MANAGEMENT OF LARGE CAPITAL PROJECTS

by

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ABSTRACT

The value of an investment project is a function of the magnitude and the distribution over time of the current capital outlay and future cash benefits pertaining to the project. Three basic problems must be resolved in capital budgeting and decision-making during project implementation: 1) It is difficult to estimate capital costs and cash benefits. 2) The realization of future benefits is uncertain. 3) Future benefits must be compared with current capital costs.

Generally, risk and uncertainty associated with an investment project are given implicit consideration by basing decisions on the most likely single-valued estimates of capital cost and cash flow. However, recent developments in investment management techniques enable risk and uncertainty to be given explicit consideration by assignment of a priori probability distributions to capital cost and cash flow estimates. These methods are enabled by the introduction of Monte Carlo computer simulation.

The problem of comparing current capital costs with future benefits can be resolved by discounted cash flow (dcf) or net present value (npv) analysis. Both methods enable the distribution over time of the cash flow to be explicitly taken into account. The minimum acceptable yield for a project is dependent upon the firm's cost of capital. The decision to undertake a project included in the set of viable projects available to the firm is constrained by the availability of resources, particularly financial and managerial resources.

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A normative model of a large industrial capital project can be divided into seven reasonably distinct phases: 1) Idea Generation, 2) Preliminary Analysis, 3) Comprehensive Feasibility Study, 4) Project Development, 5) Project Implementation, 6) Start-Up, and 7) Post-Completion Audit. A decision to proceed with a project is generally made at the completion of the feasibility study phase; however, the decision can reasonably be reviewed and revoked at the completion of the project development phase. Beyond this point the implementation process is essentially irreversible, as cash outlays accelerate for fixed and intangible assets which have little or no salvage value.

To ensure optimization of the project's value to the firm, a competent and sufficient management team must be provided to direct the implementation. For a large single undertaking, definable in terms of a specific end result which is unique, complex and involves a high degree of interdependence of task accomplishment, a project or task force organization is invariably utilized. The uniqueness, frequency, and critical importance of project decision-points demand a high degree of senior executive attention and control.

Modern network methods (PERT/CPM) enable the separation of the planning and scheduling functions and aid in the establishment of an efficient, coordinated work flow. Network diagrams provide an explicit means of considering dependencies between events, even for large projects which include several thousand or more significant activities. Network analysis enables critical activities to be distinguished from non-critical activities, and thus project durations can be controlled or minimized by application of resources to specific key areas. Established computer routines are available to systematically 'crash' projects and to aid in

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schedule formulation which facilitates stabilization of resource input levels.

A case study of a hypothetical industrial project is used to illustrate the comprehensive feasibility study, project development, and project implementation phases. Although confidential requirements prevented the use of a specific project, the case is realistic in that the data base was synthesized from several actual projects of corresponding

Examination of the methodology of capital project management on an overall basis indicates that the integrated systems concept approach is required for maximum efficiency of resource utilization. The future

scope

will undoubtedly see rationalization of the fragmented approach to problems in economics, finance, engineering and administration; as well as more widespread application of modern techniques in data processing, management science and information system design.

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CHAPTER I

INTRODUCTION

The title <u>Management of Large Capital Projects</u> has a number of significantly different connotations. We will consider large capital projects to be investments in industrial plants. In the western world, such plants are almost invariably owned and operated by private enterprise, and the prime function of the plant is to earn a profit for the owner, whether he be a private individual or a diverse collection of common stockholders. Construction of a new plant or purchase of an existing plant is an investment to a business man, in that a current outlay of funds is made to provide a future stream of benefits. To an economist, only the construction of a new plant adds to the nation's stock of capital, and hence qualifies as an investment - the foregoing of present consumption in order to enable greater consumption in the future. In this thesis, the aspect of investment which will be examined in some detail is the process by which industrial plants are conceived and born.

Scope of Management

The management scope for capital projects is broad. The major portion of the literature surveyed focuses on the analysis of investment proposals and the capital budgeting process by which management allocates it's scarce funds. The generation of investment proposals, the planning and control of construction and the start-up of the new plants are treated less extensively

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in business literature. Only occasionally in the literature consulted is an attempt made to treat capital project management on an integrated systems concept basis.

Technical competence in the diverse disciplines of economics, finance, law, engineering, and administration and management is required for various facets of the implementation of a capital project. As is typical in modern complex business situations, successful execution is contingent on a high degree of integration and coordination to prevent sub-optimization. The difficulty in efficiently managing large undertakings and groups of professionals is recognized. Gaddis writes that we must optimize management knowledge in order to transform management from an art to a profession. It is necessary to organize more effectively for massive engineering.¹

Preview

The investment environment and principals of financial analyses are examined very briefly in Chapter II. This section is not intended as a brief treatment of these crucial aspects of investment, but rather it is included to establish the terms of reference under which a large capital project is implemented. Rational decision-making for the planning and control of a capital project is contingent on a basic understanding of investment goals and the investment environment. Cost/time/value² are the variables which determine the benefit of an investment project to the firm. The investment models developed in Chapter II provide a basis for capital project management.

¹P. O. Caddis, "The Age of Massive Engineering", <u>Harvard Business</u> <u>Review</u>, (January - February, 1961), pp. 138 - 145.

²The cost/time/value skeleton is used by John W. Hackney in <u>Management</u> and <u>Control of Capital Projects</u>, (New York: John Wiley and Sons, 1965), one of the few books which considers management of capital projects on an integrated systems concept basis.

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The project birth process is examined in Chapter III. This thesis is primarily concerned with the construction of large multi-million dollar plants in the chemical, pulp and paper, mining or similar process industries, where large plant construction is a relatively common occurrence, but where each project presents varied and unique problems. There is, of course, much common ground with projects undertaken by utility companies where large-scale construction may be almost continuous; with projects carried out by government or agencies where the profit motive is absent; and with large building or civil engineering projects which are comparable in magnitude, but which do not have complexities in planning and design attributable to complex production equipment. The descriptive model presented in Chapter III is normative. While it is unlikely that any specific project would follow the modus operandi presented, the model does illustrate the process and scope of a typical large industrial capital project from idea generation to start-up.

Scope and methodology of project management are examined in Chapter IV. The optimal organizational form and management method for accomplishing a specific, unique and complex task within established cost/time/value constraints differ from that applicable to normal corporate activity. The systems approach, where objectives take precedence over organizational form, is indicated. Predominance of professionals, time constraints and limited availability of personnel call for substitution of human resources management in lieu of traditional hierarchal methods.

Planning and scheduling of a project requires consideration of a large number of interdependent activities. Conventional Cantt bar chart arrays can be used. With traditional methods, however, it is difficult

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to take explicit account of dependencies and to establish the effects of deviations from established schedules as the project progresses. Network methods (PERT/CPM) are considered in Chapter V.

A case study of a hypothetical project is presented in Chapter VI to illustrate the project process. Although hypothetical, the case is realistic in that the data base was synthesized from several actual projects of corresponding scope. Confidential requirements prevented the use of a single project for the case study.

Methodology

Chapter II is based entirely on a survey of current books and periodical articles on investment analysis and the investment environment. The remaining chapters are based to a large extent on the writer's industrial experience in the implementation of engineering projects, supplemented by literature studies, particularly for the chapters on project management and network (PERT/CPM) methods. The data base for the case study includes project documentation from a number of pulp and paper industry projects on which Sandwell and Company Limited, Consultants, have been engaged since 1963.

CHAPTER II

INVESTMENT ENVIRONMENT AND ANALYSIS

Basic Problems

Three basic problems must be resolved to enable evaluation of a capital investment project:

- It is difficult to estimate the magnitude of future benefits and the capital cost of obtaining these benefits.
- 2. Benefits from an investment occur in the future; hence the realization of the benefits is uncertain, and the degree of uncertainty must be recognized.
- 3. The value of future benefits must be compared with required capital investment.¹

Expected future benefits are determined from estimates of future revenues and operating costs. Varied factors - total product demand, expected market share, selling price and so forth - must be considered when estimating future revenues. Revenue forecasts, whether based on relatively crude surveys of buyer or sales force opinion or more sophisticated time series or statistical demand analysis, are generally difficult to prepare. Operating costs are developed from analysis of the proposed manufacturing and marketing operations and on estimated costs of required inputs. Expected operating costs can typically be estimated with somewhat more confidence than expected revenues.

1G. David Quirin, The Capital Expenditure Decision (Homewood, Illinois: Richard D. Irwin, 1967), p. 3.

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It is generally less difficult to estimate capital costs than future benefits. Initial estimates for preliminary investment evaluation can often be derived from capital costs for existing plants of similar design published in industry or corporate literature. Final capital cost estimates based on reasonably complete basic engineering are generally expected to be accurate within 5 to 10 per cent.

The certainty of investment benefits is a function of the predictability of the input and output market environment, and of technological development. The major portion of investment required for large industrial plant projects is in fixed assets. Obsolescence of specialized equipment due to unforeseen developments can result in rapid erosion of expected benefits. In rapidly changing, yet highly capital-intensive industries, uncertainty due to dynamic change is particularly significant.

The third problem of equating future benefits with present cost can be resolved quite satisfactorily by the concept of present value discounting of future benefits or cash flows.

Assuming annual year-end compounding and a constant rate of interest, the present value of future benefits can be determined as follows:

$$E(PV) = \sum_{t=1}^{n} \frac{E(CB_t)}{(1+r)t} \qquad (t = 1, 2, 3 \dots n)$$

Where E(PV) is the Expected Present Value of Future Benefits, $E(CB_t)$ is the Expected Value of the Cash Benefit for Year t, and r is the Discount Rate.

The flow of funds in the firm is illustrated on Figure 1. Interest on debt and non-cash expenses, such as depreciation and depletion, are not deducted from profits when determining annual cash benefits or cash flow. The cash benefits realizable from an investment are not equivalent to the net earnings determined for financial reporting.

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Investment Analysis

Three basic methods for determining investment acceptability or ranking are in common usage:

1. Return on Investment

2. Payback Period

3. Discounted Cash Flow or Net Present Value

Return on investment is the ratio of the annual net or gross income to the total investment. If the magnitude of the annual income varies over time, a weighted average is used. In comparing return on investment calculations, it is imperative that the exact definitions of income and investment are known. An exhibit in a study by the National Industrial Conference Board illustrates how the calculated return on investment for a particular project could range from 16-2/3 per cent to 60 per cent, depending on the definitions used for income and investment.²

The rationale of the return on investment method is conceptually faulty, in that it does not take into account the timing of future benefits. Profit received in twenty years is given the same weighting as profit received in the next year.

The payback period is the length of time required to equate the future profits to the capital investment. This method has a distinct advantage over the return on investment method, in that it recognizes that profits received in the immediate future are more valuable than profits received at a later date. However, used alone, the payback method is deficient in assigning zero weight to profits received after the payback period. Two projects with equal payback periods would be given the

²Norman E. Pflomm, <u>Managing Capital Expenditures:</u> Studies in Business Policy, No. 107, National Industrial Conference Board (New York, 1963), p. 43.

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same ranking, even though the benefit stream of one project terminated at the end of the payback period, while the benefit stream of the other continued.

The payback period is, however, useful in assessing the relative risks of projects with comparable returns. Forecasts of revenues in the distant future are more susceptible to error than forecasts of those in the near future.³ The payback period is often used to aid in the assessment of risk, along with the return on investment or discounted cash-flow method of ranking.

The concept of present value, introduced on page 6, provides the basis for the discounted cash flow (dcf) and net present value (npv) methods of investment analysis. The discounted cash flow method involves finding the interest rate - commonly known as the internal rate of return by which the present value of the future benefits is made equal to the current investment.

In the net present value method, future benefits are discounted at a specific interest rate, and the present value of the future benefits is compared to the capital cost. Both the dcf and npv methods are conceptually correct, in recognizing the time distribution of the cash flow.

The internal rate of return must be determined by trial and error. For large projects, the time and expense for calculation is insignificant, and standard computer programs are available. Occasionally if negative cash flows are incurred in the latter stages of the project life, there may be multiple solutions for the internal rate of return. This is more an abstract problem than a practical one.¹ A modification of the

⁴For example, see P. S. Kirshenbaum, "A Resolution of the Multiple Rate of Return Paradox", <u>The Engineering Economist</u>, October - November, 1964. p. 11 - 16.

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³Ibid, p. 42.

discounted cash flow methods known as the MAPI system has been developed by the Machinery and Allied Products Institute. This system is intended primarily for analysis of equipment replacements, rather than for the evaluation of large projects.⁵

Application of dcf or npv analysis provides a reasonable and operational solution to the third problem of investment evaluation - the comparison of future benefits with present capital cost - but it does not provide a solution to the first two basic problems - the uncertainty of receiving future benefits and the difficulty in estimating the benefits and the capital cost. Operational techniques by which explicit account can be taken of uncertainty and risk are currently being used to a limited extent; and it is expected that in the not-too-distant future their use will be quite widespread, at least for large projects.

Trends in Investment Analysis

Uncertainty and risk can be treated in one of three ways:

- Decisions can be based on the most likely single-valued estimates of capital cost and cash flow. This is the basis on which the majority of capital expenditure decisions are made.
- 2. Decisions can be based on multivalued estimates for capital cost and cash flow associated with a priori, discrete or continuous probability distributions. In the discrete case, outcome possibilities can be calculated directly. With continuous distributions, Monte Carlo simulation techniques can be employed.

5Pflomm, op. cit., p. 47.

3. Decisions can be based on multivalued estimates of future outcome under circumstances where estimates of the probability of outcomes cannot be made with even remote confidence. Proposals in this sort fall into the category of 'speculations' rather than investments, and as such do not concern us here.⁶

For small investment projects, analysis based on single-valued estimates is probably the most practical, unless a sufficiently low-cost and easy-to-use computer program is available. Where more sophisticated analysis is warranted, models employing multivalued estimates are operational and are currently being utilized. A good example is a Monte Carlo simulation model being used by the Weyerhaeuser Company, which enables a probability distribution for the expected internal rate of return to be determined. Inputs for this model are assigned subjectively-determined beta distributions.⁷

David B. Hertz, a director of McKinsey and Co., reports that the results of simulation studies indicate the following:

- There is a wide gap in financial performance between some commonly-used investment policies and the best policies.
- Policies which take explicit account of risk consistently give better results than single-point determinate decision rules.

⁶Gerald W. Smith, <u>Engineering Economy: Analysis of Capital Expen-</u> ditures (Ames, Iowa: Iowa State University Press, 1968), p. 331.

⁷R. M. Curley, R. L. Schock and B. E. Wynne, "Simulation Applied to Project Risk Analysis", in <u>Operations Research and Design of Management</u> Information Systems, ed. by J. F. Pierce, Special Technical Association Publication No. 4, Technical Association of the Pulp and Paper Industry (New York, 1967), pp. 228 - 245.

- 3. Long-run financial results are highly dependent on the risk accepted for a given return or on the return achieved for a given level of risk.
- npv and dcf methods give better results than such commonly used methods as average annual return, which do not take into account the time value of money.⁸

Cost of Capital

The maximization of long-run wealth is generally accepted as the principal goal of the firm's stockholders. Equity funds will be provided to the firm by stockholders, who expect that the all-inclusive return will be as good or better than that of any alternate available to them. The all-inclusive return includes both dividends and capital gain or loss from later sale of stock. Retained earnings, which are in effect the present stockholders' funds, should be employed by the firm if they are worth more to the stockholders when used by the firm, than if handed over as cash to the stockholders.⁹

Borrowed funds should be used only to the extent that they do not detract from the market value of the stockholders' holdings.¹⁰ Under conditions of certainty, borrowed funds could be used to finance any asset which had a guaranteed return larger than the cost of borrowing. Under the real-world conditions of uncertainty, the use of borrowed funds

⁸David B. Hertz, "Investment Policies that Pay Off", <u>Harvard Business</u> Review, January - February 1968, p. 105.

10Ibid, p. 97

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⁹Quirin, op. cit., p. 97.

is optimized when the ratio of debt to equity is such that the value placed on the equity by stockholders is maximized. At this point the financial risk due to any greater use of debt would be considered excessive, and the leverage considered prudent would be fully exploited. While such an optimum debt - equity ratio is conceptually obtainable; in practice its determination is quite subjective, and it can only be approximated.

A specific asset or group of assets can be financed in some optimum manner to maximize the stockholders' equity. Similarly, given a particular financial structure, an optimum group of assets can be purchased to maximize the value of equity. The capital-budgeting or investmentdecision process is basically an attempt to achieve this latter maximization.

Helliwell defines the cost of capital as "the minimum return that will obtain its use".¹¹ Given a particular financial structure and the estimated minimum return required for each category in the structure, the weighted average cost can be estimated.

The cost of debt capital can be estimated quite readily. The cost is adjusted for the tax deductibility of interest.

 $K_d = (1 + T)R$

where K_d is Cost of Debt Capital, T is the Marginal Tax Rate, and R is the Rate of Interest - actual for an existing debt, or estimated for a potential debt.¹²

The cost of equity capital is dependent on a complex relationship between the earnings per share and dividend payout, and the manner in

11John F. Helliwell, Public Policies and Private Investment, (Oxford: Clarendon Press, 1968), p. 4.

¹²Quirin, op. cit., p. 100.

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which the market evaluates these earnings and dividends. A number of models have been developed for evaluation of market value of common stock, and hence the implicit cost of equity capital. Since no one of the models is theoretically pure or universally accepted, we shall assume that K_e - the Cost of Equity Capital - is subjectively determined, possibly with the aid of one of the valuation models. We shall also make the simplifying assumption that the cost of subscribed capital and retained earnings are equal.

Other forms of capital such as preferred stocks, convertible debentures, and so forth, which are intermediate between pure debt and pure equity, may be considered to have intermediate costs.

On this basis the cost of capital for a simple hypothetical firm may be estimated as follows:

	Portion of Capital	Estimated Cost	Weight	
Current Liabilities 7% Bonds 5% Preferred Capital Stock Retained Earnings	•20 •30 •05 •25 •20	- (150) .08 .18 .18	.010 .004 .045 .036	
Cost of Capital, 'K'	•		.095	

FIGURE 2

TYPICAL CALCULATION FOR COST OF CAPITAL

It must be recognized that the cost of capital calculated in this manner is quite subjective, and should be used as a guideline rather than as an absolute measure.

Firms which do attempt to determine their cost of capital set a minimum standard for capital projects which is greater than their estimated

cost of capital. This is in recognition of the fact that not all capital projects are expected to earn a profit, and that some will fail.¹³

A large new plant or expansion includes a certain portion of discretionary and required investment for services, safety requirements, pollution abatement, and so forth. Thus the minimum required return for a major new facility may be somewhat lower than for specific cost reduction, quality improvement, or small incremental projects. In the limiting case where a proposed investment project is to be the sole asset of a new company, the cost of capital is by definition the investment yield. In this case the cost of equity capital is the residual after determination of the expected return on the investment and the cost of debt financ-The minimum cost at which capital can be obtained will determine ing. whether a specific plant will be constructed by a new company. The decision to build a major new plant by an existing company will be governed by more complex factors; including the firm's existing cost of capital, the incremental cost of financing the new plant, and the longrange effect on the firm's cost of capital as a result of the incremental financing.

Industry Practice

Surveys of the investment-decision practices of Canadian industry, conducted during recent years, indicate that the level of sophistication is perhaps somewhat lower than might be expected. Nicholson and Ffolliot of the University of Western Ontario mailed questionnaires on capital

13Pflomm, op. cit., p. 41.

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expenditure evaluation procedures to approximately 300 Canadian firms, and received replies from approximately 100.¹⁴ In the order of 20 per cent of the respondents used the theoretically preferred discounted cash flow (dcf) method as a prime indicator of investment profitability, although use of dcf as a secondary measure increased the number who employed dcf to some extent to 42 per cent. Less than one-third had attempted to compute their cost of capital. In a significant number of cases, apparent inconsistencies, such as deduction of depreciation in payback or dcf calculations, were indicated.

Helliwell reports that approximately the same portion of Canadian firms employ dcf, but that its use appears to be increasing.¹⁵ Similar patterns are indicated by the findings of earlier studies conducted in the United States by Istvan¹⁶ and the National Industrial Conference Board.¹⁷

While accuracy of a mathematical nature is obviously not possible, sensitivity analysis and simulation permits explicit consideration of the effect on the rate of return due to variations of investment analysis

14J. T. Nicholson and J. D. Ffolliot, "Are Investment Practices Inadequate?", <u>The Business Quarterly of Western Ontario</u> (Winter, 1965), p. 83 - 93; and J. T. Nicholson and J. D. Ffolliott, "Investment Evaluation Criteria of Canadian Companies", <u>The Business Quarterly of Western Ontario</u>, (Summer, 1966), p. 54 - 62.

15Helliwell, op. cit., pp. 77, 79.

¹⁶Donald F. Istvan, Capital Expenditure Decisions: How They are <u>Made in Large Corporations</u>, (Bloomington: Bureau of Business Research, Indiana University, 1961).

17_{Pflomm}, op. cit.

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inputs. Considering the crucial nature of the investment decision, these modern techniques will undoubtedly become more widely used in evaluating large projects. Precision of measurement is not possible, but results can be checked for range and reliability.¹⁸ Currently, the dispersion of the net returns of projects is frequently considered by the use of range estimates, by the use of risk classes, or sometimes merely by the listing of events which would cause the cash flow from the project to be different from that estimated.¹⁹

A surprising practice of firms in evaluating investment proposals is to place considerably more emphasis on the accuracy of capital cost estimates than on estimates of future cash flow.²⁰ This apparent inconsistency probably stems from the fact that even though capital cost estimates are often crude, the capital outlays will at least be made in the immediate, and hence, more predictable future.

Investment Models for Project Analysis

and Management

In order to establish parameters for the analysis and management of capital investment projects, it is desirable to construct a model of the investment process. The present value concept permits future benefits to be compared with current capital costs. Two alternate models will be

18_{Nicholson} and Ffolliot, "Are Investment Practices Inadequate?", op. cit., p. 85.

19_{Helliwell}, op. cit., p. 68. 20_{Ibid}, p. 68. presented - one intended principally as a basis for the determination of the viability of investment projects, and the other principally as a basis for decision-making during project implementation. Both models are based on the assumption that the objective of an investment project is the maximization of long-term wealth.

The models will be based on the simplifying premise that all disbursements and receipts occur in a lump sum at the end of a year. The actual cash flows will, of course, have a wide range of frequency, uniformity and regularity. The year-end approximation is almost invariably used in economic analysis, as the accuracy of analysis inputs does not warrant more accurate timing. To maintain consistency with commonly-used evaluation methods, year-end compounding will be assumed.

Negative cash flows - capital expenditures - typically take place over a significant period for large projects of the class with which we are mainly concerned. It is common for the project implementation to take place over two, three or more years. When analyzing small investment proposals, such as equipment replacements or minor additions or modifications, it is generally assumed that investment occurs as a lump sum at the completion of the project implementation. For large projects, however, the time distribution of the capital expenditure should be taken into account in analysis.

The model intended primarily for investment analysis is illustrated as follows: where r is the Internal Rate of Return, K is the Estimated Cost of Capital, I_{t_c} is the Capital Expenditure made in Year t_c , and CB_t is the Cash Benefit in Year t.

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Where:

$$\sum_{t_c=1}^{n} I_{t_c} (1+r)^{t_c} - \sum_{t=1}^{m} \frac{CB_t}{(1+r)^t}$$

$$(t_c = 1, 2, 3 \dots n; and t = 1, 2, 3 \dots m)$$





INTERNAL RATE OF RETURN (dcf) MODEL

The above model must be solved by trial and error. Manual calculations are relatively simple and computer programs for solution are readily available, so this does not present a procedural problem. The measure of profitability which is produced - the internal rate of return - facilitates ranking of investments, and is analogous to commonly held concepts of investment yield. The model is based on the assumption that cash receipts are reinvested at a yield equal to the internal rate of return. This assumption generally does not present a problem when using the model to evaluate proposals, which are not mutually exclusive. However, a more realistic measure of reinvestment yield is desirable for decision-making during project implementation, where decisions must frequently be made between alternate ways of accomplishing the same objective (i.e. mutually exclusive opportunities).²¹ A simple illustration comparing the results of the dof and nov methods is included in Appendix C.

The present value of past or future disbursements or receipts is determined at a uniform point in time by compounding or discounting. The rate of return which a firm considers as the minimum acceptable for an investment project can be considered as the firm's opportunity cost. If this opportunity cost is used as the compounding or discount rate, the value of disbursements or receipts so calculated represents their present value to the firm.

²¹For determining project viability, the dcf method provides a measure of profitability which can be thought of as being compatible with a corporate goal of maximizing return on investment. When comparing mutually exclusive proposals, unrealistic results can be generated by using an unrealistic reinvestment rate; and hence, the present value method is preferred. The reinvestment assumption is the subject of conflicting discussion in capitalbudgeting literature. For a synopsis, see G. A. Pollack, "The Capital Budgeting Controversy: Present Value vs Discounted Cash Flow Method", selected reading included in Robert G. Murdick and Donald D. Deming, The Management of Capital Expenditures, (New York: McCraw-Hill, 1968), pp. 236 -248.

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Decision-making during project implementation frequently involves consideration of alternate cash flow distributions. The desirability of a particular distribution is a function of its net present value, determined by discounting at the firm's opportunity cost. The net present value model is illustrated as follows:

Where:

NPV is the Net Present Value, and \mathbf{r}_{0} is the firm's Opportunity

Cost.

Maximize: NPV = $\sum_{t_c=1}^{n} I_{t_c} (1+r_o)^{t_c} - \sum_{t=1}^{m} \frac{CB_t}{(1+r_o)^t}$

Subject to: $r_o \ge K$

FIGURE 4

NET PRESENT VALUE (npv) MODEL

CHAPTER III

PROJECT PHASES

A normative model of a large capital project from the initial idea to completion can be divided into seven reasonably distinct phases:

Idea Generation

- 2. Preliminary Analysis
- 3. Comprehensive Feasibility Study
- Project Development <u>L</u>.
- 5. Project Implementation
- 6. Start-Up

1.

7. Post-Completion Audit

The phases listed above are similar to those proposed by Magyar, illustrated on Figure 5. The Post-Completion Audit, a specific project activity, has been substituted for the more general operations phase. Except for the exploitation of natural resources with a limited life, such as mineral or petroleum deposits, or in the case where a reasonably well-defined product-life-cycle is anticipated, the abandonment phase included by Magyar is an unplanned activity arising out of the operating environment. Since the abandonment phase is not part of the project's planned progress, it is not included. The inevitability of operations being terminated must, however, be considered in the determination of

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COST	\$50 - \$508	ES, 007 - 850,098	\$38,088 - \$300,988	\$10,000 - \$50,060				\$10,000 - \$30,009
TIME	1 10 5 DATS	I TO 2 HONTHS	0 TO 12 MONTHS	4 TO 2 MONTHS	MONTRLY ROBTINE	RODTINE	ROUTENE	1 TO 2 NORTHS
· · ·			·SHORT & LORG TERM IMPLICATIONS					
			• RELATE TO SPONSOR'S ASSET BASE	- CONTRAST BITH OTHER OPPERTUNISIES FOR AVAILABLE FUNDS			•	
		ASSESS RISES	. PROJECT BATE OF RETURN	-RANK ITS INVESTMENT WORTH			•	
		RESEARCH & DEVELOPMENT	· SERSITIVITY ARALYSIS	OPERATING STATEMENTS & BALANGE SHEETS				
•		RATE OF RETURN	+ CASH FLOW ESTIMATES	ALIZRUATIVES				•
		-ROUGH ESTIMATES OF INVESTMENT, OFERATING COSTS REVENUES A	- PREPARE CONTRACTS	ASSESS FIRANCIAS	- JUSTIFICATIONS FOR CHANCES		* REED FOR CHANGES IN SCOPE	ABARDOUNEST
ECONOMIC EVALUATION		-PRELIMINARY FLOW SHEETS &	L-ULIAILED FLUW SHEEFS & ERGIBLEBING DESIGN FOR Specifications	MAAGENENT	A PRIOR ESTINATES • REVISED FORECASIS		· COMPARISONS WITH DEJECTIVES	+ ASSESS ALTERBATIVES + DEVELOP BUDGET & PLANS FOR
SCOPE OF	• QUALITATIVE REVIEW	·LITERATURE SEARCHES	- SPECIFY PROJECT LIFE	DEVELOP BUDGETS & PLANS FOR INFLEMENTATION, OFFENTION, MARKETING FONTROL	- CONPARISONS WITH OBJECTIVES	- WARKET RESEARCH	· DUGET REVIEWS	• EXTERNAL INFLUENCES
•	- TECHNICAL SOURDRESS	. DEFINE PROJECT SCOPE	· MARKET RESEARCH	BIDS FROM CONTRACTORS & SUFFLIERS	+ PROSRESS REPORTS	- COMPARISONS WITH OBJECTIVES IF PRIOR ESTIMATES	- OPERATIONS ANALYSIS	· SHORT & LONG TERM IMPLICATIONS
	- CHARTER RIGHTS	. DEFINE SPONSOR'S OBJECTIVES	•DEFINE SPONSOR'S EVALUATION CRITERIA.	PROBE EXTERNAL INFLUENCES	• ENTER CONTRACTS	. PROGRESS REPORTS	· PROGRESS REFORTS	· REASONS FOR ABANDONNERT
STAGE	EVALUATION	FEASIBILITY	COMPREHENSIVE FEASIBILITY & DESIGN	PLANNING B BUDGETING	CONSTRUCTION	STAR F - UP	OPERATIONS	ABANDONMENT
EVALUATION	l IDEA	2	3	4	5	6	7	8
NATURE OF CORSE THE DECISION NET	DER REJECT, OR PROCEEL IDEA WITH FURTHER STUDIE	REJECT, DE PROCEED WI S DETAILED STUDIES. PLANNING & DESIGN	TH REJECT ON ALLOW P TO COMPETE FO AVAILABLE CAPITA	IOJEGT DEFER, ON CAPITAL EXI	AUTHORIZE EROITURE		CONSI ABANDO	DER INPROVE, CONSI INERT REPLACE DR REW I ABARCON 1
	ANALYST	• •	· · ·					•
								U
LEVEL AND SEQUENCE OF KEY DECISIONS	MANAGER	,						
		/ -	EXECUTIVE E.		\			
	· · · · · · · · · · · · · · · · · · ·			J	DIRECTOR			
•		RECOMMEND	ED STAGE-WIS	E APPROACH	TO ECONOMIC	EVALUATION		

FIGURE 5

EXAMPLE OF PROJECT LIFE-CYCLE MODEL

Source: William B. Magyar, "Economic Evaluation of Engineering Projects", <u>The Engineering Economist</u>, (Winter 1968), p. 84.

project viability. The timing of abandonment on project worth becomes less significant, the greater the discount rate and the longer the operational life. At a discount rate of 10 per cent, a uniform stream of benefits of \$1 per annum to infinity is worth \$10; while a fifteen-year stream is worth \$7.60. At a discount rate of 20 per cent, the value of the uniform benefit stream is decreased to \$5 and \$4.70 for an infinite and a fifteen-year life, respectively.

Hackney describes phases in project conception similar to those listed above, and draws an apt analogy between engineering construction projects and the flight of a rocket.

Modern engineering projects are big, complicated and expensive. Things happen so fast there is little chance for second guessing ••• condition reporting instruments and control systems for capital ventures must be sensitive and responsive, they must indicate promptly and clearly any deviations from good performance and make it possible to take effective and timely action. Good control can substantially improve the chance of success. It can all but eliminate the possibility that a project will have to be destroyed in flight because of a malfunction.¹

The project process described in this chapter is a <u>normative model</u>. All steps may not always be carried out or required, and preferred methods may not always be used. For example, if the firm is very fortunate, the profit potential indicated by the preliminary-analysis stage may be so large that a comprehensive feasibility study will be skipped, and the firm will proceed directly to the project development stage.

Idea Generation

The activities in this stage are more diverse and less amenable to definition than the activities of the other stages. The history and

1Hackney, op. cit., p. 4.

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organizational structure of the owner or promoter will determine when and how ideas for projects are germinated. Some projects such as new plants or expansions to serve growing markets, or projects developed to enable exploitation of company-controlled resources may be the result of systematic corporate planning activities. Research and development may provide the impetus for new product projects. The inspiration for other new products may be based on perceived customer needs.

Preliminary Analysis

The first step in evaluating an investment project is to perform sufficient analysis to determine if more detailed and comprehensive analysis in the form of a full-scale feasibility study is warranted.

Data which is available free or at little cost provides the bulk of the inputs for the preliminary analysis. Government and industry publications are consulted. Relevant firm and personal data and experience are incorporated.

It is due to the factors involved in this stage that there is a tendency for firms to concentrate in particular fields or areas. Since the outsider's investigation usually costs more and takes longer, the insider has an advantage both in cost and in speed of decision in those industries where changes in products or technology are frequent.² The possibility of using specialized consultants at this point may also be limited; as the scope of investigation is probably not yet well defined, and management may not yet be prepared to allocate specific funds for specific analysis.

²Helliwell, op. cit., p. 92.

A primary objective at this phase is to prepare preliminary estimates of revenue, operating costs and capital costs, to permit preliminary estimation of the internal rate of return. Preliminary investigation of major variables such as the product specifications, basic production process and key input and product market structure, is required.

Wherever possible, costs are based on readily available industry and firm data. Approximate estimating methods consistent with the accuracy of the data are employed. For example, plant capital costs may be lumpsum estimates derived from scaled costs of existing plants, after adjustment for inflation and varied conditions. Accuracy expected for estimates of this sort would generally not be better than ± 25 per cent.

Alternatives which are significantly different in major concept are considered at this stage. The emphasis, however, is on proving or disproving the viability of the basic idea, rather than on development of the idea.

If an acceptable return on investment is indicated by the preliminary investigations, the terms of reference must be defined, and the cost of a full-scale feasibility study estimated. The decision to proceed with a feasibility study for a major project may entail a considerable investment. Magyar indicates a cost of from \$50,000 to \$500,000 for a comprehensive feasibility study.³ The return on this investment will be zero if the feasibility study results are unfavourable. On the other hand, failure to undertake feasibility analysis and to proceed with good projects may be fatal to the firm's long-run future.

³William B. Magyar, "Economic Evaluation of Engineering Projects", The Engineering Economist, (Winter 1968), p. 78.

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Comprehensive Feasibility Study

At the beginning of the feasibility study phase a project begins to take on a definite form. It assumes a name, and gains the recognition of the firm's executives. Investigations are commenced under the terms of reference, which are formulated at the conclusion of the preliminary analysis. As comprehensive studies progress, the objectives and scope are periodically reviewed, and revised if required.

The focus of the feasibility study is the preparation of:

- 1. Revenue Forecasts
- 2. Operating Cost Forecasts
- 3. Capital Cost Estimates

The above data enables the estimation of the internal rate of return. It is assumed that dcf analysis would be used, and that the internal rate of return would be the key measure of project viability. If any of the other less-conceptually desirable measures of investment profitability were used, the scope and objectives of the feasibility study would not be significantly affected.

Formulation of a Monte Carlo model of the project facilitates explicit consideration of risk and uncertainty, and enables determination of the project's sensitivity to changes in key variables. A mathematical model also aids in the consideration of alternates and permits rapid updating.

<u>Revenue Forecasts.</u> The investigation and analysis required for the preparation of revenue forecasts varies considerably with the product. The output from large-scale process plants will very likely be sold in
relatively well-defined industrial or commercial markets. Since there are typically relatively few suppliers and purchasers in such markets, the reactions of competitors and customers to a new source of supply will have a significant effect on sales and prices. Thus while the methodology of preparing the sales forecast may be relatively simple and straightforward, considerable subjective judgment may be required in correctly evaluating data.

It is imperative that the sales forecast be as realistic as possible, as the production rate established from the sales forecast is the key to engineering analysis and estimation of plant and manufacturing costs. Due to time constraints, it is likely that preliminary plant process design will be based on sales estimates produced in the preliminary analysis phase. Revision may be required if the sales forecast is significantly altered as a result of more intensive investigation.

In many process industries, economic production cannot be achieved in plants of less than a certain minimum size. In such cases, the decision to proceed to even the feasibility study phase may hinge on the probability of a market of sufficient size to support the minimum economically-sized plant.

Alternate channels of distribution are considered, particularly if marketing costs are great or if marketing will be a key factor in the project's success. Estimated marketing costs will probably be determined in conjunction with the preparation of sales forecasts, or will be based on common industry ratios to sales.

Preliminary Plant Design. To enable estimation of plant capital and operating costs, preliminary basic design of the plant is required.

Preliminary flow diagrams and plant layouts, which take into account major components, are prepared. For existing products, good preliminary designs can be based on existing industry knowledge. For new products, extensive research and development, including pilot plant tests, may be required to formulate realistic preliminary designs. The emphasis at this stage is on preparation of good workable designs, rather than on refinements. Alternates are considered where major cost or operational differences are expected. The objective is to complete preliminary engineering for a good plant which will work, but not necessarily the best plant or the plant which will actually be constructed.

<u>Plant Capital Costs.</u> The purchase of major process equipment comprises the bulk of the capital cost for a process plant. For example, in the pulp and paper industry, purchase of mechanical and electrical equipment and materials typically represents 40 to 50 per cent of the total plant cost.⁴

The requirements for major process equipment are determined from the preliminary process flow diagrams. Purchase costs for these items are then estimated, based on preliminary quotations from suppliers or from historic cost data, adjusted as required. Occasionally more detailed and fundamental cost estimating may be required for major unique equipment. The cost of the major process equipment forms the basis for estimating costs of minor equipment, piping, electrical equipment and installation labour. Ratios of costs for these items to the cost of major process equipment are determined from analysis of historic costs for similar

⁴D. F. Williamson and I. C. Innes, "Site Evaluation and Selection", Journal of the Technical Association of the Pulp and Paper Industry, (April 1968), p. 57A.

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FIGURE 6

SYSTEM DIACRAM OF COST RELATIONSHIPS FOR PROCESS PLANTS

Source: J. W. Hackney, <u>Control and Management of Capital Projects</u>, (New York: John Wiley and Sons, 1965), p. 33.

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projects. A formal model for cost estimating in this manner is illustrated on Figure 6.

Site preparation and building costs may be estimated with sufficient accuracy based on the above ratio method, or approximate unit cost methods may be employed. Building costs are often based on typical costs per unit of area or volume. Costs for service and transportation facilities may be based on approximate unit costs and assumed designs.

Adjustments for current business conditions in the capital goods manufacturing industry, local construction labour productivity and costs, competitive climate in the construction industry, inflationary trend and so forth may significantly influence the total estimated cost. Hence, the quality of the capital cost estimate is very directly related to the quality of the technical personnel employed on the feasibility study. Rapidly changing economic environment may limit the period during which the capital costs are applicable. The accuracy of capital cost estimates for feasibility studies is typically expected to be in the order of \pm 15 per cent.

<u>Total Investment.</u> Pre-start-up expenses, such as for organizing and training the operating staff, marketing and promotional expenses, legal expenses and so forth are considered as capital costs when calculating the return on investment. Similarly, start-up expenses and workingcapital requirements are included. Although some of these items will be treated as expenses in company accounts, for financial analysis they should be considered as capital outlays, since they represent the purchase of a future stream of benefits. Deductability for tax purposes is considered, however, when estimating cash flow.

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<u>Operating Cost Forecasts.</u> Material, power and fuel balances are derived from the preliminary process flow diagrams. Raw material and energy costs may be determined from prevailing rates; or for key items tentative negotiations may be entered into with suppliers. Allowances for costs of miscellaneous operating supplies may be estimated on the basis of industry experience.

- Labour costs are based on estimated manning requirements; rates are based on industry and local conditions. It is necessary, of course, to allow for all required indirect as well as direct labour, and to provide for fringe benefits and supervision. Plant and head office administrative costs can be estimated on the basis of industry experience.

It is often desirable for operating costs to be tabulated or shown graphically to illustrate annual and per-unit costs at various production rates. This facilitates break-even analysis and consideration of changes in sales forecasts.

For consistency, revenue and operating cost forecasts, particularly for the early years of the project operation, should be comparable in accuracy to capital cost estimates. It is, however, not uncommon for considerably more emphasis to be placed on capital cost estimates than on cash flow estimates.⁵

Alternates. In the early stages of the feasibility study, it may be necessary to consider a large number of alternatives. For example, in the case of a \$15 million petroleum pipeline and refinery project, forty alternates were considered, twenty analyzed in detail, and two more

5Helliwell, op. cit., p. 93.

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subsequently added.⁶ To reduce computational effort, capital and operating cost estimates are built up in blocks, which may be utilized in a number of alternates. Mathematical modelling and computer calculations facilitates analysis of a large number of alternates. Those responsible for technical analysis weed out the obviously unsuitable cases, and make recommendations for the best alternatives; but the final decision on the best alternate rests with top management. Failure to consider all reasonable alternatives may result in an erroneous decision.⁷

<u>General Considerations.</u> While determination of the internal rate of return as the measure of project profitability is the prime objective of the comprehensive feasibility study; in a firm with existing operations, consideration must be given to the effect on the overall performance. The incremental cash flow of the project, both negative and positive portions, must be considered in conjunction with projections of the firm's overall flow of funds. The effect of the project on the overall company accounts may be evaluated by preparation of pro forma financial statements covering the years during the project's implementation and the initial years of operation. If heavy start-up expenses and incremental debt charges result in a significant short-term drop in the firm's reported earnings per share, it is likely that common stock market prices will be adversely affected.⁸ Even though the goal of the firm's owners - the shareholders - is generally assumed to be long-term rather than short-term

⁶Milton F. Usry, <u>Capital-Expenditure Planning and Control</u>, (Austin, Texas: Bureau of Business Research, The University of Texas, 1966), p. 187. 7Ibid, p. 185.

⁸For a discussion which presents the hypothesis that the optimum capital expenditure program should be based on maintaining a continuous growth in earnings, rather than simply wealth or long-run profit maximization, see E. M. Lerner and A. Rappaport, "Limit DCF in Capital Budgeting", <u>Harvard Business Review</u>, (September - October, 1968), p. 133 - 139.

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wealth maximization, management is likely to give some consideration to detrimental short-term effects.⁹

By the same token, management must consider the short-term effects on the firm's human resources due to heavy requirements for managerial and technical staff to implement and operate a large new project. Project go-ahead is as contingent on the availability of the required human resources as it is on the availability of financial resources. Consideration may be given to anticipated reactions of government, the general public, and the firm's major customers and suppliers. It is difficult to evaluate these factors quantitatively; nevertheless, they must be given some weight. In some cases, significant implications of this sort may not have been detected at the preliminary analysis stage, and may only be brought to light when the scope of the project is more accurately defined during the feasibility study.

Project engineering undertaken in the feasibility study stage includes the formulation of preliminary basic plans for the project design and construction activities, and the preparation of outline schedules showing the expected duration of major sections of the work.

<u>Summary.</u> The results of a comprehensive feasibility study are generally summarized in a report which would typically include the following:

- 1. Feasibility Study Objectives
- 2. Summary of Principal Environmental Factors
- 3. Description of Alternates Considered

9Helliwell, op. cit., p. 85.

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4. For Each Alternate Considered in Detail

- Revenue Forecast

- Operating Cost Forecast

- Capital Cost Estimates

- Internal Rate of Return Forecast

5. Description of Study Methodology and Data Sources

6. Discussion of Effect on Overall Operations of the Firm

7. Discussion on Unquantified and Intangible Considerations

8. Conclusions of Study

9. Recommendations for Management

Based on the findings of the feasibility study, the company management, probably at the executive committee or board of directors level, would then decide on whether or not to proceed to the project development phase. Although formal and final approval of the project may not be confirmed until the completion of the project development phase, the key decision-point is at the completion of the comprehensive feasibility study. At this point, the relevant key variables affecting the project's profitability and desirability to the company have been determined and analyzed, to the extent consistent with the available data and the objectives of the firm. If a decision made to proceed with a project is revoked at a later date, or if a project terminated at this point is later revived, it will likely be due to significant environmental or technological changes or revisions in the proposed method of financing the project.

Project Development

Work in this phase is usually undertaken on the assumption that the project will proceed, even though authorization to spend or commit funds may be limited to that required for the project development work. In specific instances, special authorizations may be made for purchase of land or key items of equipment with long delivery or critical supply, or sales contracts may be negotiated. However, such purchases or contracts are frequently made with provision for cancellation.

The objectives of this stage are to:

- 1. Complete basic engineering.
- 2. Develop comprehensive plans and schedules for detailed design, equipment purchasing, construction, staffing and initial plant operation and marketing.
- 3. Formulate detailed budgets for the project implementation and initial plant operation and marketing.
- 4. Obtain firm tenders for major equipment and contracts.
- 5. Finalize project financing.

During the carrying out of this work the conclusions, recommendations and decisions of the feasibility study will be periodically reviewed, particularly for the effects of any environmental changes or for the implications of any new data or analysis.

Engineering. Basic process engineering and plant layouts are completed, using as a starting-point the preliminary process flow diagrams and equipment layouts developed during the feasibility study phase. Alternate process methods and equipment arrangements are considered. Investigations of alternate sites and transportation and service facilities are concluded, and optimum choices made. The objective is to 'freeze', as far as possible, the basic plant design.

Specifications are prepared for major items of equipment, and enquiries are issued to prospective suppliers. Alternate structural systems and building materials are investigated, and best selections made. Plant electrical, instrumentation and service systems are analyzed and defined. Provision to be made for air and water pollution abatement are discussed with governing authorities, and approvals obtained.

On completion of analysis of alternates, the basic design is finalized. Preliminary requirements for minor equipment items such as pumps, compressors, heat exchanges, electrical controls and motors, instrumentation and so forth are determined. Basic site, equipment and building layouts are completed, and preliminary structural designs are made. Major piping and electrical service requirements, particularly between plant units, are determined. Minor piping and service requirements are determined later in the detailed design phase.

The basic engineering described above is used as a basis for preparation of a detailed construction budget. This budget, which is broken down by a detailed code of accounts, provides a detailed delineation of the project facilities, and forms the principal control document for cost control during plant construction.

Costs for major items of equipment are based on firm quotations. Costs for minor equipment and materials are based on historic cost records or estimated prices provided by suppliers. Building material requirements are determined from rough take-offs from preliminary designs. Building material unit costs are determined from cost records and discussions with experienced contractors. Labour costs are determined partially by fundamental

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estimating of time required, and partially from historic ratios to material costs or equipment weights. Minor piping and services costs are estimated, based on ratios to basic equipment costs.

In addition to the direct costs, allowances are made for indirect costs - construction plant and equipment, purchasing and expediting, supervision and management, and so forth. It is important that all cost estimates reflect current and applicable site conditions. Factors such as climate, local labour productivity, hours worked per week and job schedule may have significant bearing on cost.

An allowance for contingencies is provided. This is not intended to provide for a change in scope, but rather to provide for unforeseen requirements which arise during the detailed design stage.

The construction budget is generally expected to have a ± 10 per cent accuracy. The principal justification for preparation of a detailed construction budget is not for the improvement in accuracy over the estimates prepared in the feasibility study stage, but rather for its function as a source-control document. A detailed delineation of the plant equipment, along with estimates broken down by a detailed code of accounts, enables management to control the project scope and cost.

Basic planning and scheduling of design and construction activities is carried out in conjunction with the completion of the basic engineering and the preparation of the construction budget. The project completion date, as well as target dates for key milestones, are established. Modern network methods for planning and scheduling will be discussed in some detail in Chapter V.

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<u>Contract Negotiations.</u> Negotiation of major contracts for supply of raw materials, power and fuel, and for sale of production will be commenced during the project development stage. Successful negotiation of acceptable supply and sales contracts may be the key factor in determining if the project is to proceed. Considerable delays, attributable to the bargaining tactics of the participating parties, may be encountered. An example is a delay of over seven months attributable to a delayed letter of intent for purchase of plant output, encountered during the implementation of a relatively small \$2.43 million petrochemical plant project.¹⁰

As far as possible, contracts for supply of process equipment and plant construction will be negotiated during this phase. Initial negotiations may be based on preliminary specifications, with provision for revision when final engineering is complete.

Construction drawings, which will not be completed until detail design is well advanced, are required to enable lump-sum price tendering for structural and mechanical-electrical erection contracts. When construction schedules are tight, cost plus or unit price contracts may be negotiated before detailed design is completed.

<u>Operating Plans.</u> Dates for commencement of plant operations are generally determined by the length of time required to construct the physical facilities. It is necessary, however, to plan and schedule operating staff employment and training to coincide with plant construction. Similarly, the distribution and marketing operations must be analyzed,

10_{Usry}, op. cit., p. 139.

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planned and scheduled, to enable a well co-ordinated start-up and efficient initial operations.

<u>Financing</u>. Finalization of arrangements can now be made for outside financing if required, or in the firm's flow of funds budgeting to provide for the negative cash flows during the construction and start-up period. Estimates of quarterly funds requirements are generally prepared at this stage.

As with contracts for the supply of other resources, contracts for financing can be brought to the point where they are ready for approval and ratification by the firm's board of directors.

<u>Organization.</u> During the feasibility study phase, personnel required can be essentially confined to a relatively small group of technical analysts. With the commencement of the project development phase, participation is required from functional departments within the firm, and extensive use may be made of one or more groups of outside consultants or contractors. The co-ordination and decision-making functions involved require that the owner appoint a senior executive to act as the project manager at the commencement of the project development phase.

Point of No Return. Referring back to Hackney's rocket analogy, the project is now on the launching pad, the count-down is complete, and the 'fire' button is presented to the firm's board of directors. Considerable money has been spent to date - almost certainly a minimum of several hundred thousand dollars for a multi-million dollar project - but this is a sunk cost and has no influence on the decision to proceed. To proceed from this point, major firm commitments must be made for raw materials

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and other plant inputs, for costly process equipment, and possibly for delivery of a product.

Assuming that the key contracts discussed above have been essentially finalized and that the decision to proceed is given shortly after the completion of the project development phase, firm commitments for major expenditures would be entered into immediately after the decision is made to proceed. Since project viability is now a function of the cost to complete rather than of total investment, the point of no return is very quickly reached.

Project Implementation

The 'critical path' from the decision to proceed to plant start-up will almost certainly be comprised of detailed design, structural construction, and fabrication and erection of equipment activities. At the beginning of this phase the emphasis is on engineering design and equipment procurement, and as construction activities get rolling the emphasis shifts to field construction.

It is assumed that the project scope remains essentially as determined in the project development phase. If major changes of scope are authorized after the decision to proceed, a certain amount of back-tracking and redoing of project development engineering will be required.

In short order after authority to commit funds has been confirmed, contracts for major process equipment, which were negotiated in the project development phase, are finalized. Purchase of major equipment with critical¹¹ delivery or for which engineering information is immediately required is of prime importance.

Initial detailed engineering is focused on the preparation of drawings and specifications for structures and buildings, and for specialized custom equipment. Final completion of structural design is contingent on receipt of engineering data and drawings from equipment suppliers, and on completion of equipment layouts and design. To allow both design and construction work to proceed, assumptions on equipment layout and dimensions based on preliminary data and experience must often be made.

Specifications for auxiliary equipment such as pumps, compressors, heat exchangers, instrumentation, motors and electrical equipment are prepared as soon as possible after the finalization of major process equipment requirements. Purchase orders for this equipment must be placed promptly to obtain the required engineering data, and to ensure that the equipment is delivered to the field in accordance with the requirements of the construction schedule.

The detailed design phase is concluded with the finalization of drawings and specifications for piping, instrumentation, and electrical work.

As well as the technical aspects of design, project engineering includes planning and scheduling of construction. Responsibilities for various aspects of the work must be determined, and contracts negotiated for the execution of these sectors according to the schedules established.

¹¹Events or activities referred to as 'critical' include not only those items which would be on the critical path of a planning network (PERT/CPM), but also events or activities for which there is little slack or float.

A wide variety of organizational arrangements are used in implementing a project. At one polar extreme, the owner's staff may undertake all of the activities in detail. At the other extreme, the owner may contract with an integrated engineering-construction company to perform and be responsible for all aspects of design, as well as the construction and start-up of the plant on a turn-key basis. Between these two extremes there are a large number of possibilities. Consultants may be utilized for process design, detailed design, construction management, or start-up assistance. Segments of the plant may be purchased as complete packages from specialized contractors. A general contractor responsible for all aspects of construction may be engaged by the owner; or alternately specialized contractors may be employed for specific sections. The optimum arrangement is dependent on the nature of the plant, the resources of the owner, and the capability of available engineering and construction companies.

The characteristics of the major forms of contracts for engineering construction are illustrated on Figure 7.

Control of the three key elements of a major capital project is most critical during the design and construction phase. Successful execution hinges on good measurement and control of:

Capital Cost	-	How much is the project going to cost?
Time	-	How soon will it start earning money?
Value	-	What is the relationship between capital
		cost and future benefits? ¹²

12_{Hackney}, op. cit., p. 7.

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Contract Form; Project Definition (PD)	Primary Advantages	Primary Disadvantages	Typical Applications	Comments	
COST-PLUS PD: Minimal, (Scope of work does not have to be clearly defined.)	 Eliminates detailed scope- definition and proposal-prepa- ration time. Eliminates costly extra nerotiations if many changes 	 Client must exercise tight cost control over project expenditures. Project cost is usually not ootimized. 	1. Major revamping of exist- ing facilities. 2. Development projects where technology is not well defined.	Cost-plus contracts should be used only where client has suf- ficient engineering staff to supervise work.	
	are contemplated. 3. Allow's client complete flexibility to supervise design		 Confidential projects where minimum industry exposure is desired. 		
	and or construction.	· · ·	4. Projects where minimum time schedule is critical.		
COST-PLUS WITH GUARAN- TEED MAXIMUM	 Maximum price is estab- lished without preparation of detailed design drawings. 	1. Contractor has little in- centive to reduce cost. 2. Contractor's fee and con-	Where client desires fast time schedule with a guaranteed limit on maximum project cost.	••••••••••••••••	
preliminary layout drawings.	2. Client retains option to approve all major project decisions.	tingency is relatively higher than for other fixed-price con- tracts, because price is fixed			
literation of the state of the spectrum.	mum price remain with client.	 on pretiminary design data. 3. Chent must exercise tight cost control over project expenditures. 		y in the second seco	
•		· .		• •	
COST-PLUS WITH GUARAN- TEED MAXIMUM AND INCENTIVE PD: General specifications and preliminary layout drawings.	 Maximum price is estab- lished without preparation of detailed design drawings. Client retains option to approve all major project decisions. 	Contractor's fee and con- tingency is relatively higher than other fixed-price con- tracts, because price is fixed on preliminary design data.	Where client desires fast time schedule with a guaranteed limit on maximum cost, and assurance that the contractor will be motivated to try for cost savings.	Incentive may be provided to optimize - features other than capital cost - e.g., operating cost.	
	to improve performance since he shares in savings.	د			
COST-PLUS WITH GUARAN- TEED MAXIMUM AND PROVISION FOR ESCALATION PD: General specifications and preliminary layout drawings.	 Maximum price is established without preparation of detailed essign dravings. Chent retains option to approve all major project decisions. Protects contractor against inflationary periods. 	 Contractor has little in- centive to reduce cost. Contractor's fee and con- tingency is relatively higher than other fixed-price con- tracts, because price is fixed on preliminary design data. Chent must exercise tight cost control over project 	 Project involving financ- ing in semi-industrialized countries. Projects requiring long time schedules. 	 Escalation cost-reimburse- ment terms should be based on recognized industrial index. Escalation clause should be negotiated prior to contract signing. 	
	•	expenditures.			
BONUS PENALTY, TIME AND COMPLETION PD: Variable, depending on other aspects of contract.	1. Extreme pressure is ex- erted on contractor to complete project ahead of schedule. 2. Under carefully controlled conditions, will result an mini- mum design and construction time.	 Defining the cause for de- lays during project execution may involve considerable dis- cussion and disagreement be- tween client and contractor. Application of penalty under certain conditions may result in considerable loss to contractor. 	Usually applied to lump-sum contracts where completion of project is absolute necessity to client in order to fulfill customer commitments.	1. Project execution should be carefully documented to minimize disagreements on reasons for delay. 2. The power to apply pen- alties should not be used lightly; maximum penalty should not exceed total expected con- bactor profit.	
		pletion may result in lower quality of work.	•	•	
BONUS PENALTY, OPERA- TION AND PERFORMANCE PD: Variable, depending on other aspects of centract.	Directs contractor's peak per- formance toward area of par- ticular importance to client.	 Application of penalty under certain conditions may result in considerable loss to contractar. Difficult to obtain exact 	Where client desires maxi- mum production of a particular byproduct in a new process plant, to meet market require- ments.	Power to apply penalties should not be used lightly.	
· · ·	· · · · · · · · · · · · · · · · · · ·	operating conditions needed to verify performance guarantee.		•	
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FIGURE 7a

ALTERNATE FORMS OF CONSTRUCTION CONTRACTS

Source:

John T. Gallagher, "A Fresh Look at Engineering Construction. Contracts", Chemical Engineering, (September 11, 1967), p. 220. - 45 -

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 Contract Form; and Project Definition (PD) 	Primary Advantages	Primary Disadvantages	Typical Applications	Comments
LUMP SUM, RASED ON DEFINITIVE SPECIFICATIONS PD: General specifications, de- sign, drawings and layout – all complete.	 Usualty results in maximum construction efficiency. Detailed project definition assures client of desired quality. 	 Separate design and construction contracts increase over-all project schedule. Noncompetitive design may result in use of over-conserva- tive design basis. Responsibility is divided between designer and con- structor. 	Where client solicits con- struction bids on a distinctive building designed by an archi- tectural firm, or where a federal government bireau solicits con- struction bids on project de- signed by an outside fum.	Clients are cautioned again use of this type of contract project is not well defined.
				••••••
LUMP SUM, BASED ON PRELIMINARY SPECIFICATIONS PD: Complete general specifi- cations, preliminary layout, and well-defined-design;	1. Competitive engineering design often results in cost re- ducing features. 2. Reduces over-all project time by overlapping design and construction 3. Single-party responsibility.	 Contractor's proposal cost is high. Fixed price is based on preliminary drawings. Contract and proposal re- quire careful and lengthy client review. 	 Turnkey contract to design and construct fertilizer plant. Turnkey contract to design and construct foreign power- generation plant. 	 Bids should be solicite only from contractors exper- enced in particular field. Client should review pro- ect team proposed by contracto
· · · · · · · ·	execution. 4. Allows contractor to in- crease profit by superior per- formance			·
	Iomance.			· · · · · ·
UNIT PRICE CONTRACTS, FLAT RATE PD: Scope of work well defined qualitatively, with approximate quantity known.	 Construction work can com- mence without knowing exact quantities involved. Reimbursement terms are clearly defined. 	 Large quantity-estimate er-, rors may result in client's pay- ing unnecessarily high unit costs or contract extra. Extensive client field su- pervision is required to measure installed quantities. 	 Gas-transmission piping project. Highway building. Insulation work in process plants. 	Contractor should define the methods of field measureme before the contract is awarde
•	•			•
UNIT-PRICE CONTRACTS, SLIDING RATE PD: Scope of work well defined qualitatively,	 Construction work can com- mence without knowing quantity requirements. Reimbursement terms are clearly defined. 	Extensive client field super- vision is required to measure in- stalled quantities.	 Gas transmission piping project. Highway building. Insulation work in process plants. 	Contractor should clearly d fine the methods of field mea urement before the contract awarded.
				•
CONVERTIBLE CONTRACTS PD: Variable: depands on type of contract conversion.	 Design work can commence without delay of soliciting com- petitive bids. Construction price is fixed at time of contract conversion, when project is reasonably well-defined. Over-all design and con- struction schedule is minimum, 	 Design may not be optimum. Difficult to obtain compati- tive bids, since other contractors are reluctant to bid against con- tractor who performed design work. 	1. Where client has confiden- tial project requiring a balance of minimum project-time with reasonable cost. 2. Where client selects partic- ular contractor based on superior past performance.	Contractors selected on the basis should be well known client.
	with reasonable cost.			
TIME AND MATERIALS PD: General scope of project.	1. Client may exercise close control over contractor's execu- tion methods. 2. Contractor is assured rea- sonable profit. 3. Reinbursement terms are	 Project cost may not be minimized. Extensive client supervi- sion is required. 	Management engineering serv- ices supplied by consulting en- gineering firm.	Eliminates lengtay sco definition and proposal-prepa tion time.
	clearly defined.	• • • • • • • • • • • • • • • • • • •		· · · · · · · · · · · · · · · · · · ·
	· .			
• •				
		FIGURE 7b		
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Contracts", <u>Chemical Engineering</u>, (September 11, 1967), p. 221.

The standard for measurement of each of these three elements is established during the project development phase. Capital cost and value of the project are determined by the basic plant design. The optimum plant design minimizes capital cost and maximizes present value of future benefits. The composition of the plant and the estimated cost of the plant are defined by the construction budget. The project control system is based on the assumption that the plant defined by the construction budget is optimal.

If the control system functions properly, deviations from the construction budget are permitted only if it is shown that the value of the plant can in fact be increased as a result of the deviation. In many cases the determination of value is quite subjective. Since in general deviations from the budget will tend to disrupt and delay design and construction, changes should be limited to those cases where increased value is definitely indicated by objective analysis.¹³

The construction budget is a source-control document for control of design. Both design costs and plant scope are constrained by limiting design to the basic design established in the project development phase, unless approval for a change is obtained from project management. Design costs are also controlled by comparison to an engineering cost budget, also established during the project development phase.¹⁴

¹⁴For a discussion on control of engineering costs, see A. L. Spaet, "Controlling Engineering Costs", <u>Consulting Engineer</u>, (August 1963), p. 110.

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¹³This system of instituting design constraints founded on an established baseline is used by the Apollo Spacecraft Project Office (ASPO) of the National Aeronautics and Space Administration (NASA) to control costs and schedules for the Apollo project. Deviations from approved plans require explicit review and approval by ASPO. A description of the "Configuration Management and Control" system used on the Apollo project is included in Richard M. Hodgetts, "An Interindustry Analysis of Certain Aspects of Project Management" (unpublished Ph.D. dissertation, Management Department, University of Oklahoma, University Microfilms, 1968).

Purchases of materials and equipment or finalization of contracts are reconciled with the construction budget. Special approvals should be required where items are not included in the defined scope of the project. Periodic reports are issued comparing expenditures plus estimates to complete with construction budget allocations. Estimates to complete are based on actual status, not on the balance remaining in the budget. J. H. Lutz notes, however, that cost reporting is not cost controlling.¹⁵ Where periodic cost reports indicate significant deviations from the budget, appropriate corrective action must be initiated. If overruns cannot be avoided, the implications on project value must be evaluated.

For construction work carried out under cost-plus or unit-cost arrangements rather than on a fixed price basis, it is essential that comprehensive up-to-date cost records be maintained, and that the work be closely controlled to ensure compliance with the scope defined by drawings and specifications. In essence, primary cost control on a cost-plus arrangement reverts back from the contractor to the owner, unless contracts include bonus incentives to the contractor for reducing costs.

Capital cost and value are also functions of the duration of design and construction activities. The value of the project varies inversely as the length of time over which negative cash flows take place.

During the project development phase, a detailed schedule establishing start and completion dates for major activities is prepared. Modern network (PERT/CPM) control methods are generally used for large complex projects.

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¹⁵J. H. Lutz, "Estimating Project Completion Costs", Chemical Engineering, (January 30, 1967), p. 164.

Very little of the design and construction process is reversible or slavageable. Hence, it is essential that status reporting and control procedures enable prompt and effective corrections of deviations from established standards.

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Start-Up

During the early stages of the project implementation phase, plant organization and manning are finalized. As the construction of the plant nears completion, the plant supervisory staff must be engaged and provision made for employing and training the operating and maintenance crews. In a company with existing operations, the nucleous for the operating organization is frequently obtained from existing plants. With new companies, key supervisory and operating staff must be enticed from firms with similar operations.

Formal training sessions for area supervisors, foremen and operators are generally required to establish sufficient familiarity and competance to enable a complex plant to be put safely into operation within an acceptable time period, and at an acceptable cost. Training sessions may be guided or conducted by the engineering personnel who were responsible for the plant process design. Comprehensive operating and maintenance manuals, prepared specifically for the new plant, are used as source material for training sessions.

As specific sections of the plant are completed they are accepted by the company, and the responsibility for these sections is assumed by the plant management. Operating personnel are often utilized to aid in the check-out and commissioning of equipment.

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Wherever practical, dry-run tests utilizing water and air are carried out before initial manufacturing operations. Additional technical staff from the contractors or other company plants is usually provided to assist the plant operating staff during the start-up. Normal mill maintenance staff is also frequently not of sufficient size to cope with start-up repairs and modifications, and must be augmented with outside crews. Particularly where new products are being produced or new process methods are being initiated, start-up problems may be extensive.

Finlayson and Gans cite planning as the key to a successful startup. Preparation of detailed schedules, thorough training of operators, and rigorous plant testing are recommended.¹⁶

Planning, scheduling and control of pre-start-up and start-up activities should be carried out in a manner consistent with those used for design and construction activities. Irrespective of their treatment for company account and taxation purposes, pre-start-up and start-up costs can be considered as part of the capital cost for profitability analysis and project management decisions. These activities have a significant effect on determining when negative cash flows cease and positive cash flows commence.

Post-Completion Audit

The post-completion audit is included in the project process because it arises directly out of the preceeding project activities, and because it can be planned and scheduled in advance. The studies on corporate

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¹⁶K. Finlayson and M. Gans, "Planning the Successful Start-Up", Chemical Engineering Progress, (December, 1967), pp. 33 - 39.

investment policies by Helliwell,¹⁷ Istvan,¹⁸ Nicholson and Ffolliot¹⁹ and Pflomm²⁰ indicate that while a significant number of firms do have established procedures for reviewing the results of investment decisions, the practice is by no means universal. It would seem irrational, however, to neglect to make an overall comprehensive review of such a unique and important corporate activity as a large investment project.

The purposes of the post-completion audit cited by the National Industrial Conference Board study are:

1. To verify the resulting savings or profit.

2. To reveal reasons for project failure.

3. To check on soundness of management's proposals.

4. To aid in assessing future capital expenditure proposals.²¹

An objective analysis of a new plant's performance in reference to the perceived environment and parameters on which the decision to undertake the project was based, may reveal flaws in the original analysis. The detection of errors in the analysis may not be of much help in improving the performance of the project in question, but it may prevent errors of a similar nature from being made in the future.

Analysis on a project basis may uncover specific areas where planned objectives are not being met.²² The failure in these areas may be due to

17_{Helliwell}, op. cit.

18_{Istvan}, op. cit.

19Nicholson and Ffolliot, "Are Investment Practices Inadequate?", op. cit.; and "Investment Criteria of Canadian Companies", op. cit.

²⁰Pflomm, op. cit. ²¹Ibid, p. 80. ²²Ibid, p. 81. sub-standard operating performance or to changes in environment. When changes in environment can be identified, it may be possible to improve profitability by revising operating plans and standards.

To facilitate comparison with expected project performance, the plant must achieve normal operating standards before the post-completion audit is taken. With a complex process plant, normal operations may not be attained for several months or more after start-up.

The post-completion audit completes the last of the project phases introduced at the beginning of this chapter.

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CHAPTER IV

PROJECT MANAGEMENT

As the project proceeds from the preliminary analysis phase into the comprehensive feasibility study phase, the rate of expenditure by the firm on the project begins to accelerate, and the impact of the project on the firm's future becomes ever more significant. Efficient use of resources applied to the project and optimization of the future benefit of the project to the firm are largely contingent on the direction given by the firm's top management.

Project objectives and constraints must be in accordance with the firm's long-term goals. In establishing the scope for feasibility analysis, management must ensure that objectives and constraints are adequately defined, but that definitions are not so restrictive that profitable opportunities will be overlooked or prematurely discarded. Recognition must be taken of the influence of the new project on the firm's existing operations. However, care must be taken to prevent reactions of affected interests from causing biased analysis.

The goals of a comprehensive feasibility study are to objectively analyze an investment opportunity, or a number of related alternate investment opportunities, to correlate the data forming the basis of the analysis into a form which can readily be perceived and reviewed by the firm's management, and to formulate conclusions and recommendations in a manner which will permit the firm's management to make objective decisions.

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Decision-making by those involved in the technical analysis is limited to determining what information will be directed to management, and how it will be presented. Technical analysis includes the elimination of obviously and clearly inferior and spurious alternates. Conclusions and recommendations are drawn to aid management decision-making.

Considering that the results of a major feasibility study may have a crucial influence on a firm's future, and that complex considerations involving existing operations and the long-term policy of the firm may directly and significantly influence the feasibility study scope and results, it is essential that a major feasibility study be closely directed and coordinated by a senior executive. A major feasibility study may cost several hundred thousand dollars. If the goals and constraints of the feasibility study are not compatible with the policy of the firm, the benefits derived from the study will be greatly reduced.

In some cases, outside consulting groups may be engaged to undertake specific sections of the feasibility study. Generally where outside groups are employed, particular attention is given to establishing their terms of reference. However, to ensure optimum advantage of the consultant's output, periodic reviews and appraisals should be carried out by senior executives of the firm. If several different groups of consultants are employed, their work must be coordinated.

At the end of the feasibility study stage, assuming that the decision is made to proceed with the project, the emphasis for senior management responsibility shifts from considerations pertaining to the firm's longterm future to the measurement and control of capital cost, time and value.

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Key decision points in the critical project development and implementation phases frequently bear extreme rewards and penalties, and once many major decisions are made they are irreversible. The firm must apply managerial resources which are consistent with the importance of project decisionmaking and control.

As the scope of work being carried out in relation to the project is enlarged, increasing contributions will be required from functional groups within the firm, and there will be increased requirements for employing outside consultants and contractors. Managerial control must be compatible with the organizational levels within the firm at which work is being carried out, and with the requirements to commit the firm to contractural agreements with outside parties.

Organization

To meet these managerial requirements for a major undertaking, the firm will almost invariably establish a project group. The control of cost, time and value for the project will be assigned to a special project group, rather than to functional departments. Hodgetts defines project management as ". . . the gathering of the best available talent to accomplish a specific and complex undertaking within time, cost and/or quality parameters, followed by disbanding of the team upon completion of the undertaking".¹ This organizational form is applicable under the following conditions:

1. The project is a large single undertaking, definable in terms of a specific end result.

1Hodgetts, op. cit., p. 7.

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- 2. The attainment of the specific end result can be easily recognized.
- 3. The project is somewhat unique, infrequent, and not familiar to functional management.
- 4. The implementation of the project is complex, involving a high degree of interdependence and detailed and specific task accomplishment.
- 5. The successful execution of the project is of critical importance to the company.²

The construction of a large multi-million dollar plant would essentially meet all of these conditions applicable to the project organizational form. Organization of tasks and personnel on a project basis is typical of consulting and construction companies which are continually engaged in this type of work.

The centralized control of a project organization enables more effective and faster decision-making. Functional groups tend to be concerned mainly with their related activities; they may frequently be overzealous in guarding their own perogatives within the project; and they lack the flexibility to change with rapidly changing project requirements.³ Project organization facilitates maintenance of an overall project perspective, and aids in the prevention of sub-optimization by participating functional groups.⁴

²John M. Stewart, "Making Project Management Work", <u>Business Horizons</u>, (Fall, 1965), pp. 56 - 57.

³C. J. Middleton, "How to Set Up a Project Organization", <u>Harvard</u> <u>Business Review</u>, (March - April, 1967), p. 75.

⁴David I. Cleland, "Why Project Management", <u>Business Horizons</u>, (Winter, 1964), p. 83.

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Projects are typically implemented under stringent time constraints. Thus, although key decisions bear major rewards or penalties, in general they must be made promptly and expeditiously. Delays can be tolerated only to the extent that they are likely to increase the value of the project. Participating groups and individuals working toward specific objectives at a predetermined pace to meet specific deadlines build up a momentum which can be destroyed by failure of project management to make prompt decisions.

Since a project is by nature somewhat unique, the problems which arise during its implementation will tend to be somewhat unique. The use of operational rules and procedures is limited in comparison to decisionmaking for more repetitive operations, and hence a relatively large number of 'decision points' will require management attention. Projecttype organization facilitates prompt and effective decision-making. The quality of the managerial resources assigned to project group determines if the decisions made are correct.

If preliminary analysis indicates that the likelihood of the project proceeding is very high, selection of the project manager and key project personnel at the start of the feasibility study stage will enable the earliest possible familiarization with environmental, inter-firm and technical parameters pertinent to the project. In the early stages, the project manager and some personnel may be utilized on a part-time basis for project duties. Alternatively, the formation of the project group may be delayed until the commencement of the project development phase. Although final approval of the project may not be formalized at the start of the project development phase, this work is generally carried out on the assumption that the project will proceed.

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To facilitate compatibility and coordination of all aspects of the implementation of the project, the project manager's scope should include responsibility for pre-start-up activities such as organization and training of operating and marketing personnel, as well as for design and construction of the physical facilities. Planning and scheduling of start-up activities must be closely coordinated with the final stages of construction and operator training. Division of responsibility for directing start-up activities between project and plant operating personnel will vary, depending on the organization of the firm and the personnel involved. At some point during the start-up phase, however, responsibility for the plant is shifted entirely to the functional operating group, and the project group is disbanded.

The above discussion is centered on the project organizational requirements of the plant owner. A number of essentially autonomous units, such as engineering consultants, equipment manufacturers and construction companies, will almost certainly provide essential contributions toward the implementation of a large project. In any one of these participating units the respective undertaking may be of sufficient magnitude and complexity to justify project status. Within the autonomous unit the project group's function is to fulfill the owner's requirements, subject to the constraints imposed by the unit's management and the contractural agreement between the owner and the autonomous unit. The project organization within an autonomous unit will be similar in scope and character to that of the owner, and this discussion is applicable to sub-projects, as well as to the overall project.

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Leadership

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Few major projects are ever successfully managed on a part-time basis.⁵ It is invariably desirable for the company to appoint a senior executive to act as the full-time project manager for a major undertaking. Middleton suggests that an executive who already has a high position of responsibility be selected, or that the chosen executive be placed in a senior position within the firm's organization; and that the project manager be assigned as important a sounding title as those of functional unit managers.⁶

The requirements for a certain position and level of the project manager within the organization are dictated to a large extent by the need to direct and coordinate the work of functional groups toward the project goals. In projects included in a survey conducted by Hodgetts, the project manager was within two echelons of the vice-presidential level in all cases.⁷ The firm's top management can prevent conflict by delineating the extent of the project manager's authority over the project, and by supporting him in his dealings with functional managers.⁸

The project manager's responsibility is to complete the project within the cost and time limitations established by the budget and the schedule. In general, the project manager will delegate by task, so that the subordinate managers within the firm's project group and within autonomous units will have essentially equivalent responsibility for sub-projects.⁹

⁵Stewart, op. cit., p. 60.

⁶Middleton, op. cit., p. 78.

7Hodgetts, op. cit., p. 105.

⁸Middleton, op. cit., p. 73.

⁹P. O. Gaddis, "The Project Manager", <u>Harvard Business Review</u> (May - June, 1959), p. 91.

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-Personnel within the project groups may formally report to supervisors who are not actively engaged on work pertaining to the project. The project manager, as well as supervisors of sub-projects, must somehow obtain the full support of these functional people who are responsible to someone else for pay raises, promotion, and other expected line superiorsubordinate relationships.¹⁰

To enable accomplishment of the specified tasks, project managers and supervisors must often rely on persuasive ability, maintenance of rapport with functional supervisors and staff, influence inherent with rank or technical standing, and informal bilateral agreements negotiated on an ad hoc basis.¹¹ The traditional vertical functional organization is combined with the horizontal project organization to form a matrix structure across such functions as engineering, production, marketing, procurement and accounting.

Within project groups, even where organizational structures are established along traditional superior-subordinate lines, work methods frequently differ markedly from the traditional authoritative model. Project management and engineering groups are composed principally of professionals and near-professionals. Project leadership must include explanations of the rational of the effort, as well as the more obvious functions of planning, organizing, directing and controlling.¹² Effective management in this environment calls for the abandonment of the traditional authoritative model in favour of a human resources model,¹³ where full participation is solicited in an effort to maximize individual contribution.

¹⁰Cleland, "Why Project Management", op. cit., p. 84.

11 Ibid, p. 84.

¹²D. I. Cleland, "Understanding Project Authority", <u>Business Horizons</u> (Spring 1967), p. 69.

13For an exposition on the Human Resources Model, see Raymond E. Miles, "Human Relations or Human Resources", <u>Harvard Business Review</u>, (July -August, 1965), pp. 148 - 163.

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The human resources approach is founded on the assumption that people, particularly professionals, are willing and able to contribute in excess of usual and traditional demands. The environment of a large capital project provides the ideal stage for the effective utilization of the human resources model. Miles establishes the suitability of this approach for project management in the following passage:

The human resources approach requires the manager to recognize, develop, and apply the full range of resources of his subordinates. One of the major problems with this approach is that it works. People develop and grow - they grow right out of their initial assignments. This problem tends to solve itself when a particular unit is faced with a large and challenging set of tasks to perform. The members simply grow into more demanding jobs with added challenge and added reward."¹⁴

The typically stringent time constraints and limited availability of trained and competent personnel for large capital projects virtually render effective project management contingent on the human resources approach.

The method of accomplishment for project tasks must accommodate time and cost constraints, and extensive interdependence between subgroups. Many specific tasks are critical to the success of the project, and are often unique and highly technically complex. Effective communications within the project group and between associated functional units is essential. In the project organization, elements of the hierarchal vertical chain exist, but prime emphasis is placed on horizontal and diagonal communications and work flow.¹⁵

14Raymond E. Miles, "The Affluent Organization", Harvard Business Review, (May - June 1966), p. 112.

15Cleland, "Understanding Project Authority", op. cit., p. 66.

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Particular leadership techniques are indicated for the project manager and supervisors to overcome 'authority-gaps', where personnel and functional groups are not directly and formally responsible to the project management; and to effectively operate in a professional environment, where communication and authority-flow is multi-directional rather than vertical. Investigation carried out by Hodgetts into project leadership techniques in the aerospace, construction and miscellaneous industries indicates that prime importance is placed on negotiation, personality and persuasive ability, competance and reciprocal favours. However, it was found that where projects were very large, the 'authority gap' was eliminated, and personnel and functional groups were made directly responsible to project management, to reduce the necessity for unwieldy and timeconsuming human relations methods.¹⁶

Successful project implementation is dependent upon effective leadership by the project manager, and by the supervisors of sub-projects. In the project environment, the optimal organizational and leadership model is fluid and multi-directional; dependent upon competance, participation, negotiation, persuasion and efficient communications, rather than on the hierarchy of traditional pyramidal organization. In consideration of the constraints imposed by the limited availability of human resources with respect both to quantity and quality, the ideal of project leadership is to develop a project team which can 'play over its head' during the relatively brief and finite project duration.

16R. M. Hodgetts, "Leadership Techniques in the Project Organization", Academy of Management Journal, (June 1963), pp. 211 - 219.

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Summary

A major capital project invariably has a significant influence on the future of a company. During the implementation of the project key decision points, which are essentially irreversible and which must be handled with dispatch, regularly require attention. To efficiently administer a major capital expenditure, a competent and sufficient project group under a capable project leader is a necessity. The organizational methods and leadership tactics required for project management are more flexible and complex than traditional arrangements.

CHAPTER V

PLANNING, SCHEDULING & CONTROL

The criterion in implementing a capital project is maximization of the project's benefit to the firm. Achievement of this maximization requires the control of cost, time and value. The foundation for control of any undertaking is the establishment of standards in the form of budgets, schedules and specifications, which are based on sound plans founded on comprehensive and objective analysis.

Initial planning is carried out during the feasibility study phase. This might be denoted as 'preplanning'. Based on preliminary market, engineering and economic analysis, preliminary flow diagrams and plant layouts which form a basic definition of the plant facilities are prepared. This preliminary plant specification establishes the framework for plant capital cost and future operating costs and revenues. The value of the project is also dependent on the timing of cash outflows for plant construction and of cash inflows resulting from profitable operations. Tentative schedules for both negative and positive cash flows are prepared during the feasibility study phase.

During the project development phase, firm and relatively detailed standards for control of cost, time and value are established. Schedules and basic plant specifications are reviewed and amplified during the detailed design and construction stages. However, the basic parameters

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are established as far as possible before intensive detailed work is commenced. This orderly development is, of course, contingent on there being no major changes in project scope once the project development phase is complete.

The composition of the plant is the prime determinate of capital cost. The major decisions governing basic plant design are made during the project development phase. In addition to production process requirements, design consideration must be given to flexibility, reliability and efficiency. A good deal of discretion and subjectivity are involved in designing for these latter three requirements. The key to control of capital cost is the control of basic plant design.¹ The construction budget, which was discussed in some detail in Chapter III, provides a comprehensive definition of the scope and composition of the plant and a detailed accounting of estimated capital cost. The principal opportunity for capital cost control is during the formulation of the construction budget. After the budget is finalized and approved, it becomes the standard for measurement and control of cost and value.

The major subject of this chapter is planning, scheduling, and control of the time factor of project implementation. Particular attention is focused on network-based systems (PERT/CPM) as an aid to project management.

Project Implementation Duration

The investment model introduced on page 19 indicated that a project's value could be increased by reducing the capital cost and/or the period

¹R. P. Sturgis, "For Big Savings - Control Costs While Defining Scope", Chemical Engineering, (August 16, 1967), pp. 188 - 190.

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over which project cash flows are negative. Capital costs can be broken down into two components - direct costs for labour and materials; and indirect costs for project management, construction facilities, and so forth. Both direct and indirect costs are influenced by the project duration.

Direct cost for materials - structural steel, cement, equipment, piping - generally does not vary according to the construction schedule, unless normal delivery time is inadequate and more prompt delivery entails greater cost. Direct cost of labour - engineers, draftsmen, equipment operators and welders - is essentially an inverse function of the time period over which the work is carried out. If ten days are required to erect one hundred tons of structural steel using a crew of ten men, it does not follow that the steel can be erected in five days by increasing the size of the crew to twenty men. Due to inefficiencies in working with the larger than optimum-sized crew, doubling the crew might only reduce the erection time from ten days to six days. This is based on the assumption that constraints of the job would not enable two ten-man crews to be utilized. If a man-day costs \$75, the labour cost for erecting the structural steel would be increased from \$75 per ton to \$90 per ton as a result of reducing the erection period from ten days to six days. In keeping with this concept of diminishing marginal productivity as the work duration is shortened, the plot of project direct-cost vs duration may be expected to be concave from above.

Indirect cost may generally be assumed to vary as the project duration on a linear basis. In many cases a specific indirect cost would be a step function of project duration; however, a linear approximation for total indirect costs is a reasonable simplification.

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The typical form of direct, indirect and total cost as functions of project duration is shown in Figure 8. Scheduling a project duration longer than the period at which total cost is minimized is irrational, as both duration and cost are greater than at the minimum point.





PROJECT COST AS A FUNCTION OF IMPLEMENTATION DURATION

 t_0 is the Implementation Time for minimum project cost. The minimum feasible duration, t_c , is called the 'Crash Time'. Beyond this point, the productivity of additional resources applied to the project is assumed to be negligible. The curves are based on the assumption that resources are utilized at normal efficiency. Any point which lies above the curves is feasible, but represents an inefficient utilization of resources.

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Conceptually, project capital cost can be expressed as a function. of the project duration and the investment model, revised to include optimization of the project duration.

Maximize: NPV =
$$\sum_{t=1}^{n} \frac{CB_t}{(1+r_0)^t} - \sum_{t_c=1}^{m} I_{t_c} (1+r_0)^{t_c}$$

 $(t = 1, 2, 3 \dots n)$ $(t_c = 1, 2, 3 \dots m)$

Where:
$$\sum_{t_c=1}^{m} I_{t_c} = f(Max t_c)$$
$$t_c = 1$$

Subject to:
$$r_o \ge K$$

Where NPV is Project Net Present Value, CB_t is the Cash Benefit in Year t, It_c is the Investment in Year t_c, r_o is the firm's Opportunity Cost, and K is the firm's Cost of Capital.

Meaningful estimation of a capital cost-duration function is contingent on essentially complete plans for plant construction. Formulation of planning to the required degree of detail is not possible until well into the detailed design stage. However, due to lead time required for major engineering and equipment fabrication activities, tentative completion dates for key events, including project completion, must be established early in the project development phase. Thus, optimization of project duration according to the above model is generally not practical.

Key completion dates can be established on the basis of judgment and experience. Alternatively, crude analysis could be carried out, based on rough estimations of capital cost at the extreme minimum cost and crash durations. If project profitability is high and incremental costs for expediting project completion are not excessive, it is feasible that the crash duration may be optimum.

The time required for field construction is generally the principal determinate of the total implementation duration of the project. The duration of field construction is difficult to estimate. Figure 9 is an example of a rough guide suitable for establishing key completion dates.

System Requirements

Control of the time factor of project implementation is accomplished by measuring the actual progress of the project against established schedules. Before schedules can be prepared, it is necessary to establish basic criteria for planning, and then to plan the project implementation. Hackney defines planning and scheduling as follows:

Planning is the determination of the individual operations or activities which must be performed in order to carry out a project, and the establishment of the sequential and dependency relationships between them.

Scheduling is the development of time requirements for each operation or activity and the relating of each to calendar time.²

Good planning hinges on a clear definition of the objectives and constraints which govern the manner in which the project can be implemented. The major problems which impinge on basic planning are:

- 1. What are the major segments of the undertaking and how are these major segments related to one another?
- 2. What resources are available to complete various sections of the work?

²Hackney, op. cit., p. 106.









FIGURE 9

OPTIMAL FIELD CONSTRUCTION DURATION

Source: J. W. Hackney, <u>Control and Management of Capital Projects</u>, (New York: John Wiley and Sons, 1965), p. 63.

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3. How will the available and viable resources be organized and which activities will be assigned to which resources?

Until the early 1960's, planning and scheduling were generally based on the utilization of Cantt bar charts. With bar charts it is difficult to account for dependencies between activities and to separate the planning and scheduling functions. Control points are established by assigning target dates to milestones which are key or major events, based on planned work accomplishment. The establishment of target dates is to a large extent arbitrary, based on subjective judgment and past experience on similar projects.

In the late 1950's, two similar network-based systems for project management were developed in an attempt to overcome the faults of traditional systems and to enable better control of project ∞ st, schedule and performance. The first system, known as the critical path method (CPM) was developed in 1957 - 1958 by M. R. Walker of DuPont and J. E. Kelley of Remington Rand. The other system was developed for the U.S. Navy in 1958 - 1959 by the consulting firm of Booz, Allen and Hamilton, and is known as the Program Evaluation and Review Technique (PERT).³

Network-Based Management Systems (PERT/CPM)

CPM was developed primarily for the planning, scheduling and control of maintenance and construction projects. CPM is activity-oriented and deterministic. Specific durations are assigned to each activity, and a single expected occurrence date is calculated for each event. PERT was

³Cecil E. Law and David C. Lach, <u>Handbook of Critical Path</u>, (Montreal, 1965), p. 2. (Handbook for CPM Course at McGill University).

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developed for controlling vast and sprawling weapons system projects and R & D programs. The first use of PERT was for the Polaris Missile project. PERT is event-oriented and probabilistic. Multiple estimates may be made for activity durations, and a probability distribution generated for the expected occurrence time of each event.

Generally, CPM is more amenable to construction projects where resources are essentially unlimited and a time constraint is imposed; while PERT is applied to military and R & D projects where resources are limited and there is no time constraint.¹ The use of multiple-time estimates in PERT is diminishing, and PERT is also tending to become more activity-oriented. PERT tends to be organized from the point of view of the man at the top, who is interested in reviewing and controlling progress, and in the completion of major sections of the work. CPM is organized more from the point of view of the man at the bottom - the man who must actually see that the work is performed.⁵ The separate systems are now tending to be merged into an overall and general system which is both activity- and event-oriented, and which can be tailored to suit the specific project requirements.⁶

The following discussion is intended to apply to the more general PERT/CPM network concept, rather than to a particular system.⁷

^LJ. P. I. Tyas, <u>Pertaining to PERT</u>, (Ottawa: Queen's Printer, 1966), p. 60.

⁵Law and Lach, op. cit., p. 252.

⁶Russell D. Archibald and Richard L. Villoria, <u>Network-Fased</u> <u>Management Systems (PERT/CPM)</u>, (New York: John Wiley and Sons, 1966), p. 15.

7In the early 1960's, a number of other less-well known acronyms including HEPP, ICON, IMPACT, LESS, PAR, PEP, PRISM, SPERT and TOPS were promoted. These have now generally given way to PERT and CPM. For a listing and synopsis, see Robert W. Miller, <u>Schedule, Cost and Profit</u> Control with PERT (New York: McGraw Hill, 1963), Appendix 3, pp. 207 - 215.

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The relatively rapid recognition and acceptance of network systems in the building and engineering construction industry is illustrated by the following conclusion to a 1962 editorial in the highly pragmatical Engineering News Record:

CPM . . . marks a major breakthrough for scientific management into construction - comparable in its impact to a major advance in [physical] technology. It forces builders to substitute explicit knowledge, rigorous analysis and clear understanding for mental calculation, rough estimation and intuition. In the intensively competative field of construction, progress in management techniques as well as in [physical] technology may well be a condition of survival.

Planning

The detailed rules and methods for constructing networks and for calculating expected completion dates for activities, slack or float times and so forth are well covered in a large number of good and readily available books and monographs, and will not be discussed in detail. The thesis bibliography lists several recent publications which provide this information. A simple example of a network system will, however, be presented briefly to illustrate the system attributes. This example may be somewhat difficult to follow for anyone who has not had some prior experience with PERT/CPM.

However, the basic logic of a network diagram is quite simple and self-evident. Arrows are used to represent activities. Nodes are used to represent events, which are the starting and completion points of each activity. A network (or arrow diagram) is prepared to show the logical sequence and dependency of activities and events. Figure 10 shows a simple network which illustrates the plan for construction of a house.

⁸Anonymous, Editorial, "CPM and Survival", Engineering News Record, (July 19, 1962), p. 116.

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For example, referring to Figure 10, the arrow 7 - 9 represents the activity, finalize financing. The node, 9, represents the event, finalization of financing. Dotted arrows such as 6 - 7 are dummy activities which take no time and consume no resources. They are used to show network logic. The network is simply a diagram showing the logical sequence and dependency of the major activities. Only eighteen activities are shown. The number of activities could be expanded many times to show more detail. Activity 10 - 11, for example, could be broken down to show detailed activities such as purchase lumber, form basement, pour concrete and so forth, which the contractor must undertake in order to build the house. The contractor may prepare his own network to plan his particular responsibilities.

Each activity which leads into an event must be completed before any activity which starts at that event can be started. For example, before the owner can move into his house - activity 15 - 16 - each of the three activities leading into event 15 must be completed. If in fact the owner is able to move into his house with one or more of these three activities not complete, the logic shown is incorrect.

Different activities shown on the network are the responsibility of different parties - owner, architect, contractor, furniture store, The network shows the dependency between the efforts of the various participants, and enables the manager to establish the effects of delay by one participant on the activities of other participants.

With a relatively simple project like the construction of a new house, an experienced manager could visualize the dependencies and act to control the project without the aid of a formal logic network. In

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effect, he would utilize an implicit logic network contained in his head, rather than an explicit logic network drawn on paper. Since the implementation of a large engineering construction project involves several thousand readily-definable activities, even a skilled and experienced manager or project management team can visualize only very roughly the implementation logic without explicit and thorough analysis. A network diagram provides an operational framework for analysis and facilitates display of the logical sequence and dependency of project activities.

The network logic does not have explicit scientific, behavorial, or empirical basis. At no point is the network self-generating or corrective. The logic of the network can be no better than the logic of the planners who prepare it.

The network shown on Figure 10 was prepared without any consideration being given to the time required to complete specific activities, or to the total duration of the project. The network concept allows initial planning to be completed before scheduling is commenced.

After completion of the network diagram, the expected duration of each activity can be estimated independently. Considering each activity independently in this manner prevents fudging and biasing estimates to meet previously established milestone-dates, as is inevitable when Cantt bar charts are utilized in planning.

The estimated time for each activity is shown below the arrow. Starting at the first event in the network, the earliest occurrence time for each event can be calculated by determining the time required for the longest series of activities leading up to each respective event. The earliest occurrence date for the final event in the project is the earliest date on which the project can be completed. The earliest occurrence date

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for each event, T_e , is shown in the upper left-hand corner of the event circle. The calculation of the earliest expected occurrence date for each event is known as the forward pass.

A target date for completion of the project can now be assigned. In our example, we will assume that the target date for project completion is to be day 220. This is noted as the latest allowable occurrence time, T_L , for event 16. Working backward, the latest allowable completion time for each event which will permit the project to be completed by day 220 can now be calculated. This is known as the backward pass.

If we now look at an activity, for example, 8 - 10, we see that the earliest possible start for this activity is day 60, and the latest possible finish which will not delay the project completion beyond the target date is day 90. The maximum allowable duration for this activity is thus 90 minus 60, or 30 days; which is 20 days more than the estimated required time of 10 days. The 20 days is known as the total float⁹ for activity 8 - 10. This is the maximum number of days that activity 8 - 10may slip without delaying project completion beyond the target date, assuming that all activities preceeding event 8 are started as early as possible, and that all succeeding activities after event 10 are started as late as possible.

The path through the network which is comprised of events having the minimum amount of float is known as the 'critical path'. The critical path on the example network is shown as a heavy line. If the total slippage of events along this path exceeds 20 days, the project completion will be delayed beyond the target date.

9'Float' is synonomous with 'slack'.

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Events not on the critical path can be allowed more slippage without delaying the completion date. For example, activity 8 - 12 requires only 30 days and the earliest start is day 60, and the latest finish is day 210. Hence, total float for activity (8 - 12) = (210 - 60) - 30 = 120 days. That is, if all preceeding activities are started as soon as possible and all succeeding activities are started at their latest feasible date, the duration of this activity is permitted to be 120 days longer than estimated without delaying the project.

In the example, the target completion date for the project was established later than the earliest possible completion date. It is more usual to set the target date as the earliest completion date, and hence the critical path will have zero float. The target completion date could have been set earlier than the earliest completion date, and in this case the critical path would have had negative float. The path with the least positive float, or alternately with the greatest negative float, is the critical path.

Free float, which is the excess time allowed for an activity when all preceeding activities are completed as soon as possible and all succeeding activities start as soon as possible, can be calculated in a similar manner. Independent float is the excess time allowed for an activity when all preceeding activities are started as late as possible, and all succeeding activities start as soon as possible.¹⁰

The network enables the planner to distinguish between those activities which are critical to the attainment of target completion dates from those non-critical activities which can be allowed to slip. Typically,

10Archibald and Villoria, op. cit., p. 102.

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no more than 5 to 15 per cent of the project activities will be on the

critical path.¹¹

The functions and attributes of the network diagram may be summar-

ized as follows:

- a) It is the basis for consideration and construction of a logical plan [and schedule].
- b) It shows the sequence and interrelationship of activities.
- c) It clearly defines responsibilities.
- d) It separates planning and scheduling, and aids in the production of a coordinated schedule.
- e) It aids in the identification of specific problems early in the project.
- f) It separates urgent things from important things.
- g) It is a simple and clear communication tool.
- h) It allows management by exception.
- i) It measures achievement against plan.
- j) It enables the simulation of alternate plans, so that they can be tested before using them.¹²

Scheduling

The planning summarized by the network diagram indicates when things can be done; scheduling determines when they should be done for best allaround project effectiveness.¹³ The resources which must be scheduled are manpower, materials, equipment, and money. Scheduling of industrial projects is generally centered on manpower, materials and equipment.

¹¹Law and Lach, op. cit., p. 162.

12 Tyas, op. cit., p. 6.

13_{Hackney}, op. cit., p. 124.

Money is generally made available to suit the required schedule, although in some case, projects may be stretched out due to financing limitations.

Activities on the critical path are given first priority in establishing schedules. If the critical path has zero float for the given project logic and activity durations, the schedule for critical activities is fixed. Schedule constraints are also imposed by equipment deliveries and imposed dates for key milestones. For example, when plants are constructed in northern regions, it is usual to require that buildings be closed in before the onset of cold weather in the fall to permit equipment erection to continue in closed and heated buildings. There may be more than one critical path and some critical paths may terminate at milestones.

The initial network logic is generally based on the assumption that there are no constraints on the availability of manpower or equipment resources. A possible exception might be where it is known that specific resources will be required for several activities. In cases of this sort, the constraint would be taken into account in the network.

Non-critical activities could be simply scheduled to commence at the earliest possible time. This would provide the maximum available margin to accommodate slippage. It is desirable, however, to avoid excessive fluctuations in the level of manpower and equipment inputs, and to minimize peaks. This applies both to total input as well as to specific resources. The float available on non-critical activities is utilized to prepare a schedule which enables manpower and equipment levelling. Delaying the start of activities to accommodate levelling reduces the available float, and more activities tend to the critical state.

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Fairly reasonable schedules can be prepared by trial and error, but it is desirable, of course, to use a more formalized and rational method.¹⁴ Unfortunately, a rigid mathematical solution is beyond current technique.¹⁵ Operational but somewhat tedious and cumbersome manual methods, which aid in formulation of good if not rigidly optimum schedules, are available.¹⁶ Considering that the network logic will almost certainly not be optimum, that estimated activity durations may be significantly in error, and that the schedule will generally be revised as the project progresses, such sub-optimization cannot be considered a serious handicap.

Resource levelling operations must take into account activity priorities and desired resource levels. Even though manual methods are slow, cumbersome and prone to error, programming resource scheduling and allocation for computor solution has had limited application due to the complexity of the problem.¹⁷ One of the most sophisticated programs, RAMPS, developed by du Pont and C-E-I-R Inc., has not been widely used due to the difficulty in setting up the required input data.¹⁸

If the earliest project completion date determined by the initial network analysis is not acceptable to management, a number of techniques for 'shortening' the critical path are available:

14R. L. Martino, Project Management and Control, Vol. III, Allocating and Scheduling Resources, (New York: American Management Association, 1965), p. 12.

15_{Ibid}, p. 14.

¹⁶For example, see Ibid; or Law and Iach, op. cit., Chapter X. A good description of the heuristic programming technique for project scheduling is included in J. D. Wiest, "Heuristic Programs for Decision-Making", Harvard Business Review, (September - October, 1966), pp. 140 - 143.

¹⁷Iaw and Lach, op. cit., p. 238.

¹⁸Archibald and Villoria, op. cit., p. 228.

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- 1. Revision of network logic.
- 2. Placing preliminary equipment orders.
- 3. Providing temporary facilities.
- 4. Elimination of non-essential components.
- 5. Crashing critical activities.¹⁹

In describing the preparation of a logic diagram, it was stressed that the diagram was merely an explicit presentation of a particular method of implementing the project. If the initial plan is not acceptable, it can be reviewed and revised. In particular, critical activities can be closely scrutinized to see if more activities can be overlapped, and to see if all preceeding activities must be 100 per cent complete. Design activities may be started earlier by basing initial design on sound assumptions, where more exact datais not yet available. Construction activities may be started earlier by placing preliminary blanket orders, and by provision of temporary facilities. Non-essential activities may often be delayed until after 'project completion', although extra cost might be involved.

It was shown earlier that total project cost was an inverse function of project duration; that is, project completion time could be shortened at the sacrifice of increased cost. To demonstrate this fact, an example was given of a specific activity - erecting structural steel. Estimation of a cost-duration function for an entire project is difficult. However, it is feasible to estimate such a function for a particular activity. A reasonable representation is enabled by estimating the normal cost and

19See Law and Iach, op. cit., p. 156.

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duration and the crash cost and duration, and assuming a linear relationship. This is shown in Figure 11.



Cost



ACTIVITY COST AS A FUNCTION OF DURATION

The slope of the linear approximation gives a cost per unit of time for crashing the particular activity. To shorten the critical path, critical activities can be selectively crashed, commencing with the activities which have the lowest cost per unit of time gained. As critical activities are crashed, activities which were not on the critical path, but which had small slacks, will tend to become critical. Manual methods, as well as computer programs, are available for systematically crashing projects.²⁰

²⁰For a detailed procedure for manual calculation, see John W. Fondahl, <u>A Non-Computer Approach to the Critical Path Method for the Construction</u> <u>Industry</u>, Technical Report No. 9, Second Edition, (Stanford, California: Department of Civil Engineering, Stanford University, 1962). Several standard computer programs are cited by Law and Lach, op. cit., p. 167.

Implementing PERT/CPM

Optimization of the benefits of network-based management systems is contingent on systematic planning and implementation of the system.

1. What are the project objectives?

The following questions must be answered in the preplanning stage:

2. What are the major elements of the work to be performed

and how are these elements related to one another?

- 3. What organizations are available to perform the work and how can they be organized?
- 4. Who will be assigned responsibility for various sections of the work?
- 5. What will be the information requirements of various levels of management?²¹

The planning, scheduling and operating cycle is shown on Figure 12.

A useable definition of project objectives for planning must be considerably more definitive than the broad concept - to maximize the firm's wealth - that we introduced in Chapter 2. Project objectives are developed into initial useable form during the feasibility study phase. The project specifications, which we now call the project objectives, are determined by the interaction of the market, product, and production process variables. Project objectives in this sense are work packages referring to specific physical facilities or to tangible services and systems. Construction of a chlorine dioxide plant and the employment, organization and training of a sales force are examples of such definitive project objectives.

²¹Archibald and Villoria, op. cit., p. 23.





(PERT/CPM) PLANNING, SCHEDULING AND OPPRATING CYCLE

References: J. P. I. Tyas, <u>Pertaining to PERT</u>, (Ottawa: Queen's Printer, August 1966), p. 10; R. D. Archibald and R. L. Villoria, <u>Network Pased Management Systems</u>, (New York: John Wiley and Sohs, 1966), p. 143.

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5 S.

The major elements of the work are defined by a work breakdown structure, which is a detailed listing of project objectives. Packages in the work breakdown structure are summarized in levels or tiers of increasing detail. The level of maximum detail may vary according to the character of the work package. For example, relatively minor items of equipment might be listed in the detailed accounts of the construction budget, while work packages pertaining to sales force operations might

be summarized in less detail.

The work breakdown structure:

- a) Defines the project tasks to be performed.
- b) Establishes the task's relationship to the project end items and project objectives.
- c) Establishes the framework for planning and scheduling .
- d) Establishes a framework for summarizing the schedule status of the project for progressively higher levels of management.
- e) Establishes the basis for constructing the . . . network of project activities and events at the desired level of detail.²²

Ideally, network formulation would be commenced at the maximum level of detail, and less detailed summaries would be prepared from the bottom up. For an engineering-construction project, detailed definition of construction activities is not possible until detailed design is well advanced. Since initial planning must be undertaken before detailed data is available, less detailed networks must be prepared initially. As details become available, these networks may be 'exploded' to show the required degree of detail.

²²Tyas, op. cit., p. 13.

The level of final detail will, of course, depend on the circumstance. Law and Lach suggest that no activity should be longer than one or two reporting periods, should be no longer than 5 per cent of the total project duration, and should not involve more than 5 per cent of the total project resource input.²³

At the maximum level of detail, it is not feasible on a large project to represent all activities on a single network. 'Subnets' or 'fragnets', which show specific portions of the project, are prepared. The fragnets are linked by common interface events, and may be summarized by less detailed master networks.

The activity-oriented approach of CPM facilitates analysis at the maximum level of detail, while the event-orientation of PERT facilitates network summarization. A key influence on the development of PERT was the necessity for summarization at several levels of detail. Systems which are activity-based at the maximum level of detail and which are summarized by events are convenient where summary networks must be prepared. $2l_4$

As the project progresses, actual completion dates are accumulated and compared with the scheduled dates. Where deviations occur, the effect is assessed and corrective action initiated as required. Periodically the network is up-dated by substitution of actual data for the estimated data for completed activities. Recalculation may indicate the need for a change in plans. Activities which were critical may become non-critical, and non-critical activities critical. Where the need is indicated, plans and schedules are revised.

²³Law and Lach, op. cit., p. 35. ²¹Ibid, pp. 199 - 205.

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It is inevitable that flaws will be revealed in initial plans, and that expectations will not be realized. Revisions to plans and schedules are necessary in every project, so it is essential that plans and schedules be updated to current conditions. Replanning and rescheduling at every reporting period is not likely to be practical, but revision should not be postponed until there are major changes.

The network logic facilitates simulation of proposed plans. As the project develops and problems are encountered, alternate methods of attack ing the problem may be tested.

As a typical engineering project approaches start-up, it is usual for schedules to break down to a large extent, and construction work may be monitored on a punch-list basis. Completion of final activities is governed not so much by sequence and dependency constraints as by resource limitations and priorities. As start-up approaches it may be desirable to curtail network-based reporting and control, at least on a detailedactivity basis.

If a network has more than a few hundred activities, manual computations are slow, prone to errors, and likely to be expensive. Computers, in general, are used where manual methods are more expensive, or where manual methods are too slow and inaccurate to provide useful results. Network calculations for a large project qualify on both counts. In selecting a computer and computer program, factors which must be considered include: accessibility, simplicity of use (node number rules, input requirements, error checking, report layouts, calendar dating, sorting techniques), program capacity, and crashing and resource allocation capabilities.²⁵

25See Law and Lach, pp. 255 - 265.

Summary

Network-based management systems (PERT/CPM) are powerful tools, enabling improvement in the efficiency of project management. Hackney reports that a 1965 survey by the Cost Control Committee, Metropolitan Section, American Association of Cost Engineers, indicated that 86 per cent of engineer-contractors were using some form of network-activity scheduling.²⁶ A questionnaire distributed by Schoderbek at about the same time to 200 firms included in Fortune's list of the top 500 indicated that approximately one-half were using PERT/CPM.²⁷ Improved control, ability to stay on top of the job, and ability to compare progress with scheduled goals were the major advantages cited by respondents. The motivation and training of personnel rather than technical problems were generally considered to be the most difficult areas in application. Schoderbek concluded that:

Despite its limitations . . [PERT/CPM] is a tested and workable tool for providing management with a maximum of planning and control for complex projects of a non-repetitive nature.²⁸

R. L. Martino, who participated in the earliest commercial utilization of network systems, suggests that a 'new breed' of management is imminent:

• • project management is the function of judiciously allocating resources to accomplish pre-selected objectives according to a plan and schedule, and reacting to deviations between predicted and actual results to forestall the development of unfavorable situations.

Being a manager requires a balance between subjective ability and objective (or scientific) method.

²⁶Hackney, op. cit., p. 129.

27Peter P. Schoderbek, "A Study of the Applications of PERT /CPM ", Academy of Management Journal, (September 1965), pp. 199 - 210.

²⁸Ibid, p. 206.

We are members of a new breed of management. This new breed cannot afford to operate on its wits alone as management in the past was able to do. Whether we like it or not, as members of this new breed, we are compelled to understand and to use all the new management techniques at our disposal. We cannot launch a new product (whether it be a toy or a missile), we cannot erect a structure (whether a house, a bridge, or a gigantic industrial complex), and, indeed, we cannot successfully complete any project unless we plan and schedule the work and then control its completion. It is no longer a question of will we use new techniques, but rather of when. The when is now!²⁹

²⁹R. L. Martino, <u>Project Management and Control</u>, Vo. II, <u>Applied</u> <u>Operational Planning</u>, (New York: American Management Association, 1964), p. 162.

CHAPTER VI

CASE STUDY

A case study of a hypothetical project will be used in this chapter to illustrate the comprehensive feasibility study, project development, and project implementation phases discussed in Chapter III. The case will be based on actual projects, for which Sandwell and Company Limited has been responsible for the engineering analysis and design and a major portion of the project management activities. Sandwell is a major consultant specializing in the forest products industry. An excerpt from a company brochure, included in Appensix B, illustrates the range of services offered by Sandwell.

It is necessary to use a hypothetical rather than an actual project, as work carried out by Sandwell is confidential between the company and its respective client. Nevertheless, the case is realistic. Actual data from several completed projects was used to synthesize the data for the hypothetical project. The data base includes Sandwell project files and first-hand observations by the author, who has been employed by Sandwell since 1963. Typical examples of key items of project documentation are included in Appendix A.

In the Canadian pulp and paper industry, operating firms frequently employ engineering consultants to carry out major comprehensive feasibility studies, to perform engineering and design for major capital projects, and

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and to assist in project management. Physical facilities are generally erected by construction firms, under direct contracts with the owner. The 'turn-key' arrangement, which is common in some other areas - particularly in the petroleum refining and chemical process industries - has not been widely used in the Canadian pulp and paper industry. With a turn-key arrangement, the owner contracts with a combined engineeringconstruction firm to design and construct the facility and to put it into operational condition.

To enable use of the turn-key arrangement, the owner must be able to prepare relatively accurate specifications of plant inputs and outputs, and of the intent and scope of the desired plant facilities. The relatively limited use of turn-key contracts for pulp and paper plants is attributable to the difficulty in specifying requirements at the beginning of the project development phase with sufficient accuracy to permit competitive bidding by engineering-construction firms.

The owner-consultant relationship presented in this case is typical of more than a dozen projects of similar function and scope, on which Sandwell has been engaged since 1963. On the basis of industry literature and intelligence, the case is very likely typical of a large number of major pulp and paper projects which have been undertaken in North America in the last decade.

An outline schedule showing duration of major phases of the work is shown in Exhibit A.¹

¹All exhibits referred to in this chapter are included in Appendix A.

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Feasibility Study

The Hypothetical Forest Products Company (HFPC) had held rights to an extensive block of timber in an undeveloped region of Canada for a number of years. Pulpwood in limited quantities was harvested from this area and shipped by rail to existing HFPC mills. Periodically the company had studied the viability of constructing a major new facility in the area to enable better utilization of the controlled resource. The long-range company plans were to provide a processing plant in the area, although the timing and product were not finalized.

In early 19%0 HFPC reviewed their long-range plans in light of federal government legislation, which provided tax incentives for industries located in depressed areas. Preliminary analysis indicated that the tax incentives were sufficiently attractive to warrant serious consideration of the construction of a plant to produce kraft pulp, newsprint or linerboard. Prompt action was required. To receive the benefits of the tax incentive, the plant was required to be in operation by the end of 19%3. In June HFPC entered into discussion with and engaged Sandwell to undertake a major portion of a comprehensive feasibility study according to the following terms of reference:

Case	Product	Capacity
1	Bleached Kraft Pulp	750 Tons/Day
2A 2B	Newsprint Newsprint	500 Tons/Day 1000 Tons/Day
3	Linerboard	600 Tons/Day

1. The following cases were to be considered:

 Sandwell was to develop preliminary engineering plans and estimate capital costs for each case. Capital cost estimates were to have an expected reliability of ± 15 per cent.

3. All cases were to be based on a specific site location which had been tentatively selected by HTPC.

4. Sandwell was to develop a manufacturing cost estimate

- for each case, based on operating at maximum mill capacity.
 5. The cost of pulpwood delivered to the mill was to be provided by HFPC. The cost of all other raw materials, as well as the cost of labour, fuel, power and so forth was to be estimated by Sandwell.
- Sandwell was to develop an estimate of annual gross profit for each case, based on mill net prices provided by HEPC and operating at maximum mill capacity.

7. Sandwell's work was to be completed by 30 December 19X0. The following discussion briefly describes the work carried cut by Sandwell to achieve the feasibility study objectives.

Preliminary process design was carried out for each case. Rough specifications were developed for each major item of equipment, and preliminary material and energy balances were prepared. An outline process flow diagram was prepared for each mill department. In all cases, process design was based on most common and accepted industry practice. Cost saving or quality improvement alternates which were not thoroughly proven were not considered. Upon completion of basic process design, preliminary mill and building layouts were prepared. Service and electrical distribution and instrumentation requirements were determined.

As the study proceeded, it became evident that addition of 350 tons per day of newsprint capacity to Case 1, a 750 ton per day kraft mill, was an additional feasible alternate. Following discussion, Sandwell was instructed to consider this additional case.

A relatively detailed capital cost estimate was prepared for each case. Suppliers for major items of equipment - paper machines, boilers, digesters, kilns - were contacted and in some cases requested to submit preliminary proposals. In other cases the cost of major equipment was estimated, based on purchases of similar items for recently-completed projects. Lump-sum estimates were made for minor equipment requirements and piping, based on similar projects. Electrical costs and building costs were based on estimated costs per installed horsepower and per cubic foot of building volume, respectively. Wherever possible, capital cost estimates were grouped in modules which were applicable to several cases.

Manufacturing cost estimates were grouped into the following categories:

- 1. Pulpwood
- 2. Other Raw Materials
- 3. Fuel
- 4. Power
- 5. Iabour

6. Administration and Overhead

7. Miscellaneous and Other

Pulpwood was by far the most significant single manufacturing cost, comprising over 25 per cent of the total manufacturing cost in the kraft pulp and linerboard cases. Requirements for raw materials, fuel and power were based on the preliminary material and energy balances developed for each case. Major suppliers were contacted and requested to make preliminary proposals. Several meetings were conducted with the hydro-electric company to establish conditions of power supply and tentative rates.

Labour cost estimates, similar to that shown in Exhibit 2, were developed for each mill department. Whenever possible, departments were defined in a manner which allowed a specific department estimate to be used for several cases. A tentative mill supervision roster was used as a basis for estimation of administration costs. Lump-sum estimates established on the basis of general industry experience were used for associated selling and head office expense.

All communication with HFPC was channeled through the company's vice-president in charge of planning, who kept technical, marketing and financial personnel advised on developments of work being carried out by Sandwell. Concurrent with Sandwell's work, HFPC functional personnel were preparing sales forecasts and estimates of start-up costs and workingcapital requirements relative to each of the cases.

The pulpwood costs provided to Sandwell during the early stages of the feasibility study were based on existing company operations in the area, and on open-market pulpwood costs. When it became evident that there was a significant possibility that pulpwood-harvesting operations would be expanded, the HFPC forest division initiated a study of their operations to determine optimum methods for larger-scale production, and to establish requirements for capital for expanded operations.

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Since the site was in a remote underdeveloped area, it was necessary for HFPC to develop preliminary plans for the provision of extensive new housing facilities at a small village near the proposed mill site. It was contemplated that a suitable arrangement could be negotiated with a real estate development company to provide the bulk of the required capital for living accommodation and services. Nevertheless, some capital outlay would be required to assist in housing development, and to provide recreational facilities essential for attraction of mill staff.

A rough draft of Sandwell's feasibility study report was turned over to HFPC early in December. Several minor contentious points were reviewed and discussed, and the final report was completed shortly before Christmas.

Plants of this nature are extremely capital-intensive. The estimated plant capital cost for each of the alternate cases was in excess of \$60 million. After the inclusion of capital requirements for woods operations, townsite, start-up expenses, working capital and so forth, the total investment required was in the order of \$100 million for any of the cases considered. In no case did annual mill net sales exceed 50 per cent of the total capital investment.

During January and February 19X1 a financial analysis and review of the alternate cases was carried out by MFPC. A decision to proceed with Case 1, a 750 ton per day bleached kraft pulp mill, was confirmed at a board of directors meeting late in February. To ensure that the mill could be put into operation by the end of 19X3 as required to receive tax benefits, Sandwell was instructed to proceed immediately with project development work.

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Project Development

Sandwell commenced detailed process design, using the preliminary plans previously prepared as a starting-point. The preliminary process design had been based essentially on most common industry practice, with only a minimal consideration being given to possible alternatives, particularly where technology was not well proven.

It was now necessary to consider in detail alternate process arrangements. For example, the feasibility study had been based on the use of batch digesters,² although continuous digesters were relatively common in the industry. An extensive analysis was now carried out, comparing capital and operating costs and expected operating characteristics between the two systems. This detailed analysis indicated that the continuous unit was a better choice, and a decision was made to design the plant on this basis. The results of major design analyses were presented in relatively formal memoranda, to facilitate decision-making by Sandwell and HFPC management, and to provide a record of basic design criteria.

Specifications were prepared for all major items of equipment, and enquiries were issued to prospective suppliers requesting firm proposals. Representative specifications were prepared for standard items such as pumps, motors, controls, and so forth, where exact requirements could not be determined until the detailed design stage. Purchase enquiries were issued and proposals analyzed on the basis of these tentative specifications, to enable selection of standard mill equipment and to aid in capital cost estimating.

²A digester is a pressure vessel in which wood chips are chemically cooked to separate the cellulose fibres from the lignin and resins.

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The tentative mill site which was used as a basis for the feasibility study was actually only one of four suitable locations. Each of these sites was now examined in detail. Factors considered included: soil conditions and natural drainage and relative costs of site preparation, services, and effluent disposal facilities. Provision for effluent disposal was a major consideration in choosing the optimum site.

Once the basic process had been established and the site location confirmed, layout of the mill equipment and buildings was completed. Buildings for pulp mills are essentially equipment enclosures, and layout priority is given to the equipment arrangement. Alternate structural systems and materials were now compared, and best selections made. Structural design criteria was established, and basic design commenced.

A capital cost estimate broken down by a detailed code of accounts was prepared. Purchase costs of all major items of equipment were based on firm quotations received from suppliers. Auxiliary equipment costs were based on verbal quotations or Sandwell current cost records. Purchased equipment comprised almost 50 per cent of the total estimated capital cost. Estimated piping, wiring, installation labour, etc., costs were based on Sandwell experience and records from other similar projects. Structural estimates were based on preliminary designs from which required quantities of materials were developed. The unit costs for structural construction were based on recent bids for similar work, adjusted for current conditions. An example page from a capital cost estimate is shown in Exhibit 3. Capital cost estimates were compiled on Sandwell's IBM 360-40 computer.

Relatively comprehensive plans for detailed design activities and field construction were developed during this phase. An example of an

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outline CPM network is shown in Exhibit 4.

The objectives of the design development phase carried out by Sandwell were to:

- Make comprehensive studies of alternate process systems, site locations, mill arrangements, structural materials and so forth, to enable an efficient plant design.
- Complete basic engineering and establish a firm and complete definition of the plant facilities.
- 3. Prepare a detailed estimate of plant capital cost, broken down by a detailed code of accounts to facilitate cost control.
- 4. Develop a basic plan and schedule for implementing the project.

The design development work established a baseline for the project implementation. The results of this phase were summarized in a report known as the Construction Budget, which included the following:

- 1. Summary of Estimates
- 2. Description of Plant
- 3. Basis of Estimates
- 4. Construction Schedule
- 5. Time-Money Schedule
- 6. Detailed Estimates
- 7. Basic Process Flow Diagrams
- 8. Drawings of Basic Plant Layout
Project Implementation

The detailed capital cost estimate of the Construction Budget compared closely with the estimate prepared for Case 1 of the feasibility study. The capital required for the mill was in excess of \$60 million, and the total capital required for the project approached \$100 million. The total cost of work carried out by Sandwell to this point exceeded \$400.000.

The project status was given a second review by HFPC top management, and in late August 19X1 the HFPC board of directors authorized the capital expenditure required to implement the project.

The work breakdown structure for the complete project is shown in Figure 13. Items which were the prime responsibility of Sandwell are indicated. Only those particular items will be discussed in detail. The organization established by Sandwell to accomplish its section of the work is illustrated in Exhibit 5.

Immediately on receiving direction to proceed, final specifications were prepared for major items of equipment for which delivery was critical or for which engineering data was urgently required. Requisitions were prepared and issued to HFPC for approval and issuance of purchase orders. All purchase orders were reconciled with the Construction Budget, and justification and approval was obtained for all items where budgeted cost was exceeded or for which provision had not been made. Required delivery dates were stipulated with all purchase orders, and an expediting program was established to review progress and to ensure that required delivery dates would be maintained.

Initial design activities were concentrated on the completion of equipment and building layouts to enable detailed structural design. A



FIGURE 13

WORK BREAKDOWN STRUCTURE

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target of early January 19X2 had been established for issuance of bid specifications and drawings for civil construction. For the purposes of this bid it was not required that drawings be complete in every detail, but the intent and scope of the work was required to be well defined.

Discussions were held with a number of general contractors who were experienced in industrial plant construction. After a review with HFPC, it was agreed that tenders for the civil work would be limited to four contractors. Bid documents were issued to the selected contractors early in January 19X2, and tenders were received in mid February. After review of the proposals, meetings were held with each of the contractors to reconcile any apparent conflicts. A contract requiring immediate start of construction and essential completion of all main structures by November 19X2 was negotiated with the chosen contractor.

To enable commencement of general civil construction as early as possible in the spring of 19%2, a separate contract had been let in September of 19%1 for general site preparation and the construction of temporary services. This work was completed in December 19%1.

As equipment layouts were finalized and engineering data became available on process equipment, detailed design of piping, electrical and instrumentation systems was commenced. A target date of the end of June 19X2 had been established for the issuance of bid specifications and drawings for a general mechanical-electrical contract. A general mechanical-electrical contract was negotiated in a similar manner to the civil contract.

Several major process units were purchased on a supply and erect basis. These items were excluded from the mechanical-electrical contract.

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The general contractor was responsible, however, for providing certain stipulated site services to independent contractors employed directly by the owner.

At the peak of construction in the summer of 19X3, the total field force numbered over 1300 men. To enable adherence to schedule and to aid contractors in enticing men to the remote location, all contractors worked a fifty to sixty hour week. A field construction camp was established for the common use of all contractors.

Sandwell prepared a master CPM network for overall plant construction. Each of the prime contractors engaged by the owner was responsible for preparing and maintaining a detailed CPM fragnet covering his own activities. The detailed networks were based on exploding activities from the master network, subject to established interface and milestone constraints. Shortly after the start of civil construction, the contractors' detailed fragnets were integrated with the master network. Each contractor was still responsible for reporting on and maintaining his own fragnet; however, master reports were also prepared on a project basis under the direction of the Sandwell field staff.

CPM reports were prepared monthly, except for a four-month period in early 19X3 at the height of mechanical construction, when reports were prepared every two weeks. In June 19X3 when construction was approaching completion, CPM reporting was discontinued, and from this point the project was monitored on a punch-list basis.

The Sandwell field staff also prepared concise weekly reports on construction progress. These reports served a dual function of keeping HFPC and Sandwell management informed of progress, and constituted an outline project diary which could be used in event of any litigation arising on project completion. Each month the field staff estimated the percentage completion on each contract. These estimates formed the basis for progress payments to the contractors.

The HFPC head office financial group had overall responsibility for project cost accounting and control of disbursements. The field staff assisted by recording receivals, freight charges, extra work authorizations and so forth. Monthly statements were issued showing expenditures, estimates to complete, and expected over- or underruns for each account.

The field staff was responsible for checking out all facilities to ensure adherence to drawings and specifications. Personnel from the mill operating-maintenance staff were used to assist in detailed check-out of mechanical and electrical equipment. A systematic procedure was implemented, utilizing cards attached to each piece of equipment, which were then signed by inspectors responsible for specific areas and functions.

As individual sections of the plant were completed, they were accepted from the contractors and responsibility for the area was assumed by the mill operating personnel. Where possible, dry runs were initiated in these areas, using water and air in lieu of process fluids.

Start-Up

During the late summer of 19X3, HFPC completed hiring of the mill operating staff, and conducted classroom training sessions. Operating manuals had previously been prepared by the mill supervisors, assisted by Sandwell process engineers. These manuals were used as texts for the classroom training sessions.

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Start-up operations were under the direction of the HFPC mill manager. Additional technical staff to assist supervisors and foremen during the difficult start-up phase was obtained from other HFPC mills and from Sandwell. Supplementary mechanical and electrical crews from the contractor were retained to aid mill maintenance staff in making required modifications.

Approximately one month was required to produce the first saleable product. During the next two months, equipment was debugged and crews gained operating experience, until by the end of December 19X3 the mill was operating at 70 per cent of maximum design capacity. Operating efficiency was further improved over the next several months, and by mid 19X4, approximately four years after the commencement of the feasibility study phase, the mill was fully operational at maximum design capacity. This was the approximate turning-point from negative to positive cash flows.

Summary

The above description, while hypothetical, is illustrative of the scope and timing of activities required to implement a large capital project in the pulp and paper industry.

CHAPTER VII

CONCLUSIONS & RECOMMENDATIONS

In this thesis, capital investment in large industrial plants has been considered in a highly pragmatic manner. As far as possible within the limited scope of the thesis, the approach has been on an interdisciplinary or systems-concept basis. The intention has been to develop a brief overall analysis, rather than to focus on specific aspects.

An outline overview of investment goals and principles of investment analysis has been included to enable development of simple dof and npv investment process models. These models, which take into account the time distribution of both negative and positive cash flows, provide an operational basis for capital budgeting and decision-making during capital project implementation.

The internal rate of return derived from the dcf model is a useable parameter for determining project viability for capital budgeting purposes. However, the assumption which is inherent in the dcf model that cash benefits are reinvested at a yield equal to the internal rate of return, can result in erroneous decisions when mutually exclusive proposals are considered.

If cash benefits from an investment are used to purchase assets either current or fixed - which are productive, a return on investment will be realized. This return is the reinvestment yield. Clearly the reinvestment yield bears no direct relationship with the internal rate of return.

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Only if the internal rate of return is representative of the profitability of investment projects available to the firm, will the internal rate of return and the reinvestment yield be equal. The rate of return on available projects is the firm's opportunity cost (of capital).

If the internal rate of return is less than the opportunity cost, a project is not viable. If the internal rate of return is greater than the opportunity cost, a project is viable. However, in choosing between mutually exclusive proposals, the best alternate does not necessarily have the greatest internal rate of return. Selection between mutually exclusive proposals should be based on maximization of npv. Investment decision during project implementation generally involve consideration of alternates; hence the npv model is preferred.

In the literature on capital budgeting consulted, the only significant constraint on the set of viable investment projects, generally considered, is the availability of funds. When the capital investment process is examined on an integrated basis, it becomes clear that the availability of human resources to manage and implement projects is a comparable constraint to the availability of capital. Similarly, non-financial considerations and considerations which cannot be quantified will impinge to a significant degree on capital-investment decisions.

Modern techniques such as Monte Carlo simulation, by which explicit account can be taken of risk and uncertainty, are essential to thorough and rational analysis of major investment opportunities. Hertz writes:

... The less certainty there is in an average estimate, the more important it is to consider the possible variations in that estimate.

Further, an estimate of the variation possible in a factor, no matter how judgmental it may be, is always better than a simple average estimate, since it includes more information about what is known and what is not known. It is in fact, this very lack of knowledge which may distinguish one investment possibility from another, so that for rational decision-making it must be taken into account.

This lack of knowledge is in itself important information about the proposed investment. To throw any information away simply because it is highly uncertain is a serious error in analysis which the new approach [Monte Carlo Simulation] is designed to correct.1

Implementation of simulation techniques is dependent on the systems approach to the management of capital investment. Marketing analysis, engineering analysis, and financial analysis cannot be carried out by separate functional groups with minimal inter-communication. The traditional feasibility study approach illustrated by the case study in Chapter VI requires revision.

The project organizational form is an example of the systems approach. Personnel are obtained and organized to accomplish a specific task. The organization is tailored to suit the task, rather than the task moulded to suit the organization. Mockler defines a system as follows:

• • • an orderly grouping of separate but interdependent components for the purpose of obtaining some predetermined objective. Three important aspects of systems are implied by this definition.

- The arrangements of components must be orderly and hierarchical no matter how complex it is.
- Since the components of the system are interdependent, there must be communication among them.
- Since a system is oriented toward an objective, any interaction among the components must be designed to achieve that objective.²

David B. Hertz, "Risk Adversion in Capital Investment", <u>Harvard</u> Business Review, (January - February 1964), p. 101.

²Robert J. Mockler, "The Systems Approach to Business Organization and Decision Making", California Management Review, (Winter 1968), p. 53. Presently the systems approach is generally confined to the project development and implementation phases, and frequently only to selected sectors of these phases. To achieve overall capital project optimization, an expansion of the systems approach to encompass the whole of the capital investment process from idea generation to start-up is indicated. The systems concept is required to avoid suboptimization and fragmented development. The organization of tasks and personnel are structured around project objectives and information flows, rather than authority and responsibility units.

Network (PERT/CPM) planning, scheduling and information system methods are an example of the application of modern management science techniques to capital project management. Application of network methods is relatively recent - the first commercial applications were made in the early 1960's. In the short interval since their introduction, network methods have undergone considerable development and have come into widespread use. However, there are areas, particularly in improving resource allocation methods, where operational improvements are required and expected.

For practical rather than fundamental reasons, the application of advanced techniques like PERT/CPM and Monte Carlo simulation is dependent on the use of high-speed, high-capacity digital computers. Without computers, large-scale utilization of such methods would be infeasible due to the cost and time required for manual calculations.

The advent of high-speed, high-capacity computers has made practical a number of management-science techniques, which are or could be used in management and implementation of capital investment projects. A study conducted in England during 1967 indicates that management science techniques

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are being applied in the construction industry by consultants and con-

tractors in the following areas:

- 1. Statistical analysis and forecasting.
- 2. Resource utilization and scheduling.
- 3. Location planning and vehicle routing.
- 4. Production planning. Productivity analysis.
- 5. Simulation of dynamic systems.
- 6. Cost analysis.
- 7. Economic evaluation.
- 8. Stock Control
- 9. Engineering design optimization. Process control.
- Information retreival and sorting.
 Replacement and maintenance planning.

In the field of engineering design, computer programs are being utilized in areas such as stress analysis of structures and piping systems, where there is sufficient repetitive work to enable amortization of the high cost of programming problems for computer solution. Project engineering involves a considerable volume of data processing. Computers are being utilized in processing of budgets, reports and schedules. The future will undoubtedly see greater mechanization of routine calculation and data processing. This will allow more resources to be devoted to engineering analysis, thus raising the efficiency of capital investment through reduced capital cost and increased value.

Research into the methodology of selecting and implementing large capital projects is indicated in the following two areas:

 Further analysis is required into the effectiveness of the fully-integrated systems concept approach to capital investment management; in comparison to the current frequently-fragmented approach to problems in economics, finance, engineering and administration.

³Construction Industry Study Group, "Review and Evaluation of Current Operational Research Work in the Construction Industry", <u>Operational</u> Research Quarterly, Vol. 19, No. 2, (June 1963), pp. 185 - 189.

2. Further evaluation is required of the scope for efficient application of modern techniques in management science, information system design and data processing to the selection and implementation of large capital projects.

Considering the increasing size and complexity of industrial installations and the trend to more capital-intensive production processes,

economic growth will be ever more dependent on efficient use of scarce resources devoted to capital investment. There is obviously scope for improving on current methodology, and the future will see more efficient Management of Large Capital Projects.

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APPENDIX A

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TYPICAL PROJECT DOCUMENTATION

Ex	hibit	u elemental integral a real contra legenda ser su litera energia di tributo per especial con esta el energia d Integra elementa integral energia de literativa energia elementa di esta energia de la casta el Page el contra
·	1.	Outline Project Schedule
	2.	Labour Cost Estimate
• •	3.	Capital Cost Estimate
•	4.	CPM Summary Network 123
	5.	Project Organization Chart
•	6.	Cost Control Schedule

		PROGRESS SCHEDULE		
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	FEASIBILITY STUDY			
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	FINANCIAL ANALYSIS & REVIEW			
	PROJECT DEVELOPMENT			
	DEFAILED DESIGN			
	SITE PREPARATION			
	CIVIL CONSTRUCTION			7 6
	MECHANICAL-ELECTRICAL CONSTRUCTION			
	OPERATOR TRAINING			
	START-UP PHASE			
	MILESTONES .			
1	FEASIBILITY REPORT ISSUED			
2	DECISION TO PROCEED WITH PROJECT			
3	PROJECT DEFINITION COMPLETE			
	AND GO-AHEAD CONFIRMED			
4	MECH-ELECT CONTRACTOR SELECTED			
6	MILL STRUCTURES ESSENTIALLY COMPLETE			
7	MECH-ELECT WORK ESSENTIALLY COMPLETE			
8	MILL OPERATIONAL			
		APPROVED		DAY MO.
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SULPHATE PULP MILL					M -1 -
Position	Rate	MH/D	<u>Cost/Day</u>	Men/Tour	Employees
Tour Foremen Pulping Group Co-ordinator Senior Operator 1st Asst. Operator 2nd Asst. Operator 3rd Asst. Operator	\$1,000 4.10 3.70 3.60 3.10 2.75	- 24 24 24 24 24 24	\$ - 98.40 88.80 86.40 74.40 66.00	1 1 1 1 1	4 4 4 5 4
 Operator	3.16	24	75.84	1	4
Recausticizing, Kiln & Water Plant	2 86	24	68 61	7	1,
Night Shift Differential	(0.135)(<u>112</u>)	15.12		
Total Labour - 350 Days Additional for Sunday Operation Salaries		168	\$573.60	8	33 \$ 201,000 15,000 48,000
Total	· *	· ·	•	· ·	\$ 264,000
Labour				MH/	A 58,800
PULP DRYING PLANT	:				× .
Machine Tender Back Tender Scale Man/Tyer Utility Man Car Loader/Shipper Warehouse Man Night Shift Differential	\$ 3.88 3.33 2.73 2.50 2.75 2.50 (0.135)	24 24 48 24 48 24 24 (<u>128</u>)	\$ 93.12 79.92 131.04 60.00 132.00 60.00 <u>17.28</u>	1 2 1 2 1 2	5 4 8 4 9 4
Total	• 	192	\$573.36	8	34
Labour - 350 Days Additional for Sunday Operation Salaries	• • •			5	\$ 200,700 15,300
Total	•	•	• • •	5	\$ 216,000
Labour			•	MH//	A 67,200

EXHIBIT 2

LABOUR COST ESTIMATE

MASTER COPY - 1				•							
		ACCOUNT	DESCRIPTION								•
COMPUTER REPORT	R U N	TEM NΩ	ITEM		MATERIAL		FEDERAL SALES	-EDEICHT	PROVINC. SALES	SUB TOTAL	SUND
			X I C M	.00	.01	.02	.03	<u>04</u>	•05	.06	•0.7
		421.00.000 421.35.000	WASHING AN INSULATION	D SCREENING (CONTINUED	(CONTINUED))						
	Α.	• 900	EXTRA WORK							, ~	
	Δ	· .	TOTAL ACCO	THU	18000	••••••••••••••••••••••••••••••••••••••	2100		1000	S1100	4
	- A -	421.37.000	MATERIAL H	ANDLING		· · ·			· · · ·		
•	Δ	.001	KNOTT ALOW CONVEYOR	ER FEED	1000	INCL.	100	, 100	100	1300	
	<u>А</u>	•002	KNOTT BLOW AND DUCTIN	ER, CYCLONE G	10000		1200	INCL.	600	11800	2
	Δ	•900	EXTRA WORK		-						
	A	· · · · · · · · · · · · · · · · · · ·	TOTAL ACCO	UNT	11000		1300	100	700	13100	2
	Δ	421.38.000	PROCESS CO	NTROLS		,				· · · · · · · · · · · · · · · · · · ·	• •
	Δ	•001	INSTRUMENT VALVES, PA	S, CONTROL NES, TUBING	95000	7600	10300	4800	5900	123600	19
	- Δ	•900	EXTRA WORK		÷-				······		· •
	·A		TOTAL ACCO	UNT	95000	7600	10300	4800	5900	123600	19
	Δ	421.41.000	MOTORS							• .	<u> </u>
	A	• 001	UNBLEACHED KNOTTER NO	PRIMARY 1 40X7	1100	200	100		100	1500	
	A	•002	UNBLEACHED KNOTTER NO	PRIMARY 2 40X7	1100	200	100		100	1500	
	A	.003	UNBLEACHED KNOTTER NO	PRIMARY 3 40X72	1100	200	100		100	1500	•••
	A	•004	UNBLEACHED KNOTTER NO	PRIMARY 4 40X72	1100	200	100		100	1500	
SAN	י ח			TYP	ICAL PULP &	PAPER CD.	LTD	APPROVE			
				VANCOUN	/ER		CANADA	LAST ISSU	JE 14 JANE	8	· i t
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CCOL	INTS 421.3	5 - 421.41	
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EXHIBIT 5

PROJECT ORGANIZATION CHART

		•	• .								· · ·
	ACCOUNT	DESCRIPTION	96.5m 98 6m tre 80 69 60 60						-125-		
	R ITEM	DESCRIPTION			BUDGET		TOTAL COM	MITMENTS	ESTIMATED	TOTAL	VARIANCE
REFORT	U N SUB ITEM	DESCRIPTION		TRANSFERS TD	AMOUNT	ALLOCATED	P.C. ND	AMOUNT	COST TO -COMPLETE	ESTIMATED	OVER(+) -UNDER(-)
	421.38.000.00	PROCESS CONTRO	LS (CONTIN	IUED)						· ·	
	421.38.001.00	INSTRUMENTS, C	ONTROL VAL	VES. PANES.	TUBING (CON	TINUED	*****	·			
	A 09 A 10	LABOR TOTAL	· · · · · · · · · · · · · · · · · · ·			14250 139640	· · ·		14250	14250	
	A 421.38.900.00	EXTRA WORK	·	1 1		• •	: `` 	•:			•
	A 06 A 07	SUB-TOTAL MAIE	RIAL		•		· · · · · ·				
	A 09	LABOR	-			. . .	· ·	~	-		-
	A 10	TOTAL		•			3	·		·	
	421.38.000.00	TOTAL ACCOUNT SUB-TOTAL MATE	RIAL	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	123490			123490	123490	
	07 09 10	SUNDRY MATERIA LABOR TOTAL	L	•		1900 14250 139640	• • •		1900 14250 139640	1900 14250 139640	
	<u> </u>			· · · · · · · · · · · · · · · · · · ·			:		<u> </u>	A	
۰.	B #421.41.000.00	*MOTORS	· · · · · · · · · · · · · · · · · · ·	•		· · · · · · · · · · · · · · · · · · ·					· · · · · · · · · · · · · · · · · · ·
	B *421.41.001.00	*UNBLEACHED PRI	MARY KNOTT	ER NO 1							
	8 06 B	SUB-TOTAL MATE	RIAL	421.51.001*	-20*		400-A* 900-01-A*				
	8 8	· . ·				•	1010 *	•	· •		· .
	B 07	SHADDY MATERIA	TOTAL.06	421 41 900*	-20*	1500*		17204	* 1500*	3220*	1720+*
	A 09	LABOR	.	→2.1 ⊕ →1 , QUU+	2.01	-			-		
	<u>B 10</u>	TOTAL	· · · · · · · · · · · · · · · · · · ·		-40	1500*		1720*	1520*	3240*	1740+*
	B *421.41.002.00 B 06	*UNBLEACHED PRI SUB-TOTAL MATE	MARY KNOTT RIAL	ER NO 2	· .	1520	1010*	1470*	s 50*	1520	
	B 07	SUNDRY MATERIA	<u> </u>	421.41.800*	-20*	-			20	20*	20+*
	B 10	TOTAL			-20	1520*	、 	14703	* 70*	1540#	· 20+*
	B *421.41.003.00	*UNBLEACHED PRI	MARY KNOTT	ER NO 3		1520	1010*	14704	5.0×	1520	
	B 00 B 07	SUNDRY MATERIA		421.41.800*	-20*	-	1010*	141(2)	20	20*	20+*
	A 09. B 10	LABOR TOTAL		•	-20	<u> </u>		1470*	- - 70*	1540*	20+*
	B *421.41.004.00	*UNBLEACHED PRI	MARY KNOTT	ER NO 4							. :
 	B 06 B 07 A D9	SUB-ILITAL MATERIAL SUNDRY MATERIAL	KIAL L	421.41.800*	-20*		1010*	1470*	<u> </u>		
	<u>B 10</u>	TOTAL	· ·		-20	1520*	· 	1470*	< <u>70</u> *	1540*	20+*
SANF	WFII		TYPICAL P	ULP & PAPER	CO. LTD.	APPROVED		COST	SAMPL RECORDING FOHIPMEN	E MILL AND FORECAS T-DETATES	FING
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APPENDIX B

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SCOPE OF SERVICES OFFERED BY SANDWELL

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SCOPE OF SERVICES

Flexibility and diversified experience enable Sandwell engineers and staff to provide the following professional engineering services on a regional and world - wide basis.

GONSULIAMONS

Senior personnel with wide practical experience are available to advise upon:

 Planning of new developments or plant improvements for pulp and paper mills, sawmills, plywood and particle board plants, thermal and hydro-electric installations, industrial and chemical plants, and environmental pollution problems

Management aspects of integration, the design, construction and economic operation of plants and their maintenance PLANNING AND PREINVESIMINT STUDIES

Over the years an increasing number of clients have continued to retain Sandwell to study and report on the technical and economic feasibility of a wide range of industrial and utilities projects. Usually such feasibility studies include all, or some of the following typical areas:

- · Management and field surveys
- Integration of operations
- Appraisal of forest or other raw materials resources
- Site selection, geological conditions and water supplies, pollution studies and effluent control
- · Power studies
- Supervision of research, pulp testing and pilot plant work
- Preliminary process and plant designs
- Estimates of capital requirements, labour, operating costs and profits
- Financial analyses

Sandwell feasibility reports are usually prepared in sufficient detail to serve as the basis for discussing the financing of a project and are recognized by leading international and national financial organizations. Destern angennaanne and engennaarne

Sandwell engineers provide all design and engineering services required for the construction of industrial and utilities developments. Such services normally include:

- · Detailed process flow diagrams
- General site and plant arrangement drawings
- Establishment of plant and equipment specifications, comparison of tenders and recommendations for purchase
- Detailed structural engineering, mechanical and electrical drawings; bills of materials and specifications for construction

In addition to carrying out engineering for major projects and developments Sandwell engineers undertake design engineering and engineering for minor projects, frequently in collaboration with a client's own organization.

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.FUIGHASING SIMMORE

The Purchasing Group is staffed by experts with many years of experience in all phases of materials and equipment purchasing, inspection and expediting, which include:

- Preparation of prospective vendor lists, purchase enquiries, analysis of tenders. Preparation of purchase requisitions or orders
- Expediting and inspection of materials, plant and equipment in all parts of the world
- Traffic and routing by the most satisfactory and economic method
- Preparation of data for import licences applications and assistance in negotiating customs duties and sales tax levels in all parts of the world
- Receiving and warehousing of materials, plant and equipment.

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Sandwell staff includes personnel with wide experience in the management and supervision of construction work such as:

- Detailed construction scheduling and progress
- Co-ordination of contractors
 work
- Inspection and acceptance of contract work
- Continuous cost analysis and budgetary control
- Certification of accounts for payment.



Sandwell's evaluation of current technical and economics developments in the pulp and paper, forestry and forest products industries is not confined to assignments undertaken for clients. Qualified members of the staff maintain a world-wide review of fibre resources, technology and economics. Reports on these subjects are embodied in Sandwell development memoranda and research papers which are published at frequent intervals. MULL MARACIONIDU AND INTERNICAL SDEVICIDE

Sandwell staff, experienced principally in the management and operation of pulp and paper mills and plants in the forest industries are available to provide management and technical services designed to bring projects into full operation and up to capacity quickly.

These services include:

- Selection and training of key supervisory and operating personnel
- Management assistance to improve efficiencies of existing mills and plants or particular sections and departments
- Development and integration of either manual or computerized systems for production control, maintenance control, cost control and stock control.

FUELDED STUDIES

Experienced personnel are available to conduct market surveys for clients throughout the world, typical projects being:

- Background studies for a preliminary market assessment
- Detailed surveys of market potential, competition, prices and consumer acceptance
- Statistical analyses and long term forecasting.

APPENDIX C

COMPARISON OF def AND npv METHODS OF AMALYSIS

The following simple illustration is intended to show how the assumption that investment benefits are reinvested at a yield equal to the internal rate of return can lead to an erroneous decision.

Consider two simple projects with the following cash flow distributions. Project 'B - A' is an artificial project representing the difference between Project A and Project B.

	Year			
	0	<u> </u>	2	
Project A Project B	- 1000 - 1000	2000 0	0 3000	
Project 'B - A'	0	2000	3000	

The internal rate of return and the net present value of these projects can readily be calculated, and the results are shown as follows. A discount rate of 12 per cent, assumed to be representative of a firm's after-tax opportunity cost, was used to calculate npv.

· · · · · · · · · · · · · · · · · · ·	Internal Rate of Return	Net Present Value (12%)		
Project A	100%	790		
Project B	73% Tot	1300		
Project 'B - A'	50%	680		

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If the projects are not mutually exclusive and if the firm's opportunity cost is 12 per cent, both projects should be undertaken, assuming that sufficient financial and other resources are available.

However, if the projects are mutually exclusive (i.e. represent different ways of accomplishing the same objective), or if sufficient resources are not available to undertake both projects, the 'best' project must be selected. If the decision were based solely on the internal rate of return (irr), Project A with an irr of 100 per cent, as opposed to Project B with an irr of 73 per cent, would be selected. The artificial Project 'B - A' has an acceptable irr of 50 per cent, indicating that the increment in going from Project A to Project B is desirable. When the cash flows are evaluated using the firm's opportunity cost - the npv is calculated -Project B is also shown to be more desirable than Project A. Clearly Project B is the better project, and a decision based solely on the irr would be erroneous.

In order for the same benefits to be obtained from Project A as from Project B, the \$2000 received in Year 1 must be reinvested to yield \$3000 in Year 2. A reinvestment yield of 50 per cent is required. If the 12 per cent opportunity cost is representative of the investment possibilities open to the firm in Year 1, it would not be possible to obtain the same benefits from Project A as are available from Project B.

Now looking at Project B, it would be necessary to borrow \$2000 in Year 1 against the \$3000 which will be received in Year 2, in order to obtain the same benefits as are obtainable from Project A. Providing that borrowing is available at a rate of less than 50 per cent, this is possible. Hence on this basis, Project B is also superior.

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The best project is indicated directly by the maximum npv. Project B has a npv of \$1380 as opposed to \$790 for Project A, and hence is preferable. In this case, the time value of money is calculated using a realistic rate of 12 per cent, rather than the internal rate of return which may or may not realistically represent the time value of money to the firm.

This simple illustration is unlikely to be representative of actual investment possibilities, and certainly not of large capital projects, which are the focus of this thesis. It does, however, show how the reinvestment rate enters into evaluation of investment proposals, and how use of the internal rate of return as the sole parameter for investment analysis can lead to erroneous decisions when comparing alternatives.