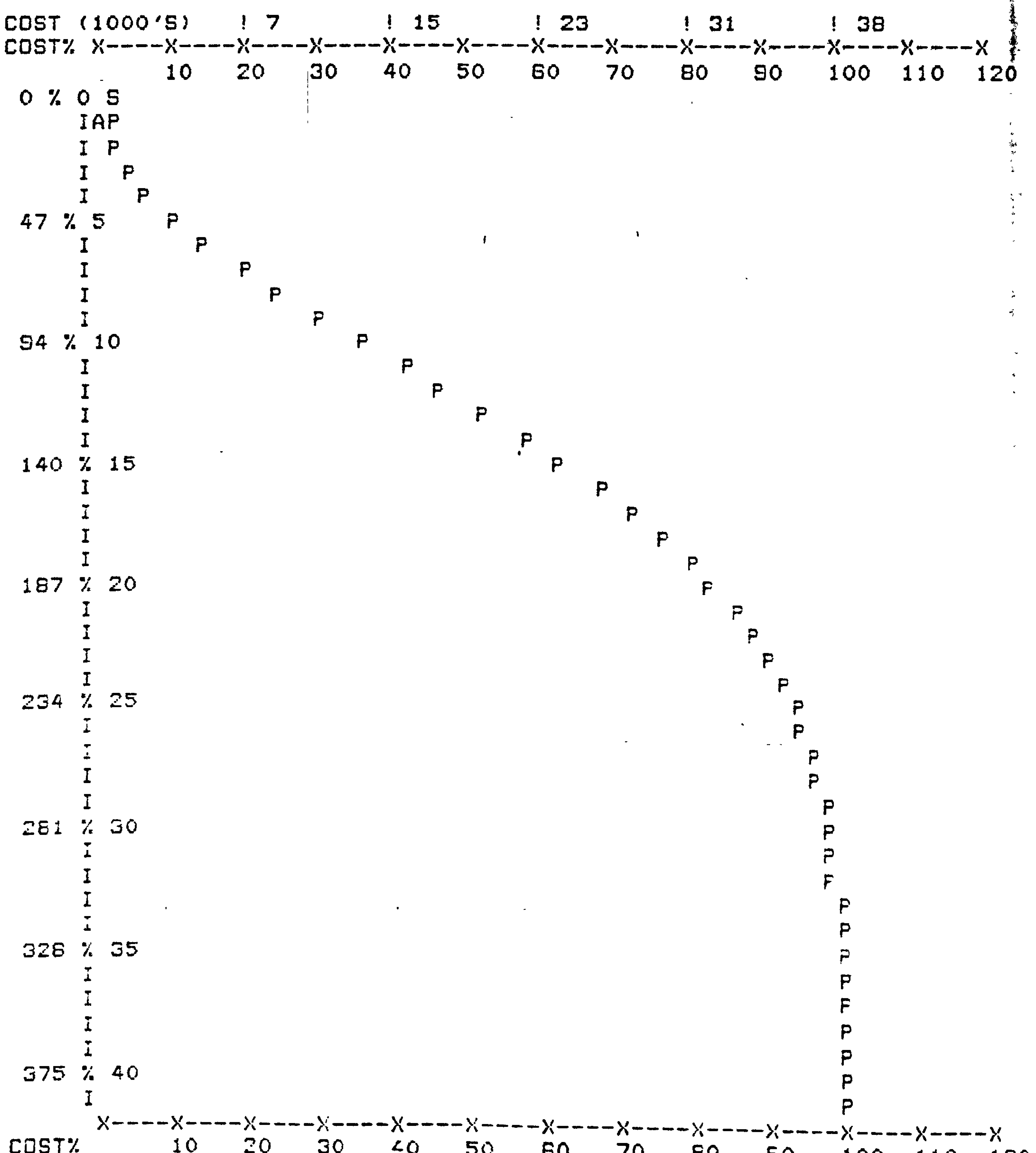
```
PROJECT TIME PREDICTION INPUT
*****************************


INPUT ELAPSED  MONTHS  TO DATE
 ?13
INPUT VALUATION TO DATE AND ANTICIPATED FINAL COST
 ?20362
 ?37043


INPUT DATA :-
PRESENT DURATION  13  MONTHS AT VALUE  20362
EXPECTED PROJECT COST  37043

PRESENT EXPECTED COST OCCURS AT PERIOD  27

MAX PREDICTED COST IS  38845.9
```

PRD	CUM. COST	PREDICTED (CUM..COST)
13	20362	20360
14	X	22430
15	X	24400
16	X	26240
17	X	27950
18	X	29500
19	X	30910
20	X	32170
21	X	33270
22	X	34240
23	X	35070
24	X	35790
25	X	36350
26	X	36690
27	X	37310
28	X	37650
29	X	37920
30	X	38140
31	X	38320
32	X	38460
33	X	38570
34	X	38650
35	X	38710
36	X	38760
37	X	38800
38	X	38830
39	X	38850
40	X	38860

```
GRAPH OF PROJECT EVALUATION
---------------------------
```

Figure 38 Prediction Case Study

DURATION 41 WEEKS AT COST 38855.1 'POUNDS'



RESPECIFY PROJECT NAME YES OR NO

The results depicted by Figure 38 show that the expected completion is likely to be month 27 assuming that the final project expenditure remains unchanged. The reason for the delay can be explained by the current valuation to date which is lower than the anticipated budget. An acceleration in the progress of the work will produce a shorter predicted final project deviation.

9.6 Monitoring and Control Applied to the Design Environment

The same principles applicable to the production of a project can be utilised for the monitoring and control of the design process where multi disciplinary terms are concerned. Since the prime resource is manpower the input in the main will be concerned with individual professions, i.e. the architect, engineer, etc. However, it is likely that some projects will require external consultants to be employed where specialist expertise does not exist within the design team. Further consumables, i.e. drawing materials and items which can be directly allocatable to the project will be necessary. Therefore provision has been made for these costs to be accrued by month/week under the cost centres previously described in the forecasting section.

Each member of the design team will be required to keep a timesheet and his hours will be allocated according to profession. A staff data file provides details regarding individual names related to code numbers and the respective monthly salary represented by an hourly rate; hence overtime is paid above the standard weeks work. Two reports are produced; the first provides an analysis of hours undertaken

Figure 39 Design Project Control Input Procedure

```
PROJ5         11:18         15-OCT-82


DESIGN PROJECT CONTROL PROGRAM MODULE
=====================================

CONVERSATIONAL MODE DATA INPUT PROCEDURE
========================================

INPUT PROJECT NAME(MAX 5 CHARACTERS) ?DES1

INPUT PROJECT BASE DATE I.E. 4,80 (MONTH 4 1980)
 ?1,83
INPUT PROJECT MONTH NUMBER
 ?9
INPUT NUMBER OF STAFF WORKING ON PROJECT
 ?6
INPUT EMPLOYEE NUMBER
 ?100
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?70
 ?0
 ?0
 ?0
 ?0
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
INPUT EMPLOYEE NUMBER
 ?200
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?68
 ?0
 ?0
 ?0
 ?0
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
INPUT EMPLOYEE NUMBER
 ?300
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?0
 ?65
 ?0

 ?0
 ?0
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
INPUT EMPLOYEE NUMBER
 ?400
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?0
 ?0
 ?75
 ?0
 ?0
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
INPUT EMPLOYEE NUMBER
 ?500
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?0
 ?0
 ?0
 ?74
 ?0
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
INPUT EMPLOYEE NUMBER
 ?5\5\600
INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)
 ?0
 ?0
 ?0
 ?0
 ?69
IS EMPLOYEE DATA O.K. ANSWER YES OR NO
 ?YES
```

by each profession and the latter gives the equivalent expenditure breakdown. Both consultants fees and allocatable overheads must be quantified financially prior to input. Figure 39 illustrates the output from a typical computer run.

Before preceding to the profitability analysis report the computer has been programmed to ask for a valuation to be made of the work carried out to date which should be input as a percentage. This necessitates the user to interprete progress accordingly, which in some cases may require a good deal of experience to make accurate assessments. It should be borne in mind that inaccurate estimates of percentage completion at this stage will undoubtedly give false results.

The subsequent reporting procedure is very similar to that already described for the production element. Each cost centre is analysed in terms of progress and profitability to date, and a general analysis of the project status is given to date. See Figure 40.

It is intended the manager in charge of the design process will be presented with a complete productivity analysis of the project which will enable him to identify adverse trends in their early stages. Consequently, decision making can be based on an up-to-date direct project assessment and the affect of such decisions can be measured in the terms provided by the monitoring and control process.

Figure 39a   Design Project Expenditure Output

```
***********************************************************************************************************
PROJECT DES1
-------

MONTH NUMBER  9
```

WK NO	NAME	TOTAL	ANALYSIS OF ACTUAL HOURS ARCH	S.E.	MECH ENG	ELECT	Q.S.
100	JONES A.	70.00	70.00	0.00	0.00	0.00	0.00
200	SMITH B.	68.00	68.00	0.00	0.00	0.00	0.00
300	RICHARDS N.	65.00	0.00	65.00	0.00	0.00	0.00
400	SMALL P.	75.00	0.00	0.00	75.00	0.00	0.00
500	SIMPSON W.	74.00	0.00	0.00	0.00	74.00	0.00
600	SIMMS D.	69.00	0.00	0.00	0.00	0.00	69.00
MONTHLY TOTALS		421.00	138.00	65.00	75.00	74.00	69.00

WK NO	NAME	TOTAL $	ANALYSIS OF EXPENDITURE $ ARCH	S.E.	MECH ENG	ELECT	Q.S.
100	JONES A.	854.0	854.00	0.00	0.00	0.00	0.00
200	SMITH B.	683.4	683.40	0.00	0.00	0.00	0.00
300	RICHARDS N.	734.5	0.00	734.50	0.00	0.00	0.00
400	SMALL P.	997.5	0.00	0.00	997.50	0.00	0.00
500	SIMPSON W.	1106.3	0.00	0.00	0.00	1106.30	0.00
600	SIMMS D.	821.1	0.00	0.00	0.00	0.00	821.10
MONTHLY TOTALS		5196.8	1537.40	734.50	997.50	1106.30	821.10

```
INPUT TOTAL COSTS EXPENDED ON EXTERNAL CONSULTANTS FOR THIS PERIOD
 ?200

INPUT TOTAL COSTS RELATING TO ALLOCATABLE
OVERHEAD EXPENDITURE ON PROJECT THIS PERIOD
 ?400

MONTHLY EXPENDITURE TO DATE

WORK CATEGORIES
```

MONTH	ARCH	S.E.	MECH ENG	ELECT	Q.S.	EXT CT'S	DIR O/H'S	TOTALS
1	144.60	0.00	0.00	0.00	0.00	0.00	100.00	244.60
2	869.90	0.00	0.00	0.00	452.00	0.00	150.00	1471.90
3	970.10	0.00	0.00	0.00	440.70	0.00	150.00	1560.80
4	981.15	0.00	0.00	0.00	429.40	0.00	150.00	1560.55
5	899.33	0.00	0.00	0.00	583.05	0.00	250.00	1732.38
6	1213.00	632.80	332.50	388.70	452.20	0.00	180.00	3199.20
7	1274.00	452.00	399.00	343.85	535.50	0.00	200.00	3204.35
8	1435.50	632.80	891.10	867.10	833.00	0.00	400.00	5059.50
9	1537.40	734.50	997.50	1106.30	821.10	200.00	400.00	5796.80
TOT	9324.98	2452.10	2620.10	2705.95	4546.95	200.00	1980.00	23830.08

Figure 40 Project Design Progress and Profitability

```
*******************************************************************************

ENTER ESTIMATED % OF DESIGN COMPLETED TO DATE FOR WORK CATEGORIES 1 TO 7
INPUT WORK CATEGORY 1
 ?28
INPUT WORK CATEGORY 2
 ?17
INPUT WORK CATEGORY 3
 ?14
INPUT WORK CATEGORY 4
 ?15
INPUT WORK CATEGORY 5
 ?33
INPUT WORK CATEGORY 6
 ?.5
INPUT WORK CATEGORY 7
 ?25


PROFITABILITY ANALYSIS REPORT
-----------------------------

PROJECT DES1

MONTH NUMBER 9

WORK CATEGORIES
```

	ARCH	S.E.	MECH ENG	ELECT	Q.S.	EXT CT'S	DIR O/H'S	TOTALS
BUDGET	12391.50	5146.16	2959.17	2876.98	3787.69	148.07	2639.45	29949.02
ESTIMATED VALUE OF WORK TO DATE	10500.00	2550.00	1890.00	1968.75	3960.00	18.75	1875.00	22762.50
ACTUAL COST TO DATE	9324.98	2452.10	2620.10	2705.95	4546.95	200.00	1980.00	23830.08
PROFIT/ LOSS	1175.03	97.90	-730.10	-737.20	-586.95	-181.25	-105.00	-1067.58

```
*******************************************************************************
```

GENERAL ANALYSIS OF PROJECT STATUS TO DATE

Figure 41

RESOURCES UTILISED TO DATE

POUNDS STERLING 23830.1

RESOURCES REMAINING

POUNDS STERLING 78544.9

OVERALL PERCENTAGE OF WORK COMPLETE TO DATE 22.2344

ESTIMATED FINAL DESIGN PRIME COST $ 103443.

SHORTFALL/GAIN ON ANTICIPATED FORECAST PROFIT/COST-1067.58

END OF REPORTING PROCEDURE

INPUT DATA :-
PRESENT DURATION 9 MONTHS AT VALUE 22762.5
EXPECTED PROJECT COST 103443

PRESENT EXPECTED COST OCCURS AT PERIOD 33

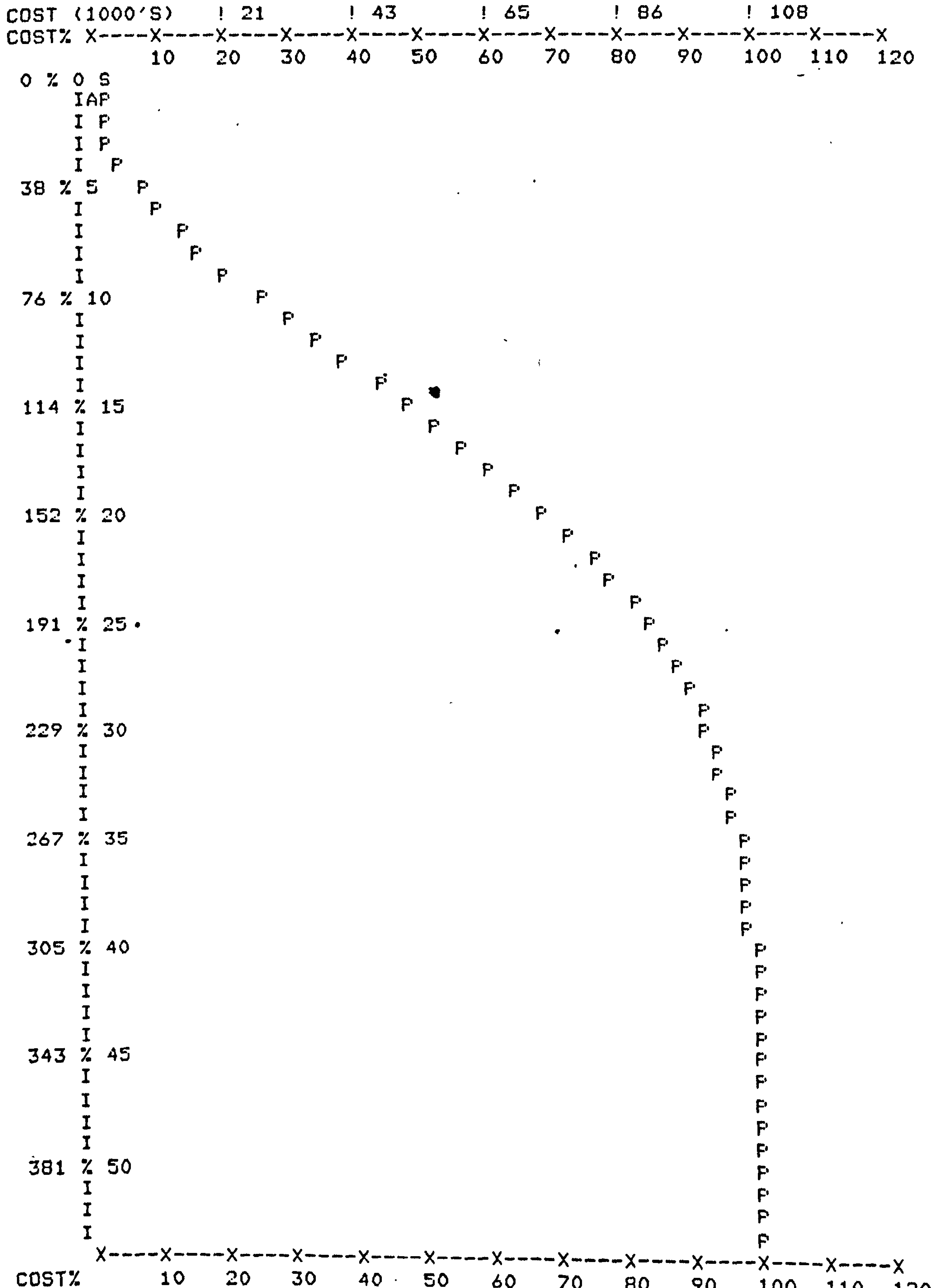
MAX PREDICTED COST IS 108311.

PRD	CUM. COST	PREDICTED (CUM. COST)
9	22762.5	22760
10	X	27370
11	X	32180
12	X	37110
13	X	42120
14	X	47130
15	X	52100
16	X	56960
17	X	61680
18	X	66220
19	X	70540
20	X	74610
21	X	78430
22	X	81970
23	X	85230
24	X	88220
25	X	90920
26	X	93360
27	X	95530
28	X	97460
29	X	99170
30	X	100650
31	X	101950
32	X	103060
33	X	104020
34	X	104830
35	X	105520
36	X	106090
37	X	106580
38	X	106970
39	X	107300
40	X	107570
41	X	107790
42	X	107970
43	X	108110
44	X	108220
45	X	108310
46	X	108380
47	X	108440
48	X	108480
49	X	108510
50	X	108540
51	X	108560
52	X	108570

GRAPH OF PROJECT EVALUATION

Figure 41

DURATION 53 WEEKS AT COST 108615. 'POUNDS'



RESPECIFY PROJECT NAME YES OR NO
?YES
RESPECIFY PROJECT NAME FOR CORPORATE PROG REFERENCE
?DES1

TIME: 4.46 SECS.

The final stage in the monitoring system provides a prediction analysis for the project in respect of final project cost and time.

The periodic valuations are stored on file as the project progresses in order to provide data for the prediction procedure previously described. The first five project valuations are ignored since the results produced have been found to be statistically unrealiable. After the fifth period the likely expenditure curve will be projected from the known curve data utilising the best fit procedure previously described.

It is intended that the manager will have a clear impression of the progress to date and the likely result of the completed project. The periodic predictions analysed collectively will give a further indication of project performance and the effectiveness of decisions taken. Figure 41 illustrates the computer output from the prediction phase of the programme.

9.7 Summary

The software developed allows for many projects to be conveniently handled by a single computer facility. The stage by stage handling of project data through both the forecasting and monitoring prediction systems is intended to provide the manager(s) will sufficient data to make viable decisions concerning the projects in hand. The method of file handling proposed and the conversational mode of programme operation is intended to enable a direct interface between the user manager and the computer itself. In this manner it is intended that the potential for misunderstanding and confusion is eliminated since no highly skilled computer expertise is required. To achieve this situation a loss of use flexibility is to be expected but since most project situations are specific then this would seem to be of little consequence. Some degree of flexibility can be provided for by allowing the user to select his own cost centre headings, in which case, within the constraints of the number of cost centres he can select whatever titles he desires; these would of course vary from project to project.

The fundamental advantage of the system proposed is that fully integrated set of programmes utilising the so called "alpha/beta" philosophy have been developed whereby the manager is given an invaluable tool with which he can forecast, monitor and control one or more projects under his durisdiction. Further the system provides an excellent basis for collecting historic data which can be utilised to improve management decision making still further in the future.

Another step in the development could be the possible incorporation of the payroll and accounting systems to provide an automatic input of actual cost. However, the development of this notion is outside the scope of this thesis.

Chapter 10

10. Corporate Control and Multi Project Management

10.1 General

The data created by the project systems previously described can be utilised to facilitate the production of reports which enable the corporate management structure of the company to control the affairs of the enterprise and make decisions based on the best possible information. Where companies are entirely project based as in the case of those in the construction industry, then the amalgam of the project data represents the total activity of the business. Hence, it is a natural step once the project based systems are installed to develop corporate systems utilising the project data already established.

As in the case of the project based systems it is seen to be of paramount importance to establish systems which eliminate the need for computer expertise. Therefore it is considered essential to develop a file handling system capable of coping with the multi project situation.

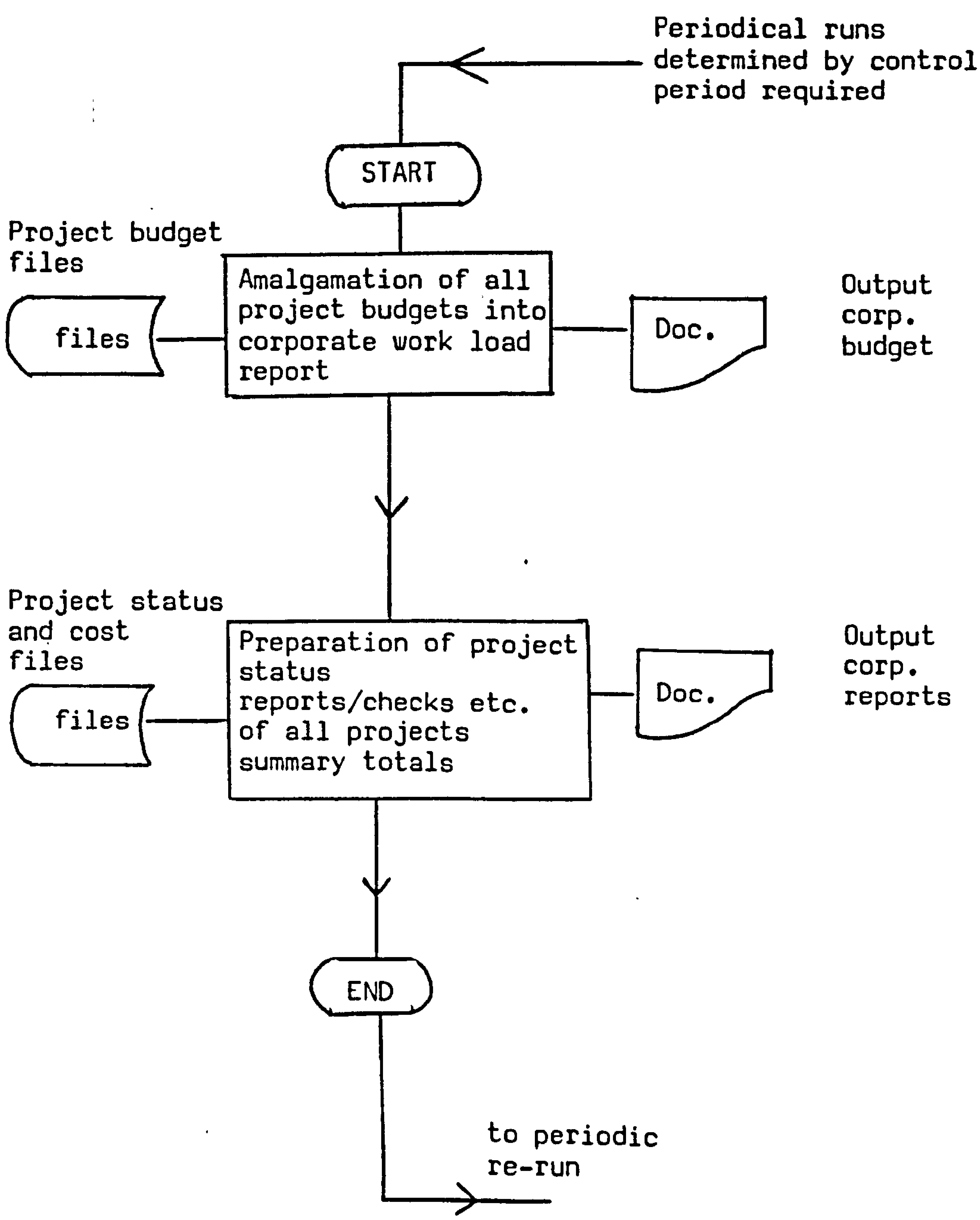
The initial stage of developing the system involves the determination of the type of information necessary to the corporate managers involved in that function. Figure 42 illustrates the system methodology proposed for this module.

10.2 Corporate Turnover System

A vital factor in the continued success of the construction company relates to the ability to obtain enough work at the right price. Because the majority of work is obtained by

Figure 42

Corporate Sub-System Methodology



competitive tendering it is vital to relate the need for the work to the competitiveness of the tender itself. In essence the current turnover will continually fall as one looks into the future to the point where no work exists. The corporate managers task will be to ensure that new work is obtained to maintain the annual turnover in accordance with corporate policy previously laid down. The amount of marketing effort required will be determined by how far orders extend into the future and the rate of work fall off envisaged. The major problem involves the relationship of mainly fixed resources to a continually varying work load. To some degree this problem can be resolved by resource scheduling and smoothing techniques. However, it would be of considerable benefit to the manager to have a complete analysis of the workload in terms of the projects in hand. The difference between the average turnover level and the total scheduled profit represents the target for the marketing effort. The project data already produced is ideally suited to this type of application and therefore a corporate turnover sub-system can be developed.

The system proposed is designed on a moving time span which can be selected by the user giving high and low span dates.

See Figure 43 for the system flow chart.
See Appendix 6 for the programme listings.

Figure 43

Corporate Turnover System Methodology

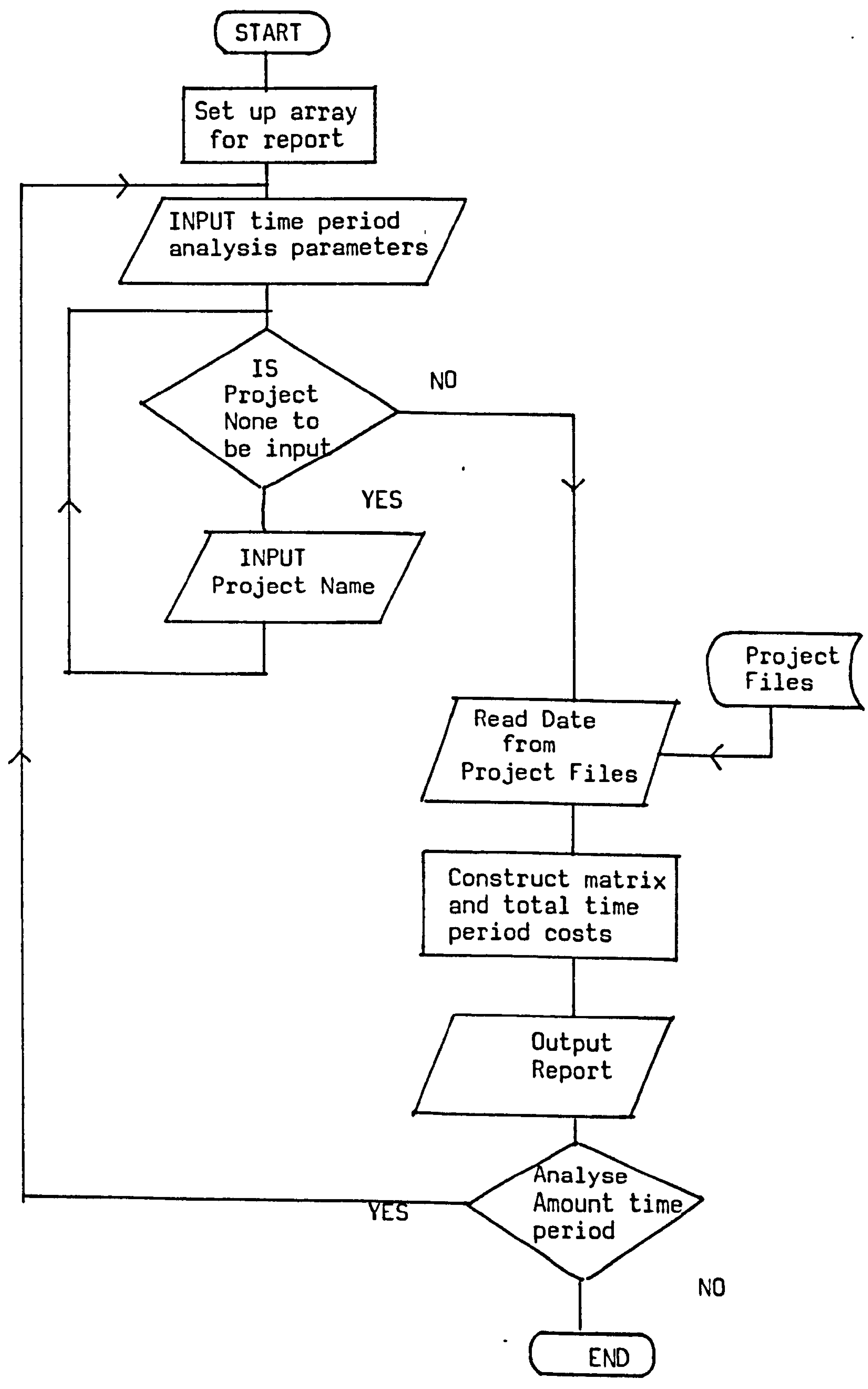


Figure 43 Corporate Turnover Report

```
CORPO           11:54          15-OCT-82


INPUT PERIOD TO BE ANALYSED i.e. MONTH,YEAR;MONTH,YEAR
 ?1,83,9,83
INPUT PROJECTS IN PROGRESS NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?DES1
 ?DES3
 ?END


CORPORATE CONTROL REPORT
------------------------

BUDGETED EXPENDITURE ON PROJECTS IN HAND
----------------------------------------

                     CALENDER TIMESCALE MONTHS/YEARS

PROJECT  1/83      2/83      3/83      4/83      5/83      6/83      7/83      8/83      9/83
=============================================================================================
DES1     628.14   1145.00   1548.85   1912.03   2703.01   4078.20   5131.07   5992.41   6810.28
DES3       0.00    604.99   1141.45   1585.02   1984.42   2725.53   4031.26   5106.65   5996.16

---------------------------------------------------------------------------------------------
         628.14   1749.99   2690.30   3497.05   4687.43   6803.72   9162.33  11099.06  12806.45
---------------------------------------------------------------------------------------------

DO YOU WISH TO ANALYSE ANOTHER PERIOD (ANS YES OR NO)
 ?YES
INPUT PERIOD TO BE ANALYSED i.e. MONTH,YEAR;MONTH,YEAR
 ?9,83,5,84
INPUT PROJECTS IN PROGRESS NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?DES1
 ?DES3
 ?END
```

Figure 43

CORPORATE CONTROL REPORT

BUDGETED EXPENDITURE ON PROJECTS IN HAND

CALENDER TIMESCALE MONTHS/YEARS

PROJECT	9/83	10/83	11/83	12/83	1/84	2/84	3/84	4/84	5/84
DES1	6810.28	7404.30	7781.05	7940.58	7882.87	7607.94	7115.77	6406.34	5479.71
DES3	5996.16	6836.54	7474.09	7899.45	8112.61	8113.58	7902.36	7478.92	6843.30
	12806.45	14240.85	15255.14	15840.04	15995.48	15721.52	15018.13	13885.26	12323.01

```
DO YOU WISH TO ANALYSE ANOTHER PERIOD (ANS YES OR NO)
 ?YES
INPUT PERIOD TO BE ANALYSED i.e. MONTH,YEAR;MONTH,YEAR
 ?5,84,1,85
INPUT PROJECTS IN PROGRESS NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?DES1
 ?DES3
 ?END
```

CORPORATE CONTROL REPORT

BUDGETED EXPENDITURE ON PROJECTS IN HAND

CALENDER TIMESCALE MONTHS/YEARS

PROJECT	5/84	6/84	7/84	8/84	9/84	10/84	11/84	12/84	1/85
DES1	5479.71	4272.36	3378.55	2192.36	1864.22	1495.41	1085.94	518.63	0.00
DES3	6843.30	5995.48	4935.46	3588.15	2368.80	2017.44	1621.92	1182.23	579.22
	12323.01	10267.83	8314.00	5780.51	4233.02	3512.85	2707.85	1700.86	579.22

10.2.1 User Procedure

The programme in common with other software in the system operates in interactively with the user to produce the report required. The following step by step procedure is necessary:

1. Input parameter dates of time periods to be analysed in order of week/year commencement and week/year completion.

2. Input Project Names in Progress.

The project budget files are then accessed and their base dates are set to an array time scale prior to the preparation of the report in accordance with the parameter dates selected.

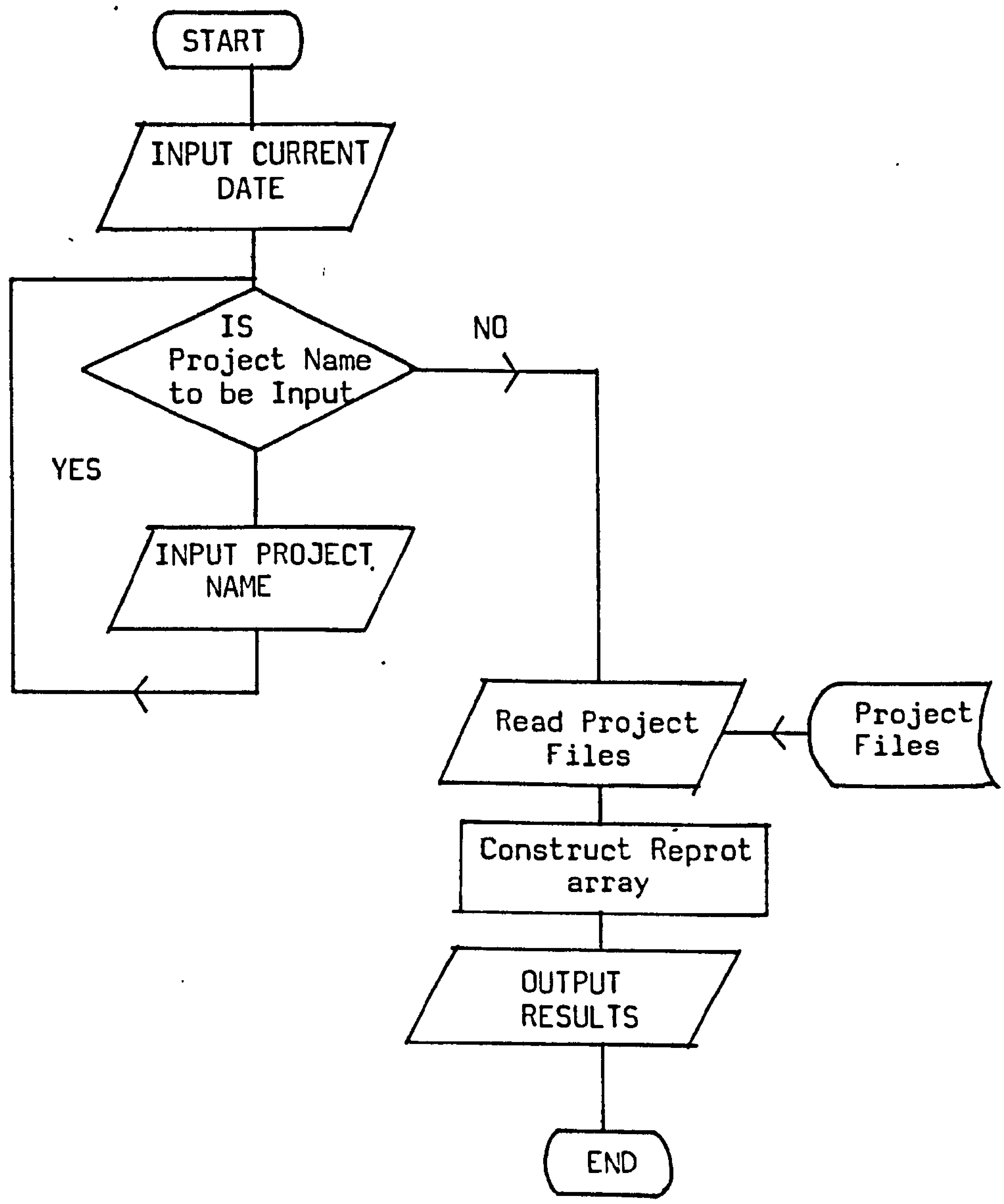
See Figure 43 which illustrates the programming procedure together with an example of the output of results.

10.3 Corporate Control System (Module 2)

This module is aimed at providing top management with summary reports which facilitate decision making at the corporate level. It is envisaged that reports will be required on a monthly basis which contain information which enable an assessment to be made of the actual project performance relating to the determined budget. Hence the components selected were as follows:

Figure 44

Corporate Control System (Module 2)



1. Final Estimated: Cost of the Project	An assessment of the final completion cost considering performance to date and the future budget.
2. Percentage Completion: to Date	Proportion of the total project completed to date based on valuation.
3. Shortfall/gain on Forecast.	An indication of profitability to date based on prime cost.
4. Predicted Completion Time	From the prediction system an estimate will be made relating to the final project.
5. Resources Utilised and remaining	The total expenditure to date will be considered in relation to the predicted final project cost.

This information will be reported by the system in the form shown by Figure 45.

The corporate manager can see at a glance the status of all current projects and if required comparisons can be made between them. A report will be given of the company profitability, based on prime cost, relating to all projects currently in progress and a monthly analysis will show trends in this respect.

Figure 45 Corporate Project Analysis

```
CORP2          11:51          15-OCT-82


CORPORATE CONTROL MODULE 2
--------------------------

INPUT CURRENT MONTH, YEAR(I.E. 3,80)
 ?9,83
INPUT PROJECT NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?DES1
INPUT PROJECT NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?DES3
INPUT PROJECT NAME(MAX FIVE CHARACTERS)TERMINATE WITH END
 ?END

****************************************************************************
MONTH  9
YEAR 19 83

PROJECT STATUS SUMMARY AND SHORTFALL/GAIN ANALYSIS TO DATE
----------------------------------------------------------

PROJECT  FINAL EST    % COMPL SHORTFALL/  PREDICTED    RESOURCES     RESOURCES
         DESIGN COST  TO DATE GAIN ON F/C TOTAL        USED          REMAINING
              $                    $      DURATION       $               $
============================================================================
DES1     103443.00    22.23   -1067.58       33        23830.10      78544.90
DES3     109733.00    20.10   -3608.20       31        24938.20      81186.80
----------------------------------------------------------------------------

OVERALL GAIN SHORTFALL ON CURRENT PROJECTS $-4675.78
****************************************************

PROJECT DES1
**************

PROFITABILITY TREND ANALYSIS
----------------------------

MH NO  MONTHLY +/-
-----------------


   1       411.65
   2      -126.50
   3      -697.30
   4     -1537.85
   5      -705.23
   6      2221.20
   7      2089.97
   8      -164.53
   9     -1067.58
  10         0.00
PROJECT DES3
**************

PROFITABILITY TREND ANALYSIS
----------------------------

MH NO  MONTHLY +/-
-----------------


   1      -162.30
   2       560.50
   3       668.80
   4      1808.80
   5       935.00
   6      4837.90
   7       639.05
   8     -3608.20
   9         0.00
```

The methodology involved in this report is shown in Figure 44.

The means of accessing project files will operate on the same principles as those previously described.

The user procedure simply requires the current date to be input together with the names of the current projects. The programme and file handling procedure is shown in Figure 45.

10.4 Application

The development of corporate control systems represents a natural step from the procedures already established in the thesis. The essence of this section relates to the development of software and systems capable of handling the data from several projects at once and presenting the relevant control information in a clear and concise manner. It may be stated that the corporate systems represent an important by product of the project control systems which enable more information decisions to be taken at the budget level. The effort and time normally required to manually obtain this type of information could be considerable. However, the system proposed will, within minutes, accumulate project data and produce typed reports at any time based on the most up-to-date information available from the project systems. The use of the corporate models is simple and will be well within the capabilities of secretarial staff to use. There would appear to be no reason why the Managing Director, for example, should not have a terminal permanently located in his office to access this information whenever he requires it.

The report information shown in Figure 45 is intended to indicate the general corporate status of the company in terms of the projects that it currently has in progress. Each project can be assessed with regard to its past and current profitability. A prediction of completion time is also given together with financial resources available to finish the project. The overall company profitability covering all projects in progress will give the corporate manager a basic assessment of the trading position of his organisation.

The object of producing the two corporate packages described in this section is to demonstrate the feasibility and potential of such an application. Naturally individual companies have there own systems and methods, hence reports of this nature can take many different forms which contain information necessary to meet specific needs.

Without doubt this type of approach could be extremely beneficial and there is little doubt that further development in this area will provide more assistance to an area of management which has been hitherto starved of reliable and efficiently produced data.

Chapter 11

11. Conclusions

The stated objective of this thesis was to research and develop a new system of project budgeting, monitoring and forecasting to meet the needs of the construction industry. In more specific terms the research was intended to initially concentrate on establishing a reliable means of simulating project expenditure curves utilising mathematical needs. A study was made of previous related work to establish the current state of the art. From this basis a programme of development work was instituted to derive improved methods. This research was successful and resulted in the production of the combined polynomial/exponential curve simulation. The subsequent testing programme proved that it was possible to curve fit samples of project expenditure to within a total curve fit error of 5%. To increase the versatility of the simulation in order to produce project budgets to fit almost any situation, two forecasting systems where developed based on a computer. The systems enabled the project programme to be considered in the preparation of the budget by the introduction of cost centres. Provision was also incorporated for alterations to expenditure, intermittent periods and allowance for inflation. The interpretation of project curves could be made in two ways, namely by selecting appropriate curve fit constant, based on previous experience or intuition, alternatively by utilising cost centre modelling.

The next stage was the institution of a contextual survey to establish the needs of the industry and the current usage of project budgeting, monitoring and control techniques relative to different types of organisation structures in the Construction Industry. The results of the survey indicated strongly the need for control systems which were easy to use and economic to prepare.

The subsequent development of a monitoring and control system was based on interactive computing procedures incorporating automatic file handling. This sub-system was designed to integrate with the budgeting packages previously described. In essence the system requires data input relating to valuation and cost to date after which a complete project profitability status is given, together with a prediction of final completion and cost.

These systems have been designed with sufficient versatility to be applied to both the areas of design and production.

Further experimentation and development has proved it possible to combine the various project data bases to produce corporate reports indicating company turnover, profitability and production performance.

It is anticipated that the whole system can be amended to suit the individual requirements of firms wishing to use this particular form of budgeting.

The contextual survey gave a clear indication of existing procedures provided a basis on which to develop the applications programmes. It was very apparent from the sites and organisations visited that there was a need for budgeting and monitoring systems which are easy to prepare and gave a meaningful representation of the project. In addition, the monitoring and control of the project should be such that the control information produced can be easily interpreted and used by managers to make decisions. The detailed findings of the survey has influenced the manner in which the reports were produced.

This research has achieved two significant developments in project forecasting, namely the development of a means whereby project expenditure can be modelled utilising the alpha-beta philosophy and the evolution of an integrated data base system to budget, monitor and predict project costs.

The work has been supported by a major effort in the area of software development involving extensive programme writing in basic and algol. The packages are currently available on Digital Corporation main frame computers, however it is my intention to rewrite the programmes for use with a powerful micro computer. I envisage that this development will bring the use of the system within the range of a vast number of potential users.

The viability of the alpha-beta polynomial has been conclusively proved by the fact that the DHSS research involving 800 projects can be simulated by using the alpha beta polynomial equation. Further the research testing programme described in Chapter 4 has demonstrated the versatility of the polynomial when used in conjunction with the exponential equation utilising the gamma constant which is directly related to the constant beta. Since the beta constant has be defined as the equiproportion point in the 's' curve it has real meaning and can be related directly to the curve. Hence a major advance has been made over previous known work in this field.

The applications procedures and programmes were geared to the findings of the contextual survey and were designed to be user friendly in the sense that managers and technical staff could use the systems without assistance from computer experts. This was achieved by the development of software programmes which were integrated by means of the project budget files and the progress files developed by the monitoring systems. The combination of project files formed individual project data bases which in turn could be used by the corporate control systems.

This research thesis has proved it possible to identify the effect of project management decision making by observing the variation in the curve fit constants and the switch points between the cubic and exponential equations. The use of the cost centre philosophy based on project method and programme has provided a viable means of determining the effect of management decisions using a more pragmatic approach which can be interpreted in the same constant terms mentioned above. It is also possible to apply the reciprocal approach by selecting known constants and switch points which are able to simulate viable project expenditure patterns suitable for budgeting and forecasting purposes.

The ability to make future predictions of project time and cost has been facilitated by the transposition of the Rayleigh Diffusion equation which has been expressed in terms of the peak cost period. Hence, by establishing the peak period cost of the existing expenditure to date, it is possible to project the curve to completion within acceptable limits of accuracy. The results from the construction projects have indicated that projections made at 66% of the elapsed project time were within an accuracy of 10%.

Scope also exists for predicting tendering costs, particularly where projections can be made knowing the nature of project expenditure in terms of the curve constants and the switch points defined earlier in the thesis. By anticipating project time the cost of the project can be predicted within known limits of accuracy. Conversely, knowing the final project cost, a completion date can be determined. Other applications relate to risk analysis and bidding strategy. Further development relating to the projection of known expenditure curves to date is foreseen, where the limits of accuracy and the confidence limits can be improved. It is expected that this research will continue with the aid of public funds.

There is potential for the development of corporate reports to include further analysis of the project data base relative to the status of the various projects under construction and the companies involved.

This thesis has laid the theoretical basis for practical application and the efforts of the author will be concentrated on developing the system in order that it can be applied in practice.

The tests referred to earlier have indicated a strong possibility that the theories can be applied to any industry where work is undertaken on a project basis. The fact that expenditure could be simulated for such diverse projects as a small refurbishment contract in the United Kingdom and a large power station in the Middle East indicated that the system could equally well be applied to oil rig construction or even major advanced technology projects. Further research would be necessary utilising the principles to establish their applicability in other areas.

To increase the potential for variety of uses, the computerised sub-system should be developed to incorporate facilities to vary the number and types of cost centre. This in turn will increase the usefulness of the system procedures over a wide range of projects having differing control requirements.

In conclusion, this work has created a new approach to the implementation of project management control which has opened up considerable possibliities for future research and development. The momentum must not be lost and I consider that this research has created a milestone and base from which to proceed in the future.

Appendix 1

4. Definition of Terminology and Symbols

In order to facilitate an unbroken text definitions of symbols and terminology are summarised below:

Period: an arbitrary time unit, e.g. month, week

Period Cost: the noncumulative cost incurred during one period, e.g. a given cost for any one month.

Redundant Period: a period during which costs are zero or relatively small, e.g. 10% of the average period cost.

Overrun: This situation occurs when the cubic equation gives a minimum after the project start or a maximum prior to the project end. Both of these are non feasible situations as they render negative period cost before the minimum or after the maximum of the cubic curve.

Convex, Concave: 'hill' and 'valley or U' shape curves respectively

Definition of Symbols:

Graph (1) reference:

1a	Cm	=	Cumulative Cost (value, budgeted cost or moneys spent)
1a	S	=	Contract Sum
1b	y	=	Cm/S = Proportion of the contract sum spent in the first m periods
1a	P	=	Contract Duration (number of periods)
1a	m	=	Current period i.e. period in which latest expenditure occurred (e.g. in months)
1b	x	=	m/P = Proportion of contract duration to date i.e. to period m
1c	Zm	=	Period (non-cumulative) cost i.e. cost incurred during period m
1c	Zp	=	Maximum or peak period cost (e.g. expenditure during the most costly month)
1c	Mp	=	Peak cost period or time at which the maximum period cost occurs (e.g. most costly month)
1d	x_p	=	Mp/P = Proportion of contract period when the maximum period cost occurs
1d	Y_p'	=	Maximum value of the slope of the alpha-beta cubic equation i.e. dy/dx at $x = x_p$ and corresponds to Zp
C,K		=	DHSS cubic equation constants
a		=	alpha constant (shaping constant)
b		=	beta constant (equiproportion constant) = $3x_p - 1$

Curve fit test (SDY)

In order to monitor the precision of the models it was calculated that the root mean squared deviations of the actual and predicted proportional cumulative costs abbreviated as SDY.

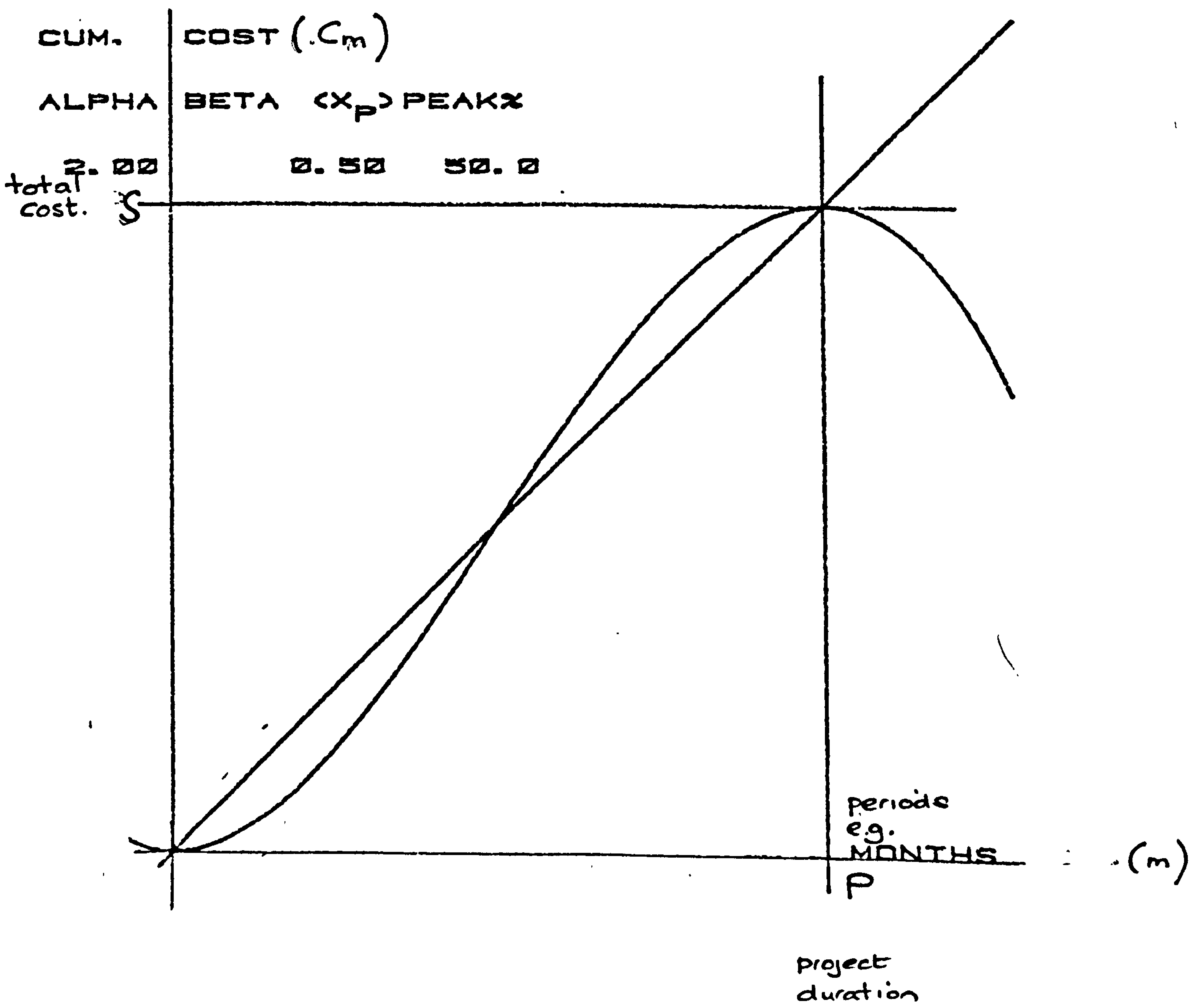
$$SDY = \left(\frac{1}{P} \left(Ya - Yp \right)^2 \right)^{.5}$$

where Ya is actual cumulative cost proportion (Y)

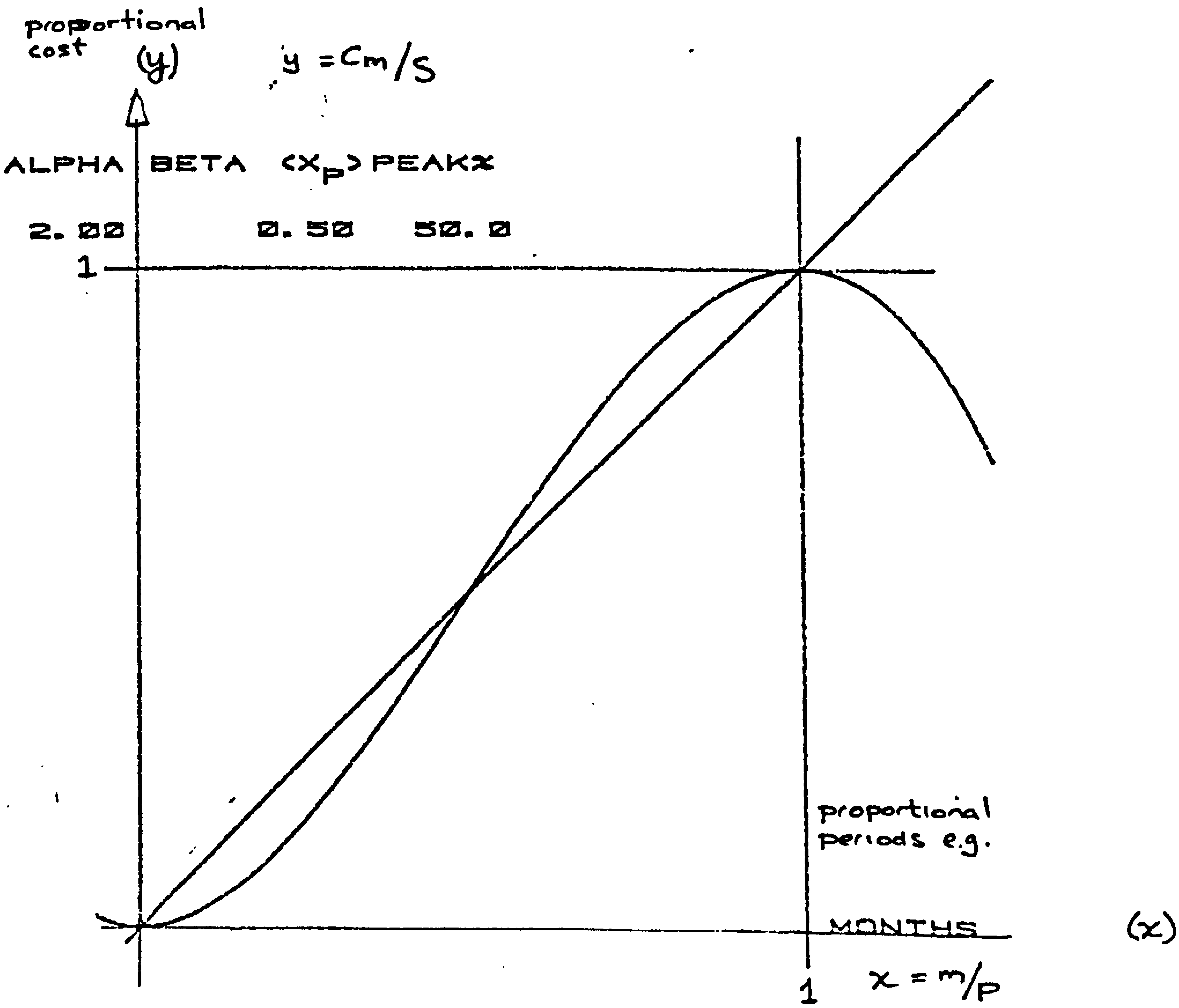
Yp is predicted cumulative cost proportion.

GRAPH 1a

1a to 1d graphs supporting notation

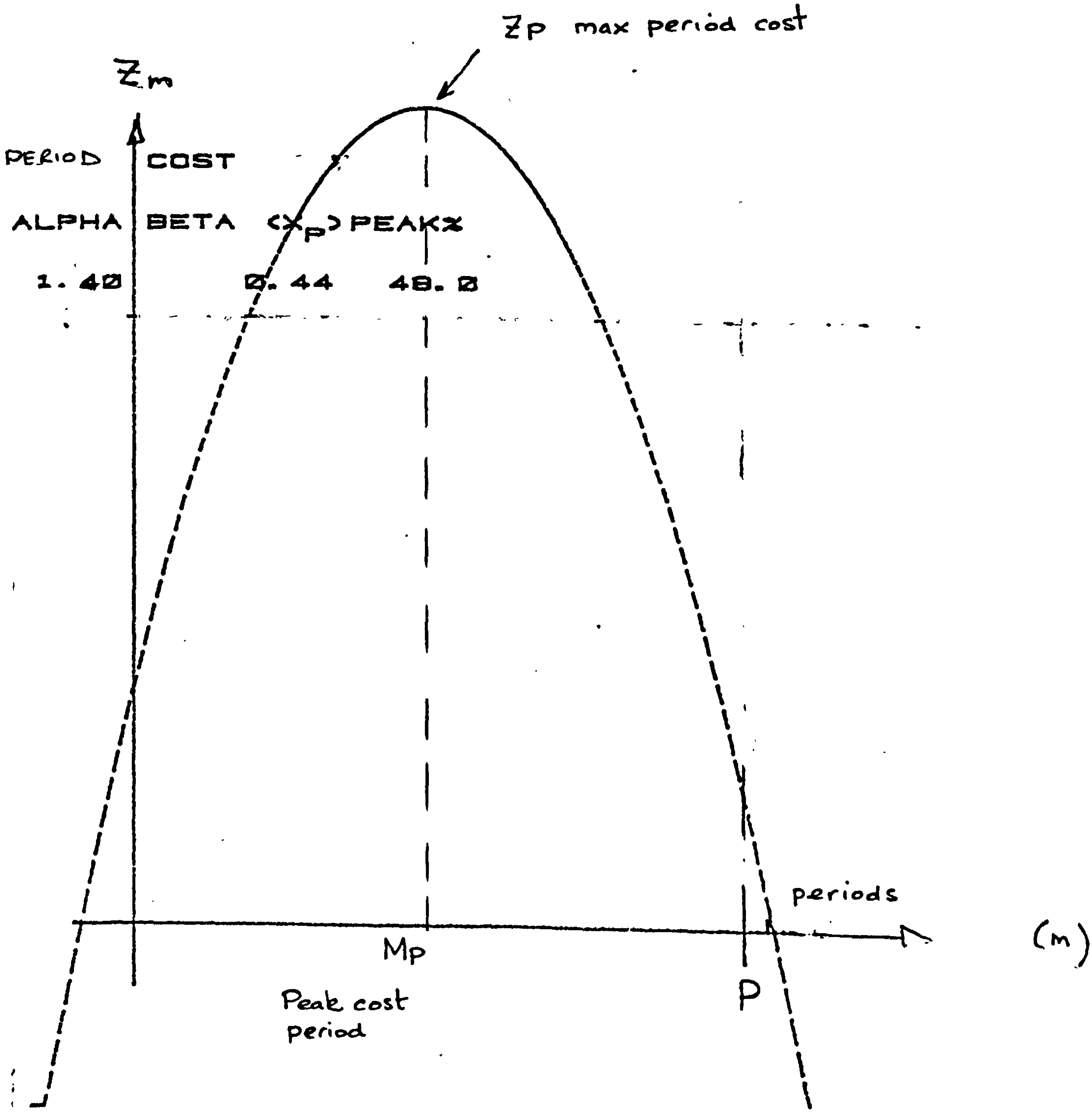


GRAPH 1b



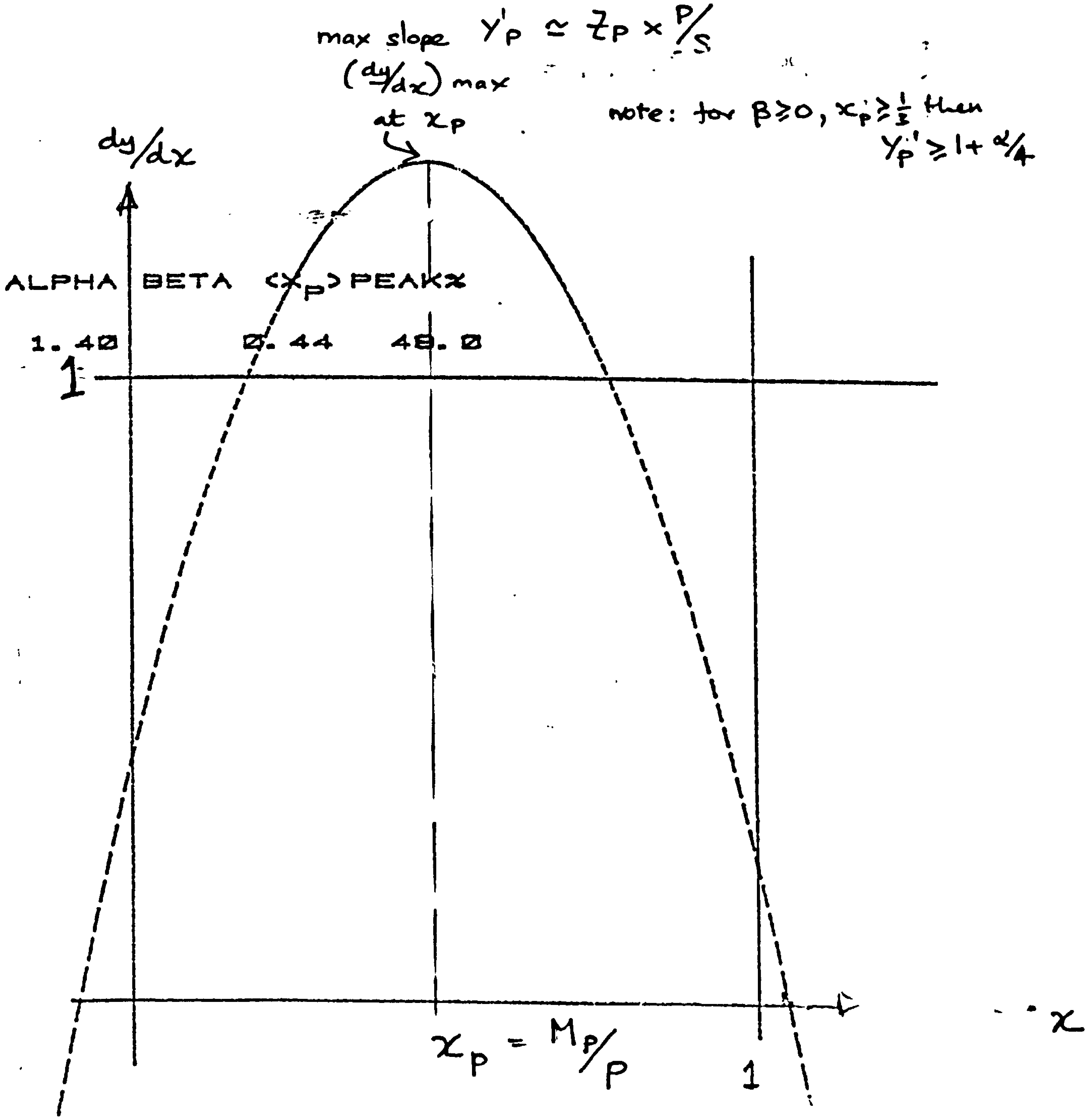
proportional cost (y)
y = Cm/S
ALPHA
BETA
<Xp> PEAK%
2.00
0.50
50.0
1
proportional periods e.g.
MONTHS
(x)
1
x = m/p

Graph 1c.


Zp max period cost
Zm
PERIOD
COST
ALPHA
BETA
(Xp) PEAK%
1.40
0.44
48.0
periods
(m)
Mp
Peak cost period
P

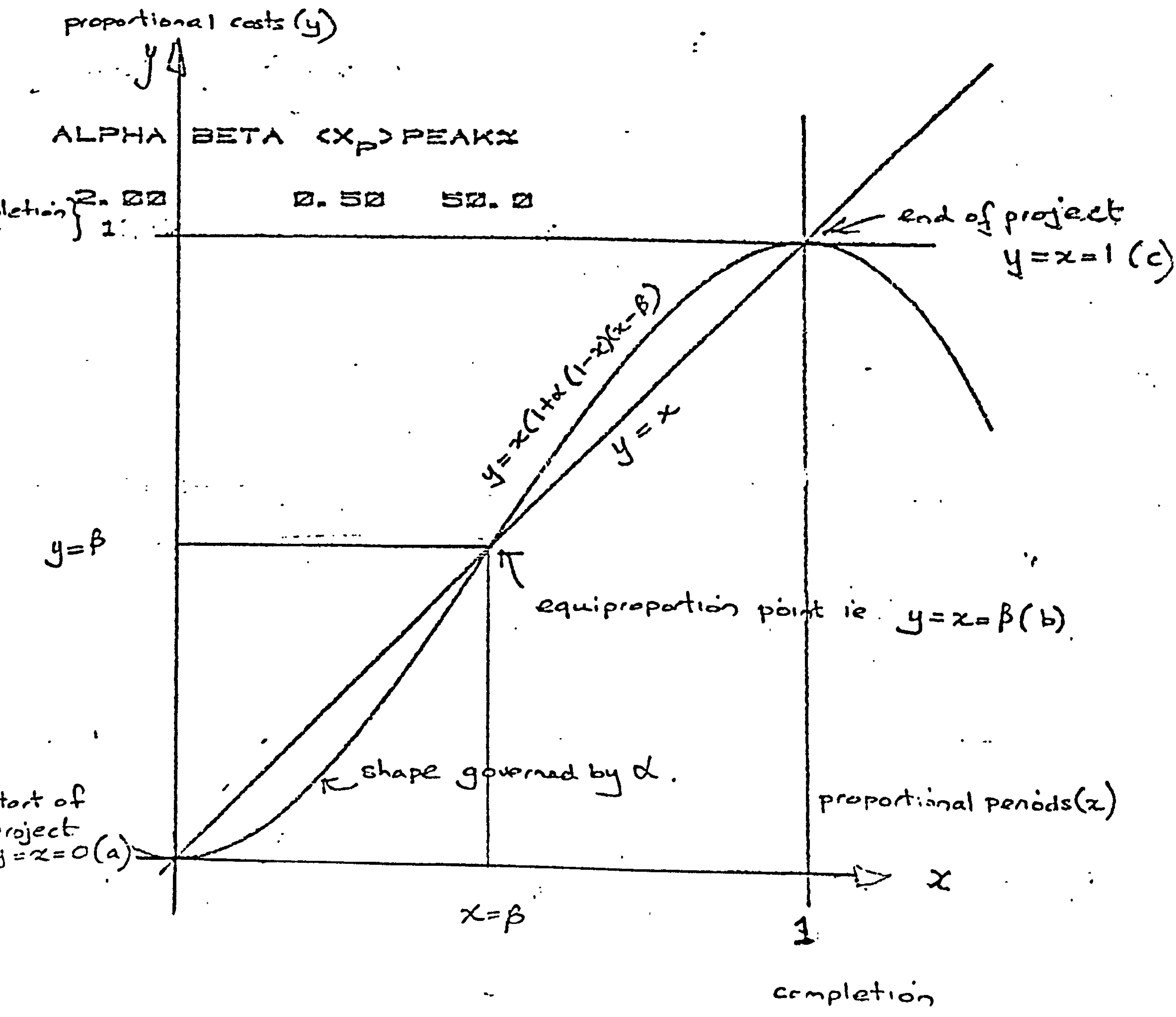
Graph 1d

α-β curve slope graph (dy/dx)



Graph 1e

Conditions in brackets.



Appendix 2

Derivation of quoted results from the ab equation

1. Mathematical properties

transformation of eqn.2. $y = x\ (1 + a\ (1 - x)(x - b))$

gives: $y = -\ ax^3 + a(1 + b)\ x^2 + (1 - ab)\ x$ ....(a)

differentiating for curve properties one obtains:

$y' = dy/dx = -3ax^2 + 2a\ (1 + b)\ x + 1 - ab$ ....(b)

$y'' = d^2y/dx^2 = -\ 6ax + 2a\ (1 + b)$ ....(c)

2. Turning points

setting $y' = 0$, transforming eqn.b. and dividing by $-\ 3a$

we obtain: $x^2 - 2x_px + k = 0$ ....(d)

where $x_p = (b + 1)/3$ and $k = (b - 1/a)/3$

solving eqn.d. for turning points gives the results that:

maximum occurs at $x = Xmax = x_p + (x_p^2 - k)^{.5}$ ....(e)

minimum occurs at $x = Xmin = x_p - (x_p^2 - k)^{.5}$ ....(f)

3. Peak period cost and its 'point'

(a) period cost Zm

From definition of $y = Cm/S$ at $x = m/P$ it follows for practical purposes that:

$y' = \frac{PdCm}{Sdm}$ is approximately $\frac{P}{S}\ Zm$

Hence:

$Zm \cong \frac{dCm}{dm} = \frac{Sdy}{Pdx}$ at $x = m/P$ $= \frac{S}{P}\ Ym'$ ....(g)

(b) point of inflection x_p

Using the second differential set at zero y" = 0 eqn.c. shows that providing a$>$0 then:

(i) the period cost Zm or Ym' are at their maximum values Zp and Yp' when y" = 0

(ii) the above condition occurs when:

$$x_p = (b + 1)/3 \qquad ......(4)$$

and

$$Yp' = 1 + a(3x_p(x_p - 1) + 1) \qquad ......(7)$$

and eqn.g. gives the peak period cost as:

$$Zp = Yp'.S/P \qquad ......(h)$$

where SP is the average period cost

4. Derivation of peak period cost relation with b

If we assume that the minimum of the 's' curve will pass through the origin it may be shown that by solving eqn.(d) with x = 0 that a = 1/b with the proviso that if b $<$.5 project overrun occurs at the project end.

By substituting in eqn.(b) with $x = x_p$ and a = 1/b then after, transformation one obtains:

$$x_p = .5Yp' (1 \pm (1 - 4/(3Yp'))\wedge .5) \qquad ....(i)$$

The condition for real values only gives the result given by equation (6):

$$Yp' > 4/3 \text{ or } Zp > \frac{4S}{3P} \qquad ....(6)$$

This result implies that when the minimum passes through the origin the peak period cost must be in excess of 33% over the average period cost (S/P).

At the peak cost period point one may evaluate Yp' by replacing x by x_p and b by $3x_p - 1$ in eqn.(b) deriving equation (7):

$$Yp' = 1 + a(3x_p (x_p - 1) + 1) \qquad ....(7)$$

and transforms into the most direct solution for alpha:

$$\text{alpha} = (Yp' - 1)/(1 + 3x_p (x_p - 1))$$

It is worth noting the extreme values of Yp' show its major dependence on the shaping constant alpha and are:

$Yp' = 1 + a$ at $Xp_2 = 0$ or 1 $Yp' = 1 + .25a$ at $Xp = .5$

to $Yp' = 1 + 3ax_p$ for $x_p > 0$

In order to obtain a practical equation for beta we have to furthur assume that Yp' is high in value. Under this condition the negative value in eqn.(i) would give an impractically low value for x_p hence using eqn.(h) we obtain equation (5):

$$x_p = (b + 1)/3 \simeq \frac{ZpP}{2S} \left(1 + \left(\frac{1 - 4S}{3ZpP}\right)^{\wedge}.5\right) \qquad ....(5)$$

5. Overrun limits

If overrun is not to occur it is necessary that the extreme give Xmin ≤ 0 and Xmax ≥ 1, the various cases are shown in graph 8. Setting the limiting condition to Xmim = 0 and Xmax = 1 and operating with equations d,e,f one obtains equation (3):

$$a \leq \min (1/b, 1/(1 - b)) \qquad ....(3)$$

By applying the condition Xmax 1 and Xmin 0 and transforming equation (d) one obtains the general relationship for a under contingency. The particular case when Xmax = 1.05 and Xmin = -.05 is given below by equation (8):

$$a = \min (1/(1.21 - 1.1b), 1/(1.1b + .11)) \qquad ....(8)$$

Relationship between peak period and gamma

$$\frac{1}{2\gamma} = x_p^2 \qquad x = x_p = \frac{\beta + 1}{3}$$

Relationship of gamma, X_p and Beta

$$\gamma = \frac{1}{2 x_p^2} = \frac{4.5}{(\beta + 1)^2}$$

Assumption that project ends at 95%

$$\text{let } y = \frac{1 - e^{-\gamma P^2/D^2}}{1 - e}$$

let y (normal completion = 0.95 i.e. P = D

$$\text{then } \frac{y \begin{pmatrix}\text{at period} \\ P\end{pmatrix}}{.95} = \frac{1 - e^{-\gamma P^2/D^2}}{1 - e^{-\gamma}}$$

$$\text{at } P = D \text{ if } y = 0.95 = \frac{1 - e^{-\gamma}}{1 - e^{-\gamma}}$$

Appendix 3

Contents:

1. Program Listings: RAMNI.BAS, RAMFI.BAS — Curve fit programs used to collect live design cost data

2. Shell Project Curve Fit Results

   Analysis by professions

   i.e. All professions
   Architect
   Mechanical
   Civil and Structural
   Electrical
   Other Professional Inputs

PROGRAM RAMNI.BAS

```
.TY RAMN1.BAS
00050    Q0$="RDA , A , B "
00100    A$="N"\GOTO900
00200    READ N,A$
00300          IF N=Z GOTO 900
00400    READ S,P
00500    FOR I=1 TO P
00600    READ X
00700    NEXT I
00800    GOTO 200
00900    Q1$="*** AB CHANGE *** PRD. "
01000    Q$="*** RD CHANGE *** PRD. "
01100    A$="Y SD= "\B$="R SD= "
01200    DIM Y(100),Y6(100),Y1(100)
01300    P4=0
01400    DIM X5(100),X(20),Y5(100),C(100,4)
01410 PRINT"FILE NAME";\INPUT X$\ FILE £1,X$
01412   PRINT"% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS";
01413   INPUT R1\ R1=R1/100
01415 READ£1,P,C\PRINT"PERIODS="P,"CLASSES="C
01417   PRINT\PRINT"PROFESSION NO. ('0' FOR ALL)";\INPUT J
01420   IF END£1 GOTO 1470
01430 FOR I=1 TO C\READ £1,X,X(I)\NEXT I
01432 READ£1,Y,X(0),Y,Y\Y=0
01440   S=S+X(J)
01445 I1=I1+1
01450 C(I1,4)=X(J)
01460   GOTO 1420
01470 S$="0"
01600   S5=0
01700 S$="Y"
01800   IF S$>= "Y" GOTO 2000
01900   PRINT"PRD.","COST","CUM.CST."," X"," Y"
02000   FOR I=1 TO P
02210 C=C(I,4)
02215 S6=C(I,2)=S6+C
02220 IF C>R1*C(I,2)/I GOTO 2240
02230   I4=I4+1
02240   S5=C(I-I4,1)=S5+C
02250   NEXT I
02260   P=P-I4
02270   FOR I=1 TO P
02280   X5(I)=I/P
02290   Y5(I)=C(I,1)/S
03000   NEXTI
03010 Z1=Z2=P-1
03020 K9=11
03050 GOTO 4000
03100 PRINT"BEST RD & AB TO DATE BY REL SD & SD OF Y"
```

```
03200   PRINT
03300   PRINT" USING 1.REL SD FOR AB 2.SD OF Y FOR RD "
03400   PRINT
03450   PRINT"NO. OF PERIODS "P\PRINT
03500 PRINT"BELOW WHICH REL SD %  DO YOU WISH OUTPUT";
03600 INPUT K9
03700   PRINT"WHICH PRDS RANGE PLS. ";\ INPUT Z1,Z2
03800   IF Z1>1 GOTO 4000
03900   PRINT"NO PRD.1 ALLOWED (2,3..) "\GOTO 3700
04000 FOR I=Z1 TO Z2
04200   DEF FNR(A,Y)=(1-EXP(-A*Y*Y))/(1-EXP(-A))
04300   '
04400   PRINT
04500   IF I=P GOTO 8300
04600 T8 =500
04700       FOR A5=.1 TO 10 BY .1
04800 GOSUB 27900
04900       NEXT A5
04950 Q=A6-.2\Q1=A6+.2
05000 FOR A5=Q TO Q1 BY .002
05100 GOSUB27900
05200 NEXT A5
05300 A5=INT(1000*A6+.5)/1000
05350 GOTO8300
05400 PRINT"RDA="A5" RD'B'="SQR(4.5/A5)-1
05500PRINT"YMAX AT X=2 "100*FNR(A5,2)"%"
05600S4=T4\S5=T5
05700 PRINT"SD OF Y="S4,"REL SD="S5
05800   GOTO 8300
05900   PRINT"YMAX AT X=2 IS "FNR(A6,2)
06000 A0=A6
06100   PRINT"RD A= "A6,"RD B= "SQR(4.5/A6)-1
06200   PRINT"USING PRD. "T6
06300   IF T6=T7 THEN T0=1 ELSE T0=0
06400   T7=T6
06500 P4=I
06600   PRINT"Y.SD.= "T4,"R.SD.= "T5
06700 GOTO8300
06800   PRINT
06900   PRINT"SOLVED RD A SOLN."
07000   GOSUB 22300\PRINT Q$;P4
07100   PRINT"________________"
07200   I2=1\P2=P
07300   A5=0
07400 A=A1\ B=B1
07500   D1=1\ D2=P \GOSUB 19000
07600   PRINT\ PRINT A$;Q4,B$;Q5
07700   IF Q5>K9OR A5=.07 THEN 8000
07800   GOSUB 10600
07900 GOSUB 29900
08000   A5=A6
08100   PRINT"++++++++++++++++++++"
08300   PRINT\PRINT
08400   'TO FIND A,B,RD
08500   '
```

```
08600 Q8=Q9=200
08700 D1=1 \D2=P
08800   FOR G1=2 TO I
08900   IF I=P GOTO 9400
08950 PRINTG1"  ";
09000   FOR G2=1 TO G1-1
09050 A=FNA(G1,G2)\ B=FNB(G1,G2)
09090 GOSUB22300
09100 FOR P7=P4 TO P BY INT(P/10)+1
09105 P4=P7\GOSUB19000
09110 NEXT P7
09200   NEXT G2,G1
09300 A=A(1)\B=B(1)\Q4=Q8
09350 FOR I1=1 TO 10\PRINT\NEXTI1
09400 GOTO11700
09550 IF S5<T5 THEN PRINT"RD BEST"
09800   PRINT"A="A1    "B="B1
09900   PRINT"SD OF Y="S8   " REL SD="S4
10000   PRINT"USING PRD"W1" &"W2\ PRINT
10100 A=A1\B=B1
10200   IF B2=B THEN B0=0 ELSE B0=1
10300   B2=B
10400   GOSUB 22300
10500   IF S$="Y" GOTO11700
10600   PRINT
10700 PRINT " RD A= "A5
10800 PRINT"A= "A1"  B= "B1" PRDS "W1" & "W2
10900   PRINT"PRD.";"    X";"      Y%";"   Y(A-B)%";"     (Y-Y:AB)%","   Y(R-DF)%";"     (Y-Y:R-DF)%"
11000   FOR I1=1 TO P
11100   Y=Y5(I1)\Y1=FNY(I1/P)\Y2=FNZ(I1/P)
11200   IF I0=I1 THEN PRINTQ1$,I0
11300   IF P4=I1 THEN PRINT Q$;P4
11400   PRINTI1;TAB(4);100*FNI(I1/P);TAB(10);100*FNI(Y);TAB(16);100*FNI(Y1);
11500   PRINTTAB(29);FNJ(Y,Y1);TAB(45);100*FNI(Y2);TAB(56);FNJ(Y,Y2)
11600   NEXT I1
```

```
11700   PRINT
11800 GOTO 15800
11900   D1=1 \D2=I
12000   GOSUB 19000
12100   IF S4<K9 OR B0=1  THEN K8=1 ELSE K8=0
12200   GOTO12700
12300   IF I=3 THEN Q6=Q5
12400   IF I<4 THEN 12700
12500   IF (Q6-Q5)/Q6>= K9/100 THEN K8=1 ELSE K8=0
12600   IF K8=1 THEN Q6=Q5
12700   PRINT" PRESENT - TO DATE PRD."I
12800   PRINT Q$;P4\PRINT"RD A="A5"RD B="B5
12900   PRINT\PRINT"YMAX AT X=2 IS "FNR(A5,2)\ PRINT
13800   I2=1\ P2=I
13900   IF I<4  GOTO14100
14000   IF K8=1  THEN GOSUB 10600
14100   PRINT A$;Q4,B$;Q5
14200   IF P4>I THEN PRINT ELSE PRINT Q$;P4\ PRINT
14300   IF P4>I THEN 14700ELSE P5=P4
14400   P4=P+1\ GOSUB 19000
14500   PRINT "AB ONLY "A$;Q4,B$;Q5
14600   P4=P5
14700   D1=I\ D2=P
14800   GOSUB 19000
14900   PRINT\PRINT"FUTURE FROM  PRD."I
15000   PRINT A$;Q4,B$;Q5
15100   I2=I\ P2=P
15200   IF K8=1 THEN GOSUB 10600
15300   IF P4<I THEN PRINT ELSE PRINT Q$;P4
15400   IF P4<I THEN 15800ELSE P5=P4
15500   P4=0 \ GOSUB 19000
15600   PRINT" RD ONLY "A$;Q4,B$;Q5
15700   P4=P5
15800   D1=1 \D2=P
15900   PRINT\PRINT"MONITORING CONSTANTS"
16000   PRINT"-------------------"
16005 PRINT
16010   T=(B+1)/3\ K=(B-1/A)/3\ K=(T*T-K)
16013   IF K<0 GOTO 16400
16016   K=SQR(K)
16020   IF T-K>0 THEN I0=INT((T-K)*P+.5) ELSE I0=0
16030   P3=INT((T+K)*P)
16040   IF P3<P4 THEN P4=INT(P3*.95)
16045   GOTO 16400
```

```
16050   PRINT Q1$;I0,Q$;P4\PRINT
16060   PRINT"A="A"B="B" PEAK COST PRD. "INT((B+1)/3*P+.5)\PRINT
16070   PRINT"XMAX= "T+K,"XMIN= "T-K
16080   PRINT"YMAX= "FNY(T+K)
16100   PRINT"COMBINED RESULT"\ GOSUB 19000
16200   PRINT\PRINT Q$;P4;
16250   PRINTQ0$,A5,A,B
16300   PRINT A$;Q4,B$;Q5\PRINT
16400 GOTO 29800
16404   PRINT
16406   PRINT"A=ACTUAL  P=FORECAST  S=IDENTICAL 'VALUES'"\PRINT"--G-- SWITCH TO GAMMA"
16407 PRINT" * REPRESENTS 4*NON-CUMULATIVE EXPENDITURE"\PRINT\PRINT
16408   PRINTTAB(20);"COST TABLE"
16412   PRINTTAB(20);"__________"
16416   PRINT
16420   GOTO 18010
16440   PRINT
16500   PRINT "IDEAL COMBINED RESULTS"
16520   K8=1
16600   PRINT
16700 I1=I\ I=P\ GOSUB 22300
```

```
16800   I=I1
16900   PRINT Q$;P4;
17000 GOSUB 19000
17100   PRINT A$;Q4,B$;Q5
17200   P4=P+1
17300   GOSUB 19000
17400   PRINT" AB ONLY RESULTS "A$;Q4,B$;Q5
17500   PRINT\ P4=0
17600   GOSUB 19000
17700   PRINT" RD ONLY RESULTS "A$;Q4,B$;Q5 \PRINT
17800   PRINT"----------------------------------------"\PRINT
17900   NEXT I
18000   GOSUB 29900
18010   PRINT\PRINT"PRD.  COST","CUM.COST","FORECAST","%ERROR"
18020   FOR I=1 TO P
18030   PRINTI;TAB(5);C(I,4),C(I,1),INT(S*Y6(I)+.5),FNJ(Y5(I),Y6(I))
18040   NEXT I
18050   PRINT
18100   STOP
18200   DEF FNZ(X)
18300   '
18400   IF EXP(-A5)<>1 GOTO 18700
18500   Z=.01
18600   GOTO 18800
18700   Z=1-EXP(-A5)
18800   FNZ=(1-EXP(-A5*X*X))/Z
18900   FNEND
19000   'RD CHANGE TESTS
19100   '
19200   Q4=Q5=0
19300 FOR I1=1 TO P
19400   Y=Y5(I1)\ X=I1/P
19420 IF FNY(X)<= 0 THEN I0=I1+1
19440 IF FNY(X)>= 1 THEN P6=I1-1
19460 IF P6<P4 THEN P4=P6
19500   IF I1<I0 OR  I1>= P4 THEN Y1=FNZ(X) ELSE Y1=FNY(X)
19600   Y3=Y-Y1 \Y4=Y3/Y
19700   Q4= Q4+Y3^2
19800   Q5= Q5+Y4^2 'R SD
19900   NEXT I1
20000 D3=P
20100   Q4=SQR(Q4/D3) ' Y SD
20200   Q5=SQR(Q5/D3) ' R SD
```

```
20300    Q4=FNI(Q4)*100
20400    Q5=FNI(Q5)*100
20410 IF Q8<Q4 GOTO 20430 'YSD
20420 Q8=Q4\A(1)=A \B(1)=B
20425    P8=P4\ I8=I0
20430 IF Q9<Q5 GOTO 20500 'RSD
20435    P9=P4\ I9=I0
20440 Q9=Q5\A(2)=A \B(2)=B
20500    RETURN
20600    'RD CONST
20700    '
20800 A4=4.5
20900    A7=A4*X*X
21000    IF A7>10  GOTO21300
21100    IF A7<.1 GOTO 21300
21200    GOTO21500
21300    A5=.07
21400    GOTO 22200
21500    E1=EXP(-A4)
21600    E2=EXP(-A4*X*X)
21700    F1=1-E2-Y*(1-E1)
21800    F2=X*X*E2-Y*E1
21900    A5=A4-F1/F2
22000    IF ABS(A5-A4)< 2E-6 GOTO 22200
22100    A4=A5 \GOTO 20900
22200    RETURN
22300    'AB TO RD CHANGE
22400    '
22420    FOR I2=1 TO P
22430 IF FNY(I2/P)>=1 THEN P6 =I2-1
22440    IF FNY(I2/P)<=0 THEN I0=I2+1
22445    NEXT I2
22450  I3=INT(.15*(P+I4))
22500 IF I<I3 GOTO 22800
22600 FOR J=I3 TO P
22700    IF J<= I GOTO 23000
22800 P4=INT(.95*P)
22900    GOTO 23800
23000    Y3=Y4=0
23050 IF J<2 GOTO 23800
23100    FOR I2=J-2 TO J
23200    Y3=Y3+ABS(Y5(I2)-FNZ(I2/P))
23300    Y4=Y4+ABS(Y5(I2)-FNY(I2/P))
23400    NEXT I2
23500 IF Y4-Y3 > .1*Y5(J) THEN P4=J-1 ELSE 23700
23600 GOTO 23800
23700    NEXT J
23800 IF P6<P4 THEN P4=P6
23850 RETURN
23900    DEF FNB(G1,G2)
24000    '
24100    X1=X5(G1)\X2=X5(G2)
24200    Y1=Y5(G1)\Y2=Y5(G2)
24300    K=(1-X2)*(Y1/X1-1)/(1-X1)/(Y2/X2-1)
24400    FNB=(K*X2-X1)/(K-1)
```

```
24500   FNEND
24600   DEF FNA(G1,G2)
24700   '
24800   Y1=Y5(G1)\X1=X5(G1)
24900   FNA=(Y1/X1-1)/(X1-FNB(G1,G2))/(1-X1)
25000   FNEND
25100   'TEST A,B
25200   '
25300   A=FNA(G1,G2)\B=FNB(G1,G2)
25320 T=(B+1)/3\K=(B-1/A)/3
25340 IF T*T-K<0 THEN 27050
25400 S1=S6=0
25500   FOR J=1 TO I
25600   X=J/P
25700   Y=Y5(J)\ Y1=(FNY(X)-Y)/Y
25800   Y3=Y1*Y
25900   D=D+(FNY(X)/Y)**2
26000   S6=S6+Y1*Y1
26100   S1=S1+Y3*Y3
26200   NEXT J
26300 D1=100*SQR(D/I)
26400   S3=100*SQR(S1/I)
26500   S9=100*SQR(S6/I) 'REL SD
26600   D=ABS(1-SQR(D/I))*100
26700   G=S9
26750   IF G9=100 THEN G=S3
26800 IF G0>G THEN G0=G ELSE 27100
26900   S8=S3\A1=A\B1=B\W1=G1\W2=G2 \S7=D
27000   S4=S9\S5=D1
27050 T=K=0
27100   RETURN
27200   DEF FNY(X)=X*(1+A*(1-X)*(X-B))
27300   '
27400   'TEST R-DF
27500   '
27600   B4=FNB(G1,G2)
27700 IF B4<-.5 THEN B4=-.5
27800   A5=4.5/(B4+1)**2
27900 S2=S6=D=0
28000 IF A5=.07 GOTO29400
28100   FOR J=1 TO I
28200   Y=Y5(J)
28300   Y1=((1-T1/100)*FNZ(J/P)-Y)/Y
28400 D=D+Y*Y1
28500 S2=S2+(Y*Y1)^2
28600   S6=S6+Y1*Y1 'R SD
28700   NEXT J
28800   S0=100*SQR(S6/I)
28900 S2=100*SQR(S2/I) 'Y SD
29000 G4=S2
29100   IF T8>G4 THEN T8=G4 ELSE 29400
29200   T4=S2\T5=S0\W3=G1\W4=G2\B5=B4 \T6=I
29300   A6=A5
```

```
29400    RETURN
29500    DEF FNI(A)=.001*INT(A*1000+.5)
29600    '
29700    DEF FNJ(A,B)=.1*INT((A-B)*1000+.5)
29750    DEF FNC(X,Y)=(Y/X-1)/(X-B)/(1-X)
29800    '
29810    A2=A\ B2=B
29820    B=3/SQR(2*A5)-1
29825 G0=G9=100
29830    FOR I=2 TO P-1
29840    Y=Y5(I)\ X=X5(I)\ A=FNC(X,Y)
29842    T=(B+1)/3\K=(B-1/A)/3
29843    IF T*T-K<0 GOTO29860
29844    T1=T+SQR(T*T-K)
29850 GOSUB 25400
29860    NEXT I
29870 A3=A1\ B3=B1\ A=A2\ B=B2
29880    T=(B3+1)/3\K=(B3-1/A3)/3
29890    T1=T+SQR(T*T-K)
29900    'GRAPH
29920    I0=I8\P4=P8\P1=P
30000    P=P+I4
30010    PRINT"ALPHA="A"  BETA="B"  GAMMA="A5
30012    PRINT\PRINT"THESE CONSTANTS REPRESENT:-"\PRINT"(BETA) PEAK PERIOD "INT((B+1)/3*P)+1
30014    PRINT"MAXIMUM DURATION "INT(P3*P/(P-I4))+1\PRINT"(GAMMA) PEAK PERIOD "INT(P*(2*A5)**-.5+1)
30015    PRINT"(GAMMA) ALPHA EQUIVALENT "A3," ERROR "S8"%"
30016    PRINT"(GAMMA) MAX DURATION ESTIMATE "INT(1+T1*P)\PRINT
30017 PRINT"CUBIC BETWEEN PERIODS "I0" AND "P4
30020 PRINT\PRINT"TOTAL PROJECTION ERROR="Q4"%"
30030 PRINT\PRINT
30040 PRINT"GRAPH OF PROJECT EVALUATION"
30050   PRINT"___________________________"
30060 PRINT\PRINT\PRINT"DURATION "P" PERIODS AT COST "S" 'POUNDS'"
30070PRINT\PRINT
30080 IF CLOG(S)>4 THEN C=1000 ELSE C=100
30090 S$=STR$(C)
30100 PRINT"COST ("S$"'S)";
30200   X=X6=S5=0
30210 K=0
```

```
30300 S1=S/C
30400   FOR J=1 TO 5
30500   PRINT TAB(6+10*J)"!"INT(S1*J*.2);
30600   NEXT J
30700   PRINT""\PRINT"COST% X";
30800   FOR I5=1 TO 12\PRINT"----X";\NEXTI5\PRINT""
30900   GOTO 32600
31000   FOR X6=0 TO P
31100   IF X6/5=INT(X6/5) OR X6=PTHEN PRINT INT(100*X6/P+.5);"%";X6 ; ELSE PRINT TAB(5)"I";
31150 IF X6=0 GOTO 31340
31200   K=C(X6,4)
31340   C(X6,1)=S5=S5+K
31345 IF X6=0 GOTO 31360
31350 IF K<=R1*S5/X6  THEN X=X+1
31360   Y2=Y5(X6)=S5/S
31420   X5=X6-X
31440   IF X5<=IO OR X5>=P4 THEN Y(X5)=FNZ(X5/P1) ELSE Y(X5)=FNY(X5/P1)
31460   IF X5=IO OR X5=P4 THEN PRINT"-G-";
31500   Y=Y6(X6)=Y(X6-X)
31600   IF Y5(X6)=Y THEN G1$="" ELSE G1$="A"
31650 IF X6>5 THEN  PRINT TAB(FNT(4*C(X6,4)/S))"*";
31700   IF Y2>Y GOTO 32000
31800   IF Y2<Y GOTO 32100
31900   PRINT TAB(FNT(Y))"S"\ GOTO 32200
32000   PRINT TAB(FNT(Y))"P";TAB(FNT(Y2));G1$\GOTO 32200
32100   PRINT TAB(FNT(Y2))G1$;TAB(FNT(Y));"P"
32200   NEXT X6
32300   PRINT TAB(6)"X";
32400   FOR I5=1 TO 12 \PRINT"----X";\NEXT I5\PRINT" "
32500   PRINT"COST%";
32600   FOR I5=1 TO 12\PRINT TAB(5+5*I5);10*I5;\NEXT I5
32700   PRINT""
32800   IF X6=P THEN32900ELSE 31000
32900 PRINT\ GOTO 16404
33000   DEF FNT(A)=INT(50*A+.5)+6
33020 PRINT\PRINT"NO. OF PERIODS= "P\PRINT
```

```
33100   '
33200   DATA 1, "N"
33300 DATA1416500
33400   DATA23
33500   DATA 20000,2E4,32500,32500,41E3,41E3,45750,45750
33600   DATA 15E3
33700   DATA100000,28E3,12E4,72500,72500,8E4,16E4,5E4,5E4,6E4,14E4,1E5
33800   DATA 5E4,4E4
33900   DATA 2,"C"
34000 DATA 3625500
34100   DATA 16
34200   DATA 28300,56600,84900,114900
34300   DATA 152700,181500,205300,229100
34400   DATA 252900,278900,303000,320100
34500   DATA 337200,348600,360000,371500
34600   DATA 3,"N"
34700  DATA 323500
34800   DATA 12
34900   DATA 10000,25000,50000,75000
35000   DATA 10000,12500,15000,20000
35100   DATA 25000,26500,27000,27500
35200   DATA 4,"N"
35300 DATA 78750
35400   DATA 12
35500   DATA 1E4,9500,9000,8500
35600   DATA 8250,8000,7900,7850
35700   DATA 5000,2500,1500,750
99999   END
```

PROGRAM LISTING RAMF1.BAS

```
.TY RPRJ11.BAS
00010   ' ORIGINAL FORM OFTHIS PROG IS NOW RPRJ21.BAS
00020   '!!!
00050 MARGIN 120
00100   DIMC(100),Y(100),X(100)
00110 DIM G(100),B(100)
00120 DIM Y5(100),C1(100),K2(100)
00150 GOTO 1005
00200   FILE £2,"F.TMP"
00250   READ £2, Q
00300   IF END £2 GOTO 700
00400   P=P+1
00500   READ£2,C(P)
00600   GOTO 300
00700   R= P-3
00750 P2=C(R+1)\P3=P2+C(R+2)
00770   PRINT"INPUT EXPECTED DURATION";\INPUT D5
00780 T1=1.5*D5
00800   F1=0 ' MONTHLY INFLATION VALUE
00805   GOTO 850
00810 PRINT "ERROR"\PRINT
00820 PRINT "TTL COST "Q
00830 FOR I=1 TO P\PRINT"R="I,C(I)\NEXT I
00840 PRINT"DRTN "C(R+1),"REDNDNT PRDS "C(R+2),"PEAK PRD."C(R+3)
00845  STOP
00850 P0=P=C(R+3)
00870   FOR I=1TO R
00880   K2(I)=(1+F1/100)^I
00885   C1(I)=C(I)
00890   C(I)= C(I)/K2(I)
00900   NEXTI
01000   I4=C(R+2)
01005   FILE £3,"P.TMP"
01010   READ £3,R,C(R),C9
01015   P=R/SQR(-2*LOG(1-C(R)/1.05/C9))
01020   BO= 3*P/R-1
01022   T=P/R \A0=1/(2.3-3.3*T)
01024   PRINT "INPUT DATA :-"\ PRINT"PRESENT DURATION "R" MONTHS AT VALUE "C(R)
01026   PRINT"EXPECTED PROJECT COST "C9
01027   T1=3*R\C=C(R)
```

```
01030   IF C/FNG(R,T1)>1.04*C9 THEN 1035 ELSE T1=T1+2*R
01033   GOTO 1030
01035   D=T1\T1=1.5*D\S9=1.1*C9
01037   IO=0\ FOR I=R TO D
01039   IF C9<C(R)*FNG(I,R) GOTO 1043
01041   NEXT I
01043   IO=I\PRINT\ PRINT "PRESENT EXPECTED COST OCCURS AT PERIOD "IO
01045   PRINT\PRINT "MAX PREDICTED COST IS "C(R)*FNG(D,R)\ PRINT\PRINT
01047   GOTO 3490
01050   PRINT"(MIN. 5 PERIODS) ";\ TO=R
01055 R5=P-3
01060 INPUT R
01070   '
01075   C=0\FOR I=1 TO R
01080 C1=C(I)-C(I-1)
01085   Z=C(I)/I*R-1
01090 PRINT "PRD"I,"COST"C1,"CUM. COST"C(I);"  Z="Z
01095  IF C1<C GOTO 1120
01100 C=C1\P1=I
01120   NEXT I
01125   PRINT"HIGHEST COST WEEK "P1" AT COST "C
01200   'TEST DURATION ETC.
01202 PRINT "GAMA"
01203   '
01204 FOR I=1 TO R-1
01206 R9=Y9=100
01208   R7=R-1
01210   S8=S9=C(R) \ Y7=C(I)/S9
01211   IF Y7 > (I/R)^2 GOTO 1215
01212   N1=S2=Y9=G(I)=0 \GOTO 1230
01215 ' PEAK SEARCH
01216 '
01218   FOR P5=2 TO R*10 BY.3
01220   P=P5 \ Y=FNG(I,R)
01223   IF Y>Y7 THEN 1226 ELSE 1228
01226   NEXT P5
01228   P=G(I)=P5\ GOSUB 5000
01230   PRINT I"  NO."N1,G(I),"E%="S2,"X*X="(I/R)^2,"YA="INT(1E4*Y7+.5)/1E4
01232 NEXT I
01242 PRINT "BETA"
01243   '
```

```
01245 FOR I=6 TO R
01250    S8=S9=C(I)
01255    Y9=R9=100
01260     R7=I
01262  IF R=R7 GOTO 1298
01265     FOR I1=-.3 TO 2  BY .3
01270     FOR J=-.5 TO 6.5 BY .03
01275     P=(1+J)/3*I
01280  B0=J
01282 A0=I1
01285    GOSUB 6000
01293 NEXT J,I1
01295 PRINT I,A,"E%="Y9,"A="A3,
01296    PRINT"B="3*A/I-1
01297  NEXT I
01298 IF G(R)=0 THEN G(R)=B(R)
01299 I3=0\PRINT\PRINT\ GOTO 1355
01300  P1=INT((B(R)+G(R))/2+.5)
01305    P0=INT(P1/3+.5)\ P1=2*P1
01307 PRINT"P0="P0,"P1="P1
01308 IF P1>3*C(T0+3) GOTO 1353
01310    FOR P=P0 TO P1 BY .2
01315 IF 1-1/P <.01 GOTO 1352
01320    K0=- LOG(1-1/P)
01325    GOSUB 8000
01327 IF N=0 GOTO 1352
01330    IF R3>I3 THEN I3=R3 ELSE 1352
01335 P9=P
01340 IF P9<.99*P1 GOTO 1350
01345 P0=P1-1\ P1=2*P1
01347 GOTO 1307
01350    I2=I1\ K2=K1\ R2=R1\ T2=T
01351 NEXT P
01352   PRINT
01353   IF P>.8*C(T0+3) GOTO 1355
01354 P=C(T0+3)
01355 PRINT"PEAK="P"NEW VALUE OR  OLD  ,INPUT PEAK ,A,B";\ INPUT P,A0,B0
```

```
01356      GOTO2415
01357    PRINT"P*"1/(1-EXP(-K0)),"SLP*"K0,"INTCPT"I2,"TAN"T2
01360    PRINT"R"R2,"SLP"K2,"TST"I3
01375    PRINT"PEAK PERIOD "P," %ERROR "INT(100*(1-R3)+.5)
01379 PRINT\PRINT
01400    Y9=100 'YSD
01500    R9=100 'REL SD
01600  FOR I= 1TO R-1
01700     FOR J=I+1 TO R
01800     K=FNK(I,J)
01900     P1=P*P-K
02000     IF P1<0 GOTO 2300
02200    D=P+P1^.5
02220 S9=C(R)/FNG(R,D)
02260    IF D1<D THEN D1=D
02300    NEXT J
02400    NEXT I
02403 IF D1>0 GOTO 2410
02406 R=R-1 \ GOTO 1400
02408 IF D1>13.2*P THEN D1=13.2*P
02410    D=D1\ PRINT"MAX DRTN. "D
02415 PRINT"ADJUSTED DNTN."D*P3/P2
02450 GOTO 3210
02500    ' RESULTS
02550    D=D5
02600    '
02625    D=D5
02650 S9=C(R)/FNG(R,D)
02700    FOR I=R TO T1 BY INT((D-R)*.1+.5)
02800 IF  I>10*P GOTO 3200
03100    GOSUB 5000
03200    NEXT I
03210 PRINT\PRINT\PRINT
03215 D=D5
03220 S9=C(R)/FNG(R,D)
03250    E=R9\D0=D9
03260    GOTO3360
03300    PRINT "BEST GAMMA RESULT"
03350    PRINT "COST "C(R)/FNG(R,D8)" DURATION "D8" (YSD)ERROR "S2
03360 IF P2=P3 GOTO 3400
03370 PRINT "ADJUSTED DRTN. "D8*P3/P2
03400 PRINT
03420 PRINT"PRESENT DURTN. "R"  AT COST "C(R)
03460 PRINT\PRINT"INPUT DURTN. "T0" WITH "I4" REDUNDANT PRDS."
03465    PRINT" AT COST "Q" KNOWN DRTN. "T0+I4
03470    PRINT"PEAK PR. SLECTED"P" GIVEN (GAMMA) PEAK "C(T0+3)
03475    PRINT \ GOTO 3800
03476 PRINT\PRINT"INPUT %MONTHLY INFLATION "\INPUT F1\G$=""\PRINT
03477 PRINT"PEAK INPUT "P"   ";
03478    PRINT"A="A0,"B="B0
03479    PRINT
03490 R6=INT(R*B0+.5)
03495    GOTO 3800
03500 PRINT"EXPECTED DURATION=" INT(R*B0+.5)" MONTHS"
03600 PRINT"AT CB.CST="C(R)*FNC(R6/R,A0,B0)" EXP.CST="C(R)*FNG(R6,R)
03700 PRINT"ALTERNATIVE SOLUTION AT "R0"%"
03800 FOR I=R TO T1 BY INT(.1*(D-R)+.5)
03900 C=C(R)/FNG(R,I)
04000 IF C>= R0*S9/100 GOTO 4150
```

```
04100 NEXT I
04150 GOTO 4400
04200 PRINT"COST="C"DRNTN"I", CUBIC COST="C(R)*FNC(I/R,A0,B0)\PRINT
04300   PRINT"INFLATED COST= "C*(1+F1/100)^I
04400  PRINT\PRINT
04500 IF R0=99 GOTO 9100
04600 R0=99
04700 GOTO 3800
04800 P=P0\R=R1\GOTO 1000
05000 '
05020   'REL SD TEST    GAMA
05040   '
05050 IF I>10*P GOTO 5300
05060   N1=S1=S2=0
05100    FOR J=1 TO I
05110 IF I>10*P GOTO 5300
05115 IF J>10*P GOTO 5300
05120 Y=FNG(J,I)
05140   Y1= C(J)/C(I)
05145   IF Y1<.9*(J/I)^2 GOTO 5200
05150   N1=N1+1
05155' Y2,S1 R.SD
05160   Y2=(Y-Y1)/Y1
05170 Y3=(Y-Y1)
05180   S1=S1+ (J/I)^2*Y2**2
05190   S2=S2 +(J/I)^2*Y3**2
05200   NEXT J
05202   S2=INT(1000*SQR(S2/(N1))+.5)/10
05203   GOTO5300
05205 IF Y9<S2 GOTO 5220
05210   Y9=S2\A=K4
05215   D8=I
05220   S1=INT(1000*SQR(S1/(N1+1))+.5)/10
05240   IF R9<S1 GOTO 5300
05260   R9=S1 \D9=I
05270   A1=K4
05280   'REL SD ERROR R9(E) DRTN D9(D0)
05300   RETURN
06000 '
06010   '    BETA
06050   'R7EL SD TEST
06100   '
06150   S1=S2=0
06200   FOR J1=R7-5 TO R7
06250   Y=FNC(J1/R7,A0,B0)*S9
06300   Y1= C(J1)
06350' Y2,S1 R7.SD
06400   Y2=(Y-Y1)/Y1
06450 Y3=(Y-Y1)/S9
06500   S1=S1+ (J1/R7)^0.*Y2**2
06550   S2=S2 +(J1/R7)^0.*Y3**2
06600   NEXT J1
06620   S2=INT(1000*SQR(S2/(6))+.5)/10
06650 IF Y9<S2 GOTO 6750
06700   Y9=S2\A=P \A3=A0
06750   S1=INT(1000*SQR(S1/(6))+.5)/10
```

```
06800   IF R9<S1 GOTO 6950
06850   R9=S1 \D9=P
06900   'REL SD ERROR R9(E) DRTN D9(D0)
06950   RETURN
07000   DEF FNA(I,R,P)=(C(I)*R/C(R)/I-1)/(I/R-3*P/R+1)/(1-I/R)
07500   DEF FNC(X,A,B)= X*(1+A*(X-B)*(1-X))
08000   '
08050   'CORRLTN
08100   '
08150   S1=S2=Z=Q1=Q2=0
08160 N=0
08200   FOR I=2TOR
08220   IF K0*I>80 GOTO 9000
08225   K=P*(1-EXP(-K0*I))
08250   IF ABS(K-G(I))<ABS(K-B(I))THEN  Y=G(I) ELSE Y=B(I)
08270 IF 1-Y/P <.01 GOTO 8600
08300   Y=-LOG(1-Y/P)
08320 N=N+1
08350   S1=S1+I          'SUM X
08400   S2=S2+Y          'Y
08450   Z=Z+Y*I          'XY
08500   Q1=Q1+I*I        'X^2
08550   Q2=Q2+Y*Y        'Y^2
08600   NEXT I
08650   IF INT(.8*(R-1))<N GOTO 8700
08660 N=0 \ GOTO 9000
08700   K1=(N*Z-S1*S2)/(N*Q1 -S1*S1)'SLOPE
08725   R1=K1*K1*(N*Q1-S1*S1)/(N*Q2-S2*S2)
08750   I1=(S2-K1*S1)/N \I9=ABS(I1)+.0001
08850   T=(K0/(1-I1)-K1)/(1+K0*K1/(1-I1))
08855     R1=SQR(R1)
08860   R3=(1-ABS(T))*R1
09000   RETURN
09100   'TABLE
09120 D=I\ S9=C
09130 T1=.9*T1\ IF D<T1 THEN D=T1
09150   PRINT"PRD  CUM. COST  PREDICTED (CUM. COST)"
09200   FOR I=RTOD
09210   C0=C(R)*FNG(I,R)
09220   C1=C(R)*FNG(I+1,R)
09230   IF C1-C0<10 THEN 9700
09300   IF I>R THEN C$="X" ELSE C$=STR$(C(I))
09303   IF I<=R AND C(I)>C(R)*(I/R)^2 THEN G$="OK" ELSE G$="!"
09400   PRINT I;TAB(7);C$,INT(.1*(C0+5))*10
09500   NEXT I
09700   'GRAPH
09750   '
```

```
09800   S=C\P1=I
09850 PRINT\PRINT
09900 PRINT"GRAPH OF PROJECT EVALUATION"
09950   PRINT"___________________________"
10000 PRINT\PRINT\PRINT"DURATION "P1" WEEKS AT COST "S" 'POUNDS'"
10050PRINT\PRINT
10100 IF CLOG(S)>4 THEN C=1000 ELSE C=100
10150 S$=STR$(C)
10200 PRINT"COST ("S$"'S)";
10250   X=X6=S5=0
10300 K=0
10350 S1=S/C
10400   FOR J=1 TO 5
10450   PRINT TAB(6+10*J)"!"INT(S1*J*.2);
10500   NEXT J
10550   PRINT""\PRINT"COST% X";
10600   FOR I5=1 TO 12\PRINT"----X";\NEXTI5\PRINT""
10650   GOTO 11650
10700  FOR X6=0 TO P1
10750   IF X6/5=INT(X6/5) OR X6=PTHEN PRINT INT(100*X6/P+.5);"%";X6 ; ELSE PRINT TAB(5)"I";
10800   IF X6=0 OR X6>R GOTO 11000
10850   C1=(FNG(X6,P1)/X6*P1-1)*4
10900   Y2=C(X6)/S
10950   GOTO 11050
11000   Y2=0
11050   Y=FNG(X6,P1)
11100   IF Y5(X6)=Y THEN G1$="" ELSE G1$="A"
11120   IF X6>1 THEN G1$=""
11130   GOTO 11200
11150 IF X6>R THEN PRINT TAB(FNT(C1))"*";
11200   IF Y2>Y GOTO 11350
11250   IF Y2<Y GOTO 11400
11300   PRINT TAB(FNT(Y))"S"\ GOTO 11450
11350   PRINT TAB(FNT(Y))"P";TAB(FNT(Y2));G1$\GOTO 11450
11400   PRINT TAB(FNT(Y2))G1$;TAB(FNT(Y));"P"
11450   NEXT X6
11500   PRINT TAB(6)"X";
11550   FOR I5=1 TO 12 \PRINT"----X";\NEXT I5\PRINT" "
11600   PRINT"COST%";
11650   FOR I5=1 TO 12\PRINT TAB(5+5*I5);10*I5;\NEXT I5
11700   PRINT""
11750 IF X6=P1 THEN GOTO 30362 ELSE 10700
11800   DEF FNT(A)=INT(50*A+.5)+6
```

```
11850  GOTO 30362
18000   'N-RFSN G1=G0-(Y-Y0)(1-E^-G0)/G0/(1-Y0)
18020   P=R/SQR(2*G5)
18025 PRINT"P,G5"P,G5
18035   IF P>10*R THEN 18300
18050   G6=1-EXP(-G5)
18150   Y6=FNG(I,R)
18200   G5=G5-(Y7-Y6)*G6/G5/(1-Y6)
18250   P=R/SQR(2*G5)
18280 PRINT "G6,Y6,G5,P" G6,Y6,G5,P
18300   RETURN
19990'
19993'FINDS DRTN
19996'
20000   DEF FNK(A,B)
20050   X1=A*(3*P-A)
20100   X2=B*(3*P-B)
20200   Y1 = C(A)/A
20300   Y2 = C(B)/B
20400   FNK=(X1*Y2-X2*Y1)/(Y2-Y1)/3
20500   FNEND
20600   DEF FNZ(W)=1-EXP(-W*W/2/P/P)
20700   DEF FNG(W,D)= FNZ(W)/FNZ(D)
30000   'BETA PEAK
30040   '
30080   DEF FNB(I,J,R)
30120   Y1=C(I)/C(R)\ Y2=C(J)/C(R)
30140   X1=I/R\X2=J/R
30150 IF Y2/X2=1 THENFNB=1 ELSE 30160
30155 GOTO 30361
30160   K=(Y1/X1-1)/(Y2/X2-1)
30200   U1=X1*(1-X1)
30240   U2=X2*(1-X2)
30280   B1=K*U2-U1
30320   B2=X1-1-K*(X2-1)
30360   FNB=B1/B2
30361   FNEND
30362   PRINT"RESPECIFY PROJECT NAME YES OR NO"\INPUT A9$
30363   IF A9$ ="NO" THEN STOP
30365   PRINT"RESPECIFY PROJECT NAME FOR CORPORATE PROG REFERENCE"
30366   INPUT X$(1)
30370   X1$=LEFT$(X$(1),5)+"S.DAT"
30375   FILE £4,X1$
30380   SCRATCH £4
30385   WRITE £4,IO
99999   END
```

```
R BASIC

READY, FOR HELP TYPE HELP.
OLD RAMNI

READY
RUN

RAMNI            14:54            27-MAR-81
```

SHELL RESULTS : ALL PROFESSIONS

```
FILE NAME ?SHELL.DAT
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58    CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?  0


 2    3    4    5    6    7    8    9   10   11   12   13   14
15   16   17   18   19   20   21   22   23   24   25   26
27   28   29   30   31   32   33   34   35   36   37   38
39   40   41   42   43   44   45   46   47
```

MONITORING CONSTANTS

ALPHA= 4.80001   BETA= 5.94137E-2   GAMMA= 7.62

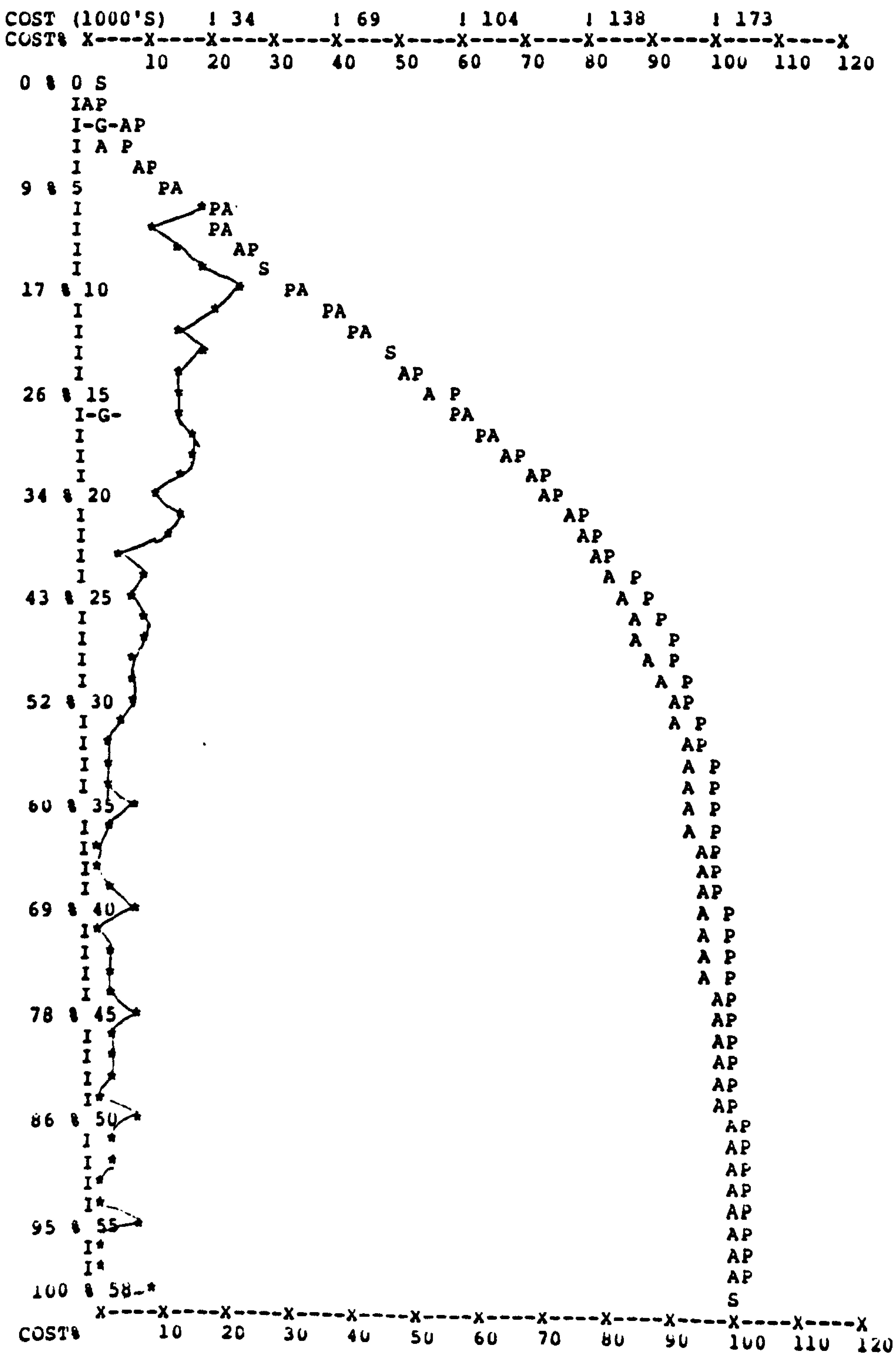
THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 21
MAXIMUM DURATION 44
(GAMMA) PEAK PERIOD 15
(GAMMA) ALPHA EQUIVALENT -3.50724   ERROR 0.194816 %
(GAMMA) MAX DURATION ESTIMATE 28

CUBIC BETWEEN PERIODS 2 AND 16

TOTAL PROJECTION ERROR= 2.5 %

GRAPH OF PROJECT EVALUATION

DURATION 58 PERIODS AT COST 173465 'POUNDS'



A=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENT** NON-CUMULATIVE EXPENDITURE

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	4	4	573	-0.3
2	587	591	2281	-1
3	4569	5160	10992	-3.4
4	9862	15022	15977	-0.6
5	7517	22539	21546	0.6
6	7873	30412	27656	1.6
7	4268	34680	34260	0.2
8	5993	40673	41314	-0.4
9	8099	48772	48772	0
10	10446	59218	56589	1.5
11	8917	68135	64720	2
12	6141	74276	73120	0.7
13	7468	81744	81744	0
14	6420	88164	90546	-1.4
15	6097	94261	99481	-3
16	5748	100009	99125	0.5
17	7177	107186	106820	0.2
18	6588	113774	114114	-0.2
19	6044	119818	120960	-0.7
20	4230	124048	127324	-1.9
21	6185	130233	133186	-1.7
22	5423	135656	138537	-1.7
23	2137	137793	143378	-3.2
24	3704	141497	147722	-3.6
25	2677	144174	151586	-4.3
26	3395	147569	154995	-4.3
27	3135	150704	157979	-4.2
28	2945	153649	160568	-4
29	2812	156461	162799	-3.7
30	1739	158200	164705	-3.7
31	1950	160150	166321	-3.6
32	1218	161368	167680	-3.6
33	1055	162423	168816	-3.7
34	677	163100	169757	-3.8
35	1051	164151	170531	-3.7
36	473	164624	171163	-3.8
37	258	164882	171163	-3.6
38	242	165124	171163	-3.5
39	757	165881	171675	-3.3
40	604	166485	172087	-3.2
41	346	166831	172087	-3
42	689	167520	172416	-2.8
43	612	168132	172677	-2.6
44	525	168657	172882	-2.4
45	914	169571	173042	-2
46	648	170219	173167	-1.7
47	524	170743	173263	-1.5
48	635	171378	173336	-1.1
49	266	171644	173336	-1
50	378	172022	173392	-0.8
51	770	172792	173434	-0.4
52	458	173250	173465	-0.1
53	11	173261	173465	-0.1
54	34	173295	173465	-0.1
55	26	173321	173465	-0.1
56	104	173425	173465	0
57	33	173458	173465	0
58	7	173465	173465	0

TIME: 238.12 SECS.

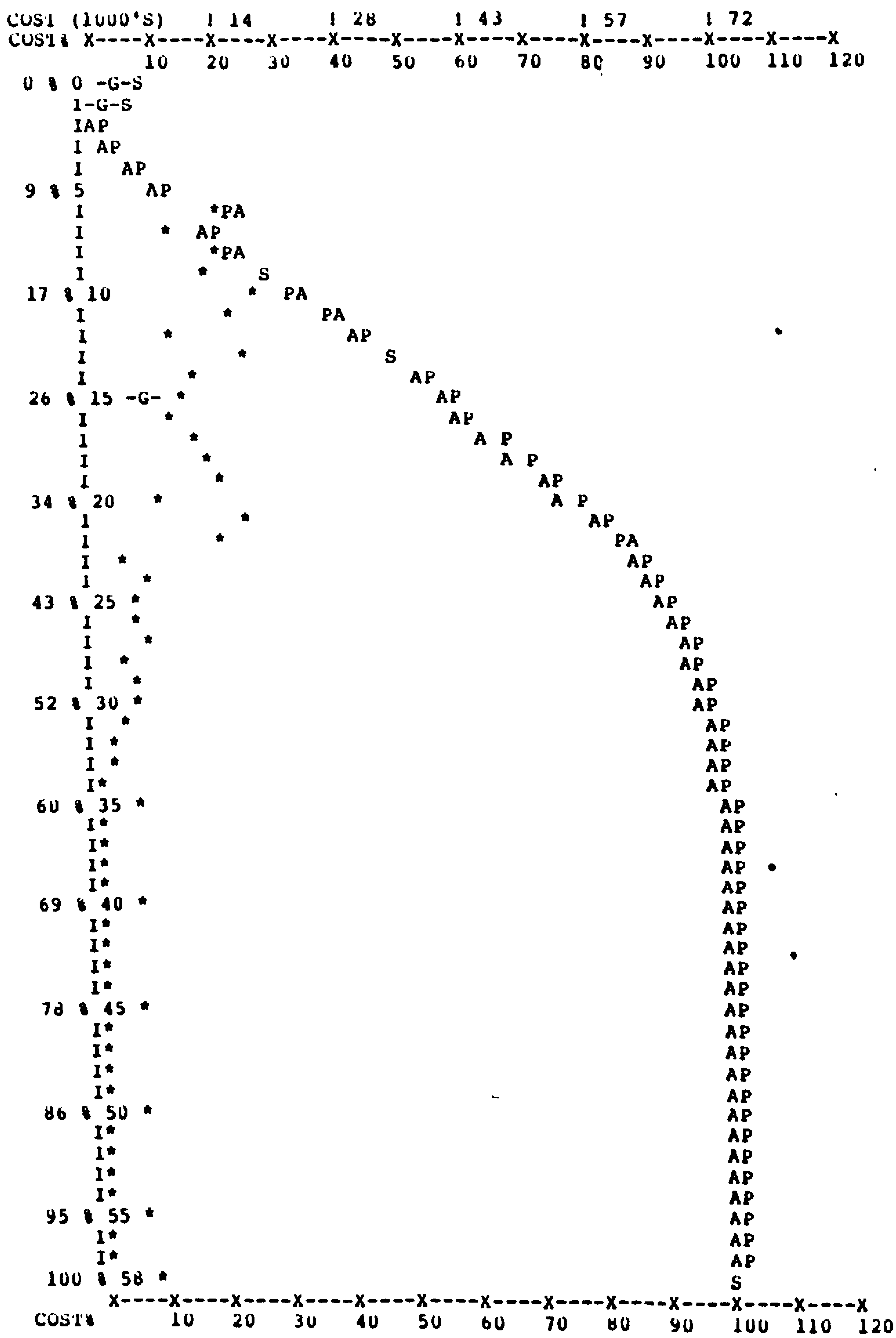
READY
RUN

KAMN1 15:10 27-MAR-81

```
READY
RUN

RAMN1            15:33            27-MAR-81
```

SHELL – ARCHITECT

```
FILE NAME ?SHELL.DAT
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58    CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?2


 2     3     4     5     6     7     8     9     10    11    12    13    14
 15    16    17    18    19    20    21    22    23    24    25    26
 27    28    29    30    31


MONITORING CONSTANTS
---------------------

ALPHA= 2.62634   BETA= 0.203822   GAMMA= 4.17

THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD  24
MAXIMUM DURATION  49
(GAMMA) PEAK PERIOD  21
(GAMMA) ALPHA EQUIVALENT  1.11998          ERROR  2.0422 %
(GAMMA) MAX DURATION ESTIMATE  57

CUBIC BETWEEN PERIODS  0  AND  14

TOTAL PROJECTION ERROR= 1.7 %


GRAPH OF PROJECT EVALUATION
---------------------------

DURATION  58  PERIODS AT COST  72230  'POUNDS'
```



A=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENTS 4*NON-CUMULATIVE EXPENDITURE

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	0	0	0	0
2	518	518	1266	-1
3	1264	1782	2944	-1.6
4	2777	4559	4998	-0.6
5	2796	7355	7393	-0.1
6	3676	11031	10096	1.3
7	2040	13071	13071	0
8	3495	16566	16284	0.4
9	3134	19700	19700	0
10	4572	24272	23284	1.4
11	3950	28222	27001	1.7
12	2105	30327	30817	-0.7
13	4370	34697	34697	0
14	2709	37406	38606	-1.7
15	2488	39894	40339	-0.6
16	2145	42039	44017	-2.7
17	3007	45046	47498	-3.4
18	3275	48321	50750	-3.4
19	3742	52063	53754	-2.3
20	1652	53715	56497	-3.9
21	4387	58102	58974	-1.2
22	3543	61645	61187	0.6
23	798	62443	63143	-1
24	1326	63769	64854	-1.5
25	1093	64862	66336	-2
26	1027	65889	67608	-2.4
27	1449	67338	68687	-1.9
28	719	68057	69595	-2.1
29	1104	69161	70351	-1.6
30	703	69864	70975	-1.5
31	752	70616	71485	-1.2
32	223	70839	71898	-1.5
33	366	71205	72230	-1.4
34	160	71365	72230	-1.2
35	190	71555	72230	-0.9
36	106	71661	72230	-0.8
37	0	71661	72230	-0.8
38	34	71695	72230	-0.7
39	95	71790	72230	-0.6
40	45	71835	72230	-0.5
41	130	71965	72230	-0.4
42	6	71971	72230	-0.4
43	18	71989	72230	-0.3
44	84	72073	72230	-0.2
45	53	72126	72230	-0.1
46	0	72126	72230	-0.1
47	0	72126	72230	-0.1
48	0	72126	72230	-0.1
49	0	72126	72230	-0.1
50	19	72145	72230	-0.1
51	19	72164	72230	-0.1
52	0	72164	72230	-0.1
53	0	72164	72230	-0.1
54	0	72164	72230	-0.1
55	26	72190	72230	-0.1
56	0	72190	72230	-0.1
57	33	72223	72230	0
58	7	72230	72230	0

TIME: 47.88 SECS.

SHELL-MECHANICAL

```
RUN

RAMN1           15:27           27-MAR-81


FILE NAME ?SHELL.DAT
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58    CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?1


 2     3     4     5     6     7     8     9     10    11    12    13    14
 15    16    17    18    19    20    21    22    23    24    25    26
 27    28    29    30    31    32    33    34
```

MONITORING CONSTANTS

ALPHA= 3.00277   BETA= 9.50035E-2   GAMMA= 5.826

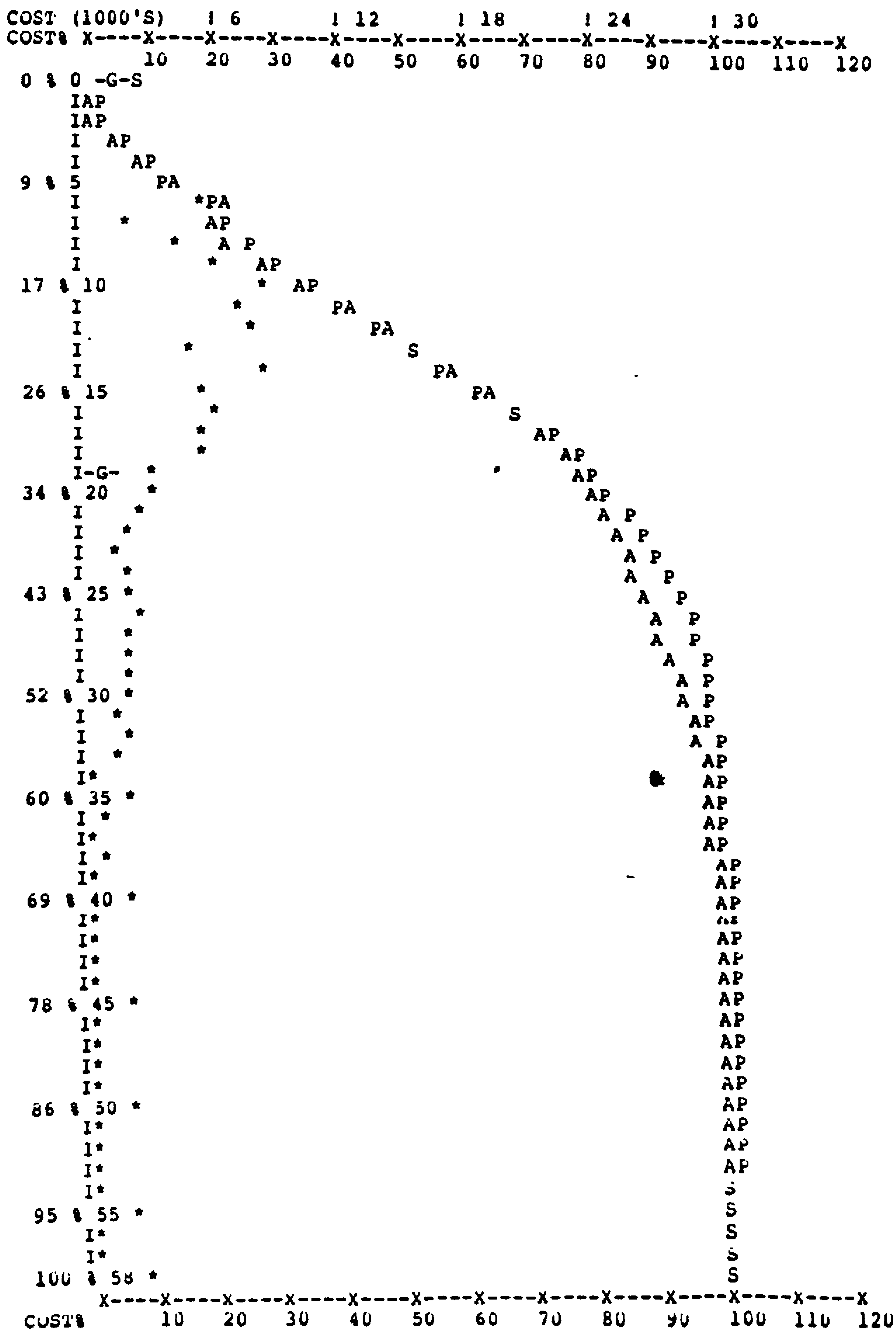
THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 22
MAXIMUM DURATION 47
(GAMMA) PEAK PERIOD 17
(GAMMA) ALPHA EQUIVALENT -2.75217   ERROR 1.20245 %
(GAMMA) MAX DURATION ESTIMATE 22

CUBIC BETWEEN PERIODS 0 AND 18

TOTAL PROJECTION ERROR= 2.9 %

GRAPH OF PROJECT EVALUATION

DURATION 58 PERIODS AT COST 30644 'POUNDS'



A=ACTUAL   P=FORECAST   S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENTS 4*NON-CUMULATIVE EXPENDITURE

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	4	4	706	-2.3
2	0	4	706	-2.3
3	937	941	1563	-2
4	1533	2474	2560	-0.3
5	1544	4018	3682	1.1
6	1385	5403	4917	1.6
7	430	5833	6252	-1.4
8	1115	6948	7675	-2.4
9	1540	8488	9171	-2.2
10	2082	10570	10730	-0.5
11	1781	12351	12337	0
12	2007	14358	13979	1.2
13	1287	15645	15645	0
14	2086	17731	17321	1.3
15	1356	19087	18993	0.3
16	1563	20650	20650	0
17	1344	21994	22278	-0.9
18	1373	23367	23865	-1.6
19	704	24071	24152	-0.3
20	732	24803	25214	-1.3
21	589	25392	26149	-2.5
22	536	25928	26961	-3.4
23	244	26172	27659	-4.9
24	430	26602	28252	-5.4
25	172	26774	28749	-6.4
26	561	27335	29162	-6
27	432	27767	29501	-5.7
28	464	28231	29775	-5
29	514	28745	29996	-4.1
30	211	28956	30172	-4
31	240	29196	30309	-3.6
32	424	29620	30416	-2.6
33	289	29909	30499	-1.9
34	17	29926	30499	-1.9
35	240	30166	30562	-1.3
36	79	30245	30562	-1
37	12	30257	30562	-1
38	90	30347	30609	-0.9
39	71	30418	30609	-0.6
40	126	30544	30644	-0.3
41	25	30569	30644	-0.2
42	15	30584	30644	-0.2
43	0	30584	30644	-0.2
44	0	30584	30644	-0.2
45	15	30599	30644	-0.1
46	0	30599	30644	-0.1
47	0	30599	30644	-0.1
48	0	30599	30644	-0.1
49	0	30599	30644	-0.1
50	0	30599	30644	-0.1
51	0	30599	30644	-0.1
52	0	30599	30644	-0.1
53	11	30610	30644	-0.1
54	34	30644	30644	0
55	0	30644	30644	0
56	0	30644	30644	0
57	0	30644	30644	0
58	0	30644	30644	0

TIME: 83.88 SECS.

SHELL - CIVIL & STRUCT. ENGINEERS

READY
RUN

RAMN1 15:45 27-MAR-81

FILE NAME ?SHELL.DAT SHELL
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58 CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?3 (CIVILS & STRUCTS)

2 3 4 5 6 7 8 9 10 11 12 13 14
15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30 31 32

MONITORING CONSTANTS

ALPHA=-8.78049E-2 BETA= 7.19382 GAMMA= 4.084

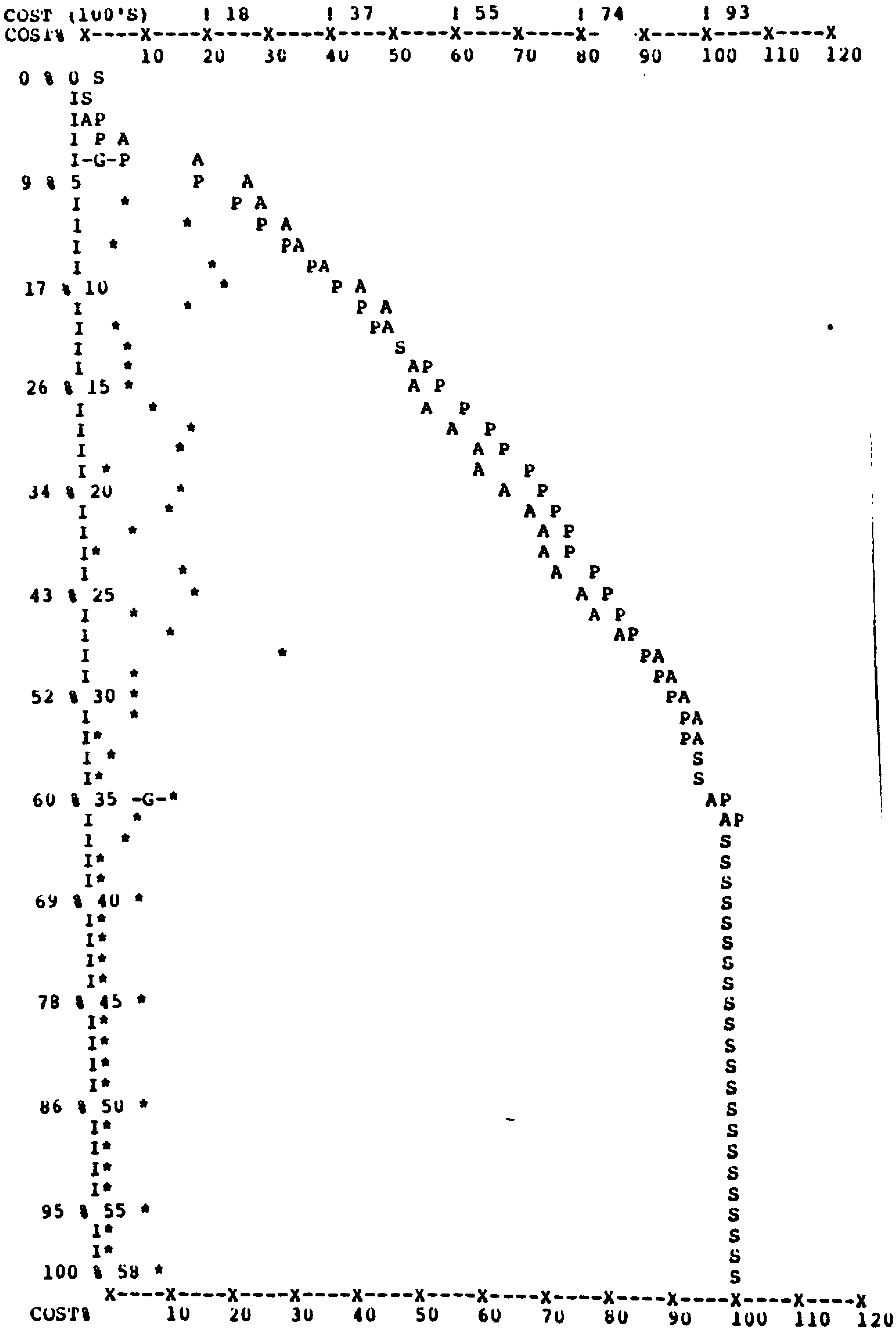
THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 159
MAXIMUM DURATION 224
(GAMMA) PEAK PERIOD 21
(GAMMA) ALPHA EQUIVALENT 27.8364 ERROR 1.07248 %
(GAMMA) MAX DURATION ESTIMATE 41

CUBIC BETWEEN PERIODS 3 AND 31

TOTAL PROJECTION ERROR= 3.8 %

GRAPH OF PROJECT EVALUATION

DURATION 58 PERIODS AT COST 9315 'POUNDS'



A=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENTS 4*NON-CUMULATIVE EXPENDITURE

COST TABLE

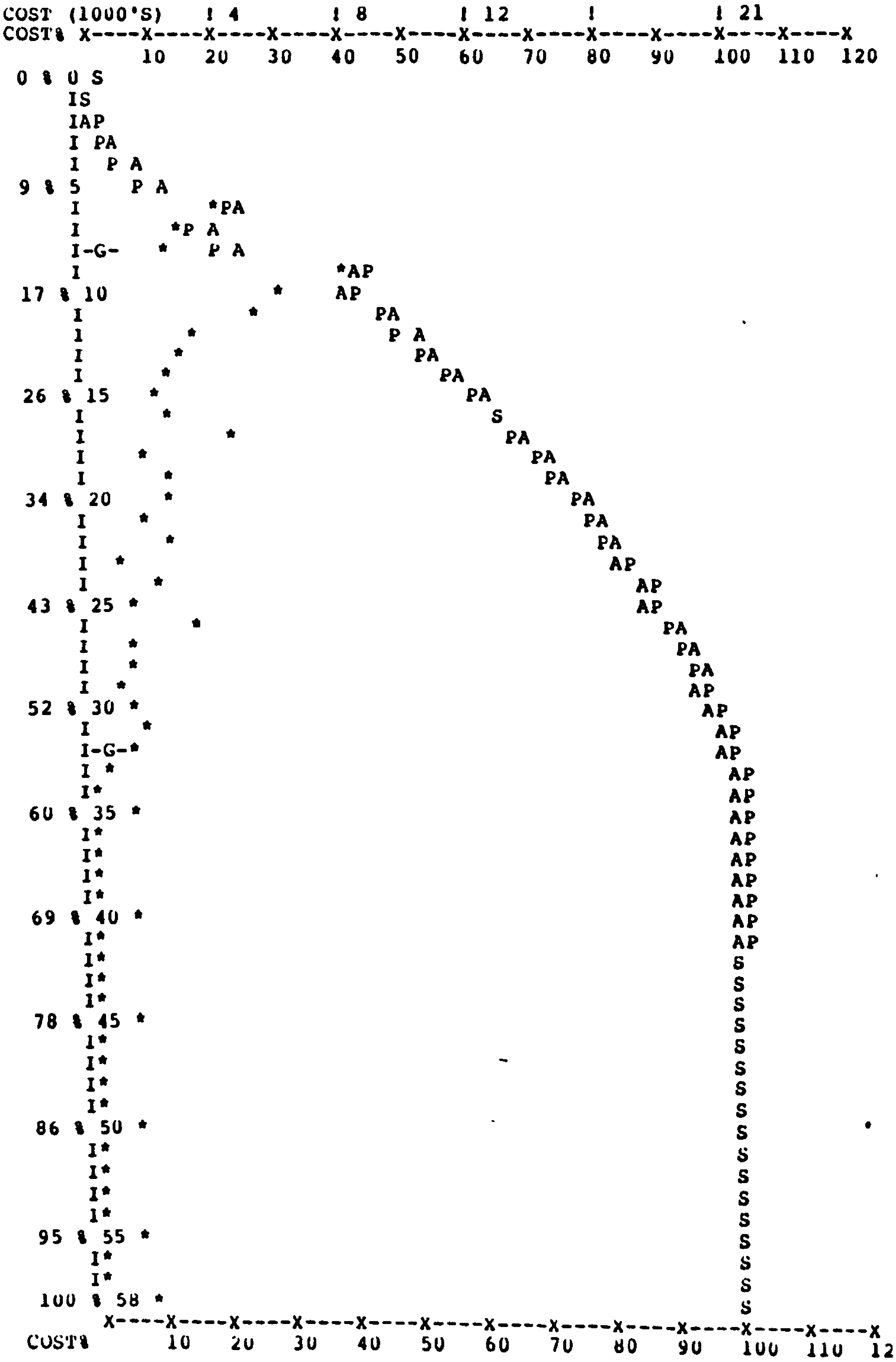
PRD.	COST	CUM.COST	FORECAST	%ERROR
1	0	0	0	0
2	4	4	35	-0.3
3	608	612	141	5.1
4	1118	1730	314	15.2
5	735	2465	1745	7.7
6	133	2598	2152	4.8
7	366	2964	2547	4.5
8	110	3074	2930	1.5
9	483	3557	3302	2.7
10	507	4064	3663	4.3
11	389	4453	4013	4.7
12	98	4551	4352	2.1
13	129	4680	4680	0
14	120	4800	4997	-2.1
15	76	4876	5304	-4.6
16	218	5094	5601	-5.4
17	367	5461	5887	-4.6
18	346	5807	6163	-3.8
19	56	5863	6429	-6.1
20	342	6205	6685	-5.2
21	275	6480	6932	-4.9
22	140	6620	7169	-5.9
23	19	6639	7169	-5.7
24	320	6959	7396	-4.7
25	358	7317	7615	-3.2
26	135	7452	7824	-4
27	295	7747	8024	-3
28	719	8466	8215	2.7
29	130	8596	8397	2.1
30	90	8686	8571	1.2
31	147	8833	8736	1
32	8	8841	8736	1.1
33	52	8893	8893	0
34	0	8893	8893	0
35	177	9070	9217	-1.6
36	156	9226	9271	-0.5
37	89	9315	9315	0
38	0	9315	9315	0
39	0	9315	9315	0
40	0	9315	9315	0
41	0	9315	9315	0
42	0	9315	9315	0
43	0	9315	9315	0
44	0	9315	9315	0
45	0	9315	9315	0
46	0	9315	9315	0
47	0	9315	9315	0
48	0	9315	9315	0
49	0	9315	9315	0
50	0	9315	9315	0
51	0	9315	9315	0
52	0	9315	9315	0
53	0	9315	9315	0
54	0	9315	9315	0
55	0	9315	9315	0
56	0	9315	9315	0
57	0	9315	9315	0
58	0	9315	9315	0

TIME: 53.89 SECS.

SHELL - ELECTRICAL

```
READY
RUN

RAMN1          15:59          27-MAR-81


FILE NAME ?SHELL.DAT
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58   CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?4


 2    3    4    5    6    7    8    9    10   11   12   13   14
 15   16   17   18   19   20   21   22   23   24   25   26
 27   28   29   30   31



MONITORING CONSTANTS
--------------------

ALPHA= 0.112711   BETA=-5.38347   GAMMA= 4.766

THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD -84
MAXIMUM DURATION  68
(GAMMA) PEAK PERIOD  19
(GAMMA) ALPHA EQUIVALENT -6.29255          ERROR  1.25298 %
(GAMMA) MAX DURATION ESTIMATE  34

CUBIC BETWEEN PERIODS  7  AND  31

TOTAL PROJECTION ERROR= 2.6 %


GRAPH OF PROJECT EVALUATION
---------------------------
```

DURATION 58 PERIODS AT COST 21055 'POUNDS'



A=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
--G-- SWITCH TO GAMMA
* REPRESENTS A$NON-CUMULATIVE EXPENDITURE

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	0	0	0	0
2	46	46	99	-0.2
3	565	611	392	1
4	904	1515	871	3.1
5	918	2433	1524	4.3
6	1071	3504	2333	5.6
7	689	4193	3276	4.4
8	655	4848	4330	2.5
9	2112	6960	7770	-3.8
10	1613	8573	8639	-0.3
11	1358	9931	9484	2.1
12	837	10768	10304	2.2
13	789	11557	11099	2.2
14	608	12165	11868	1.4
15	554	12719	12611	0.5
16	609	13328	13328	0
17	1124	14452	14018	2.1
18	465	14917	14681	1.1
19	679	15596	15316	1.3
20	618	16214	15923	1.4
21	395	16609	16501	0.5
22	619	17228	17051	0.8
23	205	17433	17571	-0.7
24	514	17947	18061	-0.5
25	340	18287	18520	-1.1
26	823	19110	18949	0.8
27	363	19473	19347	0.6
28	277	19750	19713	0.2
29	248	19998	20048	-0.2
30	227	20225	20349	-0.6
31	393	20618	20618	0
32	180	20798	20993	-0.9
33	139	20937	21055	-0.6
34	0	20937	21055	-0.6
35	0	20937	21055	-0.6
36	0	20937	21055	-0.6
37	0	20937	21055	-0.6
38	0	20937	21055	-0.6
39	40	20977	21055	-0.4
40	30	21007	21055	-0.2
41	0	21007	21055	-0.2
42	48	21055	21055	0
43	0	21055	21055	0
44	0	21055	21055	0
45	0	21055	21055	0
46	0	21055	21055	0
47	0	21055	21055	0
48	0	21055	21055	0
49	0	21055	21055	0
50	0	21055	21055	0
51	0	21055	21055	0
52	0	21055	21055	0
53	0	21055	21055	0
54	0	21055	21055	0
55	0	21055	21055	0
56	0	21055	21055	0
57	0	21055	21055	0
58	0	21055	21055	0

TIME: 57.80 SECS.

SHELL PROFESSIONAL

```
READY
RUN

RAMN1          16:05          27-MAR-81


FILE NAME ?SHELL.DAT
% COST LEVEL EQUIVALENT TO REDUNDANT PERIODS ?10
PERIODS= 58    CLASSES= 7

PROFESSION NO. ('0' FOR ALL) ?5


 2     3     4     5     6     7     8     9    10    11    12    13    14
15    16    17    18    19    20    21    22    23    24    25    26
27    28    29    30
```

MONITORING CONSTANTS

ALPHA= 1.08596   BETA= 0.145014   GAMMA= 3.674

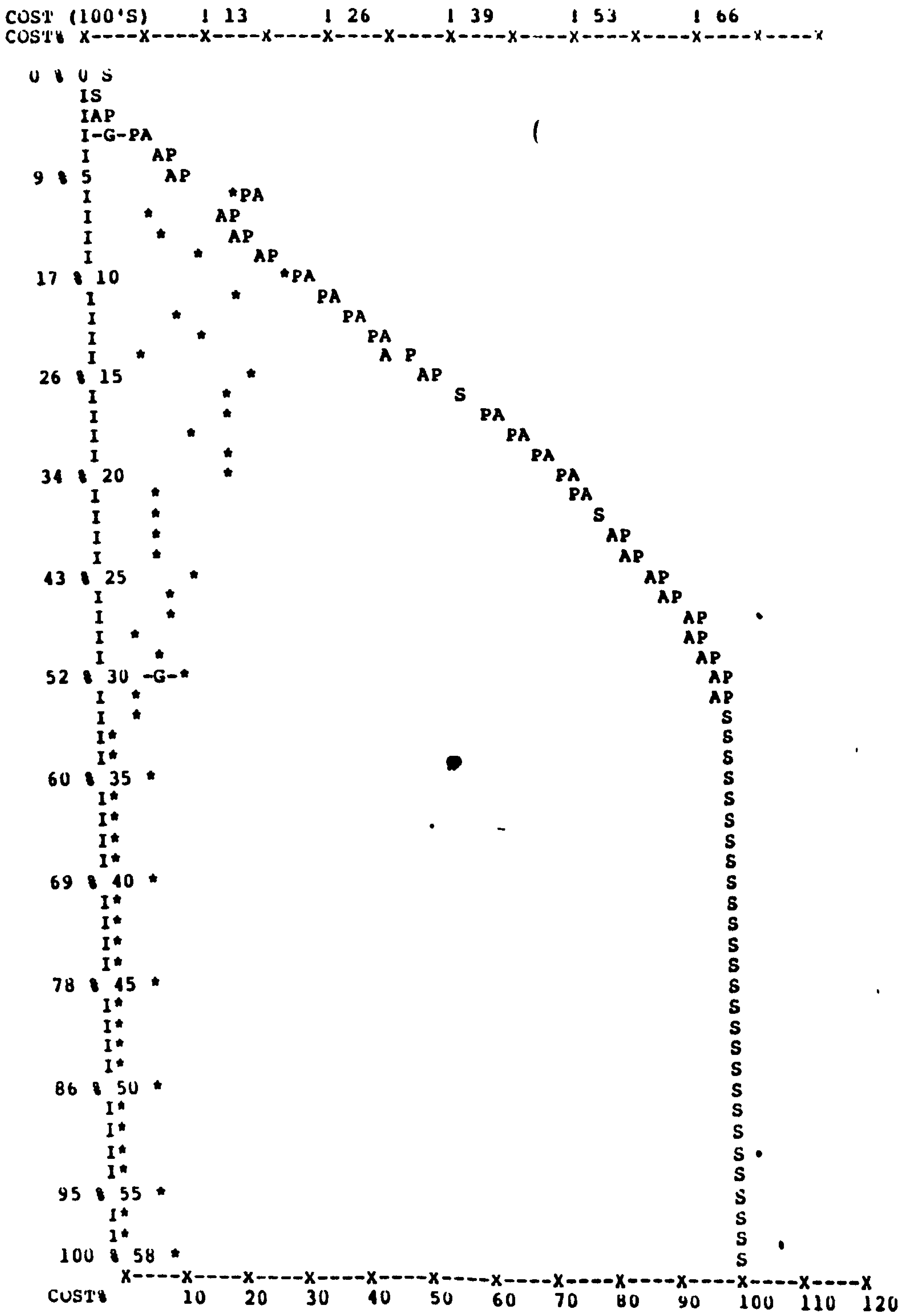
THESE CONSTANTS REPRESENT:-
(BETA) PEAK PERIOD 23
MAXIMUM DURATION 59
(GAMMA) PEAK PERIOD 22
(GAMMA) ALPHA EQUIVALENT 13.7496   ERROR 0.181107 %
(GAMMA) MAX DURATION ESTIMATE 42

CUBIC BETWEEN PERIODS 2 AND 29

TOTAL PROJECTION ERROR= 1.4 %

GRAPH OF PROJECT EVALUATION

DURATION 58 PERIODS AT COST 6645 'POUNDS'



*=ACTUAL P=FORECAST S=IDENTICAL 'VALUES'
-G-- SWITCH TO GAMMA

COST TABLE

PRD.	COST	CUM.COST	FORECAST	%ERROR
1	0	0	0	0
2	19	19	26	-0.1
3	177	196	103	1.4
4	405	601	613	-0.2
5	190	791	844	-0.8
6	356	1147	1088	0.9
7	136	1283	1341	-0.9
8	169	1452	1602	-2.3
9	275	1727	1871	-2.2
10	491	2218	2145	1.1
11	372	2590	2424	2.5
12	190	2780	2705	1.1
13	254	3034	2987	0.7
14	84	3118	3269	-2.3
15	390	3508	3549	-0.6
16	318	3826	3826	0
17	345	4171	4098	1.1
18	224	4395	4365	0.5
19	342	4737	4624	1.7
20	321	5058	4874	2.8
21	145	5203	5113	1.3
22	138	5341	5341	0
23	147	5488	5555	-1
24	141	5629	5755	-1.9
25	241	5870	5938	-1
26	172	6042	6104	-0.9
27	163	6205	6250	-0.7
28	81	6286	6376	-1.4
29	135	6421	6480	-0.9
30	70	6491	6544	-0.8
31	77	6568	6600	-0.5
32	77	6645	6645	0
33	0	6645	6645	0
34	0	6645	6645	0
35	0	6645	6645	0
36	0	6645	6645	0
37	0	6645	6645	0
38	0	6645	6645	0
39	0	6645	6645	0
40	0	6645	6645	0
41	0	6645	6645	0
42	0	6645	6645	0
43	0	6645	6645	0
44	0	6645	6645	0
45	0	6645	6645	0
46	0	6645	6645	0
47	0	6645	6645	0
48	0	6645	6645	0
49	0	6645	6645	0
50	0	6645	6645	0
51	0	6645	6645	0
52	0	6645	6645	0
53	0	6645	6645	0
54	0	6645	6645	0
55	0	6645	6645	0
56	0	6645	6645	0
57	0	6645	6645	0
58	0	6645	6645	0

Appendix 4 - Program Listings

1. Forecasting and Alteration Programs

FEST2.BAS	Design Application
ALT1.BAS	Design Application
FEST3.BAS	Construction Application
ALT2.BAS	Construction Application

2. Curve Fit Program

RAM.BAS

DESIGN BUDGETING PROGRAM (FEST2.BAS)

```
00001   MARGIN 132
00050   DIM P(10),O(10),F(10),L(10),A5(200,8),Y(200),Y1(200),Y2(200),Y3(200),Y4(200),Y5(200),Y6(200),X1(200)
00075   DIM T1(200),T2(200),T3(200),T4(200),T5(200),T6(200),T7(200),A6(200,8)
00080   DIM A7(200,8)
00150   PRINT"DESIGN FEE ESTIMATION PROGRAM"
00250   PRINT"-----------------------------"
00350   PRINT
00450   PRINT
00550   PRINT"INPUT PROJECT NAME(MAX FIVE CHARACTERS)"
00650   INPUT Y$
00750   X1$=LEFT$(Y$,5)+"G.DAT"
00760   X3$=LEFT$(Y$,5)+"P.DAT"
00770   PRINT
00810 PRINT "INPUT ESTIMATED FEE INCOME FOR THE FOLLOWING:-"
00820 PRINT "ARCHITECTURE";\INPUT A
00830 PRINT "STRUCTURAL ENGINEERING";\INPUT A1
00840 PRINT "MECHANICAL ENGINEER";\INPUT F(6)
00850 PRINT "ELECTRICAL ENGINEER";\INPUT F(7)
00860 PRINT "QUANTITY SURVEYING";\INPUT F(8)
00870 PRINT "EXTERNAL CONSULTANTS";\INPUT F(9)
00880 PRINT "ALLOCATABLE OVERHEADS";\INPUT F(10)
00890 PRINT
00900 PRINT "INPUT % OF ARCHITECTS FEES ALLOCATED TO SUB/S & SUP/S"\INPUT A2,A3
00910   F(1)=A2/100*A\F(2)=A3/100*A\F(3)=(100-A2-A3)/100*A
00920 PRINT "INPUT % OF STRUCTURAL ENGINEERS FEES ALLOCATED TO SUB/S"\INPUT A4
00930 F(4)=A4/100*A1\F(5)=(100-A4)/100*A1
00940 PRINT
00950 PRINT "INPUT % TO COVER OVERALL O/H CHARGE AND % PROFIT EXPECTED"\INPUT G,P
00955   PRINT"INPUT DURATION OF PROJECT IN MONTHS";\INPUT N1\LET N2=N1
00960 REM CALC PRIME COST, OVERHEADS AND PROFIT.
00970 FOR X = 1 TO 10
00980 O(X) = F(X) * G/100
00990 L(X) = F(X) * P/100
01000 U(X) = F(X) - O(X) - L(X)
01005 T(X) = U(X)+L(X)+O(X)
```

```
01010 NEXT X
01020 PRINT
01030 LET H$ = "PRIME COST"
01040 LET H1$ = "OVERHEAD"
01050 LET H2$ = "PROFIT"
01060 LET H3$ = "TOTAL"
01070 PRINT "ANALYSIS OF ESTIMATE"
01080 PRINT "--------------------"
01090 PRINT
01100 PRINT
01110 PRINT "                 ARCHITECT                     STRUCTURAL ENG        MECH       ELECT   Q.S.       EXT        DIR"
01120 PRINT "                 SUB/S      SUP/S      FIN      SUB/S      SUP/S      ENG        ENG                CT'S       O/H'S"
01130   FOR X=1TO116
01140   PRINT"-";
01150 NEXT X
01160 PRINT
01170 PRINT USING 1210,H$,U(1),U(2),U(3),U(4),U(5),U(6),U(7),U(8),U(9),U(10)
01180 PRINT USING 1210, H1$,O(1),O(2),O(3),O(4),O(5),O(6),O(7),O(8),O(9),O(10)
01190 PRINT USING 1210, H2$,L(1),L(2),L(3),L(4),L(5),L(6),L(7),L(8),L(9),L(10)
01195 PRINT
01200 PRINT USING 1210, H3$,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10)
01210 :'LLLLLLLLLL  ######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##
01250 PRINT
01260 PRINT
01270 PRINT "INPUT STANDARD/AVERAGE COST PER MAN HOUR";\INPUT S
01280 PRINT
01285   M=M+1
01290 PRINT "STANDARD MAN HOURS AVAILABLE TO EACH PROFESSION"
01300 PRINT "-----------------------------------------------"
01310 PRINT "ARCHITECTURE          ";(F(1)+F(2)+F(3))/S
01320 PRINT "STRUCT ENGINEERING    ";(F(4)+F(5))/S
01330 PRINT "MECHANICAL ENG        ";F(6)/S
01340 PRINT "ELECT ENG             ";F(7)/S
01350 PRINT "QUANTITY SURVEYING    ";F(8)/S
01380 PRINT
01390 PRINT
01400 PRINT "STATE % OF ARCHITECTS WORK COMPLETE BEFORE FOLLOWING OTHER PROF. START"
01500 PRINT "INPUT VALUES FOR S.E.,MECH,ELECT.,Q.S.,EXT. CT'S.,DIR O/H'S RESPECTIVELY"
01600 INPUT L1,L2,L3,L4,L5,L6
01700 PRINT "STATE % OF ARCHITECTS WORK TO COMPLETE AFTER FOLLOWING HAVE FINISHED"
01800 PRINT "INPUT VALUES FOR S.E.,MECH,ELECT.,Q.S.,EXT CT'S., DIR O/H'S RESPECTIVELY"
01900 INPUT F1,F2,F3,F4,F5,F6
02000   PRINT
02005   FILE #1,"EST2.TMP"
02010   SCRATCH #1
02015   FILE #2,"EST3.TMP"
02020   SCRATCH #2
02025   FILE #3,"EST4.TMP"
02030   SCRATCH #3
02035   FILE #4,"EST5.TMP"
```

```
02040   SCRATCH #4
02045   FILE #5,"EST6.TMP"
02050   SCRATCH #5
02055   FILE #6,"EST7.TMP"
02060   SCRATCH #6
02065   FILE #7,"EST8.TMP"
02070   SCRATCH #7
02100 REM A,B GENERATOR
02110PRINT
02130   PRINT"LIKELY % DURATION EXCESS";\INPUT D1
02140   PRINT"INPUT PEAK COST MONTH";
02150   INPUT B1 \B1=B1/N1
02160   B=(B1+1)/3
02170   DEF FNA(X)=1/(3*X*X-2*(B+1)*X+B)
02180   D0=-D1/200 \D2=1+D1/100
02190   IF FNA(D2)>FNA(D0) THEN A=FNA(D0) ELSE A=FNA(D2)
02195   A=INT(A*1000+.5)/1000 \B=INT(B*1000+.5)/1000
02200 PRINT"ALPHA= "A,"BETA= "B
02210 PRINT
02275   C1=F(1)+F(2)+F(3)-((F(1)+F(2)+F(3))*G/100+(F(1)+F(2)+F(3))*P/100)
02300   M=1
02325   Y4=0
02350   FOR N=1TON1
02400   X3=M/N1
02500   Y5=C1*(X3*(1+(A*(1-X3)*(X3-B))))
02505   Y(N)=Y5
02510   T1(N)=Y5
02515   X1(N)=Y5-Y4
02520   Y4=Y5
02600   WRITE #1,X1(N),T1(N)
02700   M=M+1
02800   NEXT N
02900   C2=F(4)+F(5)-((F(4)+F(5))*G/100+(F(4)+F(5))*P/100)
03000   M=1
03100   FOR X=1 TO N1
03200   IF(Y(X)/C1)*100>L1 GOTO 3500
03300   M=M+1
03400   NEXT X
03500   LET L1=M
03600   LET M=1
03700   FOR X = 1TO N1
03750   IF(Y(X)/C1)*100>(100-F1) GOTO 4000
03800   M=M+1
03900   NEXT X
04000   LET F1=M
04100   N2=F1-L1
04200   M=1
04250   Y4=0
04300   FOR N=1TON2
04400   X3=M/N2
04500   Y5=C2*X3*(1+A*(1-X3)*(X3-B))
04505   T2(N)=Y5
04510   Y1(N)=Y5-Y4
04520   Y4=Y5
04600   WRITE #2,Y1(N),T3(N)
04700   M=M+1
04800   NEXT N
04900   C3=F(6)-((F(6)*G/100)+(F(6)*P/100))
05000   M=1
05100   FOR X=1 TO N1
05200   IF(Y(X)/C1)*100>L2 GOTO 5500
05300   M=M+1
05400   NEXT X
05500   LET L2=M
05600   LET M=1
05700   FOR X=1 TO N1
```

```
05800   IF(Y(X)/C1)*100>(100-F2)GOTO 6100
05900   M=M+1
06000   NEXT X
06100   LET F2=M
06200   N3=F2-L2
06300   M=1
06350   Y4=0
06400   FOR N=1 TO N3
06500   X3=M/N3
06600   Y5=C3*X3*(1+A*(1-X3)*(X3-B))
06605   T3(N)=Y5
06610   Y2(N)=Y5-Y4
06620   Y4=Y5
06700   WRITE #3,Y2(N),T3(N)
06800   M=M+1
06900   NEXT N
07000   C4=F(7)-((F(7)*G/100)+(F(7)*P/100))
07100   M=1
07200   FOR X=1 TON1
07300   IF(Y(X)/C1)*100>L3 GOTO 7600
07400   M=M+1
07500   NEXT X
07600   LET L3=M
07700   LET M=1
07800   FOR X=1 TON1
07900   IF(Y(X)/C1)*100>(100-F3)GOTO 8200
08000   M=M+1
08100   NEXT X
08200   LET F3=M
08300   N4=F3-L3
08400   M=1
08450   Y4=0
08500   FOR N=1 TO N4
08600   X3=M/N4
08700   Y5=C4*X3*(1+A*(1-X3)*(X3-B))
08705   T4(N)=Y5
08725   Y3(N)=Y5-Y4
08730   Y4=Y5
08800   WRITE #4,Y3(N),T4(N)
08850   M=M+1
08900   NEXT N
09000   C5=F(8)-((F(8)*G/100)+(F(8)*P/100))
09100   M=1
09200   FOR X=1 TON1
09300   IF(Y(X)/C1)*100>L4 GOTO 9600
09400   M=M+1
09500   NEXT X
09600   LET L4=M
09700   LET M=1
09800   FOR X=1 TO N1
09900   IF(Y(X)/C1)*100>(100-F4)GOTO 10200
10000   M=M+1
10100   NEXT X
10200   LET F4=M
10300   N5=F4-L4
10400   M=1
10450   Y4=0
10500   FOR N=1 TO N5
10600   X3=M/N5
10700   Y5=C5*X3*(1+A*(1-X3)*(X3-B))
10705   T5(N)=Y5
10710   Y4(N)=Y5-Y4
10715   Y4=Y5
10750   M=M+1
```

```
10800  WRITE #5,Y4(N),T5(N)
10900  NEXT N
11000  C6=F(9)-((F(9)*G/100)+(F(9)*P/100))
11100  M=1
11200  FOR X=1 TO N1
11300  IF(Y(X)/C1)*100>L5 GOTO 11600
11400  M=M+1
11500  NEXT X
11600  LET L5=M
11700  LET M=1
11800  FOR X=1 TO N1
11900  IF(Y(X)/C1)*100>(100-F5)GOTO 12200
12000  M=M+1
12100  NEXT X
12200  LET F5=M
12300  N6=F5-L5
12400  M=1
12410
12432  Y4=0
12455
12500  FOR N=1 TO N6
12600  X3=M/N6
12700  Y5=C6*X3*(1+A*(1-X3)*(X3-B))
12705  T6(N)=Y5
12750  M=M+1
12760  Y5(N)=Y5-Y4
12770  Y4=Y5
12800  WRITE #6,Y5(N),T6(N)
12900  NEXT N
13000  C7=F(10)-((F(10)*G/100)+(F(10)*P/100))
13100  M=1
13200  FOR X=1 TO N1
13300  IF(Y(X)/C1)*100>L6 GOTO 13505
13400  M=M+1
13500  NEXT X
13505  LET L6=M
13510  LET M=1
13515  FOR X=1 TO N1
13520  IF(Y(X)/C1)*100>(100-F6)GOTO 13535
13525  M=M+1
13530  NEXT X
13535  LET F6=M
13540  LET N7=F6-L6
13545  M=1
13547  Y4=0
13550  FOR N=1 TO N7
13555  X3=M/N7
13560  Y5=C7*X3*(1+A*(1-X3)*(X3-B))
13561  Y6(N)=Y5-Y4
13562  Y4=Y5
13563  T7(N)=Y5
13565  WRITE #7,Y6(N),T7(N)
13567  M=M+1
13570  NEXT N
13585
13600 RESTORE #1
13700 FOR X=1 TO N1
13800 READ #1,A5(X,1),A6(X,1)
13900 NEXT X
14000 FOR X=1 TO (L1-1)
14100   A5(X,2)=0\A6(X,2)=0
14200 NEXT X
14300 RESTORE #2
14400 FOR X=L1 TO(F1-1)
14500 READ #2,A5(X,2),A6(X,2)
14600 NEXT X
```

```
14700 FOR X=F1TO N1
14800   A5(X,2)=0\A6(X,2)=0
14850 NEXT X
14900 RESTORE #3
15000 FOR X=1 TO(L2-1)
15100   A5(X,3)=0\A6(X,3)=0
15200 NEXT X
15300   FOR X=L2 TO (F2-1)
15400 READ #3,A5(X,3),A6(X,3)
15500 NEXT X
15600 FOR X=F2 TO N1
15700   A5(X,3)=0\A6(X,3)=0
15800 NEXT X
15900 RESTORE #4
16000 FOR X=1 TO(L3-1)
16100   A5(X,4)=0\A6(X,4)=0
16200 NEXT X
16300 FOR X=L3 TO(F3-1)
16400 READ #4,A5(X,4),A6(X,4)
16500 NEXT X
16600 FOR X=F3TO N1
16700   A5(X,4)=0\A6(X,4)=0
16800 NEXT X
16900 RESTORE #5
17000 FOR X=1 TO(L4-1)
17100   A5(X,5)=0\A6(X,5)=0
17200 NEXT X
17300   FOR X=L4 TO (F4-1)
17400 READ #5,A5(X,5),A6(X,5)
17500 NEXT X
17600 FOR X=F4TO N1
17700   A5(X,5)=0\A6(X,5)=0
17800 NEXT X
17900 RESTORE #6
18000 FOR X=1 TO (F5-1)
18100   A5(X,6)=0\A6(X,6)=0
18200 NEXT X
18300 FOR X=L5 TO( F5-1)
18400 READ #6,A5(X,6),A6(X,6)
18500 NEXT X
18600 FOR X=F5 TO N1
18700   A5(X,6)=0\A6(X,6)=0
18800 NEXT X
18900 RESTORE #7
19000 FOR X=1 TO(L6-1)
19100   A5(X,7)=0\A6(X,7)=0
19200 NEXT X
19300 FOR X=L6 TO(F6-1)
19400 READ #7,A5(X,7),A6(X,7)
19500 NEXT X
19600 FOR X=F6TO N1
19700   A5(X,7)=0\A6(X,7)=0
19800 NEXT X
19900 FILE #8,X1$
19950   SCRATCH #8
20600 FOR X=1 TO N1
20700 FOR Y=1 TO 7
20800 A5(X,8)=A5(X,8)+A5(X,Y)
20900 NEXT Y
21000 NEXT X
21050 X1=X+1
21100 FOR Y=1 TO 8
21200 FOR X = 1 TO N1
21300 A5(X1,Y)=A5(X1,Y)+A5(X,Y)
21400 NEXT X
21500 NEXT Y
```

```
21510   FOR X=1TON1
21520   FOR Y=1 TO 7
21530   WRITE #8,A5(X,Y)
21540   NEXT Y
21550   NEXT X
21600 PRINT "PROJECT ESTIMATE AND PROGRAMME OF PRIME COST EXPENDITURE"
21700 PRINT "-------------------------------------------------------"
21800 PRINT
22000   PRINT"     ARCH      STRU/     MECH/     ELECT     Q.S.     EXT      DIR      TOTAL      MONTH"
22100   PRINT"               ENG       ENG       ENG                CT'S     O/H'S"
22200 FOR X=1 TO90
22300 PRINT "-";
22400 NEXT X
22500 PRINT
22600 FOR X=1 TO N1
22700 PRINT USING 22800,A5(X,1),A5(X,2),A5(X,3),A5(X,4),A5(X,5),A5(X,6),A5(X,7),A5(X,8),X
22800 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##  ###
22900 NEXT X
22910   FOR X=1TO90
22920   PRINT"-";
22930   NEXT X
22940   PRINT
23000 PRINT USING 23100,A5(X1,1),A5(X1,2),A5(X1,3),A5(X1,4),A5(X1,5),A5(X1,6),A5(X1,7),A5(X1,8)
23100 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##
23150   Y4=0
23200 FILE #9,X3$
23300 SCRATCH #9
23305   S4=0
23310   FOR Y=1TO7
23320   FOR X=1TON1
23330   A7(X,Y)=S4=S4+A5(X,Y)
23340   NEXT X
23345   S4=0
23350   NEXT Y
23400   FOR X=1TON1
23410   FOR Y=1TO7
23420   WRITE #9,A7(X,Y)
23430   NEXT Y
23440   NEXT X
23500   PRINT
23510   FILE #1,"G.TMP"
23520   SCRATCH #1
23530   FOR X=1TON1
23540   FOR Y=1TO7
23550   WRITE #1,A5(X,Y)
23560   NEXT Y
23570   NEXT X
23600   PRINT"END OF RUN"
23700   PRINT
23800   PRINT"FILES SAVED"\PRINT X1$,X3$
23850   CHAIN "RAM.BAS"
23900   END
```

FORECASTING ALTERATION PROGRAM (ALTI.BAS)

```
00050 MARGIN 132
00100   DIM A6(200,9),T3(20),T4(20),A7(200,9)
00200   PRINT"FORECAST ALTERATION AND ADJUSTMENT PROGRAM"
00300   PRINT
00400   PRINT
00500   PRINT"INPUT PROJECT NAME";\INPUT Y$
00600   X1$=LEFT$(Y$,5)+"G.DAT"
00700   X3$=LEFT$(Y$,5)+"P.DAT"
00800   FILE #1,X1$
00850   RESTORE #1
00900   PRINT
01000   PRINT
01100   PRINT"ARE THERE ANY REDUNDANT PERIODS TO BE ALLOWED FOR IN TIME SPAN"
01200   PRINT"ANSWER YES OR NO"\INPUT A$
01300   IF A$="YES"THEN 1400
01310   R=1
01320   IF END #1,GOTO 1380
01330   FOR C=1TO7
01340   READ #1,A6(R,C)
01350   NEXT C
01360   R=R+1
01370   GOTO 1320
01380   R1=R-1
01390   GOTO 5200
01400   PRINT
01500   PRINT"HOW MANY REDUNDANT PERIODS"\INPUT Y
01600   PRINT"ON ? SPECIFY REDUNDANT PERIOD PARAMETERS IN ASCENDING ORDER"
01700   INPUT T3
01800   INPUT T3(1)
01900   FOR R=1TO(T3-1)
02000   FOR C=1TO7
02100 READ #1,A6(R,C)
02200   NEXT C
```

```
02300   NEXT R
02400   FOR R=T3TOT3(1)
02500   FOR C=1TO7
02600   LETA6(R,C)=0
02700   NEXT C
02800   NEXT R
02850   IF Y=1 GOTO 4900
02900    FOR Z=1 TO Y-1
03000   INPUT T4(Z)
03100 FOR R=T3(Z)+1 TO T4(Z)-1
03200   FOR C=1TO7
03300   READ #1,A6(R,C)
03400   NEXT C
03500   NEXT R
03650   INPUT T3(Z+1)
03700   FOR R=T4(Z)TOT3(Z+1)+1
03800   FOR C=1TO7
03900   A6(R,C)=0
04000   NEXT C
04100   NEXT R
04300   NEXT Z
04320 PRINT
04400   IF END #1, GOTO 5050
04600 FOR C=1TO7
04700   READ #1,A6(R,C)
04800   NEXT C
04900   R=R+1
05000 GOTO 4400
05025   IF Y>1 GOTO 5200
05050   R1=R-1
05200   PRINT
05300   PRINT"TOTAL REVISED PROJECT DURATION IN MONTHS";R1
05400   PRINT
05500   PRINT"DO YOU WISH TO MAKE ANY ALTERATIONS"
05600   PRINT"INPUT YES OR NO"\INPUT A$
05700   IF A$="NO" THEN 6900
05800   PRINT"INPUT MONTH NUMBER AND PROFESSION"
05900   PRINT"I.E. 11,2 MEANS MONTH 11, STRUCT ENG "
06000   INPUT R,C
06100   PRINT"INPUT AMOUNT IN POUNDS STERLING"\INPUT C1
06200   LET A6(R,C)=C1
06300   PRINT
06400   PRINT"DO YOU WISH TO MAKE ANY MORE ALTERATIONS"
06500   PRINT"ANSWER YES OR NO"
06600   INPUT A$
06750   IF A$="YES" THEN 5800
06800   PRINT
06900   PRINT
07000   PRINT"DO YOU WISH TO MAKE AN ALLOWANCE FOR INFLATION"
07100   PRINT"ANSWER YES OR NO"\INPUT A$
07200 IF A$="NO" THEN 8100
07300   PRINT
07400   PRINT"INPUT ANNUAL INFLATION RATE AS A %"\INPUT I1
07600   FOR R=1TOR1
07700   FOR C=1TO7
07800     A6(R,C)=A6(R,C)*(1+R*I1/1200)
```

```
07900    NEXT C
08000    NEXT R
08050 FOR I=1TOR1
08060 A6(I,8)=0\NEXT I
08100    FOR R=1TOR1
08200    FOR C=1TO7
08300    A6(R,8)=A6(R,8)+A6(R,C)
08400    NEXT C
08500    NEXT R
08600    R2=R1+1
08700    FOR C=1TO8
08800    FOR R=1TOR1
08900    A6(R2,C)=A6(R2,C)+A6(R,C)
09000    NEXT R
09100    NEXT C
09200    SCRATCH #1
09300    FOR R=1TOR1
09400    FOR C=1TO7
09500    WRITE #1,A6(R,C)
09600    NEXT C
09700    NEXT R
09800    FILE #2,X3$
09900    SCRATCH #2
10000    FOR C=1TO8
10050 S5=0
10100    FOR R=1TOR1
10200 A7(R,C)=S5=S5+A6(R,C)
10500    NEXT R
10600    NEXT C
10605    PRINT
10610    FOR I=1TOR1
10710    FOR J=1TO7
10810    WRITE #2,A7(I,J)
10910    NEXT J
11010    NEXT I
21550    FOR I=1 TO 2
21555    PRINT
21556    PRINT
```

```
21600 PRINT "PROJECT ESTIMATE AND PROGRAMME OF PRIME COST EXPENDITURE"
21610   IF I=2 THEN 21640
21620   PRINT"ANALYSIS ON A MONTHLY BASIS"
21630   GOTO 21700
21640   PRINT"ANALYSIS ON AN ACCUMULATIVE BASIS"
21700 PRINT "------------------------------------------------------------"
21800 PRINT
22000   PRINT"     ARCH      STRU/     MECH/     ELECT     Q.S.      EXT       DIR       TOTAL      MONTH"
22100   PRINT"               ENG       ENG       ENG                 CT'S      O/H'S"
22200 FOR X=1 TO90
22300 PRINT "-";
22400 NEXT X
22500 PRINT
22600 FOR X=1TOR1
22610   X1=R2
22615   X1=R2
22620   ON I GOTO 22650,22700
22650 PRINT USING 22800,A6(X,1),A6(X,2),A6(X,3),A6(X,4),A6(X,5),A6(X,6),A6(X,7),A6(X,8),X
22670 IF I=1 GOTO 22900
22700 PRINT USING 22800,A7(X,1),A7(X,2),A7(X,3),A7(X,4),A7(X,5),A7(X,6),A7(X,7),A7(X,8),X
22800 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##  ###
22900 NEXT X
22910   FOR X=1TO90
22920   PRINT"-";
22930   NEXT X
22940   PRINT
22945   ON I GOTO 22950,23152
22950 PRINT USING 23100,A6(X1,1),A6(X1,2),A6(X1,3),A6(X1,4),A6(X1,5),A6(X1,6),A6(X1,7),A6(X1,8)
22970 IF I=1 GOTO 23150
23100   :$$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$
23150   NEXT I
23152   FILE #9,"G.TMP"
23154   SCRATCH #9
23156   FOR X=1TOR1
23158   FOR Y=1TO7
23160   WRITE #9,A6(X,Y)
23162   NEXT Y
23164   NEXT X
23200   CHAIN "RAM.BAS"
99999  END
```

PRODUCTION BUDGET PROGRAM [FEST3.BAS]

```
ty fest3.bas
00001   MARGIN 132
00050   DIM P(10),O(10),F(10),L(10),A5(200,8),Y(200),Y1(200),Y2(200),Y3(200),Y4(200),Y5(200),Y6(200),X1(200)
00075   DIM T1(200),T2(200),T3(200),T4(200),T5(200),T6(200),T7(200),A(200,8),A1(200,8),P1(20)
00080   DIM A7(200,8)
00150   PRINT"PROJECT CASH FLOW ANALYSIS AND FORECAST"
00250   PRINT"--------------------------------------"
00350   PRINT
00450   PRINT
00550   PRINT"INPUT PROJECT NAME(MAX FIVE CHARACTERS)"
00650   INPUT Y$
00750   X1$=LEFT$(Y$,5)+"G.DAT"
00760   X3$=LEFT$(Y$,5)+"P.DAT"
00765   X4$=LEFT$(Y$,5)+"A.DAT"
00770   PRINT
00810   PRINT"INPUT BUDGET FOR EACH COST CENTRE"
00820 PRINT "SUBSTRUCTURE";\INPUT A0
00830 PRINT "SUPERSTRUCTURE";\INPUT A1
00840 PRINT "FINISHINGS";\INPUT F(6)
00850 PRINT "EXT WORKS";\INPUT F(7)
00860 PRINT "DRAINAGE";\INPUT F(8)
00870 PRINT "NOMINATED S/C'S";\INPUT F(9)
00880 PRINT "SITE O/H'S";\INPUT F(10)
00890 PRINT
00900   PRINT"INPUT DURATION OF PROJECT IN WEEKS"
01000   INPUT N1
01380 PRINT
01390 PRINT
01400   PRINT"STATE THE START WEEK FOR EACH COST CENTRE I.E."
01500   PRINT"SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H"
01600 INPUT L1,L2,L3,L4,L5,L6,L7
01700   PRINT"STATE FINISH WEEK FOR EACH COST CENTRE I.E."
01800   PRINT"SUBSTR,SUPERSTR,FIN,EXT WKS,DRAINS,NOM S/C,SITE O/H"
01900 INPUT F1,F2,F3,F4,F5,F6,F7
02000   FILE #1,X4$
02005   SCRATCH #1
02010   D$="INPUT % ALLOCATION OF LABOUR,PLANT,MATERIAL"
02015   PRINT D$\PRINT"SUBSTRUCTURE"\INPUT P1(1),P1(2),P1(3)
02020   PRINT D$\PRINT"SUPERSTRUCTURE"\INPUT P1(4),P1(5),P1(6)
02025   PRINT D$\PRINT"FINISHES"\INPUT P1(7),P1(8),P1(9)
02030   PRINT D$\PRINT"EXT WKS"\INPUT P1(10),P1(11),P1(12)
02035   PRINT D$\PRINT"DRAINAGE"\INPUT P1(13),P1(14),P1(15)
02040   FOR X=1TO15
02045   WRITE #1,P1(X)
02050   NEXT X
02200   PRINT"INPUT ALPHA, BETA SUBSTRUCTURE"\INPUT A,B
02210 PRINT
02275   C1=F(1)+F(2)+F(3)-((F(1)+F(2)+F(3))*G/100+(F(1)+F(2)+F(3))*P/100)
02300   M=1
02325   Y4=0
02350   FOR N=L1 TO F1
02355   N7=F1-L1+1
02400   X3=M/N7
02500   Y5=A0*(X3*(1+(A*(1-X3)*(X3-B))))
02505   Y(N)=Y5
02510   T1(N)=Y5
02515   X1(N)=Y5-Y4
02520   Y4=Y5
02525   A(N,1)=X1(N)\A1(N,1)=T1(N)
```

```
02700   M=M+1
02800   NEXT N
04000   PRINT"INPUT A,B SUPERSTRUCTURE"\INPUT A,B
04200   M=1
04250   Y4=0
04255   N2=F2-L2+1
04300   FOR N=L2 TO F2
04400   X3=M/N2
04500   Y5=A1*X3*(1+A*(1-X3)*(X3-B))
04505   T2(N)=Y5
04510   Y1(N)=Y5-Y4
04520   Y4=Y5
04525   A(N,2)=Y1(N)\A1(N,2)=T2(N)
04700   M=M+1
04800   NEXT N
06200   PRINT"INPUT A,B FINISHES"\INPUT A,B
06300   M=1
06350   Y4=0
06400   FOR N=L3 TO F3
06450   N3=F3-L3+1
06500   X3=M/N3
06600   Y5=F(6)*X3*(1+A*(1-X3)*(X3-B))
06605   T3(N)=Y5
06610   Y2(N)=Y5-Y4
06620   Y4=Y5
06625   A(N,3)=Y2(N)\A1(N,3)=T3(N)
06800   M=M+1
06900   NEXT N
08300   PRINT"INPUT A,B EXT WKS"\INPUT A,B
08400   M=1
08450   Y4=0
08500   FOR N=L4 TO F4
08550   N4=F4-L4+1
08600   X3=M/N4
08700   Y5=F(7)*X3*(1+A*(1-X3)*(X3-B))
08705   T4(N)=Y5
08725   Y3(N)=Y5-Y4
08730   Y4=Y5
08735   A(N,4)=Y3(N)\A1(N,4)=T4(N)
08850   M=M+1
08900   NEXT N
10300   PRINT"INPUT A,B DRAINAGE"\INPUT A,B
10400   M=1
10450   Y4=0
10500   FOR N=L5 TO F5
10550   N5=F5-L5+1
10600   X3=M/N5
10650
10700   Y5=F(8)*X3*(1+A*(1-X3)*(X3-B))
10705   T5(N)=Y5
10710   Y4(N)=Y5-Y4
10715   Y4=Y5
10750   M=M+1
10755   A(N,5)=Y4(N)\A1(N,5)=T5(N)
10900   NEXT N
12300   PRINT"INPUT A,B S/C'S"\INPUT A,B
12400   M=1
12410
12432   Y4=0
12435
12500   FOR N=L6 TO F6
12550   N6=F6-L6+1
12600   X3=M/N6
12700   Y5=F(9)*X3*(1+A*(1-X3)*(X3-B))
12705   T6(N)=Y5
12750   M=M+1
```

```
12760    Y5(N)=Y5-Y4
12770    Y4=Y5
12775    A(N,6)=Y5(N)\A1(N,6)=T6(N)
12900    NEXT N
13540    PRINT"INPUT A,B SITE O/H'S"\INPUT A,B
13545    M=1
13547    Y4=0
13550    FOR N=L7 TO F7
13551    N7=F7-L7+1
13555    X3=M/N7
13560    Y5=F(10)*X3*(1+A*(1-X3)*(X3-B))
13561    Y6(N)=Y5-Y4
13562    Y4=Y5
13563    T7(N)=Y5
13564    A(N,7)=Y6(N)\A1(N,7)=T7(N)
13567    M=M+1
13570    NEXT N
13585
19900 FILE #8,X1$
19950    SCRATCH #8
20500 FOR X=1 TO N1
20700 FOR Y=1 TO 7
20800 A(X,8)=A(X,8)+A(X,Y)
20900 NEXT Y
21000 NEXT X
21050 X1=X+1
21100 FOR Y=1 TO 8
21200 FOR X = 1 TO N1
21300 A(X1,Y)=A(X1,Y)+A(X,Y)
21400 NEXT X
21500 NEXT Y
```

```
21510   FOR X=1TON1
21520   FOR Y=1 TO 7
21530   WRITE #8,A(X,Y)
21540   NEXT Y
21550   NEXT X
21551   for x=1to90
21552   print"-";
21553   next x
21554   print
21555   print
21556   print  .
21557   print
21600 PRINT "PROJECT ESTIMATE AND PROGRAMME OF PRIME COST EXPENDITURE"
21700 PRINT "-------------------------------------------------------"
21800 PRINT
21850   PRINT"COST CENTRE ANALYSIS"
21855   PRINT"--------------------"
21955   PRINT
22000     PRINT"    SUBS      SUPER       FIN        EXT        DRAIN       NOM        SITE         TOT      WKS"
22100   pRINT"              STR                    WKS        -AGE        S/C'S      O/H'S"
22200 FOR X=1 TO90
22300 PRINT "-";
22400 NEXT X
22500 PRINT
22600 FOR X=1 TO N1
22700 PRINT USING 22800,A(X,1),A(X,2),A(X,3),A(X,4),A(X,5),A(X,6),A(X,7),A(X,8),X
22800 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##  ###
22900 NEXT X
22910   FOR X=1TO90
22920   PRINT"-";
22930   NEXT X
22940   PRINT
23000 PRINT USING 23103,A(X1,1),A(X1,2),A(X1,3),A(X1,4),A(X1,5),A(X1,6),A(X1,7),A(X1,8)
23100 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##
23150   Y4=0
23200 FILE #9,X3$
23300 SCRATCH #9
23305   S4=0
23310   FOR Y=1TO7
23320   FOR X=1TON1
23330   A7(X,Y)=S4=S4+A(X,Y)
23340   NEXT X
23345   S4=0
23350   NEXT Y
23400   FOR X=1TON1
23410   FOR Y=1TO7
23420   WRITE #9,A7(X,Y)
23430   NEXT Y
23440   NEXT X
23500   PRINT
23510   FILE #1,"G.TMP"
23520   SCRATCH #1
23530   FOR X=1TON1
23540   FOR Y=1TO7
23550   WRITE #1,A(X,Y)
23560   NEXT Y
23570   NEXT X
23600   PRINT"END OF RUN"
23700   PRINT
23800   PRINT"FILES SAVED"\PRINT X1$,X3$,X4$
23850   CHAIN "RAM.BAS"
23900   END
```

ALTERATION PROGRAM: ALT2.BAS

```
00050 MARGIN 132
00100   DIM A6(200,9),T3(20),T4(20),A7(200,9)
00200   PRINT"FORECAST ALTERATION AND ADJUSTMENT PROGRAM"
00300   PRINT
00400   PRINT
00500   PRINT"INPUT PROJECT NAME";\INPUT Y$
00600   X1$=LEFT$(Y$,5)+"G.DAT"
00700   X3$=LEFT$(Y$,5)+"P.DAT"
00800   FILE #1,X1$
00850   RESTORE #1
00900   PRINT
01000   PRINT
01100   PRINT"ARE THERE ANY REDUNDANT PERIODS TO BE ALLOWED FOR IN TIME SPAN"
01200   PRINT"ANSWER YES OR NO"\INPUT A$
01300   IF A$="YES"THEN 1400
01310   R=1
01320   IF END #1,GOTO 1380
01330   FOR C=1TO7
01340   READ #1,A6(R,C)
01350   NEXT C
01360   R=R+1
01370   GOTO 1320
01380   R1=R-1
01390   GOTO 5200
01400   PRINT
01500   PRINT"HOW MANY REDUNDANT PERIODS"\INPUT Y
01600   PRINT"ON ? SPECIFY REDUNDANT PERIOD PARAMETERS IN ASCENDING ORDER"
01700   INPUT T3
01800   INPUT T3(1)
```

```
01900   FOR R=1TO(T3-1)
02000   FOR C=1TO7
02100 READ #1,A6(R,C)
02200   NEXT C
02300   NEXT R
02400   FOR R=T3TOT3(1)
02500   FOR C=1TO7
02600   LETA6(R,C)=0
02700   NEXT C
02800   NEXT R
02850   IF Y=1 GOTO 4900
02900    FOR Z=1 TO Y-1
03000   INPUT T4(Z)
03100 FOR R=T3(Z)+1 TO T4(Z)-1
03200   FOR C=1TO7
03300   READ #1,A6(R,C)
03400   NEXT C
03500   NEXT R
03650   INPUT T3(Z+1)
03700   FOR R=T4(Z)TOT3(Z+1)+1
03800   FOR C=1TO7
03900   A6(R,C)=0
04000   NEXT C
04100   NEXT R
04300   NEXT Z
04320 PRINT
04400   IF END #1, GOTO 5050
04600 FOR C=1TO7
04700   READ #1,A6(R,C)
04800   NEXT C
04900   R=R+1
05000 GOTO 4400
05025   IF Y>1 GOTO 5200
05050   R1=R-1
05200   PRINT
05300   PRINT"TOTAL REVISED PROJECT DURATION IN WEEKS";R1
05400   PRINT
```

```
05500   PRINT"DO YOU WISH TO MAKE ANY ALTERATIONS"
05600   PRINT"INPUT YES OR NO"\INPUT A$
05700   IF A$="NO" THEN 6900
05800   PRINT"INPUT WEEK NUMBER AND COST CENTRE"
05900   PRINT"I.E. 11,2 MEANS WEEK 11, SUPERSTRUCTURE "
06000   INPUT R,C
06100   PRINT"INPUT AMOUNT IN POUNDS STERLING"\INPUT C1
06200   LET A6(R,C)=C1
06300   PRINT
06400   PRINT"DO YOU WISH TO MAKE ANY MORE ALTERATIONS"
06500   PRINT"ANSWER YES OR NO"
06600   INPUT A$
06750   IF A$="YES" THEN 5800
06800   PRINT
06900   PRINT
07000   PRINT"DO YOU WISH TO MAKE AN ALLOWANCE FOR INFLATION"
07100   PRINT"ANSWER YES OR NO"\INPUT A$
07200 IF A$="NO" THEN 8100
07300   PRINT
07400   PRINT"INPUT ANNUAL INFLATION RATE AS A %"\INPUT I1
07600   FOR R=1TOR1
07700   FOR C=1TO7
07800     A6(R,C)=A6(R,C)*(1+R*I1/1200)
07900   NEXT C
08000   NEXT R
08050 FOR I=1TOR1
08060 A6(I,8)=0\NEXT I
08100   FOR R=1TOR1
08200   FOR C=1TO7
08300   A6(R,8)=A6(R,8)+A6(R,C)
08400   NEXT C
08500   NEXT R
08600   R2=R1+1
08700   FOR C=1TO8
08800   FOR R=1TOR1
08900   A6(R2,C)=A6(R2,C)+A6(R,C)
09000   NEXT R
09100   NEXT C
09200   SCRATCH #1
09300   FOR R=1TOR1
09400   FOR C=1TO7
09500   WRITE #1,A6(R,C)
09600   NEXT C
09700   NEXT R
09800   FILE #2,X3$
09900   SCRATCH #2
10000   FOR C=1TO8
10050 S5=0
10100   FOR R=1TOR1
10200 A7(R,C)=S5=S5+A6(R,C)
10500   NEXT R
10600   NEXT C
10605   PRINT
10610   FOR I=1TOR1
10710   FOR J=1TO7
10810   WRITE #2,A7(I,J)
10910   NEXT J
11010   NEXT I
21550   FOR I=1 TO 2
21555   PRINT
21556   PRINT
```

```
21600 PRINT "PROJECT FORECAST AND PROGRAMME OF PRIME COST EXPENDITURE"
21610   IF I=2 THEN 21640
21620   PRINT"ANALYSIS ON A WEEKLY BASIS"
21630   GOTO 21700
21640   PRINT"ANALYSIS ON AN ACCUMULATIVE BASIS"
21700 PRINT "------------------------------------------------------------"
21800 PRINT
22000   PRINT"     SUB        SUPER     FIN       EXT       DRAIN    NOM       SITE     TOTAL       WEEK"
22100   PRINT"                STR                 WKS       -AGE     S/C'S     O/H'S"
22200 FOR X=1 TO90
22300 PRINT "-";
22400 NEXT X
22500 PRINT
22600 FOR X=1TOR1
22610   X1=R2
22615   X1=R2
22620   ON I GOTO 22650,22700
22650 PRINT USING 22800,A6(X,1),A6(X,2),A6(X,3),A6(X,4),A6(X,5),A6(X,6),A6(X,7),A6(X,8),X
22670 IF I=1 GOTO 22900
22700 PRINT USING 22800,A7(X,1),A7(X,2),A7(X,3),A7(X,4),A7(X,5),A7(X,6),A7(X,7),A7(X,8),X
22800 :######.## ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##  ###
22900 NEXT X
22910   FOR X=1TO90
22920   PRINT"-";
22930   NEXT X
22940   PRINT
22945   ON I GOTO 22950,23152
22950 PRINT USING 23100,A6(X1,1),A6(X1,2),A6(X1,3),A6(X1,4),A6(X1,5),A6(X1,6),A6(X1,7),A6(X1,8)
22970 IF I=1 GOTO 23150
23100   :$$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$ $$$$$$.$$
23150   NEXT I
23152   FILE #9,"G.TMP"
23154   SCRATCH #9
23156   FOR X=1TOR1
23158   FOR Y=1TO7
23160   WRITE #9,A6(X,Y)
23162   NEXT Y
23164   NEXT X
23200   CHAIN "RAM.BAS"
99999  END
```

RAM.BAS CURVE FIT PROGRAM

```
.TY RAM.BAS
00050   Q0$='RDA , A , B '
00100   A$='N'\GOTO900
00200   READ N,A$
00300         IF N=Z GOTO 900
00400   READ S,P
00500   FOR I=1 TO P
00600   READ X
00700   NEXT I
00800   GOTO 200
00900   Q1$='*** AB CHANGE *** PRD. '
01000   Q$='*** RD CHANGE *** PRD. '
01100   A$='Y SD= '\B$='R SD= '
01200   DIM Y(100),Y6(100),Y1(100)
01300   P4=0
01400   DIM X5(100),X(20),Y5(100),C(100,4)
01410 FILE £1,'G.TMP'
01420   IF END£1 GOTO 1470
01430   READ £1,X
01440   S=S+X
01450   P=P+1
01460   GOTO 1420
01470   P=P/7\RESTORE£1
01600   S5=0
01700 S$='Y'
01800   IF S$>= 'Y' GOTO 2000
01900   PRINT'PRD.','COST','CUM.CST.',' X',' Y'
02000   FOR I=1 TO P
02100   C=0
02120   FOR J=1 TO 7
02140   READ £1,X
02160   C=C+X
02180   NEXT J
02200   '
02210 C(I,4)=C
02215 S6=C(I,2)=S6+C
02220 IF C>R1*C(I,2)/I GOTO 2240
02230   I4=I4+1
02240   S5=C(I-I4,1)=S5+C
02250   NEXT I
02260   P=P-I4
02270   FOR I=1 TO P
02280   X5(I)=I/P
02290   Y5(I)=C(I,1)/S
03000   NEXTI
03010 Z1=Z2=P-1
03020 K9=11
03050 GOTO 4000
03100 PRINT'BEST RD & AB TO DATE BY REL SD & SD OF Y'
03200   PRINT
03300   PRINT' USING 1.REL SD FOR AB 2.SD OF Y FOR RD '
03400   PRINT
03450   PRINT'NO. OF PERIODS 'P\PRINT
03500 PRINT'BELOW WHICH REL SD %  DO YOU WISH OUTPUT';
03600 INPUT K9
03700   PRINT'WHICH PRDS RANGE PLS. ';\ INPUT Z1,Z2
03800   IF Z1>1 GOTO 4000
03900   PRINT'NO PRD.1 ALLOWED (2,3..) '\GOTO 3700
04000 FOR I=Z1 TO Z2
04200   DEF FNR(A,Y)=(1-EXP(-A*Y*Y))/(1-EXP(-A))
04300   '
```

```
04400   PRINT
04500   IF I=P GOTO 8300
04600 T8 =500
04700       FOR A5=.1 TO 10 BY .1
04800 GOSUB 27900
04900       NEXT A5
04950 Q=A6-.2\Q1=A6+.2
05000 FOR A5=Q TO Q1 BY .002
05100 GOSUB27900
05200 NEXT A5
05300 A5=INT(1000*A6+.5)/1000
05350 GOTO8300
05400 PRINT'RDA='A5' RD'B'='SQR(4.5/A5)-1
05500PRINT'YMAX AT X=2 '100*FNR(A5,2)'%'
05600S4=T4\S5=T5
05700 PRINT'SD OF Y='S4,'REL SD='S5
05800   GOTO 8300
05900   PRINT'YMAX AT X=2 IS 'FNR(A6,2)
06000 A0=A6
06100   PRINT'RD A= 'A6,'RD B= 'SQR(4.5/A6)-1
06200   PRINT'USING PRD. 'T6
06300   IF T6=T7 THEN T0=1 ELSE T0=0
06400   T7=T6
06500 P4=I
06600   PRINT'Y.SD.= 'T4,'R.SD.= 'T5
06700 GOTO8300
06800   PRINT
06900   PRINT'SOLVED RD A SOLN.'
07000   GOSUB 22300\PRINT Q$;P4
07100   PRINT'________________'
07200   I2=1\P2=P
07300   A5=0
07400 A=A1\ B=B1
07500   D1=1\ D2=P \GOSUB 19000
07600   PRINT\ PRINT A$;Q4,B$;Q5
07700   IF Q5>K9OR A5=.07 THEN 8000
07800   GOSUB 10600
07900 GOSUB 29900
08000   A5=A6
08100   PRINT'++++++++++++++++++++'
08300   PRINT\PRINT
08400   'TO FIND A,B,RD   -
08500   '
08600 Q8=Q9=200
08700 D1=1 \D2=P
08800   FOR G1=2 TO I
08900   IF I=P GOTO 9400
08950 PRINTG1'   ';
09000   FOR G2=1 TO G1-1
09050 A=FNA(G1,G2)\ B=FNB(G1,G2)
09090 GOSUB22300
09100 FOR P7=P4 TO P BY INT(P/10)+1
09105 P4=P7\GOSUB19000
09110 NEXT P7
09200   NEXT G2,G1
09300 A=A(1)\B=B(1)\Q4=Q8
09350 FOR I1=1 TO 10\PRINT\NEXTI1
```

```
09400 GOTO11700
09550 IF S5<T5 THEN PRINT"RD BEST"
09800   PRINT"A="A1     "B="B1
09900   PRINT"SD OF Y="S8    " REL SD="S4
10000   PRINT"USING PRD"W1" &"W2\ PRINT
10100 A=A1\B=B1
10200   IF B2=B THEN B0=0 ELSE B0=1
10300   B2=B
10400   GOSUB 22300
10500   IF S$="Y" GOTO11700
10600   PRINT
10700 PRINT " RD A= "A5
10800 PRINT"A= "A1"  B= "B1" PRDS "W1" & "W2
10900   PRINT"PRD.";"   X";"     Y%";"   Y(A-B)%";"    (Y-Y:AB)%","   Y(R-DF)%";"    (Y-Y:R-DF)%"
11000   FOR I1=1 TO P
11100   Y=Y5(I1)\Y1=FNY(I1/P)\Y2=FNZ(I1/P)
11200   IF I0=I1 THEN PRINTQ1$,I0
11300   IF P4=I1 THEN PRINT Q$;P4
11400   PRINTI1;TAB(4);100*FNI(I1/P);TAB(10);100*FNI(Y);TAB(16);100*FNI(Y1);
11500   PRINTTAB(29);FNJ(Y,Y1);TAB(45);100*FNI(Y2);TAB(56);FNJ(Y,Y2)
11600   NEXT I1
11700   PRINT
11800 GOTO 15800
```

```
11900  D1=1 \D2=I
12000  GOSUB 19000
12100  IF S4<K9 OR B0=1  THEN K8=1 ELSE K8=0
12200  GOTO12700
12300  IF I=3 THEN Q6=Q5
12400  IF I<4 THEN 12700
12500  IF (Q6-Q5)/Q6>= K9/100 THEN K8=1 ELSE K8=0
12600  IF K8=1 THEN Q6=Q5
12700  PRINT' PRESENT - TO DATE PRD.'I
12800  PRINT Q$;P4\PRINT'RD A='A5'RD B='B5
12900  PRINT\PRINT'YMAX AT X=2 IS 'FNR(A5,2)\ PRINT
13800  I2=1\ P2=I
13900  IF I<4  GOTO14100
14000  IF K8=1  THEN GOSUB 10600
14100  PRINT A$;Q4,B$;Q5
14200  IF P4>I THEN PRINT ELSE PRINT Q$;P4\ PRINT
14300  IF P4>I THEN 14700ELSE P5=P4
14400  P4=P+1\ GOSUB 19000
14500  PRINT 'AB ONLY 'A$;Q4,B$;Q5
14600  P4=P5
14700  D1=I\ D2=P
14800  GOSUB 19000
14900  PRINT\PRINT'FUTURE FROM  PRD.'I
15000  PRINT A$;Q4,B$;Q5
15100  I2=I\ P2=P
15200  IF K8=1 THEN GOSUB 10600
15300  IF P4<I THEN PRINT ELSE PRINT Q$;P4
15400  IF P4<I THEN 15800ELSE P5=P4
15500  P4=0 \ GOSUB 19000
15600  PRINT' RD ONLY 'A$;Q4,B$;Q5
15700  P4=P5
15800  D1=1 \D2=P
15900  PRINT\PRINT'MONITORING CONSTANTS'
16000  PRINT'____________________'
16005 PRINT
16010  T=(B+1)/3\ K=(B-1/A)/3\ K=(T*T-K)
16013  IF K<0 GOTO 16400
16016  K=SQR(K)
16020  IF T-K>0 THEN I0=INT((T-K)*P+.5) ELSE I0=0
16030  P3=INT((T+K)*P)
16040  IF P3<P4 THEN P4=INT(P3*.95)
16045  GOTO 16400
16050  PRINT Q1$;I0,Q$;P4\PRINT
16060  PRINT'A='A'B='B' PEAK COST PRD. 'INT((B+1)/3*P+.5)\PRINT
16070  PRINT'XMAX= 'T+K,'XMIN= 'T-K
16080  PRINT'YMAX= 'FNY(T+K)
16100  PRINT'COMBINED RESULT'\ GOSUB 19000
16200  PRINT\PRINT Q$;P4;
16250  PRINTQ0$,A5,A,B
16300  PRINT A$;Q4,B$;Q5\PRINT
16400 GOTO 29800
16404  PRINT
16406  PRINT'A=ACTUAL  P=FORECAST  S=IDENTICAL 'VALUES''\PRINT'--G-
16407 PRINT' * REPRESENTS 4*NON-CUMULATIVE EXPENDITURE'\PRINT\PRINT
16408  PRINTTAB(20);'COST TABLE'
16412  PRINTTAB(20);'__________'
16416  PRINT
16420  GOTO 18010
16440  PRINT
16500  PRINT 'IDEAL COMBINED RESULTS'
16520  K8=1
16600  PRINT
16700 I1=I\ I=P\ GOSUB 22300
```

```
16800   I=I1
16900   PRINT Q$;P4;
17000 GOSUB 19000
17100   PRINT A$;Q4,B$;Q5
17200   P4=P+1
17300   GOSUB 19000
17400   PRINT" AB ONLY RESULTS "A$;Q4,B$;Q5
17500   PRINT\ P4=0
17600   GOSUB 19000
17700   PRINT" RD ONLY RESULTS "A$;Q4,B$;Q5 \PRINT
17800   PRINT"----------------------------------------"\PRINT
17900   NEXT I
18000   GOSUB 29900
18010   PRINT\PRINT"PRD.  COST","CUM.COST","FORECAST","%ERROR"
18020   FOR I=1 TO P
18030   PRINTI;TAB(5);C(I,4),C(I,1),INT(S*Y6(I)+.5),FNJ(Y5(I),Y6(I))
18040   NEXT I
18050   PRINT
18100   STOP
18200   DEF FNZ(X)
18300   '
18400   IF EXP(-A5)<>1 GOTO 18700
18500   Z=.01
18600   GOTO 18800
18700   Z=1-EXP(-A5)
18800   FNZ=(1-EXP(-A5*X*X))/Z
18900   FNEND
19000   'RD CHANGE TESTS
19100   '
19200   Q4=Q5=0
19300 FOR I1=1 TO P
19400   Y=Y5(I1)\ X=I1/P
19420 IF FNY(X)<= 0 THEN I0=I1+1
19440 IF FNY(X)>= 1 THEN P6=I1-1
19460 IF P6<P4 THEN P4=P6
19500   IF I1<I0 OR  I1>= P4 THEN Y1=FNZ(X) ELSE Y1=FNY(X)
19600   Y3=Y-Y1 \Y4=Y3/Y
19700   Q4= Q4+Y3^2
19800   Q5= Q5+Y4^2 'R SD
19900   NEXT I1
20000 D3=P
20100   Q4=SQR(Q4/D3) ' Y SD
20200   Q5=SQR(Q5/D3) ' R SD
20300   Q4=FNI(Q4)*100
20400   Q5=FNI(Q5)*100
20410 IF Q8<Q4 GOTO 20430 'YSD
20420 Q8=Q4\A(1)=A \B(1)=B
20425   P8=P4\ I8=I0
20430 IF Q9<Q5 GOTO 20500 'RSD
20435   P9=P4\ I9=I0
20440 Q9=Q5\A(2)=A \B(2)=B
```

```
20500   RETURN
20600   'RD CONST
20700   '
20800 A4=4.5
20900   A7=A4*X*X
21000   IF A7>10  GOTO21300
21100   IF A7<.1 GOTO 21300
21200   GOTO21500
21300   A5=.07
21400   GOTO 22200
21500   E1=EXP(-A4)
21600   E2=EXP(-A4*X*X)
21700   F1=1-E2-Y*(1-E1)
21800   F2=X*X*E2-Y*E1
21900   A5=A4-F1/F2
22000   IF ABS(A5-A4)< 2E-6 GOTO 22200
22100   A4=A5 \GOTO 20900
22200   RETURN
22300   'AB TO RD CHANGE
22400   '
22420   FOR I2=1 TO P
22430 IF FNY(I2/P)>=1 THEN P6 =I2-1
22440   IF FNY(I2/P)<=0 THEN I0=I2+1
22445   NEXT I2
22450  I3=INT(.15*(P+I4))
22500 IF I<I3 GOTO 22800
22600 FOR J=I3 TO P
22700   IF J<= I GOTO 23000
22800 P4=INT(.95*P)
22900   GOTO 23800
23000   Y3=Y4=0
23050 IF J<2 GOTO 23800
23100   FOR I2=J-2 TO J
23200   Y3=Y3+ABS(Y5(I2)-FNZ(I2/P))
23300   Y4=Y4+ABS(Y5(I2)-FNY(I2/P))
23400   NEXT I2
23500 IF Y4-Y3 > .1*Y5(J) THEN P4=J-1 ELSE 23700
23600 GOTO 23800
23700   NEXT J
23800 IF P6<P4 THEN P4=P6
23850 RETURN
23900   DEF FNB(G1,G2)
24000   '
24100   X1=X5(G1)\X2=X5(G2)
24200   Y1=Y5(G1)\Y2=Y5(G2)
24300   K=(1-X2)*(Y1/X1-1)/(1-X1)/(Y2/X2-1)
24400   FNB=(K*X2-X1)/(K-1)
24500   FNEND
24600   DEF FNA(G1,G2)
24700   '
24800   Y1=Y5(G1)\X1=X5(G1)
24900   FNA=(Y1/X1-1)/(X1-FNB(G1,G2))/(1-X1)
25000   FNEND
25100   'TEST A,B
25200   '
```

```
25300   A=FNA(G1,G2)\B=FNB(G1,G2)
25320   T=(B+1)/3\K=(B-1/A)/3
25340   IF T*T-K<0 GOTO 27050
25400 S1=S6=0
25500   FOR J=1 TO I
25600   X=J/P
25700   Y=Y5(J)\ Y1=(FNY(X)-Y)/Y
25800   Y3=Y1*Y
25900   D=D+(FNY(X)/Y)**2
26000   S6=S6+Y1*Y1
26100   S1=S1+Y3*Y3
26200   NEXT J
26300 D1=100*SQR(D/I)
26400   S3=100*SQR(S1/I)
26500   S9=100*SQR(S6/I) 'REL SD
26600   D=ABS(1-SQR(D/I))*100
26700   G=S9
26750   IF G9=100 THEN G=S3
26800 IF G0>G THEN G0=G ELSE 27100
26900   S8=S3\A1=A\B1=B\W1=G1\W2=G2 \S7=D
27000   S4=S9\S5=D1
27050   T=K=0
27100   RETURN
27200   DEF FNY(X)=X*(1+A*(1-X)*(X-B))
27300   '
27400   'TEST R-DF
27500   '
27600   B4=FNB(G1,G2)
27700 IF B4<-.5 THEN B4=-.5
27800   A5=4.5/(B4+1)**2
27900 S2=S6=D=0
28000 IF A5=.07 GOTO29400
28100   FOR J=1 TO I
28200   Y=Y5(J)
28300   Y1=((1-T1/100)*FNZ(J/P)-Y)/Y
28400 D=D+Y*Y1
28500 S2=S2+(Y*Y1)^2
28600   S6=S6+Y1*Y1 'R SD
28700   NEXT J
28800   S0=100*SQR(S6/I)
28900 S2=100*SQR(S2/I) 'Y SD
29000 G4=S2
29100   IF T8>G4 THEN T8=G4 ELSE 29400
29200   T4=S2\T5=S0\W3=G1\W4=G2\B5=B4 \T6=I
29300   A6=A5
29400   RETURN
29500   DEF FNI(A)=.001*INT(A*1000+.5)
29600   '
29700   DEF FNJ(A,B)=.1*INT((A-B)*1000+.5)
29750   DEF FNC(X,Y)=(Y/X-1)/(X-B)/(1-X)
29800   '
29810   A2=A\ B2=B
29820   B=3/SQR(2*A5)-1
29825 G0=G9=100
29830   FOR I=2 TO P-1
29840   Y=Y5(I)\ X=X5(I)\ A=FNC(X,Y)
29842   T=(B+1)/3\K=(B-1/A)/3
29843   IF T*T-K<0 GOTO29860
```

```
29844    T1=T+SQR(T*T-K)
29850 GOSUB 25400
29860    NEXT I
29870 A3=A1\ B3=B1\ A=A2\ B=B2
29880    T=(B3+1)/3\K=(B3-1/A3)/3
29890    T1=T+SQR(T*T-K)
29900    'GRAPH
29920    I0=I8\P4=P8\P1=P
30000    P=P+I4
30010    PRINT"ALPHA="A"    BETA="B"    GAMMA="A5
30012    PRINT\PRINT"THESE CONSTANTS REPRESENT:-"\PRINT"(BETA) PEAK PERIOD "INT((B+1)/3*P)+1
30014    PRINT"MAXIMUM DURATION "INT(P3*P/(P-I4))+1\PRINT"(GAMMA) PEAK PERIOD "INT(P*(2*A5)**-.5+1)
30015    PRINT"(GAMMA) ALPHA EQUIVALENT "A3," ERROR "S8"%"
30016    PRINT"(GAMMA) MAX DURATION ESTIMATE "INT(1+T1*P)\PRINT
30017    PRINT"CUBIC BETWEEN PERIODS "I0" AND "P4
30020 PRINT\PRINT"TOTAL PROJECTION ERROR="Q4"%"
30030 PRINT\PRINT
30040 PRINT"GRAPH OF PROJECT EVALUATION"
30050    PRINT"___________________________"
30060 PRINT\PRINT\PRINT"DURATION "P" WEEKS AT COST "S" 'POUNDS'"
30070PRINT\PRINT
30080 IF CLOG(S)>4 THEN C=1000 ELSE C=100
30090 S$=STR$(C)
30100 PRINT"COST ("S$"'S)";
30200    X=X6=S5=0
30210 K=0
30300 S1=S/C
30400    FOR J=1 TO 5
30500    PRINT TAB(6+10*J)"!"INT(S1*J*.2);
30600    NEXT J
30700    PRINT""\PRINT"COST% X";
30800    FOR I5=1 TO 12\PRINT"----X";\NEXTI5\PRINT""
30900    GOTO 32600
31000    FOR X6=0 TO P
```

```
31100   IF X6/5=INT(X6/5) OR X6=PTHEN PRINT INT(100*X6/P+.5);"%";X6 ; ELSE PRINT TAB(5)"I";
31150 IF X6=0 GOTO 31340
31200   K=C(X6,4)
31340   C(X6,1)=S5=S5+K
31345 IF X6=0 GOTO 31360
31350 IF K<=R1*S5/X6  THEN X=X+1
31360   Y2=Y5(X6)=S5/S
31420   X5=X6-X
31440   IF X5<=I0 OR X5>=P4 THEN Y(X5)=FNZ(X5/P1) ELSE Y(X5)=FNY(X5/P1)
31460   IF X5=I0 OR X5=P4 THEN PRINT"-G-";
31500   Y=Y6(X6)=Y(X6-X)
31600   IF Y5(X6)=Y THEN G1$="" ELSE G1$="A"
31650 IF X6>5 THEN  PRINT TAB(FNT(4*C(X6,4)/S))"*";
31700   IF Y2>Y GOTO 32000
31800   IF Y2<Y GOTO 32100
31900   PRINT TAB(FNT(Y))"S"\ GOTO 32200
32000   PRINT TAB(FNT(Y))"P";TAB(FNT(Y2));G1$\GOTO 32200
32100   PRINT TAB(FNT(Y2))G1$;TAB(FNT(Y));"P"
32200   NEXT X6
32300   PRINT TAB(6)"X";
32400   FOR I5=1 TO 12 \PRINT"----X";\NEXT I5\PRINT" "
32500   PRINT"COST%";
32600   FOR I5=1 TO 12\PRINT TAB(5+5*I5);10*I5;\NEXT I5
32700   PRINT""
32800   IF X6=P THEN32900ELSE 31000
32900 PRINT\ GOTO 16404
33000   DEF FNT(A)=INT(50*A+.5)+6
33020 PRINT\PRINT"NO. OF PERIODS= "P\PRINT
33100   '
```

```
33200   DATA 1, "N"
33300 DATA1416500
33400   DATA23
33500   DATA 20000,2E4,32500,32500,41E3,41E3,45750,45750
33600   DATA 15E3
33700   DATA100000,28E3,12E4,72500,72500,8E4,16E4,5E4,5E4,6E4,14E4,1E5
33800   DATA 5E4,4E4
33900   DATA 2,"C"
34000 DATA 3625500
34100   DATA 16
34200   DATA 28300,56600,84900,114900
34300   DATA 152700,181500,205300,229100
34400   DATA 252900,278900,303000,320100
34500   DATA 337200,348600,360000,371500
34600   DATA 3,"N"
34700  DATA 323500
34800   DATA 12
34900   DATA 10000,25000,50000,75000
35000   DATA 10000,12500,15000,20000
35100   DATA 25000,26500,27000,27500
35200   DATA 4,"N"
35300 DATA 78750
35400   DATA 12
35500   DATA 1E4,9500,9000,8500
35600   DATA 8250,8000,7900,7850
35700   DATA 5000,2500,1500,750
99999   END
```

Appendix 5

Program Listings

Project Monitoring and Control

PROJ5.BAS	Design monitoring
PROJ7.BAS	Construction monitoring
RPRJ11.BAS	Prediction Program

PROJ5.BAS

MONITORING & CONTROL PROGRAM (PROJ5.BAS) DESIGN APPLICATION

```
00001   REM X$=PROJ NAME 'U'
00002   REM X1$=PROJ NAME'G'
00003   REM X3$=PROJECT NAME 'P'
00004   REM Y$=PROJ. NAME INPUT BY USER;  T9(1-12)=TEMP. STORAGE FOR FILE-UPDATING
00005   REM W=CURRENT WEEK NO.
00006   REM M=NO. OF STAFF WORKING ON PROJECT
00007   REM N=EMPLOYEE NUMBER
00008   REM N(R)=EMPLOYEE NO ON FILE
00009   REM N$(R)=EMPLOYEE NAME
00010   REM R1(R)=SALARY RATE FACTOR
00011   REM A(R,C)=TABLE OF STANDARD HOURS
00012   REM M1=NO OF STAFF + 1
00013   REM H=STANDARD HOUR CHARGE
00014   REM A1(R,C)=TABLE OF EXPENDITURE
00015   REM W2(R)=CURRENT WEEK ON FILE
00016   REM Y1(R)=EST.EXP. PER WEEK
00017   REM Y2(R)=ACCUM WEEKLY EXP.
00018   REM E(1)=PROJ PRIME COST
00019   REM E(2) TO E(11)=ESTIMATED % ALLOC. TO WORK CATERGORIES
00020   REM P(1) TO P(10)=% COMPLETIONS TO DATE
00021   REM E1(2) TO E1(11)=EST. VALUE OF WORK COMP. TO DATE FOR EACH CAT.
00022   REM E3(2) TO E3(11)=PROFIT/LOSS TO DATE EACH CAT.
00023   REM H1=STANDARD HOURS USED TO DATE
00024   REM H2=STANDARD HOURS REMAINING
00025   REM H3=CASH BUDGET REMAINING
00026   REM P8=OVERALL % COMPLETE TO DATE
00027   REM I3=% TO COVER PAY INCREASES
00028   REM H5=INCRESED HOURLY RATE
00029   REM T=EST. FINAL DESIGN COST
00030   REM R3=AVE. RESOURCE AVAILABILITY
00031   REM I1=WORK CAT.
00032   REM R4=NO OF RESOURCE UNITS AVAILABLE
00033   REM H4=AVE.HOURS WORKED PER DAY
00034   REM T1 $T2=ANTICIPATED TIME TO COMPLETION
00050   margin 132
00100   DIM A(200,8),W2(200,8),R1(200), N$(200), N(200),A1(200,9),A3(100,9),E(12),E1(11),E3(11),Y1(200)
```

```
00110   DIM T9(12),A2(200,9)
00200   PRINT"DESIGN PROJECT CONTROL PROGRAM MODULE"
00300   PRINT"-------------------------------------"
00400   PRINT
00500   PRINT"CONVERSATIONAL MODE DATA INPUT PROCEDURE"
00600   PRINT"----------------------------------------"
00700   PRINT
00800   PRINT"INPUT PROJECT NAME(MAX 5 CHARACTERS)";
00900   INPUT Y$
00910   X$=LEFT$(Y$,5)+"U.DAT"
00920   PRINT
00930   PRINT"INPUT PROJECT BASE DATE I.E. 4,80 (WEEK 4 1980)"
00940   INPUT P8,P9
00950   X6$=LEFT$(Y$,5)+"T.DAT"
00960   FILE # 2,X6$
00970   SCRATCH #2
00980   WRITE #2,P8,P9
01000   PRINT"INPUT PROJECT WEEK NUMBER"
01100   INPUT W
01200   PRINT"INPUT NUMBER OF STAFF WORKING ON PROJECT"
01300   INPUT M
01400   FOR R=1TOM
01500   PRINT"INPUT EMPLOYEE NUMBER"
01600   INPUT N
01700   FILES STAFF.DAT
01800   RESTORE #1
01850   REM READS EMPLOYEE NO, NAME AND SALARY RATIO FROM STAFF FILE
01900   READ #1,N(R),N$(R),R1(R)
02000   IF N=N(R) GOTO 2300
02100   GOTO 1900
02150   REM PROCEDURE FOR READING THE HOURS OF EACH EMPLOYEE TO CATEGORIES
02300   PRINT"INPUT ACTUAL HOURS WORKED ALLOCATED 1 TO 5 (I.E. 10,0,20........ETC)"
02400    FOR C=1TO5
02450   INPUT A(R,C)
02500   NEXTC
02505   PRINT"IS EMPLOYEE DATA O.K. ANSWER YES OR NO"
02510   INPUT Q$
02515   IF Q$="NO" GOTO 2400
02600   NEXT R
02640   PRINT
02641   FOR I=1TO98
02642   PRINT"-";
02643   NEXT I
```

```
02645  PRINT
02650  PRINT"PROJECT ";Y$
02651  PRINT
02662  PRINT
02665  PRINT"WEEK NUMBER ";W
02700  PRINT
02800  PRINT"  WK NO NAME          TOTAL   ANALYSIS OF ACTUAL HOURS"
02900  PRINT
03050  PRINT"                                  ARCH   S.E.   SERV   COMM   Q.S."
03060  PRINT"                                                ENG"
03150  FOR I=1TO62
03160  PRINT"-";
03170  NEXT I
03200  PRINT
03300  PRINT
03350  REM STATEMENTS 3400 TO 4800 MAKE ADDITIONS TO TABLES
03900  FOR R=1TOM
04000  FOR C=1TO5
04100  A(R,8)=A(R,8)+A(R,C)
04200  NEXT C
04300  NEXTR
04350  M1=M+1
04400  FOR C=1TO8
04500  FOR R=1TOM
04600  A(M1,C)=A(M1,C)+A(R,C)
04700  NEXTR
04800  NEXTC
04900  FOR R=1TOM
04950  REM FORMAT FOR TABLE
05000  PRINT USING 5100,N(R),N$(R),A(R,8),A(R,1),A(R,2),A(R,3),A(R,4),A(R,5)
05100      :##### 'LLLLLLLLLLL ####.## ###.## ###.## ###.## ###.## ###.##
05200  NEXTR
05300  PRINT
05310  FOR I=1TO62
05315  PRINT"-";
```

```
05320   NEXT I
05400   PRINT USING 5500,A(M1,8),A(M1,1),A(M1,2),A(M1,3),A(M1,4),A(M1,5)
05500        :  WEEKLY  TOTALS    ####.## ###.## ###.## ###.## ###.## ###.##
05600   PRINT
05700   PRINT
05815   PRINT
05817   PRINT
05820   PRINT"WK NO NAME                 TOTAL   ANALYSIS OF EXPENDITURE $"
05840   PRINT"                             $"
05861   PRINT"                                    ARCH    S.E.    SERV     COMM    Q.S."
05862   PRINT"                                                    ENG               "
05885   FOR I=1TO67
05890   PRINT"_";
05895   NEXT I
06000   FOR R=1TOM
06100   FOR C=1 TO 5
06200   A1(R,C)=A(R,C)*R1(R)
06300   NEXTC
06400   NEXTR
06500   FOR R=1TOM
06600   FOR C=1TO5
06700   A1(R,8)=A1(R,8)+A1(R,C)
06800   NEXTC
06900   NEXTR
07000   M1=M+1
07050   FOR R=1TOM
07100   FOR C=1TO8
07200   A1(M1,C)=A1(M1,C)+A1(R,C)
07300   NEXTC
07400   NEXTR
07500   FOR R=1TOM
07600   PRINT USING 8100,N(R),N$(R),A1(R,8),A1(R,1),A1(R,2),A1(R,3),A1(R,4),A1(R,5)
08100        :##### 'LLLLLLLLLLL #####.# ####.## ####.## ####.## ####.## ####.##
08200   NEXT R
08250   PRINT
08255   FOR I=1 TO 67
08260   PRINT"_";
08265   NEXT I
08300   PRINT USING 8400,A1(M1,8),A1(M1,1),A1(M1,2),A1(M1,3),A1(M1,4),A1(M1,5)
08400        :  WEEKLY TOTALS     #####.# ####.## ####.## ####.## ####.## ####.##
08410   FOR I=1TO84
08420   PRINT"_";
```

```
08430   NEXT I
08431   PRINT
08441
08445   PRINT
08450   PRINT"INPUT TOTAL COSTS EXPENDED ON EXTERNAL CONSULTANTS FOR THIS PERIOD"
08455   INPUT A1(M1,6)
08460   PRINT
08465   PRINT"INPUT TOTAL COSTS RELATING TO ALLOCATABLE"
08470   PRINT"OVERHEAD EXPENDITURE ON PROJECT THIS PERIOD"
08475   INPUT A1(M1,7)
08480   A1(M1,8)=A1(M1,8)+A1(M1,6)+A1(M1,7)
08500   FILE #2,X$
08505   FILE #6,"PROJ1.TMP"
08510   ' (TEMP. FILE TO ALLOW APPENDING OF WEEK-TO-WEEK DATA)
08515   RESTORE #2
08520   SCRATCH #6
08525   IF END #2, GOTO 8544
08530   READ #2,T9(1),T9(2),T9(3),T9(4),T9(5),T9(6),T9(7),T9(8),T9(9)
08535   WRITE #6,T9(1),T9(2),T9(3),T9(4),T9(5),T9(6),T9(7),T9(8),T9(9)
08540   GOTO 8525
08544   FILE #2,X$
08548   FILE #6,"PROJ1.TMP"
08550   RESTORE #6
08555   SCRATCH #2
08560   IF END #6, GOTO 8590
08565   READ #6,T9(1),T9(2),T9(3),T9(4),T9(5),T9(6),T9(7),T9(8),T9(9)
08570   WRITE #2,T9(1),T9(2),T9(3),T9(4),T9(5),T9(6),T9(7),T9(8),T9(9)
08575   GOTO 8560
08590   ' (...NOW WE CAN GET ON WITH THE REAL STUFF)
08600   WRITE #2,W,A1(M1,1),A1(M1,2),A1(M1,3),A1(M1,4),A1(M1,5),A1(M1,6),A1(M1,7),A1(M1,8)
08650   PRINT
08655   PRINT "WEEKLY EXPENDITURE TO DATE"
08660   PRINT
08665   PRINT "WORK CATEGORIES"
08670   PRINT
08676   PRINT"WEEK      ARCH      S.E.      SERV      COMM      Q.S.      EXT       DIR       TOTALS"
08677   PRINT"                              ENG                           CT'S      O/H'S"
08681   FOR I=1 TO 85
08682   PRINT"-";
08683   NEXT I
08685   PRINT
08690   PRINT
```

```
08695   RESTORE #2
08700   FOR R=1 TO W
08705   FOR C=1TO9
08710   READ #2,A3(R,C)
08715   NEXT C
08720   PRINT USING 8725,A3(R,1),A3(R,2),A3(R,3),A3(R,4),A3(R,5),A3(R,6),A3(R,7),A3(R,8),A3(R,9)
08725   :###  ######.## ######.## ######.## ######.## ######.## ######.## ######.## #######.##
08730   NEXT R
08735   W1=W+1
08740   FOR C=2 TO 9
08745   FOR R=1 TO W
08750   A3(W1,C)=A3(W1,C)+A3(R,C)
08755   NEXT R
08760   NEXT C
08761   PRINT
08762   FOR I=1 TO 85
08763   PRINT"-";
08764   NEXT I
08765   PRINT USING 8770,A3(W1,2),A3(W1,3),A3(W1,4),A3(W1,5),A3(W1,6),A3(W1,7),A3(W1,8),A3(W1,9)
08770   :TOT  ######.## ######.## ######.## ######.## ######.## ######.## ######.##  ######.##
08775   PRINT
08800   PRINT
08810   FOR I=1 TO 84
08815   PRINT"-";
08820   NEXT I
08825   PRINT
08830   PRINT
08900   PRINT"ENTER ESTIMATED % OF DESIGN COMPLETED TO DATE FOR WORK CATEGORIES 1 TO 7"
09000   FOR C=1 TO 7
09100   PRINT"INPUT WORK CATEGORY";C
09200   INPUT P3(C)
09300   NEXT C
09400   PRINT
09550   REM FILE GENERATED BY ESTIMATING PROG (WK NOS, WEEKLY EXP, ACC EXP)
09600   X1$=LEFT$(Y$,5)+"G.DAT"
09660   X3$=LEFT$(Y$,5)+"P.DAT"
09675   REM FILE GENERATED BY ESTIMATING PROGRAM (% WK CAT ALLOCATIONS)
09700   PRINT
09710   FILE #4,X3$
09720   RESTORE #4
```

```
09740   IF END #4, GOTO 9787
09750   READ #4,E(1),E(2),E(3),E(4),E(5),E(6),E(7)
09760   Y5=Y5+1
09770   GOTO 9740
09780   PRINT"???? FILE ERROR IN",X1$
09785   STOP
09787   R=1
09788   E(8)=E(1)+E(2)+E(3)+E(4)+E(5)+E(6)+E(7)
09790   FILE #4,X3$
09795   RESTORE #4
09910   IF END #4,GOTO 9960
09920   READ #4,A2(R,1),A2(R,2),A2(R,3),A2(R,4),A2(R,5),A2(R,6),A2(R,7)
09930   IF R-W=0 THEN 9960
09940   R=R+1
09950   GOTO 9910
09960   FOR C=1TO7
09970   A2(R,8)=A2(R,8)+A2(R,C)
09980   NEXT C
10600   PRINT
10700   PRINT
10800   PRINT"PROFITABILITY ANALYSIS REPORT"
10900   PRINT"-----------------------------"
11000   PRINT
11100   PRINT"PROJECT ";Y$
11200   PRINT
11300   PRINT"WEEK NUMBER";W
11400   PRINT
11500   PRINT"WORK CATEGORIES"
11600   PRINT
11700   PRINT"                    ARCH      S.E.      SERV      COMM      Q.S.      EXT       DIR       TOTAL
11800   PRINT"                                        ENG                           CT'S      O/H'S"
11850   FORI=1TO91
11860   PRINT"-";
11870   NEXT I
11900   PRINT
12600   FOR C=1 TO 7
12650   REM VALUE TO DATE = % COMP/100*EST5 CAT VALUE * % EST ALLOC
12700   E1(C)=E(C)*P3(C)/100
12800   E1(8)=E1(8)+E1(C)
12850   NEXT C
```

```
12860  PRINT
12865  PRINT USING 12870,A2(R,1),A2(R,2),A2(R,3),A2(R,4),A2(R,5),A2(R,6),A2(R,7),A2(R,8)
12870  :BUDGET      ######.## ######.## ######.## ######.## ######.## ######.## ######.## ########.##
12880  PRINT
13900  FOR C=1 TO 8
13950  D=C+1
14000  E3(C)=E1(C)-A3(W1,D)
14100  NEXT C
14120  PRINT"ESTIMATED"
14130  PRINT"VALUE OF"
14200  PRINT USING 14300,E1(1),E1(2),E1(3),E1(4),E1(5),E1(6),E1(7),E1(8)
14300  :WORK TO     ######.## ######.## ######.## ######.## ######.## ######.## ######.## ########.##
14400  PRINT"DATE"
14500  PRINT
14600  PRINT
14700  PRINT"ACTUAL"
14800  PRINT USING 14900,A3(W1,2),A3(W1,3),A3(W1,4),A3(W1,5),A3(W1,6),A3(W1,7),A3(W1,8),A3(W1,9)
14900  :COST        ######.## ######.## ######.## ######.## ######.## ######.## ######.## ########.##
15000  PRINT"TO DATE"
15100  PRINT
15200  PRINT
15300  PRINT USING 15400,E3(1),E3(2),E3(3),E3(4),E3(5),E3(6),E3(7),E3(8)
15400  :PROFIT/     ######.## ######.## ######.## ######.## ######.## ######.## ######.## ########.##
15500  PRINT"LOSS"
15504  X5$=LEFT$(Y$,5)+"V.DAT"
15505  FILE #7,X5$
15510  FILE #8,"PRO1.TMP"
15515  RESTORE #7
15520  SCRATCH #8
15525  IF END #7 GOTO 15545
15530  READ #7,T8
15535  WRITE #8,T8
15540  GOTO 15525
15545  FILE #7,X5$
15550  FILE #8,"PRO1.TMP"
15555  RESTORE #8
15560  SCRATCH #7
15565  IF END #8,GOTO 15590
15570  READ #8,T8
15580  WRITE #7,T8
```

```
15585   GOTO 15565
15590   WRITE #7,E3(8)
15600   PRINT
15650    FOR I=1TO91
15660   PRINT"-";
15670   NEXT I
15700   PRINT
15710   PRINT
15720   PRINT
15730   PRINT
15800   PRINT "GENERAL ANALYSIS OF PROJECT STATUS TO DATE"
15900   PRINT "------------------------------------------"
16000   PRINT
16100   PRINT
16200   PRINT "RESOURCES UTILISED TO DATE"
16300   PRINT "--------------------------"
16400   PRINT
16700   PRINT "POUNDS STERLING     ";A3(W1,9)
16800   PRINT
16900   PRINT
17000   PRINT "RESOURCES REMAINING"
17100   PRINT "___________________"
17200   PRINT
17550   H3=E(8)-A3(W1,9)
17600   PRINT "POUNDS STERLING         ";H3
17700   PRINT
17800   PRINT
17900   P8=E1(8)/E(8)*100
18000   PRINT "OVERALL PERCENTAGE OF WORK COMPLETE TO DATE ";P8
18100   PRINT
18450   T=A3(W1,9)+(E(8)-E1(8))
18500   PRINT "ESTIMATED FINAL DESIGN PRIME COST $  ";T
18600   PRINT
18650   Q=(E(8)-T)+E(9)
18700   PRINT "SHORTFALL/GAIN ON ANTICIPATED FORECAST PROFIT/COST";Q
18800   PRINT
18900   PRINT
19000   PRINT"DURATION PREDICTION PROCEDURE"
19100   PRINT"-----------------------------"
19200   PRINT
19225 GOSUB 30000
```

```
20300   PRINT
20550   PRINT
20600 GOSUB 33000
20650   PRINT
20700   PRINT "END OF RUN"
20750   X6$=LEFT$(Y$,5)+"C.DAT"
20760   FILE #1,X6$
20770   SCRATCH #1
20780   WRITE #1,T,P8,Q,R,A3(W1,9),H3
20800   PRINT "----------"
20900 STOP
30000' FORECAST AND GRAF CONTROL
30100   PRINT" INTERMEDIATE GRAPHICS AND INITIAL FORECASTS"
30200   A(1)=0\P1=P1(1)=1
30300   PRINT\PRINT"DO WISH TO SET YOUR OWN FORECASTING CONSTANTS ";
30400   INPUT Y1$
30500   IF Y1$<"Y" THEN B(2)=0 ELSE 30700
30600   N8=1 \GOTO 31200
30700   PRINT"INPUT % OF COMPLETION AT THE TURNING POINT"
30800   PRINT"I.E. WHEN CASH OUTLAY STARTS TO DROP ";
30900   INPUT T
31000   B(2)=3*T/100-1
31050 A(2)=A(1)
31100   N8=2\ P1(2)=0
31200   'TEMPRY END
31250    GOTO 35500
31300   RETURN
33000   'FORECAST OUTPUT
33100   PRINT\ PRINT"CUMULATIVE COSTS"
33600   PRINT"WEEK BUDGETED PREDICTED   OWN"
33700   PRINT"NO.              DHSS     PREDICTION"
```

```
33800   FOR R=1 TO Y5
33850   R1=R/Y5
33900   PRINT R;TAB(5);A2(R,8);TAB(14);E(8)*FNF(R1,1);
34000   IF B(2)=0 THEN PRINT TAB(26);"   * " ELSE PRINT TAB(26) E(8)*FNF(R1,2)
34100   NEXT R
34200   PRINT\PRINT
34300   RETURN
34499   'CUM.COST CALC. ACTUAL & %(FNF)
34500   DEF FNF(X,J)
34600   FNF=X*(1+A(J)*(1-X)*(X-B(J)))
34700   FNEND
35500   'ALFA,BETA
35600   S5=E(8)
35700   IF S5<1E5 THEN A1=.8+S5/3.6E5
35800   IF S5<2E6 THEN A1=1.5
35900   IF S5<1E7 THEN A1=1.45+S5/5E7 ELSE A1=1.8
36000   IF S5<1E5 THEN B1=3*S5/1E6
36100   IF S5<7.5E5 THEN B1=.29+S5/7E6
36200   IF S5<4E6 THEN B1=.4+S5/2E7 ELSE B1=.6
36300   A(1)=A1 \B(1)=B1
36400 GOTO31300
99999   END
```

MONITORING & CONTROL PROGRAM (PROJ7.BAS)
PRODUCTION APPLICATION

```
.TY PROJ7.BAS
00050   margin 132
00100   DIM A(200,20),W2(200,20),R1(200), N$(200), N(200),A1(200,20),A3(200,20),E(20),E1(20),E3(20),Y1(20)
00110   DIM T9(20),A2(200,20),P2(20),P3(20),E8(20),T8(20)
00111 DIM P1(20),E2(20)
00200   PRINT'PROJECT CONTROL PROGRAM MODULE'
00300   PRINT'=============================='
00400   PRINT
00500   PRINT'CONVERSATIONAL MODE DATA INPUT PROCEDURE'
00600   PRINT'========================================'
00700   PRINT
00800   PRINT'INPUT PROJECT NAME(MAX 5 CHARACTERS)';
00900   INPUT Y$
00910   X$=LEFT$(Y$,5)+'U.DAT'
00915   PRINT' INPUT PROJECT WEEK NUMBER'
00916   INPUT W
00920   PRINT
00925   IF W>1 THEN 1200
00930   PRINT'INPUT PROJECT BASE DATE I.E. 4,80 (MONTH 4 1980)'
00940   INPUT P8,P9
00950   X6$=LEFT$(Y$,5)+"T.DAT'
00960   FILE £ 2,X6$
00970   SCRATCH £2
00980   WRITE £2,P8,P9
01200   REM PROCEDURE FOR READING CENTRE COSTS
01300   J=0
01400   FOR I=2TO6
01500   PRINT'COST CENTRE NO. ';I-1
01600   PRINT'INPUT LABOUR, PLANT AND MATERIAL COSTS RESPECTIVELY'
01700   INPUT T9(J+2),T9(J+3),T9(J+4)
01800   J=J+3
01900   NEXT I
02000   PRINT'CC6 NOM/S-C'S'\INPUT T9(17)
02100   PRINT'CC7 SITE O/H'S'\INPUT T9(18)
02200   REM STORES WEEK NO.
02300 T9(1)=W
02400   REM CALC TOTALS FOR WEEK
02500   FOR I=2 TO 18
02600   T9(19)=T9(19)+T9(I)
02700   NEXT I
02800   REM PROCEDURE READ %'S FROM FILES CC1 TO CC5
02900   X8$=LEFT$(Y$,5)+'A.DAT'
03000   FILE £1,X8$
03100   FOR I=1TO15
03200   READ £1,P1(I)
03300   NEXT I
08500   FILE £2,X$
08505   FILE £6,'PROJ1.TMP'
08510   ' (TEMP. FILE TO ALLOW APPENDING OF MONTH TO MONTH DATA)
08515   RESTORE £2
08520   SCRATCH £6
08525   IF END £2, GOTO 8544
```

```
08526   FOR I=1TO19
08527   READ £2,T8(I)
08528   NEXT I
08529   FOR I=1TO19
08530   WRITE £6,T8(I)
08531   NEXT I
08532   GOTO 8525
08544   FILE £2,X$
08548   FILE £6,'PROJ1.TMP'
08550   RESTORE £6
08555   SCRATCH £2
08560   IF END £6, GOTO 8590
08561   FOR I=1TO19
08562   READ £6,T8(I)
08563   NEXT I
08564   FOR I=1TO19
08565   WRITE £2,T8(I)
08566   NEXT I
08575   GOTO 8560
08590   ' (...NOW WE CAN GET ON WITH THE REAL STUFF)
08610   FOR I=1TO19
08620   WRITE £2,T9(I)
08630   NEXT I
08631   FOR I=1TO95\PRINT'*';\NEXT I
08650   FOR I=1 TO 5\PRINT\NEXT I
08655   PRINT 'MONTHLY EXPENDITURE TO DATE'
08660   PRINT
08665   PRINT'COST CENTRES'
08670   PRINT
08676   PRINT'MONTH      SUBSTRUCTURE                        SUPERSTRUCTURE                        FINISHINGS'
08677   PRINT'           LABOUR     PLANT     MAT            LABOUR     PLANT      MAT             LABOUR     PLANT
08681   FOR I=1 TO 97
08682   PRINT'=';
08683   NEXT I
08685   PRINT
08690   PRINT
08700   RESTORE £2
08702   FOR R=1 TO W
08705   FOR C=1TO19
08710 READ £2, A3(R,C)
08715   NEXT C
08717 NEXT R
08718 FOR R=1 TO W
08720   PRINT USING 8725,A3(R,1),A3(R,2),A3(R,3),A3(R,4),A3(R,5),A3(R,6),A3(R,7),A3(R,8),A3(R,9),A3(R,10)
08725   :£££  ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ £££££££.££
08730   NEXT R
08735   W1=W+1
08740   FOR C=2 TO 19
08745 FOR R=1 TO W
08750   A3(W1,C)=A3(W1,C)+A3(R,C)
08755   NEXT R
08760   NEXT C
```

```
08761   PRINT
08762   FOR I=1 TO 95
08763   PRINT"-";
08764   NEXT I
08765   PRINT USING 8770,A3(W1,2),A3(W1,3),A3(W1,4),A3(W1,5),A3(W1,6),A3(W1,7),A3(W1,8),A3(W1,9),A3(W1,10)
08770   :TOT  ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££
08810   FOR I=1 TO 95
08815   PRINT"-";
08820   NEXT I
08825   PRINT
08830   PRINT
08835   PRINT"                  EXTERNAL WORKS                  DRAINAGE                       NOM          SITE    TOTALS"
08840   PRINT"              LAB     PLANT     MATERIAL      LAB      PLANT    MATERIAL      S/C'S       O/H'S"
08850   PRINT"-----------------------------------------------------------------------------------------------"
08851   FOR R=1TOW
08855   PRINT USING 8860,A3(R,1),A3(R,11),A3(R,12),A3(R,13),A3(R,14),A3(R,15),A3(R,16),A3(R,17),A3(R,18),A3(R,19)
08860   :£££   ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££
08861   NEXT R
08865   PRINT"-----------------------------------------------------------------------------------------------"
08870   PRINT USING 8885,A3(W1,11),A3(W1,12),A3(W1,13),A3(W1,14),A3(W1,15),A3(W1,16),A3(W1,17),A3(W1,18),A3(W1,19)
08885   : TOT ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££
08886   FOR I=1TO95
08887   PRINT"*";
08888   NEXT I
08889   PRINT\PRINT\PRINT
08900   PRINT"ENTER ESTIMATED % COMPLETED TO DATE FOR WORK CATEGORIES 1 TO 7"
09000   FOR C=1 TO 7
09100   PRINT"INPUT WORK CATEGORY";C
09200   INPUT P3(C)
09300   NEXT C
09310   FOR I=1TO95\PRINT"*";\NEXT I
09400   PRINT
09550   REM FILE GENERATED BY ESTIMATING PROG (WK NOS, WEEKLY EXP, ACC EXP)
09600   X1$=LEFT$(Y$,5)+"G.DAT"
09660   X3$=LEFT$(Y$,5)+"P.DAT"
09675   REM FILE GENERATED BY ESTIMATING PROGRAM (% WK CAT ALLOCATIONS)
09700   PRINT
09710   FILE £4,X3$
09720   RESTORE £4
09740   IF END £4, GOTO 9787
09750   READ £4,Z(1),Z(2),Z(3),Z(4),Z(5),E(16),E(17)
09760   Y5=Y5+1
09770   GOTO 9740
09780   PRINT"???? FILE ERROR IN",X1$
09785   STOP
```

```
09787   R=1
09788   E(18)=Z(1)+Z(2)+Z(3)+Z(4)+Z(5)+E(16)+E(17)
09789   FOR C=1 TO 3
09790   E1(C)=Z(1)*P1(C)/100
09791   NEXT C
09792   FOR C=4TO6
09793   E1(C)=Z(2)*P1(C)/100
09794   NEXT C
09795   FOR C=7TO9
09796   E1(C)=Z(3)*P1(C)/100
09797   NEXT C
09798   FOR C=10 TO 12
09799   E1(C)=Z(4)*P1(C)/100
09800   NEXT C
09801   FOR C=13 TO 15
09802   E1(C)=Z(5)*P1(C)/100
09803   NEXT C
09804   E1(16)=E(16)
09805   E1(17)=E(17)
09806   FILE £4,X3$
09807   RESTORE £4
09910   IF END £4,GOTO 9960
09920   READ £4,P2(1),P2(2),P2(3),P2(4),P2(5),A2(R,16),A2(R,17)
09930   IF R-W=0 THEN 9955
09940   R=R+1
09950   GOTO 9910
09955   FOR J=1 TO 3
09960   A2(R,J)=P1(J)/100*P2(1)
09965   NEXT J
09970   FOR J=4 TO 6
09975   A2(R,J)=P1(J)/100*P2(2)
09980   NEXT J
09985   FOR J=7 TO 9
09990   A2(R,J)=P1(J)/100*P2(3)
09995   NEXT J
10000   FOR J=10 TO 12
10005   A2(R,J)=P1(J)/100*P2(4)
10010   NEXT J
10015   FOR J=13 TO 15
10020   A2(R,J)=P1(J)/100*P2(5)
10025   NEXT J
10030   FOR C=1 TO 17
10035   A2(R,18)=A2(R,18)+A2(R,C)
10040   NEXT C
```

```
10600   PRINT
10700   PRINT
10800   PRINT'PROFITABILITY ANALYSIS REPORT'
10900   PRINT'----------------------------'
11000   PRINT
11100   PRINT'PROJECT ';Y$
11200   PRINT
11300   PRINT'WEEK NUMBER';W
11400   PRINT
11500   PRINT'COST CENTRES'
11600   PRINT
11700   PRINT'                    SUBSTRUCTURE                    SUPERSTRUCTURE                    FINISHES'
11701   PRINT'                    LAB        PLANT      MAT       LAB        PLANT      MAT        LAB        PLANT
11850   FORI=1TO101
11860   PRINT'=';
11870   NEXT I
11900   PRINT
12650   REM VALUE TO DATE = % COMP/100*EST5 CAT VALUE * % EST ALLOC
12660   FOR C=1 TO3
12670   E2(C)=E1(C)*P3(1)/100
12680   NEXT C
12690   FOR C=4 TO 6
12700   E2(C)=E1(C)*P3(2)/100
12701   NEXT C
12705   FOR C= 7 TO 9
12710   E2(C)=E1(3)*P3(3)/100
12715   NEXT C
12720   FOR C=10 TO 12
12725   E2(C)=E1(C)*P3(4)/100
12730   NEXT C
12735   FOR C=13 TO 15
12740   E2(C)=E1(C)*P3(5)/100
12745   NEXT C
12776   E2(16)=E1(16)*P3(6)/100
12777   E2(17)=E1(17)*P3(7)/100
12780   FOR C=1TO17
12800   E2(18)=E2(18)+E2(C)
12850   NEXT C
12860   PRINT
12865   PRINT USING 12870,A2(R,1),A2(R,2),A2(R,3),A2(R,4),A2(R,5),A2(R,6),A2(R,7),A2(R,8),A2(R,9)
12870   :BUDGET     ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££
12880   PRINT
```

```
13900   FOR C=1 TO 18
13950   D=C+1
14000   E3(C)=E2(C)-A3(W1,D)
14100   NEXT C
14120   PRINT'ESTIMATED'
14130   PRINT'VALUE OF'
14200   PRINT USING 14300,E2(1),E2(2),E2(3),E2(4),E2(5),E2(6),E2(7),E2(8),E2(9)
14300   :WORK TO     ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ £££££££:
14400   PRINT'DATE'
14500   PRINT
14600   PRINT
14700   PRINT'ACTUAL'
14800   PRINT USING 14900,A3(W1,2),A3(W1,3),A3(W1,4),A3(W1,5),A3(W1,6),A3(W1,7),A3(W1,8),A3(W1,9),A3(W1,10)
14900   :COST        ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ £££££££
15000   PRINT'TO DATE'
15100   PRINT
15200   FOR I=1 TO 101\PRINT'-';\NEXT I
15300   PRINT USING 15400,E3(1),E3(2),E3(3),E3(4),E3(5),E3(6),E3(7),E3(8),E3(9)
15400   :PROFIT/     ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ ££££££.££ £££££££
15500   PRINT'LOSS'
15504   X5$=LEFT$(Y$,5)+'V.DAT'
15505   FILE £7,X5$
15510   FILE £8,'PRO1.TMP'
15515   RESTORE £7
15520   SCRATCH £8
15525   IF END £7 GOTO 15545
15530   READ £7,T8
15535   WRITE £8,T8
15540   GOTO 15525
15545   FILE £7,X5$
15550   FILE £8,'PRO1.TMP'
15555   RESTORE £8
15560   SCRATCH £7
15565   IF END £8,GOTO 15590
15570   READ £8,T8
15580   WRITE £7,T8
15585   GOTO 15565
15590   WRITE £7,E3(8)
15600   PRINT
15601   FOR I=1TO101
15602   PRINT'=';
15603   NEXT I
15604   PRINT\PRINT\PRINT
15605   PRINT'                    EXTERNAL WORKS                    DRAINAGE                         NOM      SITE
```

```
18650   Q=(E(18)-T1)
18700   PRINT 'SHORTFALL/GAIN ON ANTICIPATED FORECAST PROFIT/COST ';Q
18800   PRINT
18900   PRINT
19100   PRINT'---------------------------'
19200 PRINT
19201 GOTO 41900
19225 GOSUB 30000
20300   PRINT
20550   PRINT
20600 GOSUB 33000
20650   PRINT
20900 GOTO 40000
30000' FORECAST AND GRAPH CONTROL
30100   PRINT' INTERMEDIATE GRAPHICS AND INITIAL FORECASTS'
30200   A(1)=0\P1=P1(1)=1
30300   PRINT\PRINT'DO WISH TO SET YOUR OWN FORECASTING CONSTANTS ';
30400   INPUT Y1$
30500   IF Y1$<'Y' THEN B(2)=0 ELSE 30700
30600   N8=1 \GOTO 31200
30700   PRINT'INPUT % OF COMPLETION AT THE TURNING POINT'
30800   PRINT'I.E. WHEN CASH OUTLAY STARTS TO DROP ';
30900   INPUT T
31000   B(2)=3*T/100-1
31050 A(2)=A(1)
31100   N8=2\ P1(2)=0
31200   'TEMPRY END
31250    GOTO 35500
31300   RETURN
33000   'FORECAST OUTPUT
33100   PRINT\ PRINT'CUMULATIVE COSTS'
33600   PRINT'WEEK BUDGETED PREDICTED   OWN'
33700   PRINT'NO.              DHSS     PREDICTION'
33800   FOR R=1 TO Y5
33850   R1=R/Y5
33900   PRINT R;TAB(5);A2(R,8);TAB(14);E(8)*FNF(R1,1);
34000   IF B(2)=0 THEN PRINT TAB(26);'   * ' ELSE PRINT TAB(26) E(8)*FNF(R1,2)
34100   NEXT R
34200   PRINT\PRINT
34300   RETURN
34499   'CUM.COST CALC. ACTUAL & %(FNF)
34500   DEF FNF(X,J)
34600   FNF=X*(1+A(J)*(1-X)*(X-B(J)))
34700   FNEND
35500   'ALFA,BETA
35600   S5=E(8)
35700   IF S5<1E5 THEN A1=.8+S5/3.6E5
35800   IF S5<2E6 THEN A1=1.5
35900   IF S5<1E7 THEN A1=1.45+S5/5E7 ELSE A1=1.8
36000   IF S5<1E5 THEN B1=3*S5/1E6
36100   IF S5<7.5E5 THEN B1=.29+S5/7E6
36200   IF S5<4E6 THEN B1=.4+S5/2E7 ELSE B1=.6
36300   A(1)=A1 \B(1)=B1
36400 GOTO31300
40000 DIM Y(300),C(300)
40005   IF W<5 GOTO 41900
40010   PRINT'PREDICTION ANALYSIS'
40015   PRINT'------------------'
```

```
40016   PRINT
40020 PRINT \ P1=1\Y=P8/100
40030 PRINT "INPUT PROPOSED ALPHA/BETA CONSTANTS TO COMPLETION" \ INPUT A,B
40040   X=1
40050   F1=-Y-A*X^3+A*(1+B)*X^2+(1-A*B)*X
40060   F2=-3*A*X^2+2*A*(1+B)*X+1-A*B
40070   X1=X-F1/F2
40080   IF ABS(X1-X)>1E-6 THEN X=X1 ELSE 40100
40090   GOTO 40050
40100   PRINT "X="X
40110   P=W/X
40120 P=INT(P+.5)
40125   PRINT
40130 PRINT "PREDICTED DURATION TO COMPLETION";P
40135   PRINT
40136   PRINT"MONTH           RATIO       PREDICTED"
40137   PRINT"                COMPL (Y)   EXPENDITURE"
40138   PRINT"----------------------------------------"
40139   PRINT
40140 FOR M=WTO P
40150 X=M/P
40160 Y(M)=X*(1+A*(1-X)*(X-B))
40170 C(M)=T1*Y(M)
40180 PRINT M,Y(M),C(M)
40190 NEXT M
40195   X6$=LEFT$(Y$,5)+"C.DAT"
40200   FILE £1,X6$
40300   SCRATCH £1
40400   WRITE £1,T1,P8,Q,P,A3(W1,18),H3
40500   PRINT
40600   PRINT"GRAPHICAL PRESENTATION OF 'S' CURVE"
40700   PRINT"-----------------------------------"
40800   PRINT
40900   PRINT
41000   PRINT"                EXPENDITURE TO DATE POUNDS STERLING"
41100   PRINT USING 41200,C(W)
41200   :WKS            ££££££££
41300   PRINT"                          I.........I.........I.........I.........I.........I.........I.........I.........I.........I"
41400   PRINT
41500   FOR M=W TO P
41600   PRINT M;TAB(26)"I";TAB(50*Y(M)+24)"*"
41650   M1=W+1
41700   NEXT M
41800   PRINT TAB(26)"I";TAB(50*Y(P)+24);T1;"FINAL EXPENDITURE FORECAST"
41810   PRINT
41900   PRINT"END OF REPORTING PROCEDURE"
42000   PRINT"--------------------------"
42010   PRINT\PRINT\PRINT\PRINT
42015   IF R>4 GOTO 42100
42020   PRINT"PERIODS LESS THAN 5 NO PREDICTION ANALYSIS POSSIBLE"
42025   GOTO 99999
42100   FILE £1,"P.TMP"
42200   SCRATCH £1
42300   WRITE £1,R,E2(18),T1
42400   CHAIN "RPRJ11.BAS",1005
99999   END
```

CURVE FIT PROGRAM RPRJ11.BAS

```
.TY RPRJ11.BAS
00010   ' ORIGINAL FORM OFTHIS PROG IS NOW RPRJ21.BAS
00020   '!!!
00050 MARGIN 120
00100   DIMC(100),Y(100),X(100)
00110 DIM G(100),B(100)
00120 DIM Y5(100),C1(100),K2(100)
00150 GOTO 1005
00200   FILE £2,"F.TMP"
00250   READ £2, Q
00300   IF END £2 GOTO 700
00400   P=P+1
00500   READ£2,C(P)
00600   GOTO 300
00700   R= P-3
00750 P2=C(R+1)\P3=P2+C(R+2)
00770   PRINT"INPUT EXPECTED DURATION";\INPUT D5
00780 T1=1.5*D5
00800   F1=0 ' MONTHLY INFLATION VALUE
00805   GOTO 850
00810 PRINT "ERROR"\PRINT
00820 PRINT "TTL COST "Q
00830 FOR I=1 TO P\PRINT"R="I,C(I)\NEXT I
00840 PRINT"DRTN "C(R+1),"REDNDNT PRDS "C(R+2),"PEAK PRD."C(R+3)
00845  STOP
00850 PO=P=C(R+3)
00870   FOR I=1TO R
00880   K2(I)=(1+F1/100)^I
00885   C1(I)=C(I)
00890   C(I)= C(I)/K2(I)
00900   NEXTI
01000   I4=C(R+2)
01005   FILE £3,"P.TMP"
01010   READ £3.R,C(R),C9
01015   P=R/SQR(-2*LOG(1-C(R)/1.05/C9))
01020   BO= 3*P/R-1
01022   T=P/R \AO=1/(2.3-3.3*T)
01024   PRINT "INPUT DATA :-"\ PRINT"PRESENT DURATION "R" MONTHS AT VALUE "C(R)
01026   PRINT"EXPECTED PROJECT COST "C9
01027   T1=3*R\C=C(R)
01030   IF C/FNG(R,T1)>1.04*C9 THEN 1035 ELSE T1=T1+2*R
01033   GOTO 1030
01035   D=T1\T1=1.5*D\S9=1.1*C9
01037   IO=O\ FOR I=R TO D
01039   IF C9<C(R)*FNG(I,R) GOTO 1043
01041   NEXT I
01043   IO=I\PRINT\ PRINT "PRESENT EXPECTED COST OCCURS AT PERIOD "IO
01045   PRINT\PRINT "MAX PREDICTED COST IS "C(R)*FNG(D,R)\ PRINT\PRINT
01047   GOTO 3490
01050   PRINT"(MIN. 5 PERIODS) ";\ TO=R
01055 R5=P-3
01060 INPUT R
01070   '
```

```
01075   C=0\FOR I=1 TO R
01080 C1=C(I)-C(I-1)
01085   Z=C(I)/I*R-1
01090 PRINT 'PRD'I,'COST'C1,'CUM. COST'C(I);'  Z='Z
01095  IF C1<C GOTO 1120
01100 C=C1\P1=I
01120   NEXT I
01125   PRINT'HIGHEST COST WEEK 'P1' AT COST 'C
01200   'TEST DURATION ETC.
01202 PRINT 'GAMA'
01203    '
01204 FOR I=1 TO R-1
01206 R9=Y9=100
01208   R7=R-1
01210   S8=S9=C(R) \ Y7=C(I)/S9
01211   IF Y7 > (I/R)^2 GOTO 1215
01212   N1=S2=Y9=G(I)=0 \GOTO 1230
01215 ' PEAK SEARCH
01216 '
01218   FOR P5=2 TO R*10 BY.3
01220   P=P5 \ Y=FNG(I,R)
01223   IF Y>Y7 THEN 1226 ELSE 1228
01226   NEXT P5
01228   P=G(I)=P5\ GOSUB 5000
01230   PRINT I'  NO.'N1,G(I),'EX='S2,'X*X='(I/R)^2,'YA='INT(1E4*Y7+.5)/1E4
01232 NEXT I
01242 PRINT 'BETA'
01243    '
01245 FOR I=6 TO R
01250   S8=S9=C(I)
01255   Y9=R9=100
01260    R7=I
01262  IF R=R7 GOTO 1298
01265    FOR I1=-.3 TO 2  BY .3
01270    FOR J=-.5 TO 6.5 BY .03
01275    P=(1+J)/3*I
01280  B0=J
01282 A0=I1
01285   GOSUB 6000
01293 NEXT J,I1
01295 PRINT I,A,'EX='Y9,'A='A3,
01296   PRINT'B='3*A/I-1
01297  NEXT I
01298 IF G(R)=0 THEN G(R)=B(R)
01299 I3=0\PRINT\PRINT\ GOTO 1355
01300  P1=INT((B(R)+G(R))/2+.5)
01305   P0=INT(P1/3+.5)\ P1=2*P1
01307 PRINT'P0='P0,'P1='P1
01308 IF P1>3*C(T0+3) GOTO 1353
01310   FOR P=P0 TO P1 BY .2
01315 IF 1-1/P <.01 GOTO 1352
01320   K0=- LOG(1-1/P)
01325   GOSUB 8000
01327 IF N=0 GOTO 1352
01330   IF R3>I3 THEN I3=R3 ELSE 1352
01335 P9=P
01340 IF P9<.99*P1 GOTO 1350
01345 P0=P1-1\ P1=2*P1
01347 GOTO 1307
01350   I2=I1\ K2=K1\ R2=R1\ T2=T
01351 NEXT P
01352   PRINT
01353   IF P>.8*C(T0+3) GOTO 1355
01354 P=C(T0+3)
01355 PRINT'PEAK='P'NEW VALUE OR  OLD  ,INPUT PEAK ,A,B';\ INPUT P,A0,B0
```

```
01356     GOTO2415
01357   PRINT"P*"1/(1-EXP(-K0)),"SLP*"K0,"INTCPT"I2,"TAN"T2
01360   PRINT"R"R2,"SLP"K2,"TST"I3
01375   PRINT"PEAK PERIOD "P," %ERROR "INT(100*(1-R3)+.5)
01379 PRINT\PRINT
01400   Y9=100 'YSD
01500   R9=100 'REL SD
01600  FOR I= 1TO R-1
01700     FOR J=I+1 TO R
01800     K=FNK(I,J)
01900     P1=P*P-K
02000     IF P1<0 GOTO 2300
02200   D=P+P1^.5
02220 S9=C(R)/FNG(R,D)
02260   IF D1<D THEN D1=D
02300   NEXT J
02400   NEXT I
02403 IF D1>0 GOTO 2410
02406 R=R-1 \ GOTO 1400
02408 IF D1>13.2*P THEN D1=13.2*P
02410   D=D1\ PRINT"MAX DRTN. "D
02415 PRINT"ADJUSTED DNTN."D*P3/P2
02450 GOTO 3210
02500    ' RESULTS
02550   D=D5
02600   '
02625   D=D5
02650 S9=C(R)/FNG(R,D)
02700   FOR I=R TO T1 BY INT((D-R)*.1+.5)
02800 IF  I>10*P GOTO 3200
03100   GOSUB 5000
03200   NEXT I
03210 PRINT\PRINT\PRINT
03215 D=D5
03220 S9=C(R)/FNG(R,D)
03250   E=R9\D0=D9
03260   GOTO3360
03300   PRINT "BEST GAMMA RESULT"
03350   PRINT "COST "C(R)/FNG(R,D8)" DURATION "D8" (YSD)ERROR "S2
03360 IF P2=P3 GOTO 3400
03370 PRINT "ADJUSTED DRTN. "D8*P3/P2
03400 PRINT
03420 PRINT"PRESENT DURTN. "R"  AT COST "C(R)
03460 PRINT\PRINT"INPUT DURTN. "T0" WITH "I4" REDUNDANT PRDS."
03465   PRINT" AT COST "Q" KNOWN DRTN. "T0+I4
03470   PRINT"PEAK PR. SLECTED"P" GIVEN (GAMMA) PEAK "C(T0+3)
03475   PRINT \ GOTO 3800
03476 PRINT\PRINT"INPUT %MONTHLY INFLATION "\INPUT F1\G$=""\PRINT
03477 PRINT"PEAK INPUT "P"  ";
03478   PRINT"A="A0,"B="B0
03479   PRINT
03490 R6=INT(R*B0+.5)
03495   GOTO 3800
03500 PRINT"EXPECTED DURATION=" INT(R*B0+.5)" MONTHS"
03600 PRINT"AT CB.CST="C(R)*FNC(R6/R,A0,B0)" EXP.CST="C(R)*FNG(R6,R)
03700 PRINT"ALTERNATIVE SOLUTION AT "R0"%"
03800 FOR I=R TO T1 BY INT(.1*(D-R)+.5)
03900 C=C(R)/FNG(R,I)
04000 IF C>= R0*S9/100 GOTO 4150
04100 NEXT I
04150 GOTO 4400
04200 PRINT"COST="C"DRNTN"I", CUBIC COST="C(R)*FNC(I/R,A0,B0)\PRINT
04300   PRINT"INFLATED COST= "C*(1+F1/100)^I
04400  PRINT\PRINT
04500 IF R0=99 GOTO 9100
04600 R0=99
04700 GOTO 3800
04800 P=P0\R=R1\GOTO 1000
05000 '
05020   'REL SD TEST    GAMA
05040   '
```

```
05050 IF I>10*P GOTO 5300
05060   N1=S1=S2=0
05100     FOR J=1 TO I
05110 IF I>10*P GOTO 5300
05115 IF J>10*P GOTO 5300
05120 Y=FNG(J,I)
05140   Y1= C(J)/C(I)
05145   IF Y1<.9*(J/I)^2 GOTO 5200
05150   N1=N1+1
05155' Y2,S1 R.SD
05160   Y2=(Y-Y1)/Y1
05170 Y3=(Y-Y1)
05180   S1=S1+ (J/I)^2*Y2**2
05190   S2=S2 +(J/I)^2*Y3**2
05200   NEXT J
05202   S2=INT(1000*SQR(S2/(N1))+.5)/10
05203   GOTO5300
05205 IF Y9<S2 GOTO 5220
05210   Y9=S2\A=K4
05215   D8=I
05220   S1=INT(1000*SQR(S1/(N1+1))+.5)/10
05240   IF R9<S1 GOTO 5300
05260   R9=S1 \D9=I
05270   A1=K4
05280   'REL SD ERROR R9(E) DRTN D9(D0)
05300   RETURN
06000 '
06010   '     BETA
06050   'R7EL SD TEST
06100   '
06150   S1=S2=0
06200   FOR J1=R7-5 TO R7
06250   Y=FNC(J1/R7,A0,B0)*S9
06300   Y1= C(J1)
06350' Y2,S1 R7,SD
06400   Y2=(Y-Y1)/Y1
06450 Y3=(Y-Y1)/S9
06500   S1=S1+ (J1/R7)^0.*Y2**2
06550   S2=S2 +(J1/R7)^0.*Y3**2
06600   NEXT J1
06620   S2=INT(1000*SQR(S2/(6))+.5)/10
06650 IF Y9<S2 GOTO 6750
06700   Y9=S2\A=P \A3=A0
06750   S1=INT(1000*SQR(S1/(6))+.5)/10
```

```
06800   IF R9<S1 GOTO 6950
06850   R9=S1 \D9=P
06900   'REL SD ERROR R9(E) DRTN D9(DO)
06950   RETURN
07000   DEF FNA(I,R,P)=(C(I)*R/C(R)/I-1)/(I/R-3*P/R+1)/(1-I/R)
07500   DEF FNC(X,A,B)= X*(1+A*(X-B)*(1-X))
08000   '
08050   'CORRLTN
08100   '
08150   S1=S2=Z=Q1=Q2=0
08160 N=0
08200   FOR I=2TOR
08220   IF K0*I>80 GOTO 9000
08225   K=P*(1-EXP(-K0*I))
08250   IF ABS(K-G(I))<ABS(K-B(I))THEN  Y=G(I) ELSE Y=B(I)
08270 IF 1-Y/P <.01 GOTO 8600
08300   Y=-LOG(1-Y/P)
08320 N=N+1
08350   S1=S1+I             'SUM X
08400   S2=S2+Y             'Y
08450   Z=Z+Y*I             'XY
08500   Q1=Q1+I*I           'X^2
08550   Q2=Q2+Y*Y           'Y^2
08600   NEXT I
08650   IF INT(.8*(R-1))<N GOTO 8700
08660 N=0 \ GOTO 9000
08700   K1=(N*Z-S1*S2)/(N*Q1 -S1*S1)'SLOPE
08725   R1=K1*K1*(N*Q1-S1*S1)/(N*Q2-S2*S2)
08750   I1=(S2-K1*S1)/N \I9=ABS(I1)+.0001
08850   T=(K0/(1-I1)-K1)/(1+K0*K1/(1-I1))
08855     R1=SQR(R1)
08860   R3=(1-ABS(T))*R1
09000   RETURN
09100   'TABLE
09120 D=I\ S9=C
09130 T1=.9*T1\ IF D<T1 THEN D=T1
09150   PRINT"PRD  CUM. COST  PREDICTED (CUM. COST)"
09200   FOR I=RTOD
09210   C0=C(R)*FNG(I,R)
09220   C1=C(R)*FNG(I+1,R)
09230   IF C1-C0<10 THEN 9700
09300   IF I>R THEN C$="X" ELSE C$=STR$(C(I))
09303   IF I<=R AND C(I)>C(R)*(I/R)^2 THEN G$="OK" ELSE G$="!"
09400   PRINT I;TAB(7);C$,INT(.1*(C0+5))*10
09500   NEXT I
09700   'GRAPH
09750   '
```

```
09800   S=C\P1=I
09850 PRINT\PRINT
09900 PRINT"GRAPH OF PROJECT EVALUATION"
09950   PRINT"____________________________"
10000 PRINT\PRINT\PRINT"DURATION "P1" WEEKS AT COST "S" 'POUNDS'"
10050PRINT\PRINT
10100 IF CLOG(S)>4 THEN C=1000 ELSE C=100
10150 S$=STR$(C)
10200 PRINT"COST ("S$"'S)";
10250   X=X6=S5=0
10300 K=0
10350 S1=S/C
10400   FOR J=1 TO 5
10450   PRINT TAB(6+10*J)"!"INT(S1*J*.2);
10500   NEXT J
10550   PRINT""\PRINT"COST% X";
10600   FOR I5=1 TO 12\PRINT"----X";\NEXTI5\PRINT""
10650   GOTO 11650
10700  FOR X6=0 TO P1
10750   IF X6/5=INT(X6/5) OR X6=PTHEN PRINT INT(100*X6/P+.5);"%";X6 ; ELSE PRINT TAB(5)"I";
10800   IF X6=0 OR X6>R GOTO 11000
10850   C1=(FNG(X6,P1)/X6*P1-1)*4
10900   Y2=C(X6)/S
10950   GOTO 11050
11000   Y2=0
11050   Y=FNG(X6,P1)
11100   IF Y5(X6)=Y THEN G1$="" ELSE G1$="A"
11120   IF X6>1 THEN G1$=""
11130   GOTO 11200
11150 IF X6>R THEN PRINT TAB(FNT(C1))"*";
11200   IF Y2>Y GOTO 11350
11250   IF Y2<Y GOTO 11400
11300   PRINT TAB(FNT(Y))"S"\ GOTO 11450
11350   PRINT TAB(FNT(Y))"P";TAB(FNT(Y2));G1$\GOTO 11450
11400   PRINT TAB(FNT(Y2))G1$;TAB(FNT(Y));"P"
11450   NEXT X6
11500   PRINT TAB(6)"X";
11550   FOR I5=1 TO 12 \PRINT"----X";\NEXT I5\PRINT" "
11600   PRINT"COST%";
11650   FOR I5=1 TO 12\PRINT TAB(5+5*I5);10*I5;\NEXT I5
11700   PRINT""
11750 IF X6=P1 THEN GOTO 30362 ELSE 10700
11800   DEF FNT(A)=INT(50*A+.5)+6
```

```
11850  GOTO 30362
18000    'N-RFSN G1=G0-(Y-Y0)(1-E^-G0)/G0/(1-Y0)
18020    P=R/SQR(2*G5)
18025 PRINT'P,G5'P,G5
18035    IF P>10*R THEN 18300
18050    G6=1-EXP(-G5)
18150    Y6=FNG(I,R)
18200    G5=G5-(Y7-Y6)*G6/G5/(1-Y6)
18250    P=R/SQR(2*G5)
18280 PRINT 'G6,Y6,G5,P' G6,Y6,G5,P
18300    RETURN
19990'
19993'FINDS DRTN
19996'
20000    DEF FNK(A,B)
20050    X1=A*(3*P-A)
20100    X2=B*(3*P-B)
20200    Y1 = C(A)/A
20300    Y2 = C(B)/B
20400    FNK=(X1*Y2-X2*Y1)/(Y2-Y1)/3
20500    FNEND
20600    DEF FNZ(W)=1-EXP(-W*W/2/P/P)
20700    DEF FNG(W,D)= FNZ(W)/FNZ(D)
30000    'BETA PEAK
30040    '
30080    DEF FNB(I,J,R)
30120    Y1=C(I)/C(R)\ Y2=C(J)/C(R)
30140    X1=I/R\X2=J/R
30150 IF Y2/X2=1 THENFNB=1 ELSE 30160
30155 GOTO 30361
30160    K=(Y1/X1-1)/(Y2/X2-1)
30200    U1=X1*(1-X1)
30240    U2=X2*(1-X2)
30280    B1=K*U2-U1
30320    B2=X1-1-K*(X2-1)
30360    FNB=B1/B2
30361    FNEND
30362    PRINT'RESPECIFY PROJECT NAME YES OR NO'\INPUT A9$
30363    IF A9$ ='NO' THEN STOP
30365    PRINT'RESPECIFY PROJECT NAME FOR CORPORATE PROG REFERENCE'
30366    INPUT X$(1)
30370    X1$=LEFT$(X$(1),5)+'S.DAT'
30375    FILE £4,X1$
30380    SCRATCH £4
30385    WRITE £4,I0
99999    END
```

Appendix 6

Program Listings

CORPØ	Future Project Turnover
CORP2	Overall Company and Project Status

CORPORATE TURNOVER PROGRAM CORPØ

```
CORPO         12:00         15-OCT-82

100 MARGIN 132
200      DIM A(500,9),A1(12,400),P$(50),A2(400,9),D(300),D1(300)
205      REM SET UP ARRAY WITH ZERO VALUES
210      FOR I=1TO12
220      FOR J=1TO400
230      A1(I,J)=0
240      NEXT J
250      NEXT I
302      REM PERIOD TO BE SET UP FOR ANALYSIS
305 PRINT 'INPUT PERIOD TO BE ANALYSED i.e. MONTH,YEAR;MONTH,YEAR'
310 INPUT W2,Y2,W3,Y3
400 PRINT'INPUT PROJECTS IN PROGRESS NAME(MAX FIVE CHARACTERS)TERMINATE WITH END'
450 I1=1\A(I,8)=0
500 INPUT X$
550 IF X$='END' GOTO 2260
555      REM BASE DATE FILES
560      X2$=LEFT$(X$,5)+'T.DAT'
570      FILE #1,X2$
580      RESTORE #1
585      REM READ BASE DATES
590      READ #1,W1,Y1
591      REM CALCULATION OF TIME PERIOD PARAMETERS (MONTHS)
592      R1=((W1+Y1*12)-80*12)
594      R3=((W3+Y3*12)-80*12)
597      REM COUNTERS
600 R=0\S1=0\P$(I1)=X$\I=1
650      REM ACCESS AND READ MAIN BUDGET COST FILE
700 X1$=LEFT$(X$,5)+'G.DAT'
1200 FILE #2,X1$
1300 RESTORE #2
1400      IF END #2, GOTO 1810
1500 READ #2,A(I,1),A(I,2),A(I,3),A(I,4),A(I,5),A(I,6),A(I,7)
1600 I=I+1
1700 R=R+1
1800 GOTO 1400
1810      FOR I=1TOR
1820 S1=0
1830      FOR J=1TO7
1840      A(I,8)=S1=S1+A(I,J)
1860      NEXT J
1870      NEXT I
1880 FOR I=1TOR
195 NEXT I
1900      REM PROCEDURE TO TRANSFER TO ARRAY A1(I,J)
1950      I=1
2210 FOR J=R1 TO R3
2220 LET A1(I1,J)=A(I,8)
2227      I=I+1
2230 NEXT J
2240 I1=I1+1
2250 GOTO 500
2260 PRINT
2262      R2=((W2+Y2*12)-(80*12))
2264      R4=((W3+Y3*12)-(80*12))
2265      REM RESET OUTPUT ANALYSIS PARAMETERS
2270 PRINT
2280 PRINT 'CORPORATE CONTROL REPORT'
```

```
/00 PRINT '-----------------------'
310 PRINT
2320 PRINT 'BUDGETED EXPENDITURE ON PROJECTS IN HAND'
2330 PRINT '---------------------------------------'
2340 PRINT
2350    REM CALC OF HEADING DATES PROCEDURE
2400 J = 1
2500 I = 1
2600 D1(I) = Y2
2700 D(J) = W2
2800 W2 = W2 + 1
2900 IF W2>12 GOTO 3300
3000 J=J+1
3050 I=I+1
3100 IF J>9 GOTO 3750
3200 GOTO 2600
3300 W2=1
3400 Y2=Y2+1
3500 J=J+1
3600 I=I+1
3700 GOTO 2600
3750    PRINT'                          CALENDER TIMESCALE MONTHS/YEARS'
3752    PRINT
3800    PRINT USING 3900,D(1),D1(1),D(2),D1(2),D(3),D1(3),D(4),D1(4),D(5),D1(5),D(6),D1(6),D(7),D1(7),D
3900    :PROJECT ##/##     ##/##     ##/##     ##/##     ##/##     ##/##     ##/##     ##/##     ##/##
3905    FOR X=1TO95
3910    PRINT'=';
3930    NEXT X
4000 PRINT
4050    I1=I1-1
4100    FOR N=1TOI1
4200    P=1
4250    REM PROCEDURE TO ENABLE OUTPUT BY PRINT USING STATEMENT
4300    FOR J=R2TOR4
4400    A2(N,P)=A1(N,J)
4500    P=P+1
4600    NEXT J
5000 PRINT USING 5100,P$(N),A2(N,1),A2(N,2),A2(N,3),A2(N,4),A2(N,5),A2(N,6),A2(N,7),A2(N,8),A2(N,9)
5100 :'LLLLL #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##
5150    NEXT N
5175    REM ADDITION OF ARRAY A2 PROCEDURE
5300 S9=0\I2=I1+1
5400 FOR M = 1 TO 9
5450 A2(I2,M)=0\S9=0
5500 FOR N= 1 TO I1
5600 A2(I2,M)=S9=S9+A2(N,M)
5700 NEXT N
5800 NEXT M
5900 PRINT
6000 FOR X = 1 TO 95
6100 PRINT '-';
6200 NEXT X
6300 PRINT USING 6400,A2(I2,1),A2(I2,2),A2(I2,3),A2(I2,4),A2(I2,5),A2(I2,6),A2(I2,7),A2(I2,8),A2(I2,9
6400 :        #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##  #####.##
6500 FOR X=1 TO 95
6600 PRINT '-';
6700 NEXT X
6800    PRINT
6900    PRINT
7000    PRINT'DO YOU WISH TO ANALYSE ANOTHER PERIOD (ANS YES OR NO)'\INPUT V$
7100    IF V$='YES' GOTO 100
99999 END
```

CORPORATE PROJECT STATUS (CORP2.BAS)

CORP2 11:52 15-OCT-82

```
10      MARGIN 132
100 DIM A(300,6),B(50,50),X$(50),N(300)
200 PRINT 'CORPORATE CONTROL MODULE 2'
300 PRINT '-------------------------'
400 PRINT
425 PRINT'INPUT CURRENT MONTH, YEAR(I.E. 3,80)'\INPUT W1,Y1
450 I = 1
500 N = 1\S=0
800 PRINT 'INPUT PROJECT NAME(MAX FIVE CHARACTERS)TERMINATE WITH END'
900 INPUT X$(I)
1000 IF X$(I) = 'END' GOTO 2200
1150     X1$=LEFT $(X$(I),5)+'C.DAT'
1160     X2$=LEFT $(X$(I),5)+'V.DAT'
1165     X3$=LEFT$(X$(I),5)+'S.DAT'
1170 FILE #1,X1$
1200 RESTORE #1
1300 READ #1,A(I,1),A(I,2),A(I,3),A(I,4),A(I,5),A(I,6)
1310     FILE #3,X3$
1320     RESTORE #3
1330     READ #3,A(I,4)
1400 FILE #2,X2$
1500 RESTORE #2
1600 IF END #2,GOTO 2000
1700 READ #2, B(I,N)
1800 N=N+1 \ N(I)=N
1900 GOTO 1600
2000 I=I+1
2100 GOTO 500
2200 I=I-1\I1=I+1
2300 FOR X=1 TO I
2400 A(I1,3)=S=S+A(X,3)
2500 NEXT X
2600 PRINT
2610     FOR X=1 TO 76
2620     PRINT'*';
2630     NEXT X
2635 PRINT
2700 PRINT 'MONTH ';W1
2800 PRINT 'YEAR 19';Y1
2850 PRINT
2900 PRINT 'PROJECT STATUS SUMMARY AND SHORTFALL/GAIN ANALYSIS TO DATE'
3000 PRINT '-----------------------------------------------------------'
3100 PRINT
3200 PRINT 'PROJECT  FINAL EST    % COMPL SHORTFALL/ PREDICTED  RESOURCES    RESOURCES'
3300 PRINT '         DESIGN COST  TO DATE GAIN ON F/C TOTAL     USED         REMAINING'
3400 PRINT '              $                    $      DURATION     $             $'
3500 FOR X= 1 TO 76
3600 PRINT '=';
3700 NEXT X
3800 PRINT
3900 FOR X=1 TO I
4000 PRINT USING 4100,X$(X),A(X,1),A(X,2),A(X,3),A(X,4),A(X,5),A(X,6)
4100 :'LLLLL  #######.##    ##.##  #######.##     ####     #######.##    #######.##
4200 NEXT X
4300 FOR X=1 TO 76
4400 PRINT '-';
4500 NEXT X
4600 PRINT
4650     PRINT
4700 PRINT 'OVERALL GAIN SHORTFALL ON CURRENT PROJECTS $';A(I1,3)
4800     PRINT'*******************************************************'
4900 PRINT
5000 FOR J= 1 TO I
5100 PRINT 'PROJECT ';X$(J)
5150     PRINT'**************'
5200 PRINT
5300 PRINT 'PROFITABILITY TREND ANALYSIS'
5400 PRINT '----------------------------'
5500 PRINT
5600     PRINT'MH NO  MONTHLY +/-'
5700 PRINT '-----------------'
5800 PRINT
5900 PRINT
6000 FOR N=1 TO N(J)
6100 PRINT USING 6200,N,B(J,N)
6200 :####  #######.##
6300 NEXT N
6400 NEXT J
6500 END
```

Appendix 7

Simulation Program Listings

SIMI.BAS

PREDI.BAS

'S' CURVE SIMULATOR SIM1.BAS

```
.TY SIM1.BAS
00050   DIM A(50)
00100   PRINT "DATA SIMULATOR"
00200   PRINT "=============="
00220 PRINT\PRINT"NON-CUMULATED COSTS/VALUATIONS"
00230 PRINT
00300   PRINT
00400   PRINT"INPUT NO. OF  PERIODS";\INPUT N
00410   PRINT
00420      FILE #1, "G.TMP"
00440   SCRATCH #1
00500   FOR X=1 TO N
00600    PRINT "PRD."X"INPUT VALUATION";\INPUT A(X)
00800   WRITE #1, A(X)
00900   NEXT X
01000 CHAIN "RAM1.BAS", 20
09999 END

.
```

PREDICTION TEST PROGRAM
PRED1.BAS

```
.TY PRED1.BAS
00100    PRINT"PROJECT TIME PREDICTION INPUT"
00200    PRINT"******************************"
00300    PRINT
00400    PRINT
00500    PRINT"INPUT ELAPSED  MONTHS  TO DATE"
00600    INPUT R
00700    PRINT"INPUT VALUATION TO DATE AND ANTICIPATED FINAL COST"
00800    INPUT A,B
00900    FILE #1,"P.TMP"
01000    SCRATCH #1
01100    WRITE #1,R,A,B
01150    CHAIN "RPRJ11.BAS",1005
01200    END
```

Appendix 8

Graphics Programs

GRF3.ALG

```
BEGIN
INTEGER C1;
REAL B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,YO,Y1,Y2,A;
REAL ARRAY A1,B1,PHI,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
P_100;C_1000;
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP:
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
R_0;
R_R/100;
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PHI=[B]");READ(PHI[J]);
WRITE("[C]A,K,B,G : FOR 1-K*EXP(-BX)-A*EXP(-GXX) [C]");
READ(A1[J],K1[J],B1[J],G1[J]);
G_G1[J];WRITE("[C] PEAK%= "); IF G=OTHEN WRITE("NONE ") ELSE PRINT(100/(2*G)^.5,3,2);
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.15,.15);
DSCALE(150,150,.5);
ORIGIN(0,25);
AMOVE(25,0);
ADRAW(25,140);
AMOVE(25,135);TEXT(" COST  ");
AMOVE(0,25);
ADRAW(140,25);
AMOVE(125,25);TEXT(" MONTHS 100% ");
AMOVE(5,125); ADRAW(130,125);
AMOVE(125,5); ADRAW(125,130);
AMOVE(0,0);
ORIGIN(25,25);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,105);
FOR J_0 UNTIL N DO
BEGIN
BEGIN
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PHI[J]; K_K1[J];
IF ENTIER(C)=C THEN C1_C ELSE C1_2;
IF A=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-25,110-J*10);
AMOVE(-25,105-J*10);
TNUM(A,1,2);
AMOVE(15,105-J*10);
TNUM(B,1,2);
AMOVE(35,105-J*10);
IF F=1 THEN GOTO CUB;
TNUM(G,1,1);
AMOVE(5,105-J*10);
TNUM(C,1,1);
AMOVE(15,105-J*10);CUB:
 IF G=OTHEN TNUM(100*(B+1)/3,3,1) ELSE TNUM(100/(1*G)^.5,3,1);
```

```
IF F=1 THEN GOTO SKP;
AMOVE(20,105-J*10);
TNUM(K1[J],1,2);
SKP:
AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.2*P UNTIL 1.2*P DO
BEGIN
IF I=0 THEN I_.01;
X_I/P;
IF F=1 THEN GOTO CB;
IF ABS(B*X)>80 OR ABS(G*X*X)>80 THEN GOTO OUT;
Y2_1-K*EXP(-B)-A*EXP(-G);
IF ABS(Y2)< 1&-5 THEN GOTO OUT;
Y1_1-K*EXP(-B*X)-A*EXP(-X*X*G);
IF ABS(Y1)> 1&5 THEN GOTO OUT;
Y_(Y1/Y2);
Y0_(1-K-A)/Y2;
IF ABS(C)<.3 THEN GOTO OUT:C_1/C;C1_1/C1;
Y0_0;
IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1-Y0;
IF Y>=0.0001  THEN Y:=Y^C-Y0;
GOTO XP;
CB:
Y_X*(1+A*(1-X)*(X-B));
Y_Y*(1+R)^I;
XP:
IF J>0 THEN DASH((J-1)*2+2,J*3);
ADRAW(X*100,Y*100);
OUT:
END;
END;
FINISH;
END;
```

GRFRD.ALG

```
BEGIN
INTEGER C1;
REAL B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,Y0,Y1,Y2,A;
REAL ARRAY A1,B1,PK,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
P_100;C_1000;
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC),2.(EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
R_0;
R_R/100;
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PEAK% [B]");READ(PK[J]);
A_PK[J]/100;
A1[J]_1;K1[J]_B1[J]_0:G1[J]_1/2/A/A;
PK[J]_1;
G_G1[J];WRITE("[C] PEAK%= "); IF G=OTHEN WRITE("NONE ") ELSE PRINT(100/(2*G)^.5,3,2);
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.15,.15);
DSCALE(250,250,1):
ORIGIN(10,20);
AMOVE(10,0);
ADRAW(10,140);
AMOVE(-20,135);TEXT("CUM.  COST 100% ");
AMOVE(0,10);
ADRAW(140,10);
AMOVE(110,10);TEXT(" MONTHS 100% ");
AMOVE(5,110); ADRAW(130,110);
AMOVE(110,5); ADRAW(110,130);
AMOVE(0,0);
ORIGIN(10,10);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,115);
IF F1[1]=1 THEN TEXT("ALPHA BETA (X )PEAK%") ELSE
TEXT("A     B     G     PK   PEAK%     INTCPT");
AMOVE(-20,113);
TEXT("                  P");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PK[J]; K_K1[J];
IF ENTIER(C)=C THEN C1_C ELSE C1_2;
IF A=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-35,110-J*10);
TEXT("(");TNUM(J,1,0);TEXT(")");
AMOVE(-25,115-J*10);
IF B=0 THEN GOTO RD;
TNUM(A,1,2);
AMOVE(15,115-J*10);
TNUM(B,1,2);
```

```
AMOVE(35,115-J*10);
IF F=1 THEN GOTO CUB;
RD:TEXT("EXP. PEAK%=");
TNUM(100/SQRT(2*G),3,1); GOTO SKP;
AMOVE(5,115-J*10);
TNUM(C,1,1);
AMOVE(15,115-J*10);CUB:
 IF G=0THEN TNUM(100*(B+1)/3,3,1) ELSE TNUM(100/(1*G)^.5,3,1);
IF F=1 THEN GOTO SKP;
AMOVE(20,105-J*10);
TNUM(K1[J],1,2);
STOP:
AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.3*P UNTIL 1.3*P DO
BEGIN
IF I=0 THEN I_.01;
X_I/P;
IF F=1 THEN GOTO CB;
IF ABS(B*X)>80 OR ABS(G*X*X)>80 THEN GOTO OUT;
Y2_1-K*EXP(-B)-A*EXP(-G);
IF ABS(Y2)< 1&-5 THEN GOTO OUT;
Y1_1-K*EXP(-B*X)-A*EXP(-X*X*G);
IF ABS(Y1)> 1&5 THEN GOTO OUT;
Y_(Y1/Y2);
Y0_(1-K-A)/Y2;
IF ABS(C)<.3 THEN GOTO OUT;C_1/C;C1_1/C1;
Y0_0;
IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1-Y0;
IF Y>=0.0001  THEN Y:=Y^C-Y0;
GOTO XP;
CB:
Y_X*(1+A*(1-X)*(X-B));
Y_Y*(1+R)^I;
XP:
IF J>0 THEN DASH(-(J-1)*2+2,J*3);
ADRAW(X*100,Y*100);
OUT:
END;
END;
FINISH;
END;
```

GRF2.ALG

```
BEGIN
INTEGER C1;
REAL YM,XM,B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,Y0,Y1,Y2,A;
STRING SC,VAL;
REAL ARRAY A1,B1,PHI,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
WRITE(" % SCALE ? TYPE IN "" ..."" [B]"); READ(SC);
P_XM_YM_100;
IF SC>="Y" THEN VAL_" %" ELSE VAL_"";
IF SC>="Y" THEN GOTO SCALE;
WRITE("[C] XMAX,YMAX ? [B]"); READ(XM,YM);
P_XM;
SCALE:
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PHI=[B]");READ(PHI[J]);
WRITE("[C]A,K,B,G : FOR 1-K*EXP(-BX)-A*EXP(-GXX) [C]");
READ(A1[J],K1[J],B1[J],G1[J]);
G_G1[J];WRITE("[C] PEAK%= "); IF G=0THEN WRITE("NONE ") ELSE PRINT(100/(2*G)^.5,3,2);
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.13,.13);
DSCALE(150,150,.5);
ORIGIN(0,25);
AMOVE(25,0);
ADRAW(25,140);
AMOVE(25,135);TEXT("COST ");
TNUM(YM,3,0);TEXT(VAL);
AMOVE(0,25);
ADRAW(140,25);
AMOVE(125,25);TEXT("MONTHS ");
TNUM(XM,3,0);TEXT(VAL);
AMOVE(5,125); ADRAW(130,125);
AMOVE(125,5); ADRAW(125,130);
AMOVE(0,0);
ORIGIN(25,25);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,105);
TEXT("A     B     G     PHI  PEAK%     INTCPT");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
IF J=0 THEN F_1;
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PHI[J]; K_K1[J];
IF ENTIER(C)=C THEN C1_C ELSE C1_2;
IF J=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-25,110-J*10);
IF F=1 THEN TEXT("CUBIC:") ELSE TEXT("EXPONENTIAL:");
AMOVE(-25,105-J*10);
```

```
TNUM(A,1,2);
AMOVE(-15,105-J*10);
TNUM(B,1,2);
AMOVE(-5,105-J*10);
TNUM(G,1,2);
AMOVE(5,105-J*10);
TNUM(C,1,2);
AMOVE(15,105-J*10);
 IF G=0THEN TEXT("NONE ") ELSE TNUM(100/(2*G)^.5,3,2);
AMOVE(20,105-J*10);
TNUM(K1[J],1,2);
SKP:
AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.2*P UNTIL 1.2*P DO
BEGIN
IF I=0 THEN I_.01;
X_I/P;
IF F=1 THEN GOTO CB;
IF ABS(B*X)>30 OR ABS(G*X*X)>30 THEN GOTO OUT;
IF VAL="" THEN Y2_1 ELSE Y2_1-K*EXP(-B)-A*EXP(-G);
IF ABS(Y2)< 1&-5 THEN GOTO OUT;
Y1_1-K*EXP(-B*X)-A*EXP(-X*X*G);
IF ABS(Y1)> 1&5 THEN GOTO OUT;
Y_(Y1/Y2);
IF ABS(C)<.3 THEN GOTO OUT;C_1/C;C1_1/C1;
IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1;
IF Y>=0.0001  THEN Y:=Y^C;
Y_YM*Y/100;
GOTO XP;
CB:
X_I/P;
Y_X*(1+A*(1-X)*(X-B));
XP:
IF J>0 THEN DASH((J-1)*2+1,J*3);
ADRAW(X*100,Y*100);
OUT:
END;
END;
FINISH;
END;
```

GRFSL.ALG

```
BEGIN
INTEGER C1;
REAL YM,XM,B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,Y0,Y1,Y2,A;
STRING SC,VAL;
REAL ARRAY A1,B1,PHI,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
SC_"Y";
P_XM_100;
YM_150;
IF SC>="Y" THEN VAL_" %" ELSE VAL_"";
IF SC>="Y" THEN GOTO SCALE;
WRITE("[C] XMAX,YMAX ? [B]"); READ(XM,YM);
P_XM;
SCALE:
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],G1[J]);
GOTO CND;EXP:
WRITE("[C] PEAK=[B]");READ(G1[J]);
A1[J]_B1[J]_0;
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.15,.15);
DSCALE(150,150,.5);
ORIGIN(0,25);
AMOVE(25,0);
ADRAW(25,140);
AMOVE(25,135);TEXT("COST% (y%) AND PERIOD COST (dy/dx) ");
TNUM(YM,3,0);TEXT(VAL);
AMOVE(0,25);
ADRAW(140,25);
AMOVE(125,25);TEXT("MONTHS ");
TNUM(XM,3,0);TEXT(VAL);
AMOVE(5,125); ADRAW(130,125);
AMOVE(125,5); ADRAW(125,130);
AMOVE(0,0);
ORIGIN(25,25);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,105);
TEXT("A     B      PEAK     ");
FOR J_1 UNTIL N DO
BEGIN
```

```
01360   BEGIN
01370   IF J=0 THEN F_1;
01375   B_B1[J];
01380   A_A1[J];
01382   F_F1[J];
01385   G_G1[J];
01387   IF F=1 THEN B_G*3-1;
01390   IF J=0 THEN GOTO SKP;
01395   COLOUR(J);
01397   AMOVE(-25,110-J*10);
01398   IF F=1 THEN TEXT("CUBIC:") ELSE TEXT("EXPONENTIAL:");
01400   AMOVE(-25,105-J*10);
01410   TNUM(A,1,2);
01420   AMOVE(-15,105-J*10);
01430   TNUM(B,1,2);
01440   AMOVE(-5,105-J*10);
01445   TNUM(G,1,2);
01468   SKP:
01470   AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
01480   END;
01500   FOR I:=-.2*P UNTIL 1.2*P DO
01600   BEGIN
01650   IF I=0 THEN I_.01;
01705   X_I/P;
01720   IF F=1 THEN GOTO CB;
01730   IF ABS(B*X)>80 OR ABS(G*X*X)>80 THEN GOTO OUT;
01734   IF VAL="" THEN Y2_1 ELSE Y2_1-EXP(-1/2/G/G);
01736   IF ABS(Y2)< 1&-5 THEN GOTO OUT;
01738   Y1_X/G/G*EXP(-X*X/G/G/2);
01740   IF ABS(Y1)> 1&5 THEN GOTO OUT;
01741   Y_(Y1/Y2);
01742   GOTO XP;
01743   IF ABS(C)<.3 THEN GOTO OUT;C_1/C;C1_1/C1;
01745   IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1;
01750   IF Y>=0.0001  THEN Y:=Y^C;
01790   CB:
01795   X_I/P;
01800   Y_1-3*A*X^2+6*A*G*X-A*(3*G-1);
01810   XP:
01850   IF J>0 THEN DASH((J-1)*2+1,J*3);
01900   ADRAW(X*100,Y*100/1.5);
01905   OUT:
02000   END;
02350   END;
09000   FINISH;
09100   END;
```

GRFRS.ALG

```
BEGIN
INTEGER C1;
REAL B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,Y0,Y1,Y2,A;
REAL ARRAY A1,B1,PK,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
P_100;C_1000;
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
R_0;
R_R/100;
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PEAK% [B]");READ(PK[J]);
A_PK[J]/100;
A1[J]_1;K1[J]_B1[J]_0;G1[J]_1/2/A/A;
PK[J]_1;
G_G1[J];WRITE("[C] PEAK%= "); IF G=OTHEN WRITE("NONE ") ELSE PRINT(100/(2*G)^.5,3,2);
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.15,.15);
DSCALE(250,250,1);
ORIGIN(10,20);
AMOVE(10,0);
ADRAW(10,140);
AMOVE(-20,135);TEXT("CUM.  COST 100% ");
AMOVE(0,10);
ADRAW(140,10);
AMOVE(110,10);TEXT(" MONTHS 100% ");
AMOVE(5,110); ADRAW(130,110);
AMOVE(110,5); ADRAW(110,130);
AMOVE(0,0);
ORIGIN(10,10);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,115);
IF F1[1]=1 THEN TEXT("ALPHA BETA (X )PEAK%") ELSE
TEXT("A     B     G     PK   PEAK%    INTCPT");
AMOVE(-20,113);
TEXT("                 P");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PK[J]; K_K1[J];
IF ENTIER(C)=C THEN C1_C ELSE C1_2;
IF A=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-35,110-J*10);
TEXT("(");TNUM(J,1,0);TEXT(")");
AMOVE(-25,115-J*10);
IF B=0 THEN GOTO RD;
TNUM(A,1,2);
AMOVE(15,115-J*10);
TNUM(B,1,2);
```

```
01440   AMOVE(35,115-J*10);
01443   IF F=1 THEN GOTO CUB;
01444   RD:TEXT("EXP. PEAK%=");
01445   TNUM(100/SQRT(2*G),3,1); GOTO SKP;
01450   AMOVE(5,115-J*10);
01455   TNUM(C,1,1);
01460   AMOVE(15,115-J*10);CUB:
01461    IF G=0THEN TNUM(100*(B+1)/3,3,1) ELSE TNUM(100/(1*G)^.5,3,1);
01462   IF F=1 THEN GOTO SKP;
01464   AMOVE(20,105-J*10);
01465   TNUM(K1[J],1,2);
01468   SKP:
01470   AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
01430   END;
01500   FOR I:=-.3*P UNTIL 1.3*P DO
01600   BEGIN
01650   IF I=0 THEN I_.01;
01700   X_I/P;
01720   IF F=1 THEN GOTO CB;
01730   IF ABS(B*X)>80 OR ABS(G*X*X)>80 THEN GOTO OUT;
01734   Y2_1-K*EXP(-B)-A*EXP(-G);
01736   IF ABS(Y2)< 1&-5 THEN GOTO OUT;
01738   Y1_1-K*EXP(-B*X)-A*EXP(-X*X*G);
01740   IF ABS(Y1)> 1&5 THEN GOTO OUT;
01741   Y_(Y1/Y2);
01742   Y0_(1-K-A)/Y2;
01743   IF ABS(C)<.3 THEN GOTO OUT;C_1/C;C1_1/C1;
01744   Y0_0;
01745   IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1-Y0;
01750   IF Y>=0.0001  THEN Y:=Y^C-Y0;
01770   GOTO XP;
01790   CB:
01800   Y_-3*A*X*X+2*(1+B)*A*X+1-A*B;
01805   Y_Y*(1+R)^I;
01810   XP:
01850   IF J>0 THEN DASH(-(J-1)*2+2,J*3);
01900   ADRAW(X*100,Y*100);
01905   OUT:
02000   END;
02350   END;
09000   FINISH;
09100   END;
```

```
!TEXT("A     B     G     PHI   PEAK");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
NEWLINE(2);
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PHI[J];
IF J=0 THEN GOTO SKP;
!COLOUR(J);
!AMOVE(-25,110-J*10);
IF F=1 THEN !TEXT("CUBIC:") ELSE !TEXT("EXPONENTIAL:");
!AMOVE(-25,105-J*10);
!TNUM(A,1,2);
!AMOVE(-15,105-J*10);
!TNUM(B,1,2);
!AMOVE(-5,105-J*10);
!TNUM(G,1,2);
!AMOVE(5,105-J*10);
!TNUM(C,1,2);
!AMOVE(15,105-J*10);
!TNUM(P1[J],1,2);
SKP:
!AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.2*P UNTIL 1.2*P DO
BEGIN
IF I=0 THEN I_.01;
X_I/P;
IF F=1 THEN GOTO CB;
C_1/C;
Y1_1-(1-A)*EXP(-B*X)-A*EXP(-X*X*G);
WRITE("[C]I[6S]     X[6S] Y1 [6S]     Y1^C[C]");SPACE(3); PRINT(I,2,1); SPACE(3); PRINT(X
 SPACE(3);PRINT(Y1); SPACE(3);PRINT(Y1^C);
Y1_Y1^C;
Y2_1-(1-A)*EXP(-B)-A*EXP(-G);
Y2_Y2^C;
Y_Y1/Y2;
GOTO XP;
CB:
Y_X*(1+A*(1-X)*(X-B));
XP:
IF J>0 THEN !DASH((J-1)*2+1,J*3);
!ADRAW(X*100,Y*100);
END;
END;
!FINISH;
END;
```

GRFTST.ALG

```
BEGIN
REAL X,Y,Y1,Y2,A,B,C,P,I,R,N,J,F,G;
REAL ARRAY A1,B1,PHI,G1,P1,F1[0:4];
!EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
!EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
P_C_100;
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PHI=[B]");READ(PHI[J]);
WRITE("[C]A,B,PEAK: FOR 1-(1-A)EXP(-BX)-A*EXP(-GXX) [C]");
READ(A1[J],B1[J],G);
G1[J]_1/2/G/G;WRITE("[C]G=");PRINT(G1[J],2,3);
P1[J]_G;CND:
END;
NEWLINE(2);
!START;
!COLOUR(1);
!TSIZE(.15,.15);
!DSCALE(150,150,1);
!ORIGIN(0,25);
!AMOVE(25,0);
!ADRAW(25,140);
!AMOVE(25,135);!TEXT("COST 100% ");
!AMOVE(0,25);
!ADRAW(140,25);
!AMOVE(125,25);!TEXT("MONTHS 100% ");
!AMOVE(5,125); !ADRAW(130,125);
!AMOVE(125,5); !ADRAW(125,130);
!AMOVE(0,0);
!ORIGIN(25,25);
F1[0]_1;A1[0]_B1[0]_0;
!AMOVE(-20,105);
```

GRF1.ALG

```
BEGIN
INTEGER C1;
REAL B,C,P,I,R,N,J,F,G;
REAL D,K,X,Y,Y0,Y1,Y2,A;
REAL ARRAY A1,B1,PHI,G1,P1,F1,K1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
P_100;C_1000;
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]1 (CUBIC) 2 (EXP) [B]"); READ(F1[J]);
IF F1[J]=2 THEN GOTO EXP;
WRITE("[C]A,PEAK [B]");READ(A1[J],P1[J]);
R_0;
R_R/100;
B1[J]:=3*P1[J]-1;
GOTO CND;EXP:
WRITE("[C] PHI=[B]");READ(PHI[J]);
WRITE("[C]A,K,B,G : FOR 1-K*EXP(-BX)-A*EXP(-GXX) [C]");
READ(A1[J],K1[J],B1[J],G1[J]);
G_G1[J];WRITE("[C] PEAK%= "); IF G=0THEN WRITE("NONE ") ELSE PRINT(100/(2*G)^.5,3,2);
CND:
END;
NEWLINE(2);
START;
COLOUR(1);
TSIZE(.15,.15);
DSCALE(300,300,1);
ORIGIN(0,10);
AMOVE(10,0);
ADRAW(10,140);
AMOVE(10,135);TEXT(" COST 100% ");
AMOVE(0,10);
ADRAW(140,10);
AMOVE(110,10);TEXT(" MONTHS 100% ");
AMOVE(5,110); ADRAW(130,110);
AMOVE(110,5); ADRAW(110,130);
AMOVE(0,0);
ORIGIN(10,10);
F1[0]_1;A1[0]_B1[0]_0;
AMOVE(-20,115);
IF F1[1]=1 THEN TEXT("ALPHA BETA (X )PEAK%") ELSE
TEXT("A    B    G     PHI  PEAK%    INTCPT");
AMOVE(-20,113);
TEXT("                  P");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
A_A1[J]; B_B1[J];F_F1[J];
G_G1[J]; C_PHI[J]; K_K1[J];
IF ENTIER(C)=C THEN C1_C ELSE C1_2;
IF A=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-35,110-J*10);
TEXT("(");TNUM(J,1,0);TEXT(")");
AMOVE(-25,115-J*10);
TNUM(A,1,2);
AMOVE(15,115-J*10);
TNUM(B,1,2);
AMOVE(35,115-J*10);
IF F=1 THEN GOTO CUB;
```

```
TNUM(G,1,1);
AMOVE(5,115-J*10);
TNUM(C,1,1);
AMOVE(15,115-J*10);CUB:
 IF G=0THEN TNUM(100*(B+1)/3,3,1) ELSE TNUM(100/(1*G)^.5,3,1);
IF F=1 THEN GOTO SKP;
AMOVE(20,105-J*10);
TNUM(K1[J],1,2);
SKP:
AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.2*P UNTIL 1.2*P DO
BEGIN
IF I=0 THEN I_.01;
X_I/P;
IF F=1 THEN GOTO CB;
IF ABS(B*X)>80 OR ABS(G*X*X)>80 THEN GOTO OUT;
Y2_1-K*EXP(-B)-A*EXP(-G);
IF ABS(Y2)< 1&-5 THEN GOTO OUT;
Y1_1-K*EXP(-B*X)-A*EXP(-X*X*G);
IF ABS(Y1)> 1&5 THEN GOTO OUT;
Y_(Y1/Y2);
Y0_(1-K-A)/Y2;
IF ABS(C)<.3 THEN GOTO OUT;C_1/C;C1_1/C1;
Y0_0;
IF Y<0.0001 AND C1*C1#1 THEN GOTO OUT ELSE Y:=Y^C1-Y0;
IF Y>=0.0001  THEN Y:=Y^C-Y0;
GOTO XP;
CB:
Y_X*(1+A*(1-X)*(X-B));
Y_Y*(1+R)^I;
XP:
IF J>0 THEN DASH((J-1)*2+2,J*3);
ADRAW(X*100,Y*100);
OUT:
END;
END;
FINISH;
END;
```

GRF.ALG

```
BEGIN
REAL Y1,X,Y,A,B,C,P,I,R,N,J;
REAL ARRAY A1,B1[0:4];
EXTERNAL PROCEDURE START,DSCALE,AMOVE,ADRAW,FINISH,ALPHA;
EXTERNAL PROCEDURE TNUM,ORIGIN,TSIZE,TEXT,DASH,COLOUR;
WRITE("XMAX,YMAX [B]");READ(P,C);
WRITE("[N]  NO. OF PLOTS (MAX 4) = [B] ");READ(N);
FOR J_1 UNTIL N DO
BEGIN
WRITE("[C]A,B [B]");READ(A1[J],B1[J]);
END;

NEWLINE(2);
START;
COLOUR(1);
TSIZE(.25,.25);
DSCALE(150,150,.5);
ORIGIN(0,25);
AMOVE(25,0);
ADRAW(25,140);
AMOVE(25,130);TEXT("COST");
TNUM(C,8,0);
AMOVE(0,25);
ADRAW(140,25);
AMOVE(125,25);TEXT("WEEKS");
TNUM(P,3,0);
AMOVE(5,125); ADRAW(130,125);
AMOVE(125,5); ADRAW(125,130);
AMOVE(0,0);
ORIGIN(25,25);
A1[0]_B1[0]_0;
AMOVE(-20,105);
TEXT("A    B");
FOR J_0 UNTIL N DO
BEGIN
BEGIN
A_A1[J]; B_B1[J];
IF A=0 THEN GOTO SKP;
COLOUR(J);
AMOVE(-25,105-J*10);
TNUM(A,1,2);
AMOVE(-10,105-J*10);
TNUM(B,1,2);
SKP:
AMOVE(-20,-20*(1+1.2*A*(-.2-B)));
END;
FOR I:=-.2*P UNTIL 1.2*P DO
BEGIN
IF I<=5 THEN X:=6 ELSE X:=I;
Y:=(1-EXP(-A^2/X^2/2));
Y1:=(1-EXP(-B^2/X^2/2));
IF Y1<1&-20THEN GOTO OUT;
Y_Y/Y1;
IF J>0 THEN DASH((J-1)*2+1,J*3);
X_X/100;Y_Y/100;
ADRAW(X*100,Y*100);
OUT:
END;
END;
FINISH;
END;
```

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