A GOAL-PROGRAMMING METHODOLOGY FOR STRATEGIC FINANCIAL DECISION-MAKING

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SUMMARY

This thesis tackles organisational viability problems, encountered in the usage of linear programming-based financial planning models for strategic decision-making. In particular, the research uses systems concepts and empirical evidence from previous studies to develop and theoretically justify the hypotheses that:

- organisational viability can be enhanced significantly in that state in which the organisation effectively balances its structural composition with its capability for environmental capital mobility;
- the unsystematic cost of capital component is, in reality, the social discount rate, while the systematic component comprises the business, financial and security-marketability risks;
- satisficing logico-mathematical models are the most suitable for effective organisational strategic financial planning.

A planning concept is developed, termed 'viability planning', defined as planning to maintain an adaptive, efficient and effective structural composition. This concept is elaborated as a decision-making modelling methodology, using (in an 'Interaction Tableau') a set of organisational characteristics whose inherent synergy has to be maximised as a prerequisite for sustaining organisational viability. A decision-analysis model in a non-preemptive goal-programming framework is proposed to obtain the optimal synergy-scenarios, that should subsequently be considered in a preemptive model framework for ranking, weighting and satisficing. A logical extension of the theoretical framework of sensitivity analysis is proposed for satisficing, deriving trade-off weights either by analysing the relationship between deviational variables in satisfying specified goal-constraints, or by optimising total trade-off value between the different non-dominated solutions obtainable from the multiple desirable objectives. Finally, using a program developed on a Harris-8ØØ computer, various aspects of the viability planning concept are experimentally tested in a case study of a holding company.

It is concluded that organisational viability modelling problems could be minimised by incorporating the capitalised-cost structure in a multi-criteria decision-making framework, the primary considerations being optimality of synergy and appropriate balancing of the preference and trade-off weights (both of which are confounded in current model-applications).

KEY WORDS: Organisational Viability, Multi-criteria models, Synergy, Capitalised-cost Structure, Satisficing

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CHAPTER ONE

GENERAL CONSIDERATIONS

1.1 Introduction

Organisational Viability is generally understood by today's management and accountants as the capability of the organisation to remain solvent over the specific horizon being considered. Most management and accounting literature - for example, Bolton (1976), Sizer (1975), Chambers (1967, 1971), etc. - indicates that in practice the usual tendency of management is to ensure the maintenance of solvency through effective (albeit sometimes inefficient) project-based cash management, capital budgeting and evaluation policies. The assumptions underlying such policies are that an organisation's transactions can all be viewed in terms of specific projects and that the aggregation of the viability-levels of these projects is the organisational viability. Thus, the tendency has been to regard project viability as synonymous with organisational viability. Further, the inefficiency of the above-mentioned policies is aggravated by the problems associated with strict adherence to any cash management or capital budgeting policies - that is, the problems of project interdependencies, disadvantageous applications of economy of scale and high opportunity costs of business transactions.

Viability is defined, in most dictionaries, as the capability of maintaining a separate existence irrespective of the circumstances encountered. Such a definition is in conformity with the systems viewpoint that viability is the capability to adapt effectively to environmental changes and interact efficiently within the particular environment. Following the line of thought underlying this definition, the interactions of an organisation with its environment should be of major consideration since it is through them that the organisation can be characterised as a business system rather than merely a legal entity. This is evidenced by the fact that in merger situations, neither of the merging organisations would be ready to give up its individual identity unless otherwise compelled by environmental pressures.

The subtle difference between the two definitions mentioned above, is what is being elaborated and exploited in this research. In particular, an interpretation of organisational viability will be developed as a planning concept and a decision-making modelling methodology. Such a development is intended to have a contextual framework which can be viewed as a compromise, emerging from two extremes of financial management practice - one emphasizing the 'power' of capital, while the other emphasizes the 'power' of decision-making adroitness. Before any such planning concept can be developed however, it is considered essential to develop a framework which can be used not only for a broad classification of organisations in terms of their viability states, but also for identifying the desirable planning strategy for any particular organisation. This framework is developed in the following section.

1.2 Framework for Identifying Viability States

The scope, range and general nature of the interaction between an organisation and its environment are, to a large extent, dependent on the organisation's capability for general mobility of resources. More often than not, it is the desire (of fund-parties within an environment) for resource-mobility channels that creates the organisations and the competitive atmosphere in that environment. Such an atmosphere aids the achievement of shifts, over time, of both consumption and production activities through the intermediation of financial markets - the capital market and the money market.

Using the investment-production separation principle, which forms the basis for interactions between organisations and their environments, a set of collectively exhaustive states of viability for organisations is identified in this research. This is essentially to analyse organisational viability in terms of the interface between the organisation as a business system and the organisation as a legal entity.

These states, in order of increasing desirability to various fund parties in the financial markets, are as follows:

- liquidation state,
- bankruptcy state,
- technical-insolvency state,
- product-alertness state,
- industry-alertness state,
- capital-alertness state, and
- balanced activity state.

Without doubt, the liquidation state signifies the situation in which dissolution is inevitable, since the organisation concerned would already have admitted its failure and its inability to reorganise. The bankruptcy state is characterised by the prevalence of a clear-cut choice between returning shortly to a more viable operating status or being dissolved. In this state, the organisation formally declares itself in a state of financial duress and asks bankruptcy court's protection from its creditors while attempting (possibly through receivers) to rectify the situation somehow. This state is usually typified by a negative net worth - that is, the organisation's liabilities exceed its assets. The technical-insolvency state is that in which an organisation does not have sufficient cash to meet its immediate payments. An organisation can operate in this state, for a considerable length of time, as a recognised failure without having to be declared bankrupt. During such a period, the organisation tries to work itself into a solvent position, though a constant possibility of dissolution lurks in the background.

The three states discussed above have a common dilemma - short-run operations will most probably differ widely from the desirable long-run trend since short-run problems are so damaging that the long-run seems too far away to matter. The point then, about these states (and indeed any other states for that matter), is that there is the need for recognising a value of an organisation to itself, the absolute minimum of which is independent of the organisation's status in the capital market and below which management cannot afford to sustain the organisation.

The product-alertness state is that in which the maintenance of a high level of resource-transformation characteristics is the order of the day. The motivation behind this is not so much to obviate the risks of becoming technically insolvent as to become a force to be reckoned with in the product market and, consequently, in the industry.

The industry-alertness state is that in which the aim is to maintain a high level of recognition within that industry to which the organisation belongs. The motivation behind this is essentially to ensure that the policies of the organisation influence, to a great extent, the behavioural characteristics of its industry at least within the economy concerned. Any organisation in this state is bound to encounter enormous pressure to go 'public' if it has not yet done so - since most participants in the financial markets realise that capital most consistently gravitates towards organisations in this state. This is evidenced by, for example, the sale in September/October '83 of some stocks in British Petroleum and Tottenham Hotspur, and also by the Stock Market expectations of stock-flotations in British Telecommunications and Reuters (Investors' Chronicle, August-October '83). Thus, arguable as it may be from an economist's viewpoint, the nature of market transactions tends to indicate that the appearance of such organisations in the financial market can only increase the level of economic activity. As long as 'going public' means floating of stocks to the general public as a listed security in the stock market, the appearance of an 'industry-alert' organisation in the stock market is bound to positively influence the consumption-investment decisions of various fund-parties in the economy.

The capital-alertness state is that in which the order of the day is to promote the organisation as a 'money-maker'. Although most shareholders would want their organisations to be in this state since they consider it an excellent one, it is actually a dangerous one for any organisation to maintain. This is because this state really indicates that the organisation is much more dependent on the capital market to survive than on its own productive capability. It also indicates that the organisation's need for the capital market is much more than the latter's need for such organisations in either's attempt to promote its relevance within the environment. This is, of course, the reverse of the indication reflected in the industry-alertness state.

The balanced-activity state is that in which the organisation aims at maintaining a stable structure which ensures an effective balance between the capital-alertness state and any of the other states. This is the state in which the organisation not only recognises its value to itself, but also strives to achieve real growth in terms of the marginal increase in that value relative to the marginal increase in the value of the organisation to its relevant fund-parties (equity-finance parties, bond-finance parties, and trading-finance parties).

From the framework, presented above, for identifying viability states, it can be realised that the first three states are mutually exclusive. Further, the following underlying assertions can be made and which subsequently form the basis for the financial theory considerations in this study:

- Every organisation has a value to itself, quite distinct from the values attached to it by potential shareholders, bondholders, and all other fund-parties alike
- Potential shareholders and all other fund-parties have the most interest in the existence of capital markets. Organisations, on the other hand, should care about the capital market only to the extent that it remains the main channel for their fund raising activities. Consequently, each organisation's value to itself

has to be seen more in the light of its productive capabilities than of its capability as a channel for 'money-making'

- As long as an organisation maintains certain characteristics which help the existence of capital markets, its goal does not necessarily have to conform to the consumption-investment decisions of its potential shareholders in any specific horizon
- The 'balanced-activity' state is that which every organisation should strive to attain, and it can be ensured by maintaining an adaptive structural composition.

Thus from the above discussion, it can be realised that strategic financial decision-making problems nowadays are mostly associated with the degree of incompatibility between the way organisations are compelled (from outside) to fulfill objectives (conforming to the standards imposed by their environment) and the way organisations are directed (from within) to maintain an internal structural composition and proportion (sustaining their own integrity as a goal-seeking system). Indeed, it is fair to say that the perception (by management and analysts alike) of strategic financial decision-making problems is coloured by environmental pressures (in the form of the capital market).

Following this line of argument, the underlying factors can be seen to be three-fold:

- the bias, in financial management practice, towards project viability rather than organisational viability, or the assumption of equivalence between both;

- the invalidity of certain financial theory assumptions but which developers of logico-mathematical models take for granted; and
- the inappropriate accounting for risk and decision-making inconsistencies in present-day financial planning model applications.

The manner in which the above mentioned factors are considered in this research is discussed in the following two sections of this chapter.

1.3 Considerations for Financial Theory

It is common knowledge that corporate financial policy mainly comprises the consideration of issues like capital budgeting, the cost of capital, capital structure, dividend policy, mergers and acquisitions, and international finance. All these pertain to the consumption-investment decision - important to all sectors of the economy, since after all directors of firms who act as agents for the owners must decide between paying out earnings in the form of dividends, which may be used for present consumption, and retaining the earnings to invest in productive opportunities which are expected to yield future consumption. The significance of capital markets cannot be overstated in the opportunities they offer individuals and organisations for the efficient transfer of funds between borrowers and lenders.

The theory of finance is greatly simplified by the usual assumption that capital markets are perfect. Furthermore, on the one hand, it propagates the 'unanimity principle' that managers of organisations need not worry about making decisions which reconcile differences of opinion among shareholders since, if investors were asked to vote on their preferred production decisions, different shareholders of the same organisation would be unanimous in their preferences. On the other hand however, it emphasizes that organisations have to issue securities in response to the preferences which they judge individuals to have. That is, the decisions of firms must be responsive to the implied individual optimisation situation, perceived to prevail in the capital market.

The problem of capital market understanding is really dependent on the organisation's interpretation of the relationship between concepts of contingent claims markets (Modigliani-Miller propositions), capital asset pricing models (CAPM) and options pricing models (OPM). While the works of many financial analysts - for example, Black, Jensen and Scholes (1972) and Fama (1970) - have left little doubt that under certain conditions the OPM, CAPM and Modigliani-Miller propositions can be shown to be consistent with each other, testing for market efficiency still remains an onerous task. For example, Copeland & Weston (1979) have shown that if capital markets are inefficient, then the assumptions underlying the CAPM are invalid. They also emphasize that if the CAPM is inappropriate (even given that capital markets are efficient), then the CAPM will still be the wrong tool to use in testing for market efficiency. This is only logical since any such test which uses the CAPM to adjust for risk will in fact be a joint test of the CAPM itself and market efficiency, inasmuch as the former assumes the latter for its own validation.

The points above bring into focus certain questions:

- Do theories which assume frictionless markets fit reality well enough to be useful, or do they simply need some modifications in order to make them provide greater insights into reality?
- To what extent can the inherent contradictions among theories actually hinder decision-makers' understanding of the options open to them in tackling problems that arise in their organisation's interaction with the capital market?
- Which is more vital for the decision-makers to understand from the point of view of organisational viability? Is it the capital market or the organisation itself as an independent entity?

In theoretically justifying and experimentally testing the proposed answers to these questions, the view is taken in this research that the assumption of perfect capital markets does not really help decision-makers from the viewpoint of organisational viability. For example, for decision-makers to be convinced of the reliability of any 'feedback' information from the financial market, market prices should be completely indicative of all available relevant information in order to denote accurate signals for capital allocation. Thus, if a firm can reap monopoly profits in the product market, the firm's security price should fully and speedily reflect the present value of the anticipated stream of such monopoly profits. This type of situation indicates the necessity, in this study, of giving much substance to the idea of markets being efficient rather than perfect. The forms of market efficiency generally known have been classified - by Fama (1970, 1976) - into weak, semi-strong and strong. In the weak form, information obtainable from past prices or returns cannot be relied upon to ensure excess returns. In the semi-strong form, the usage of publicly available information - such as annual reports, investment advisory data, etcetera, (over and above the information in past prices) - cannot be relied upon to ensure excess returns. With the strong form of market efficiency, no investor can earn excess returns through the usage of any information, whether publicly available or not. It is not difficult to realise that the existence of investment bankers, private placement offerers and over-the-counter dealers in the capital market casts a lot of doubt over the validity of assuming the strong form in most industrialised economies of today. Consequently, in this research, it is considered most realistic to assume that capital markets nowadays are in most cases only efficient in the weak and semi-strong forms. Indeed, the very existence of 'middle men' in capital markets is an evidence of the validity of this assumption.

Thus, this research considers financial theory only to the extent that the relevant questions, mentioned above, are answered, based on the assumption of weak and semi-strong forms of capital market efficiency. The view is taken that analysts can offer considerable benefits to decision-makers by influencing their structuring of organisational policies. In particular, analysts need to propagate not only a more practical and realistic cost of capital evaluation, but also firm-valuation models the implementation of which strikes the delicate balance between the unanimity principle (which is easier to implement) and the much more complex capital market reality. The extent to which such a balance is achieved is one of the aspects concentrated upon in chapter three when discussing some models that have gained considerable popularity in the academic world of financial management theory.

In order to achieve a more stable and consistent collaborative effort between any organisation's accounting and planning systems, an examination of desirable strategies for organisational growth is carried out in this study, which involves some refinement of existing theories on issues such as horizon valuations and risk analysis in investments and financing.

1.4 Considerations for Logico-Mathematical Models

The substantial nature of the data requirements (and the assumptions underlying the usage) of any linear programming-based financial planning model suggest that in practice the estimates of that data may be so speculative that managers have little confidence in using such models to enhance the judgemental aspects of the decision-making process. Even though all the data required by such models may be relevant, some assumptions about them are bound to be implied by any decision taken. The model-building process requires these assumptions to be made explicit so that the consequences of the best estimates possible can be studied systematically. However, these assumptions fall into two categories. One category comprises those assumptions about the nature of the objective function to be optimised and its constraints. These include the usual assumptions of linearity, continuity and non-negativity which are fundamental to linear programming; the consequences of which are fully exploited by the iterative procedure involved. The other category of assumptions pertains to those which cannot easily and confidently be explicitly expressed due to the inherent uncertainties and also due to the conflicting and incommensurate nature of the multiple desirable objectives in any organisational problematic situation. The greater the uncertainty, the more there is the need for flexibility in the decision-making process (in other words, the more there is the need for increasing the variety of response).

The above discussion suggests that any Operational Research and Systems Analysis (ORSA) developments, pertaining to decision models (especially for strategic planning, where the theories involved have some non-quantitative bases), could easily be regarded as mere academic exercises if the judgemental aspects of the decision-making process are not appropriately taken into account in the model-building. Present management practice - for example, as studied by Kahndelwal (1981) - gives an indication of this. In fact, in a survey (Kim and Farragher, 1981), an important observation was that the use of long-range capital budgets, sophisticated capital budgeting techniques, risk assessment techniques, risk adjustment techniques, and management science techniques was inversely proportional to the overall riskiness of the firms surveyed. Thus, there is still a particularly large gap between the precepts of analysts' works, so far, on organisational strategic planning and today's business practice.

The organisational viability problem is a multi-dimensional one, since it essentially concerns the maintainability of the 'balanced-activity' state, highlighted in Section 1.2 of this chapter. The assumptions which a decision-maker makes about his organisation and how it behaves are bound to have a significant impact on the way that the organisation functions and the kinds of problems and opportunities it will have in trying to achieve the desirable viability state.

Management is centred around planning, and the planning process is a highly judgemental one. However, the assumptions which a decision-maker makes about the relevant parties outside his organisation may not necessarily be consistent with the logical requirements for sustaining the organisation's viability in the long-run. Indeed the decision-makers themselves may not be aware of such requirements.

Consequently, the consideration of logico-mathematical models in this study will focus upon the inconsistency problems associated with organisational planning. It will also focus upon the derivation of an appropriate methodology with the distinctive characteristics of ease of use and versatility of adaptation to the end-users' individual circumstances.

1.5 Structure of the Thesis

The considerations, discussed in the earlier sections of this chapter, constitute the basis for structuring this thesis in the form described below.

Chapter Two is a discussion of the concept of viability planning by first looking at organisational planning problems (as perceived by management, accountants and analysts), gathered from the literature as well as during discussions in the Holding Company used as a case study in a later chapter. Following this is a discussion of the development of normative decision rules in evaluation considerations. The viability planning concept is further elaborated by discussing the underlying processes (in organisations) which indicate the relevance of a new approach to the understanding of organisational viability.

In Chapter Three, the development of the capitalisation model is emphasized as one of the crucial problem-structuring phases when the viability planning concept is applied to organisational strategic financial planning. Also in this chapter, arguments are presented about the inappropriateness of the cost of capital and the viability planning framework. Areas that might be worth improving in the computer programming aspect are also suggested. Thus, the final chapter is not only a general conclusion of the whole work done in the research, but also a discussion to motivate further improvement of the interface between the proposed viability planning methodology and the real world of strategic financial decision-making in general.

CHAPTER TWO

THE CONCEPT OF VIABILITY PLANNING

2.1 Introduction

Most management theorists and analysts will agree that Management is an art based on science. The skill of effective management rests on combining the elements of the organisation in such a way that they yield the highest effect - bearing in mind that all environmental variables constantly gravitate around three basic elements (ideas, physical resources and people), which continuously require new adjustments in the management process. Thus, management involves decision-making and the decisions have to be made in the face of numerous uncertainties. The conceptual and implementing process of managers however, differs from that of management scientists. Managers' effectiveness rests in their ability to work in, and with, a complex system which they do not totally control and which they, being only human, will never comprehend in all its complexity. The effectiveness of management scientists, on the other hand, can only be appreciated through the enhancement of qualitative judgement gained by scholars of management and practising managers.

Consequently, an assertion can be made about the management process that performance levels essentially depend not only on the individual experiences and intuition of managers, but also on the qualitative judgement exercised in decision-making. An organisation's viability depends on the nature of its drift towards adaptation in accordance with the laws of its own existence. This drift in turn depends on the conceptual and structural models of the organisation perceived and encouraged by its decision-makers.

Viability Planning, as it is introduced in this research, can be defined as planning for structural stability during the application of whichever conceptual model the management perceives as the most survival-ensuring to maintain.

This chapter is therefore concentrated on the issue of structural stability. In particular, certain aspects of organisational planning problems will be discussed in order to highlight the influences (on management) of the accounting system in their organisation, as well as of the environment in general. The understanding of such influences should help to identify what the focus ought to be in evaluation considerations. Of particular interest will be the capitalisation model and the processes which underlie the conceptualisation of any organisation as an open system and which also help to appropriately interpret basic accounting concepts in conformity with the requisite conditions for sustaining a high level of synergy in the organisation.

Consequently, this chapter will present the prerequisites for developing any capitalisation model, the theoretical and practical justifications for a new approach to the evaluation and use of the cost of capital in organisations. Finally, growth strategies and valuation considerations will be discussed, since these are of primary concern in applying the concept of viability planning to organisational strategic financial decision-making.

2.2 Viability Planning and Organisational planning problems

Viability Planning can be viewed as a way of doing comprehensive planning, by 'backward integrating' strategic flexibility to match current tactical plans and develop new ones.

Every organisation has its own set of distinctive behavioural features. However, a common characteristic of organisations is that both the system and its constituent sub-systems concurrently try to adjust themselves to disturbances so as to maintain their own integrity. To the extent that there is unison of purpose in doing this, the achievement of some degree of synergy is assured. Most organisations are plagued with various planning problems due to insufficient achievement of synergy and this, due to the inherent inter-connectedness of the sub-systems of the organisation, could inevitably make what is planned for and what consequences are achieved to be entirely unrelated.

An important aspect of Viability Planning is therefore concerned with implementation. In order to ensure that any model developed is comprehensible to the users (and is amenable to evolutionary improvements suggested by the users during implementation and subsequent use), the ability to handle virtually any element of structural disruption (which could be cost, work-load, information management, and so on) has to be perhaps the most distinctive characteristic of the methodology for viability planning in enhancing organisational decision-making.

The issue of implementation brings into focus certain organisational planning problems usually encountered. A typical one is that in most organisations, although everyone may agree that a particular problem is a significant one, each manager usually finds himself with no shortage of significant problems, most of which will necessitate urgent reviews of the individual's day-to-day efforts, objectives and decisions. That is, no one person in the organisation may have been charged with the viability planning problem nor may indeed have actually taken the kinds of decisions indicated by any model developed for this purpose. In fact, there is usually a wide-spread belief within organisations that if some of the day-to-day problems could be solved, long range problems would be ameliorated and executive talent would be more readily available for their solution. Such a belief only indicates that the organisation's transformation characteristics are unstable - in which case, every environmental change would impose considerable changes in the transformation characteristics which in turn would cause more day-to-day problems to be faced even before those on hand have been solved.

Another problem usually encountered in the application of planning models is that most of their users may not really be making decisions about the aggregate parameters required by the model. A user may be making decisions at a different level of aggregation which will result in the phenomena described by those parameters, but he may not really be dealing with them as decision variables. For example, an analyst who is keen on capacity planning problems might tackle a planning problem by developing a model based on production schedules. Making capacity decisions from such a model-application could mean that by the time problems are recognised, it would really be too late for the model to provide an effective solution. The lead-time involved in shifting products from one technology or factory to another might be from three to twelve months, while situations necessitating shiftings between technologies or factories might often occur in intervals less than the range of possible lead-times. In the end, even a capacity planning problem would have to be viewed in terms that are operational to the people who in fact make capacity changes.

The above discussion indicates that in developing a viability planning model, one needs not only to isolate the proper levels of aggregation while tackling those problems usually addressed by classic aggregate planning models, but also to provide at the same time the necessary opportunities for users to build on whatever level of problem perception exists in their organisation.

2.3 The Issue of Management 'Subjugation'

Field studies such as those of Luck et al (1971) and Child (1975/76) confirmed that there are series of mismatches between theories of finance and management and the way organisational strategic decision-making is exercised. Perhaps the key reason for these mismatches is that usually some antipathy exists between analysts and accountants. If accountants are supposed to provide necessary information for management decision-making and operational research and systems analysis (ORSA) practitioners are supposed to devise methodologies to help management rightly interpret and use this information, then the major question is how can ORSA practitioners and accountants come to a realistic and unified understanding of the appropriate measurement system that gives direction to their contributions in easing the formidable task of management decision-making?

An interesting issue usually encountered is the confusion over the measurement of profit. ORSA practitioners usually use the economists' interpretation which is essentially cash flow. However, while the analysts will concentrate on cash flow left over after costs of operations and new investment are deducted from revenue, accountants do not deduct gross investment as outlays are made - instead the book value of new investment is capitalised on the balance sheet and written off at some depreciation rate. Following the logic behind the accounting definition, the tendency would be to accept that the change in the value of assets can adequately be accounted for by the pre-fixed depreciation factor. What would obviously be more appropriate should be to use a value of the asset which has to include some contribution from the 'package' within which the particular asset has been put into operation.

Extending further the issue of the confusion over the interpretation of profits, what is worth mentioning is the resulting misinterpretation top management may at certain times attach to the organisational goal of shareholders' wealth maximisation. The accounting definition implies the maximisation of earnings per share, while from an economist's viewpoint, maximising price per share will be the obvious objective since it more appropriately conforms to the concept of firm valuation by the market rather than firm's asset valuation by management. The fact is that the first approach does not depend on the capability of the accounting system to 'dress up' the organisation, but the second approach leaves room for this dependence.

Generally, it will be fair to assume that management confusion prevailing in organisations may be largely due to a widespread tendency among operating executives to think of information exclusively in terms of their companies' accounting systems and the reports thus generated. Management in many firms have thus found themselves in helpless situations - 'subjugated' by the conventional wisdom of the administrative personnel and valuation considerations in present-day financial management practice.

Chapter Four is concentrated on a review of conventional financial planning models with the aim of highlighting the theoretical and practical reasons why such models prove to be unsatisfactory from the viewpoint of organisational viability.

Chapter Five closely examines the current 'state of the art' of multiple criteria decision-making modelling, and discusses the manner in which attempts have been made to tackle the problems of simultaneous implementation of conflicting organisational goals, and also the problems of inconsistencies of the decision-making process in general.

Chapter Six is then concentrated on the development of a viability planning methodology, using goal programming and decision analysis techniques - in a manner which not only ensures consideration of all combinations of uncertainties perceived by the decision-makers as regards their organisation's survivability, but also sustains consistency in the search for compromise plans among the multiple desirable objectives of the organisation. A viability planning model is developed on the University's Harris 800 Computer based on the proposed methodology in this chapter.

Chapter Seven embarks on the development of the Interaction Tableau, and subsequently the viability planning model. The discussion here not only highlights the manner in which conventional financial planning model-application problems are tackled, but also emphasizes the relevance (to strategic financial management) of understanding multiple criteria decision-making modelling.

Chapter Eight is a case study of an international engineering-based private group of companies. The problem pertains to the development of a project appraisal and review system for the Holding company with particular emphasis on the modernisation of the plants of one of the sub-group companies. This case study is used to test various aspects of the viability planning concept experimentally. Particular consideration is given to the derivation of the appropriate cost of capital for the Holding Company. There is also a detailed consideration of how the problems of project interdependencies, horizon truncation in model-applications and simultaneous incorporation of desirable investment and financing decision-rules into such applications might best be tackled by the Planning Department of the company.

The final chapter (Chapter Nine) is a discussion of the logical conclusions that can be drawn from issues raised in the previous chapters and also from the findings gathered in applying the proposed viability planning methodology to the case study elaborated in the previous chapter. Certain aspects are then highlighted that might be worth special consideration in any future research aimed at a full-scale practical justification of value of assets can adequately be accounted for by the pre-fixed depreciation factor. What would obviously be more appropriate should be to use a value of the asset which has to include some contribution from the 'package' within which the particular asset has been put into operation.

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The striking point is that a good deal of the multifarious book-keeping transactions recorded in business organisations are not actually used as inputs to decision processes. In the first place, they are not structured in a way to make them help management direct attention to derivable information for further decision processes; and secondly, the derivable information is usually inadequate and inappropriate since it has all been generated within the organisation and in a rather arbitrary manner. If valuation models are aimed at enhancing decision-making processes in any organisation, the components of such models must be such that the assignment of values to the coefficients and the decision variables go beyond simple extraction from the normal book-keeping transactions recognised by conventional accounting and administrative practices nowadays. This is where much collaboration is needed by all concerned to ensure that the needed change is recognised to be fundamental. It is precisely in this aspect that conventional aggregate planning schemes fall flat, since such schemes are based on a single decided goal and usually in accordance with the recommendations from conventional administrative and accounting reports.

2.4 Evaluation Considerations

Extending the previous discussion about derivable information, what seems to be frequently overlooked is that while the nature of an organisation's product is the basis for its interactions with its employees, suppliers and customers, it is the nature of the organisation's interactions with potential 'fund parties' which actually plays a crucial role in determining the fate of the organisation's investment credit and growth. In the first case, what is handled is essentially data as a final good, produced for itself alone - for example, fulfillment of orders, production schedules, stock replenishment charts, value-added charts, employee records, and so on. In the second case however, what is handled is data in the form of information as an intermediate good to be an input to a further process - that of certain business decision-making within or outside the organisation, but which can modify the latter in one way or another. Some of such information may indicate the need for improving the company's image in the outside world on issues like credit-worthiness, job security, customer satisfaction, board's confidence in management, and even social acceptance of the majority shareholding community. Some other such information may indicate the need for improving company image within itself, especially on issues such as employee-identification with the organisation rather than with the job, distribution of authority, work satisfaction, and so on.

The distinction of data from information in this manner makes recognisable the necessity for firm valuation models to have variables that have to be interpreted as information rather than as pure data. The implication here is that the models should be based on the cost-benefit approach rather than the much more straightforward, but misrepresenting, cost-effective approach. The cost-effective approach assumes that although the inputs to a system are variable, the output is relatively fixed in utility. On the other hand, the cost-benefit approach assumes that both the inputs and the outputs vary, and thus this approach recognises the existence of several systems and therefore attempts to measure which of these systems, or combinations of sub-systems is the most efficient while maximising the desired output.

What complicates further the treatment of information is the consideration for the time-span after a decision is taken before it is worthwhile monitoring that decision. In the case of pure data, it is more of a short term nature, while in the other case, the time-span of any decision on the issues involved may run into months, or even years, if not indefinitely. The essential procedure then should involve a careful selection of the several increments of information about parameters, which conform with what the shared rationality of the majority in society accepts as the most appropriate feedback filters of organisational viability.

Society uses the ability of the organisation to earn a return on invested capital as the means of judging the efficiency of the organisation as a wealth-assurer. Should return on investment fall, the organisation sooner or later loses the ability to compete for resources and loses profits to other organisations who perhaps have produced goods that people do want, and can afford, to buy. Thus, there is an environmental standard - the current opportunity cost of capital or the current social rate of return - against which an organisation's 'efficiency of capital' can be measured. This aspect of the interaction with the environment is direct and through it, the environment is assured of enough feedback information which helps in its continual adjustments of the economic standard. The other aspect of an organisation's interaction with the environment is indirect since the latter does not (in a free economy) dictate how any organisation should choose the assets to acquire or should allocate its resources. The environmental standard in this case comprises economic standards such as contribution to gross national product, labour utilisation and so on. This mode of interaction is therefore essentially focused on what may be called 'functional efficiency' and through it the environment has an appreciation of its sustainability of any desired level of technological growth and development. The crucial point then is that decision-makers have to help their organisation develop a structure which is consistent with its environment by maintaining an appropriate balance between 'efficiency of capital' and 'functional efficiency'.

It is important to realise that while it is not difficult to recognise all the indicators of capital efficiency, it is very difficult to recognise all the indicators of functional efficiency. A mistaken view usually held in organisations is that functional efficiency can only be measured in terms of productivity of those sub-systems which are directly involved with transformation of input materials to saleable outputs within or outside the organisation. An in-depth analysis of variations in any organisation's operations however, will reveal that there are also indicators of functional efficiency at the organisation-environment interface where the organisation's objectives have to agree with those of the environment if all of the sub-system level activity is to be of any use. Examples of this can be seen in organisational operations such as accounts receivable management, inventory control, manpower planning, management of assets and so on.

In accounts receivable management, it is generally thought that control of credits interacts with merchandising such that tight credit interferes with selling, while loose credit makes sales easier to obtain. A closer look will however reveal that credit policies are in reality an interface where sales activity comes face to face with the supply of money and credit in the environment. If credit availability in the environment is low relative to the needs of the organisation, pressure will be exerted on the organisation to extend credit in order to ensure the desired level of sales. On the other hand, a generally liquid situation will make for less pressure to grant credit and more emphasis will be on merchandising. In other words, for any given policy, an environmental condition of tight credit will result in an increase in the level of accounts receivable which will force the organisation to counteract in other ways in order to maintain a healthy balance sheet ratio. In inventory control, the general practice is to effectuate control by relating inventory levels to sales. If however when sales increase, an attempt is made to increase inventory, a more unstable production activity may result than if inventory is allowed to assume or reach whichever level is appropriate to absorb fluctuations in sales. Similarly, reducing inventory in the belief that 'idle' capital will be reduced is simply passing on the sales fluctuations to manufacturing in the form of short runs, smaller purchases and unstable hiring. On the one hand, unstable production activity could result - which could lead to high stock-out costs and customer dissatisfaction. On the other hand, high inventory levels could result - which could make pricing uncompetitive. Thus inventory policies can be seen to be in reality an interface where the production and storage activities come face to face with the oligopolistic nature of the environment. In manpower planning, if the conventional usage of the transition matrix is adhered to, then any environmental change which necessitates changes in the resource transformation characteristics (such as technology, new product development, etc.) would render manpower planning in the organisation totally insensitive to cost optimisation during necessary redundancies, recruitments and staff development programmes. If however an organisation complements conventional manpower planning with appropriate de-specialisation and career planning, human resource evaluation can be made much more reliable. Manpower planning policies are thus an interface where the human development objectives of the organisation are indicated to the environment (and indeed, to the employees). In asset management, the problem is one of justifying and monitoring the degree to which acquisitions are planned to balance flow and the degree to which they are planned to balance capacity. Conventional usage of pay-back period, net present value or internal rate of return on individual assets could result in a situation where unexpected 'bumps' in the required budget are much more frequent than necessary - thereby making more often than necessary the 'fund-seeking trips' of the organisation to the capital market. Thus asset management policies are in reality an interface where the investment activities of the organisation come face to face with the supply and demand situation for medium and long bonds or equity-funds in the environment.

Indicators of functional efficiency, such as those discussed above, should not be confused with the financial ratios usually used in conventional management accounting. In fact it is necessary to emphasize that conventional financial ratios may not only colour management's view about functional efficiency, but can also be very misleading. For example, a company with obsolete plant may have a rate of asset turnover which is the median in its industry, but because the plant is obsolete it may have a very low ratio of operating profit to sales and return on net operating assets. Its operating profit to sales ratio may be lower because it has very high production costs. Material costs may be well above average because wastage is high, but the major cause of the high production costs may be the cost of direct labour. Because the plant is obsolete, it may employ more direct labour, have a lower value-added per employee and a high rate of labour turnover. Furthermore, even though the rate of asset turnover is high, the organisation may have a low rate of work-in-process turnover and a high rate of finished stock turnover. This is highly probable since an obsolete plant makes the work-in-process cycle longer than that of the organisation's competitors while its sales may be limited mainly by its ability to produce.

From the above discussion, one can say that it is imperative for decision-makers to recognise certain parameters which can be used as indicators of capital efficiency and functional efficiency for their individual organisations. Such parameters then constitute the basic viability factors of the organisation. Profit is undoubtedly central to all involvements, but its maximisation is not necessarily central since what must be ensured is that the profitability-base of the organisation is sustainable over a very long period of time. An insight worth emphasizing is that the profit basis is always external to the firm, while within the firm-structure there are only costs. This is indeed an important view, for it seeks to place the whole idea of viability planning in the proper perspective. Sometimes it is still assumed that the generation of profits is entirely within the capacity of the organisation and its managers. Nothing can be further from the truth; profits flow in from the outside, and it is in this context that the social outlook on profits is actually meaningful. Viability planning therefore by necessity addresses itself to cost considerations within the organisation to improve the profitability basis. The concept of viability planning has some precipitating force in motivating the planner to realistically doubt the organisation's powers to control the future, and therefore make the present recommendations so as to preserve future options. In fact the greater the uncertainty, the more there is a need for flexibility and non-commitment. In other words, the need for increasing the variety of response prevails in perpetuity.

Thus, before placing further emphasis on the issue of basic viability factors, it is necessary to consider how to develop an appropriate structure for any organisation in terms of cost-parameters which reflect both capital efficiency and functional efficiency.

2.5 Developing a Capitalisation Model

Every organisation is built from, and made up of, various types of resources - human, financial, physical assets and materials. To each of these resources, attributable parameters are acquisition costs, running or periodic costs, return on capital outlay, life-span and salvage value.

Let the acquisition cost of a particular resource be C_a

the current expected periodic cost be C_p

the current desired rate of return, that is,

the organisation's implied cost of capital, be r

the number of periods in expected service life be n

and the expected salvage settlement at disposal be S_v

Using the concept of constant payment annuities, whereby the capital recovery factor is

$$\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]$$

an equivalent uniform annual cost, C_{pv}, can be calculated as follows:

$$C_{pv} = C_a\left[\frac{r(1+r)^n}{(1+r)^n-1}\right] + C_p \pm S_v\left[\frac{r}{(1+r)^n-1}\right] \qquad (2.1)$$

It must be noted that in the above formula, the salvage settlement component carries a '+/-' sign. This is because it has to be '+' for the human resource (representing contributions to pension schemes, redundancies, etc), while for all other resources, it has to carry a '-' sign.

If the periodic cost is expected to grow at an average rate, say g_{cp}, then the equivalent uniform annual cost from the stream of growing periodic costs will be:

$$C_{gp} = C_p\left[\frac{(1+g_{cp})(1+r)^n - (1+g_{cp})^{n+1}}{n(r-g_{cp})(1+r)^n}\right] \qquad (2.2)$$

This equation is, of course, the present value of the stream divided by the number of periods.

For an economic evaluation of the acquisition and usage of the resource therefore,

$$C_{pv} = C_a\left[\frac{r(1+r)^n}{(1+r)^n-1}\right] + C_p + C_{gp} \pm S_v\left[\frac{r}{(1+r)^n-1}\right]$$

$$= C_a\left[\frac{r(1+r)^n}{(1+r)^n-1}\right] + C_p + C_p\left[\frac{(1+g_{cp})(1+r)^n - (1+g_{cp})^{n+1}}{n(r-g_{cp})(1+r)^n}\right] \pm$$

$$S_v\left[\frac{r}{(1+r)^n-1}\right] \qquad (2.3)$$

Accepting that capitalised cost is the amount in the present whose return will yield the equivalent uniform annual cost, one can obtain the capitalised cost CAPC, of a resource simply by dividing the equivalent uniform annual cost of the resource by the current annual market-required rate of return r_{MKT}.

That is, $CAPC = C_{pv}/r_{MKT}$. Thus,

$$CAPC = \left(\frac{r}{r_{MKT}}\right)\left\{C_a\left[\frac{(1+r)^n}{(1+r)^n-1}\right] \pm S_v\left[\frac{1}{(1+r)^n-1}\right]\right\} +$$

$$C_p\left(\frac{1}{r_{MKT}}\right)\left[1 + \frac{(1+g_{cp})(1+r)^n - (1+g_{cp})^{n+1}}{n(r-g_{cp})(1+r)^n}\right] \qquad (2.4)$$

Similar calculations can be done for all the resources in an organisation, thereby having a Capitalisation model reflecting its cost-structure. Such a model (also called the capitalised-cost model in this research) can be developed on a basis similar to the presentation in Table 2.1 which shows the various forms of input variables that can be used.

A detailed version of such a table could include resource sub-groups as follows:

Table 2.1 Forms of Input Variables for the Capitalisation Model

	MANPOWER	PHYSICAL ASSETS	MATERIALS
C_a	Current Recruitment & Devt. Costs	Acquisition Cost	Assets' Acquisition Cost
C_p	Current Annual Pay & Fringe Benefits (incl. pension contribution, etc.)	Current Average Running Cost (excl. manpower)	Ordering & Holding Costs (excl. manpower)
g_{cp}	Expected Growth Rate for C_p		
n	Pension Age minus Average Age within the cluster	Expected Total Service Life minus Years in Operation	Expected Product Life minus Years in market
S_V	Redundancy or Hand-shake Settlement	Expected Salvage Settlement	Saleable Value of Inventory

Manpower Resources - pupil apprentice,

- line semi-skilled,
- line skilled,
- graduate trainee,
- lower management,
- top management;

Physical Assets - within economic life,

- within service (beyond economic) life,
- in extra service;

Material Resources - raw materials,

- intermittent consumables,
- normal consumables,
- energy inputs.

Having obtained a capitalisation model of the organisation, it is essential to understand certain fundamental processes that underlie the development of any viability planning model. A detailed discussion of such processes follows in the next section.

2.6 Understanding the Necessary Processes

In conceptualising the organisation as an open system, it is vital to recognise three collectively exhaustive regulatory processes. These are the homeostatic, mediative and proactive processes which project the organisation as a system of relationships, bound together by purposes, ideologies and expectations. Thus these processes set the organisation off from its environment and serve to differentiate the many parts involved in the necessary variety of interactions.

The homeostatic processes are those that must operate within the system in order to maintain a steady state; in other words, in order to assure the internal stability of the organisation. The mediative processes are those that focus on ways of intervention, not necessarily directed towards maintaining a steady state, but instead towards altering the behaviour and attitudes of all parties with a conscious intent. In mediative processes, the environment is conceived as establishing a force on the organisation thereby requiring some internal change. The proactive processes are those which are directed at actively seeking out environmental possibilities. Instead of being reactive to environmental pressure, the system's behaviour is proactive and in a sense induces change in the environment to conform to the creative use of resources available within the organisation.

A set of continua along which the above three types of processes may be described include dimensions such as passive-active, conservative-innovative, extroverted-introverted, etc. The homeostatic processes are positioned towards the passive end of the scale, since they present the organisation as a system tending towards a steady state. It is characteristic of homeostatic processes to maintain the required steady state with the least management intervention. The mediative processes are more active in character than the homeostatic ones, the primary differences arising from the source of the stimulus. Mediative processes occur under the impact of environmental pressure (that is, a set of forces in the environment creates the need for internal adaptation), whereas homeostatic processes become necessary where internal disruptions act as stimuli.

Mediative processes require a more active mode of behaviour, since they tap into functions that only managers can perform. Because of their location in the organisation, managers stand closer to the environmental processes than do other employees, and the higher the manager's status, the more he becomes concerned with the issues arising outside the boundaries of the organisation. Comparing the mediative with the homeostatic processes then, what becomes noticeable is the tendency of management to be more aggressive and less permissive in the former. Nevertheless, the aggressive mode has certain limits in mediative processes. When it is possible, for example, to separate goals and objectives from means and procedures, managers may seek to limit aggressive responses to the formulation and communication of goals while withdrawing in favour of informal processes for establishing means and procedures. One will expect something of this pattern to occur especially under conditions of decentralisation in an organisation.

The proactive processes imply a conversion and release of aggressive energy directed toward altering the environment. They are anything but conservative, and they typically generate the type of managerial behaviour that tends to induce resistance, counter-aggression, and in some cases outright hostility. Proactive processes differ sharply from the more conservative homeostatic and mediative processes - in terms of goals, the homeostatic processes stress maintaining the stability of the system as the fundamental goal, sometimes to the point where it becomes a substitute for activity in the environment; proaction, on the other hand, disrupts internal relations in the service of changing the environment.

Following the open system concept, it appears that mediative processes should be the most appropriate to use as a starting basis for realistically analysing the viability of any organisation. This is because they are inevitable due to the environment being dynamic, and also because they usually encompass homeostatic processes. Moreover, it is the robustness of the mediative processes that determines the proactive ones of the organisation.

Having discussed the fundamental processes in some detail, what then are the sort of activities to which the processes can be related (and consequently which should be of concern in viability planning)? Some examples of such activities are given below.

Activities necessitating motivation as proactive processes:

- capital intervention schemes,
- accounts receivable management,
- human resource valuation schemes,
- shareholder-wealth maximisation schemes,
- intra-sectoral technology assessment schemes,
- value judgements in strategic decision-making.

Activities necessitating motivation as mediative processes:

- inter-sectoral technology assessment schemes,
- information flow management,
- work-in-process management,
- suppliers' credit management,
- profit maximisation and/or cost minimisation schemes,
- translation exposure management,
- transaction exposure management.

Activities necessitating motivation as homeostatic processes:

- operations management,
- behavioural goal schemes,
- work-load balancing schemes.

Such activities constitute the basis upon which the parameters to be used in any viability planning model ought to be represented. Before embarking on elaboration of the manner in which any viability planning model has to be developed however, it is necessary to discuss some of the activities mentioned above in order to elicit and have a better comprehension of who indeed are viability planners in any organisation, that is, the end-users of any viability planning model. An interesting group of activities is that arising from trade credit policies. The activities in this case are accounts receivable management, suppliers' credit management and operations management - which are representative of the proactive, mediative and homeostatic processes respectively in any organisation (as will be explained shortly).

The first two activities imply that the activists have to be accountants. However, a closer examination will reveal that because of the nature of the processes involved, non-financial decision-makers of the organisation also have a major role to play. Generally, trade credits flow between organisations, such credits being recorded in the books of the recipient as suppliers' credit and in the books of the grantor as customers' credit or accounts receivable. From the standpoint of the economy as a whole, only the net balance of trade credit is therefore important since it measures some influence of organisations on the flow of funds in the economy. However, when considering an individual organisation's trade credit policy, it is not difficult to realise that the factors inducing the organisation to obtain credit from suppliers differ from those influencing its decision to give credit to customers. Undoubtedly, the volume of credit granted - like every other investment - ought to be based on profitability calculations, taking into consideration profits accruing from the expansion of output and interest income. Also the volume of suppliers' credit which the organisation utilises - like every other decision to raise funds - should be determined by the price of such credits relative to the price of funds from other sources in the economy. This is the glaring practice which indicates just one of the determinants of trade credit policies - that is, the economic activity of the organisation and its financial structure as reflected by its balance sheet and profit & loss statement. However, there is another - perhaps not so glaring - determinant of trade credit policies. This pertains to the general factors associated with the sector to which the organisation belongs, commercial practices in the market, the size of the organisation, its age, its past experience with suppliers and customers, the technological nature of its material transformation characteristics and so on. This other determinant is the one that brings in the non-financial decision-makers. For example, if an organisation produces goods whose production cycle is short or which are sold directly to the final consumer, the amount of customer credits is bound to be relatively small since most transactions will be in cash. On the other hand, if the production cycle is long, requiring the maintenance of comparatively large stocks, the amount of customer credits granted may be considerable. Also, in oligopolistic markets, credits serve as a substitute for price competition. This other determinant thus indicates the proactive nature of accounts receivable management in which capacity planners, line and sales staff have to be very much involved. As regards suppliers' credits, the amount of raw materials purchased and the size of inventories held (two factors connected with the technological nature of the production process) are bound to have a decided effect on the policy. The effect in this case will however arise as a mediative response from the organisation to the terms generally offered in the funds' market.

In the example given above, what is noticeable is that while the financial decision-makers have a major role to play in looking at the opportunity cost of any trade credit policy implementation, the non-financial decision-makers have a crucial role to play in considering the accounting value (or shadow price) of such policies to the organisation. Furthermore, in the end, the feasibility of any trade credit policy implementation has to be evaluated from the viewpoint of operations management - where the homeostatic nature of the implementation will probably be mostly felt. The example given above therefore shows also that while proactive and mediative processes will usually necessitate homeostatic ones, the latter do not usually warrant either of the former processes.

2.7 The Concept of Synergic Packages

Synergy can be defined as a measure of performance which is concerned with the consolidated effect of the various constituent sub-system activities rather than the sum of the individual efficiency levels attainable in each separate sub-system activity. In other words, synergy is concerned with the effectiveness of the whole organisation rather than with the efficiency of the individual constituent sub-systems. It is generally understood that the comparative profile of an organisation in any field of activity is an indication of how well the organisation's capabilities match the requirements for success in that particular field of activity. On the other hand, the inherent potential of an organisation defines the extent to which any field of activity offers the possibility of achievement in critical performance areas. An organisation's synergic package can then be defined as comprising the parameters for matching the comparative profiles with the inherent potential in every field of activity in terms of growth, flexibility of operations, stability, size and duration of financial commitment and/or any such desired organisational goal.

Using a synergic package has certain cybernetic connotations in the sense that it concerns a set or package (of resources, related services and, in some cases, whole sub-systems) which effectuates changes in the strategic plan of the organisation in a more significant proportion than would otherwise be realised if the package's components were separately considered. The synergic package thus represents a channel for identifying the boundaries of the organisation as a 'purposeful' rather than a 'purposive' system.

> ".... A purposeful system is one which can produce the same outcome in different ways in the same (internal or external) state and can produce different outcomes in the same and different states. It selects ends as well as means and thus displays 'will' and commitment when necessary. ..... A purposive system, though it is multi-goal-seeking with different goals having a common property, and though it chooses the means by which to pursue its goals, does not select the goal since the latter is determined only by the initiating event. Examples of this are computers, game-machines, etc. ...." (Ackoff, 1971)

The boundary identification problem can only be appropriately tackled if the management information system is good and also if the value judgements expected of the decision-makers are not beyond their comprehension capability. Unfortunately however, management information systems in most organisations today need total 'overhauling', since not only have they been mostly developed really as accounting systems, but also the problems associated with them have rarely been looked at as an overall organisational problem. A good synergic package necessitates a management information system, the basis of which is not centred around the organisation's accounting system nor is it centred around any particular sub-system. If it were, sub-optimisation tendencies would be inevitably encouraged and most probably without the awareness of the decision-makers.

It is important to realise that a synergic package is called for essentially because of four fundamental concepts which underlie the formation and subsequent transactions of any organisation. These concepts are discussed below.

The 'business entity' concept:

- This pertains to the view of any organisation as an entity distinct from its owners, its operators or those who are otherwise associated with them. The directors of the organisation are entrusted with the finance supplied by the shareholders, debenture holders and creditors. The directors are seen to be individuals who have enough knowledge and experience in observing the relevant aspects of company law in structuring and motivating the behaviour of organised labour and in resource utilisation in order to yield rates of return higher in utility than the market rate. Thus, the importance of capital markets cannot be overstated in the recognition and usage of this concept. Accordingly, any organisation has to be viewed as a channel through which funds allocation is being attempted by individuals with few productive opportunities but sufficient wealth to individuals with many opportunities and capabilities but insufficient wealth. In other words, this concept emphasizes that as long as the capital market exists, there will always be such entities as that particular organisation, thereby ensuring that everyone has the chance to be better off than he would have been without capital markets. The implication here is that every organisation has to maintain certain criteria which enhance the sustainability of the capital market. It is not difficult to realise that such criteria have to pertain to firm valuation, the level of which has to be acceptable to all the fund parties involved.

The 'going concern' concept:

- This concept is based on perpetuity of organisational operations. The organisation is viewed as an economic/financial system for adding value to its resources such that the prospects of maintaining the 'business entity' are sustained and the consumption-investment decision of the various fund-parties involved can be considered justified. The essential point here is to consider to what degree managers of the organisation are acting in the best interest of the owners. It is not difficult to realise therefore that the criteria involved have to pertain to profitability levels and dividend policy.

The 'money measurement' concept:

- This is an essential common denominator concept in that facts and events can be expressed in monetary terms. While money is probably the only practical denominator, the use of money implies homogeneity, a basic similarity between one pound and another. This concept, because of this implication, can sometimes impose severe limitations on the scope of management understanding of many transactions. For example, in periods of inflation, homogeneity of resources in monetary terms can be very misleading and is usually inapplicable in transactions. Nevertheless, the most important point about this concept is that it does indicate that a common denominator is essential for all concerned to be able to appreciate the existence of the business entity in their own way.

The cost concept:

- This is the concept which emphasizes that within the firm-structure, there are only costs. The criteria to maintain in this case therefore ought to pertain to cost considerations through which the profitability basis of the organisation can be improved. It must be said that this is one concept which has been used in a misleading way by accounting systems. They do not normally reflect the worth of assets except at the moment of acquisition. In such systems, depreciation charges to the profit & loss account are intended to represent the portion of the cost of the resource utilised during the accounting period, while the written down value of the asset represents the proportion of the cost of the resources unused at the end of the period. The depreciation process does not normally provide a fund to replace the asset at the end of its useful life. It does reduce the profit available for distribution to shareholders and it has no clear relationship to changes in the market value of the asset or to the latter's real worth to the organisation. Furthermore, depreciation is a function of time, obsolescence and deterioration (in which case, the weight to be given to each factor when deciding the depreciation method should differ from one asset to another). Nevertheless, accountants usually apply the same method of depreciation to all assets or the same method to assets falling into a very wide group, even though the assets within each group may be very heterogeneous as regards the effects of time, obsolescence and deterioration. For example, one method is generally applied to plant and machinery, another to vehicles, another to buildings, and so on. Another misleading consequence of accounting systems' handling of the cost concept is that if an organisation pays nothing for an item it acquires, the item will usually not appear in the accounting records as an asset. Similarly, the inappropriate treatment of the human-assets value by most accounting systems can give rise to significant differences between the book-value of an organisation's assets, their break-up value, the value of the organisation if sold as a going concern, and the market value of its shares.

2.8 Connective Summary

From the above discussions, it can be realised that whichever problem an organisation encounters, there has to be an overall economic criterion whose satisfaction in turn ensures successful simultaneous application of the four fundamental concepts. A synergic package therefore has to comprise parameters which can be used to develop that overall economic criterion. Such parameters may well be return on capital employed, budgetary targets, value of new investments and the organisation's targeted value. In other words, the synergic package has to comprise parameters through which the policy decisions about organisational productive direction can be sustained irrespective of environmental uncertainties.

An organisation's economic status can be represented by a function of definable - tangible and intangible - quantities:

$$W = f(Q_1, Q_2, \ldots\ldots\ldots\ldots, Q_n),$$

where each Q_i represents a component contributing to the organisation's wealth status, W, which management tries to improve by means of a series of interactions among the components as well as with the environment. Thus, an interaction group comprises some wealth status components, that are essentially involved in a dynamic transaction process, the mode of which identifies the particular group, while effectuating any set of resource-changes. A transaction, on the other hand, may be represented by a vector:

$$Q_i = f(q_{i1}, q_{i2}, \ldots\ldots\ldots\ldots, q_{im}),$$

where $q_{ij} > \emptyset$, and each denotes an environmental factor of some specific relevance to the particular transaction. While the components of wealth status are mostly in the form of the organisation's sub-systems, the interaction groups through which benefit valuation (using an overall economic criterion) can be enhanced for the organisation are what should be considered the 'synergic package' for that organisation.

Thus, in a modified form, an organisation's wealth status can be represented as:

$W = f(Q_1 \ \ Q_2, \dots, Q_k, Q_{k+1}, \dots, Q_n$

where $Q_1 \ \ Q_2 \ \ Q_3 \ \ Q_k$ denote the 'Interaction Group' which makes up the organisation's synergic package, while $Q_{k+1}, \dots, Q_n$ are other wealth-status components which do nor necessarily contribute significantly to the achievement of synergy.

In this chapter, emphasis is laid om the necessity to develop the 'capitalisation model' and identify the organisation's synergic package. These are pre-requisites for any Viability Planning modelling. The implications of this approach on issues such as the cost of capital, growth analysis and valuation relationships constitute the foci of attention in the next chapter.

CHAPTER THREE

COST OF CAPITAL AND VALUATION CONSIDERATIONS

3.1 Introduction

Regardless of the goal which an organisation adopts, what it always inevitably incurs is the cost of capital. Investment capital is the funds raised by an organisation to finance whatever the decision-makers have selected to invest in. The projects are not necessarily selected and then financed; rather the two processes work in conjunction. In fact during the course of project evaluation as well as normal business transactions, the finance group of the organisation has to continually provide feed-back on the state of the financial markets and the appropriate cost of capital to use as the basis for the various decision criteria for the organisation.

The history of financial markets has shown that not only are interest rates and security prices distinctly cyclical over time, but also that there appears to be a relationship between the supply and demand factors which accompany, if not foreshadow, the cyclical pattern of the cost of capital. Management therefore not only have to cope with the frequency and speed which characterise changes in the market, but also need (perhaps more importantly) to consistently demonstrate the ability to match the right business with the right market situation.

Financial theory postulates proportional relationships between the return any security has to give an investor in order to make the investor purchase it and the risk attached to that purchase. As the risk increases, the return expected by the investor has to increase also. This proportional relationship means that a well-functioning market will see all securities fluctuate in unison in response to changes in interest rates in general and to changes in increased general uncertainty. The fluctuations related to these general market factors are, of course, beyond the control of management. However, it is widely believed that if management can lower the risk image of the organisation among investors, then a proportional lowering of the cost of capital would be achieved. Also, if management specifically tailor securities to fill a void in the diversification plans of any specific group of investors, such a tactic is bound to make the group of investors willing to pay more for the securities, thus lowering the cost of capital. A general application of this concept is to offer the types of securities which are relatively rare on the market and to avoid selling those which are in abundant supply.

Without doubt, an organisation's finance group really needs to look beyond the immediate surroundings of the organisation and step outside its confines in order to see it as do the potential suppliers of capital. In other words, management needs to adopt the viewpoint of those outside the organisation and understand their position, because the cost of capital for the organisation is essentially the investors' required rate of return. What is then needed is to understand which factors determine the cost of capital for the individual securities the organisation can offer potential investors.

3.2 Cost of Capital Considerations

Among the various factors, which affect investors' determination of the required rate of return, are interest rates on competing securities, investors' purchasing-power risk, the organisation's business and financial risks, and the marketability risk of the particular security intended for sale. Thus it is also vital to identify what types of securities the organisation should be able to offer and what specific factors affect the cost of capital for each type of security.

3.2.1 Determinants of the Cost of Capital

There are basically two factor-categories which affect the cost of capital for an organisation's securities. One of them is the supply-demand consideration in the financial markets. This affects the cost of capital for all securities by changing the default-free interest rate and forcing the cost of capital for competing securities to change in the same direction. The other category comprises the risk associated with the individual security which increases the cost of capital above the default-free interest rate by an amount proportional to the associated risk.

The cost of capital (CC) may be expressed as: CC = NIR + RF
where NIR represents the nominal or market interest rate, and RF represents the risk-adjustment factor.

The NIR is the price mechanism which equates the supply of funds with the demand for funds. It is actually the sum of two components - the real interest rate (RIR) and the purchasing-power risk (PPR). The former compensates the investor for surrendering the money, while the latter compensates him for any increase in the price of items not purchased with the money instead. Potential investors refrain from buying securities which do not compensate for anticipated inflation, and so organisations are forced to raise the interest rate they are willing to pay until they can attract the funds. This forces up the cost of capital for all types of securities during periods of anticipated acceleration in the rate of inflation. As the expectation of inflation accelerates, the PPR also increases, and interest rates and cost of capital rise.

The risk-adjustment factor (RF) has three components - the business risk, the financial risk, and the marketability risk.

The business risk is strictly related to the organisation and not to the general market, economic factors of supply-demand conditions in the financial markets, or the rate of anticipated inflation. The business risk (BR) associated with an organisation's securities arises from the very nature of the organisation's operating environment, which imparts a degree of uncertainty even to the most secure organisation with the most honourable intention of meeting its debt obligations as well as its investors' expectation of dividends. Several conditions in the general operating environment can affect investors' interpretation of the degree of risk. First, if the organisation's prospects are clouded at any moment, investors typically require a higher rate of return. Secondly, if the organisation's history has been shaky, erratic and hard to predict, or relatively less stable (perhaps dotted with extremely bad years in which the fulfilment of loan obligations was less certain), investors will require a higher rate of return. Thirdly, if the organisation's fulfilment of its obligations deteriorates, investors will demand a higher rate return. Finally, if the organisation's operations are inherently unstable (subject, for instance, to the business cycle or the vagaries of politically unstable countries), investors require higher rates of return, thereby forcing up the cost of capital.

The financial risk is associated with the methods by which the organisation finances its investments and which can increase the variability of earnings available to meet debt obligations as well as expected dividends over and above the variability imparted by the organisation's operating environment. It can come about either through the use of too much debt and fixed obligations in the financial structure of the organisation or through inept matching of the loan obligations to the organisation's cash inflows. For example, if the investors do see an unduly large amount of debt maturing in the near future, they will demand a very high return for providing any necessary additional capital.

It should be noted that the business and financial risks have the central theme of variability in operating earnings which impairs the organisation's ability to meet its promised and/or expected payments. The essential difference is that while business risk pertains to the particular operating environment (generally understood, for example, from the 'industrial recipe'), the financial risk pertains to the capability of management to develop and implement financial plans most suitable to perceived organisational needs.

The marketability risk is somehow in a different league since it only reflects the degree to which investors are convinced that they can realise the going market value of the owned securities in cash if and when they decide to sell. In other words, the focus here is on whether or not the investors' motive for arbitrage profits can be satisfied. This risk is therefore a time-dimensioned variable, dependent on the relative supply and demand conditions which affect the volatility of price changes between sales, given all other risk factors remain constant. If the number of potential bidders is usually small when the owner of the security goes to sell it, or if the amount of the security offered for immediate sale is large in relation to the typical amount that could be expected to be bought at one time by potential bidders, the owner of the security runs the risk of having to take a lower-than-prevailing market price to induce buyers to absorb the floated securities. Under such circumstances, potential bidders will require a higher rate of return to compensate for this marketability risk. To avoid such circumstances, management therefore have to try to make their securities plainly visible in large markets such as an organised stock exchange, where numerous buyers and sellers exist. This makes potential investors feel that the organisation's securities have a high degree of marketability and can be sold with relatively little deviation from the going price. Of course, this strategy would not be suitable for 'close' organisations, where there is a lot of consideration given to dilution of owners' control.

Bolten's (1976) definition of the cost of capital can then be expressed as: CC = NIR + RF = (RIR + PPR) + BR + FR + MR

where NIR = f(economic activity, govt. fiscal policy, inflation expectations, etc.)

BR = f(type of industry, degree of fit with that industry)

FR = f(degree of appropriateness as an investment channel generally)

MR = f(average yield of the usual security-trading activity of the organisation).

From the above functions, it can be readily observed that management has very little control on the NIR itself, but they do have the means to efficiently respond to the effects it can have on the organisation's involvements. Such means centre around the structuring of general guidelines into a preparatory procedure for the consideration of investments by using viability planning models. These guidelines can include timing the sale of securities to troughs in the interest rate cycle, tailoring securities to the segment of the market with the lowest interest rates, avoiding financing long-term projects with a disproportionate amount of short-term funds, and maintaining adequate negotiating power even if securities become inevitably sold in a period of high interest rates.

There is continual environmental pressure on any organisation's cost of capital especially since the NIR depends on the capital required by the government for investments. This capital is generally drawn from the private sector where it would otherwise be spent on consumer goods or invested by the private sector itself. From the consumers' viewpoint, the rate of return on any investment has to be at least equal to the risk-free long-term interest rate which is in other words, the current rate of government bonds. From the private sector's viewpoint, the rate of return on any investment has to be at least equal to $\frac{I_g}{(1 - t_c)}$, where I_g, t_c are respectively the risk-free long-term interest rate and the tax rate applied to private institutions (that is, the prevailing corporate tax). The composite opportunity cost attributable to government sources of capital is called the 'social discount rate' (SDR), and is traditionally used by planners for public projects.

Economists - for example, Baumol (1952), Marglin (1963) and Sen (1967) - have shown that the relationship between the market rate of interest and the social discount rate can be viewed in terms of possible options between two specific problems encountered in game theory. One, the isolation paradox, is an N-person extension of the two-person non-zero-sum game of the prisoners' dilemma (Howard, 1971). Here, each individual in the N population is assumed to have a strictly dominant strategy and the pursuit of this by each produces an overall result that is Pareto-inferior. The population could do better than this by collusion, but the collusive solution would need enforcement. The second, the assurance problem, has a different analytical structure. It is obtained by assuring each individual that the others (that is, his contemporaries) are doing the right thing and that he would need to conform in order not to end up worse-off than others. Here, there is no dominant strategy and any equilibrium point in the non-cooperative game may be Pareto-optimal.

Based on the 'assurance problem', Lind's (1964) derivation of the SDR suggests that the Pareto-optimal equilibrium point can be represented as:

$$[w_{ohc} + (N-1).w_{chc}]\ (1+SDR) = w_{oc} + (N-1).w_{cc}$$

where, $\emptyset < w_{cc}, w_{chc}, w_{ohc} < 1$

- w_{cc} - the weight per unit attached to the consumption of an individual's contemporaries;
- w_{chc} - the weight per unit attached to the consumption of the heirs of the individual's contemporaries in a future generation;
- w_{ohc} - the weight per unit attached to the consumption of the individual's heirs in the future generation;
- w_{oc} - the weight attached to the individual's own consumption; and
- N - the size of the population.

If $w_{oc} = 1$ (that is, assuming unit weight for an individual's present generation consumption), then

$$SDR = \frac{1 + (N-1).w_{cc}}{w_{ohc} + (N-1).w_{chc}} - 1$$

Based on the 'isolation paradox', Sen's (1972) derivation of NIR represents the strictly dominant strategy of each individual as:

NIR =

$$NIR = \frac{w_{oc}}{S_{oh} + (N-1).w_{chc}/w_{ohc}}$$

where, S_{oh} denotes the proportion of one's savings that accrues to one's heirs, and $0 < S_{oh} < 1$.

Also if $w_{oc} = 1$, then

$$NIR = \frac{1}{S_{oh} + (N-1).w_{chc}/w_{ohc}}$$

From the viewpoint of welfare economics,

SDR $\lesseqgtr$ NIR according as the balance of emotions $\dfrac{w_{chc}}{w_{ohc}} \lesseqgtr \dfrac{w_{cc}}{1}$

and depending on the feasible pairs of values of (S_{oh}, w_{ohc}).

The fiscal policies of governments and also the existence of financial markets are sufficient to obviate situations where

$\dfrac{w_{chc}}{w_{ohc}} < \dfrac{w_{cc}}{1}$. Otherwise, the marginal benefits to the owners of capital would fall short of the marginal benefits to the community, thereby destroying the incentives for participating in the production-consumption decisions vital for economic growth.

Also, in a rational-economic world,

$\dfrac{w_{chc}}{w_{ohc}} > \dfrac{w_{cc}}{1}$ might be acceptable if, and only if, $S_{oh} = 1$. But this would not be possible in a world of taxes, duties, etc. Consequently, this also cannot be an acceptable option in any growing economy.

Indeed, analysts such as Ackoff (1977 & 1983) and Howard (1971) suggest that nowadays, society is involved in a perpetual 'meta-game' in which each individual tries to exercise his/her rational, albeit limited, judgement in order to ensure the achievement of the equilibrium points in his/her implicit payoff matrix.

It can thus be seen that in general, the appropriate equilibrium situation would be to accept the balance of emotions:

$$\frac{w_{chc}}{w_{ohc}} \gtreqless \frac{w_{cc}}{1}$$ and as such, accept that the SDR = NIR.

The nominal interest rate (NIR) that should be considered by management therefore must be the 'social discount rate' (SDR). The point then is that although it represents the real rate of return required from public projects, it is the realistic NIR that should be used by any organisation in all its business involvements, and most especially when doing viability planning. The usage of the SDR initiates a mediative process in that it is centred around management's consideration of the non-controllable part of the organisation's composite cost of capital.

The 'social discount rate' is normally calculated as:

$$SDR = k_{GC}.I_g + \frac{(1 - k_{GC}).I_g}{1 - t_c} = I_g.\ \frac{1 - k_{GC}.t_c}{1 - t_c}$$

where $0 < k_{GC} < 1$ is the proportion of investments drawn into capital for the government. It must be emphasized that although the risk-free rate is usually taken as the yield on current government treasury bills, it is the SDR that actually gives a measure of it in real terms. This is because parameter k_{GC} is determined essentially by the government's fiscal policy and inflation expectations. The implications here are that:

- the government treasury bills are considered to be the main channels for the government to express its inflation expectations in the financial markets,
- the inflation expectations of the government are considered to be the most reliable compared with those from other available sources, and
- the government bears no business, financial and marketability risks on its own (and consequently, government bonds are considered the most secure investment channels, although they are perhaps the least-yield investment channels obtainable in the capital markets).

In the context of the above considerations, the cost of capital therefore has to be considered as an economic cost, rather than merely as an accounting cost. It represents the minimum rate of earnings' growth that the system must attain if it is to attract 'free energy' in the form of financial resources from the environment in which it is situated, at the planned cost of finance determined in accordance with its planned finance-mix policy. If the organisation plans for a rate of growth of earnings that is lower than its cost of capital, the market value of its shareholders' equity will fall in the long run, since difficulties would in all likelihood be encountered in financing future growth and increased finance charges would also be incurred. On the other hand, if future earnings are planned to be higher than the cost of capital in real terms, then capital would probably be more freely available and would most probably cost less.

There is, of course, a much wider scope for manoeuvrability on the risk-adjustment factor (as will become apparent in the following sub-section).

3.2.2 The Risk Factor Model

The risk factor model is essentially an expression of the organisation's business, financial and marketability risks in such a way that it is usable in estimating the implied cost of capital for investors. Also, and perhaps more importantly, management can use it to achieve a better understanding of the basic nature of survivability for their organisation, what it takes to succeed in its industry, and the critical elements of performance which exert considerable influence on the organisation's financing and investment opportunities.

The business risk has to typify the industry within which the organisation operates. Hence, this component can be expressed as the bias between say, its Altman's Z-index and the corresponding index for the particular industry's 'good-business-risk' category. Z-index is usually derived by using discriminant analysis as a screening technique when analysing the riskiness of various business firms. It is of general accord that certain statistics seem to foreshadow impending financial difficulty. In fact, various studies - Beaver (1966), Altman (1968,1971) - have shown that certain ratios exhibit early warning characteristics when compared to industry norms or changes over time. A range of

Z-index values is usually obtained for use as a risk-assessment criterion. Any organisation with Z-index below the range is categorised as a 'potentially bad' business (that is, likely to become technically insolvent in the not too distant future), any organisation with Z-index above the range is categorised as a 'potentially good' business, while any organisation with Z-index within the range is categorised to be in the 'grey' area (that is, indeterminant-risk business). For example, Altman's discriminant model (Copeland & Weston, 1979) for small companies, in the transportation engineering (railroad) industry, is:

$$Z = 1.21X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5$$

where X_1 = working capital / total assets

X_2 = retention / total assets

X_3 = earnings before interest & taxes / total assets

X_4 = market value of equity / book value of debt

X_5 = sales / total assets

$Z > 2.99$ indicates 'potentially good'

$Z < 1.81$ indicates 'potentially bad', and

$1.81 < Z < 2.99$ indicates 'indeterminant-risk'

Although such an indicator as the Z-index is usually used in evaluating credit-worthiness of firms, the underlying concept can be applied to derive a reliable estimate of the business risk component in the cost of capital. The following procedure is proposed:

- For the economy as a whole, a range of Z-index values is obtained which, irrespective of the type of industry, simply indicates the risk status associated with an organisation as a business entity within that economy
- For each type of industry in the economy, a range of the characteristic Z-index values is obtained. The difference between its extreme values and those of the corresponding nation-wide Z-index range is then taken as a measure of the risk status associated with each particular industry in that economy.
- Finally, for any specific organisation, the Z-index is obtained. The bias between its value and that of the 'good-business-risk' category within its industry is then taken as a measure of the risk associated with the particular organisation's operating environment (over and above the risk associated with the organisation due to the operating environment of its industry as a whole).

Thus, the sum of the two estimated risks, explained above, represents the business risk component of the cost of capital. The derivation can be done as follows:

Let Z_{GE} represent the Z-index value beyond which an organisation is categorised as a 'potentially good' business entity in the economy concerned;

Z_{BE} represent the Z-index value below which an organisation is categorised as a 'potentially bad' business entity;

Z_{GI}, Z_{BI}, Z_{MI} - the corresponding 'good', 'bad' and 'mean' levels, respectively, of the Z-index values for the particular organisation's industry

$Z_{\emptyset}$ - the Z-index for the organisation being studied, and

R_f - the risk-free long-term interest rate.

Then the business risk component of the cost of capital is:

$$BR = \frac{Z_{GE} - Z_{MI}}{Z_{GE} - Z_{BE}}.(1 + \frac{Z_{GI} - Z_{\emptyset}}{Z_{GI} - Z_{BI}}).R_f$$

In cases where it is more practical to use a combination of some other performance indicators - such as the degree of operating leverage (DOL), the inventory turnover ratio (ITR), the return on capital (ROC), etc. - the corresponding formulation for business risk will be:

$$BR = R_f . \sum_{i=1}^{N_Y} \frac{Y_{GEi} - Y_{MIi}}{Y_{GEi} - Y_{BEi}}.(1 + \frac{Y_{GIi} - Y_{\emptyset i}}{Y_{GIi} - Y_{BIi}}).W_{Yi}$$

$$i=1, \ldots, N_Y \qquad \sum_{i=1}^{N_Y} W_{Yi} = 1$$

where,

N_Y denotes the number of indicators used;

Y_{GEi}, Y_{BEi} represent the 'good' and 'bad' levels, respectively, of indicator i for all organisations in the economy;

Y_{GIi}, Y_{BIi}, Y_{MIi} represent the 'good', 'bad' and 'mean' levels, respectively, within the industrial sector concerned;

Y_{Oi} - the organisation's value of indicator i, and

W_{Yi} - the weight attached to indicator i within the industrial sector concerned.

The financial risk has to indicate the degree of justification in regarding the organisation as an investment channel. Perhaps the best indicator of this is the earning power ratio (EPR), since it is a measure of how well the assets of the organisation are being deployed. This can then be compared with the corresponding 'yield' of asset deployment in other organisations. Better still, the EPR for the organisation can be compared with the risk-free long-term interest rate (that is, the earnings from gilt-edge securities such as treasury bonds, etc.).

Let $EPR_{\emptyset}$ represent the organisation's earning power ratio

and $R_f = I_g$, denoting earnings obtainable from gilt-edge securities

If $EPR_{\emptyset} > I_g$ the effect of the risk over the implied cost of capital can be ignored.

If $EPR_{\emptyset} < I_g$ the corresponding increase in the implied cost of capital has to be taken as $(I_g - EPR_{\emptyset})$ percentage points.

Thus,

$$FR = I_g - EPR_{\emptyset}$$

The marketability risk is a function of the number of security-units outstanding, the number of security-units floated, the average daily trading and the time span between market exposure of the particular security and actual requirement of fund. Such a function can be expressed in terms of the difference between average daily percentage change in the stock-exchange index and average daily change in the organisation's number of security-units traded. However, a simple and more practical estimation method (and which still includes all the above-mentioned factors) is proposed here as follows:

$$MR = \frac{(N_{SEC.FL} - N_{SEC.SOLD}) \cdot P_{MKT}}{N_{SEC.FL} \cdot P_{TARGETED} - C_{FL}}$$

where,

MR represents the percentage points imposed by the marketability risk (over and above the effects of the business and financial risks) on the implied cost of capital; and

$N_{SEC.FL}$, $N_{SEC.SOLD}$ represent no. of security-units floated and sold, respectively

$P_{TARGETED}$, P_{MKT} - respectively, targeted and actual market unit price of security; and

C_{FL} - flotation cost associated with the placement of the particular security in the market.

Finally, the cost of capital (CC) can therefore be expressed as:

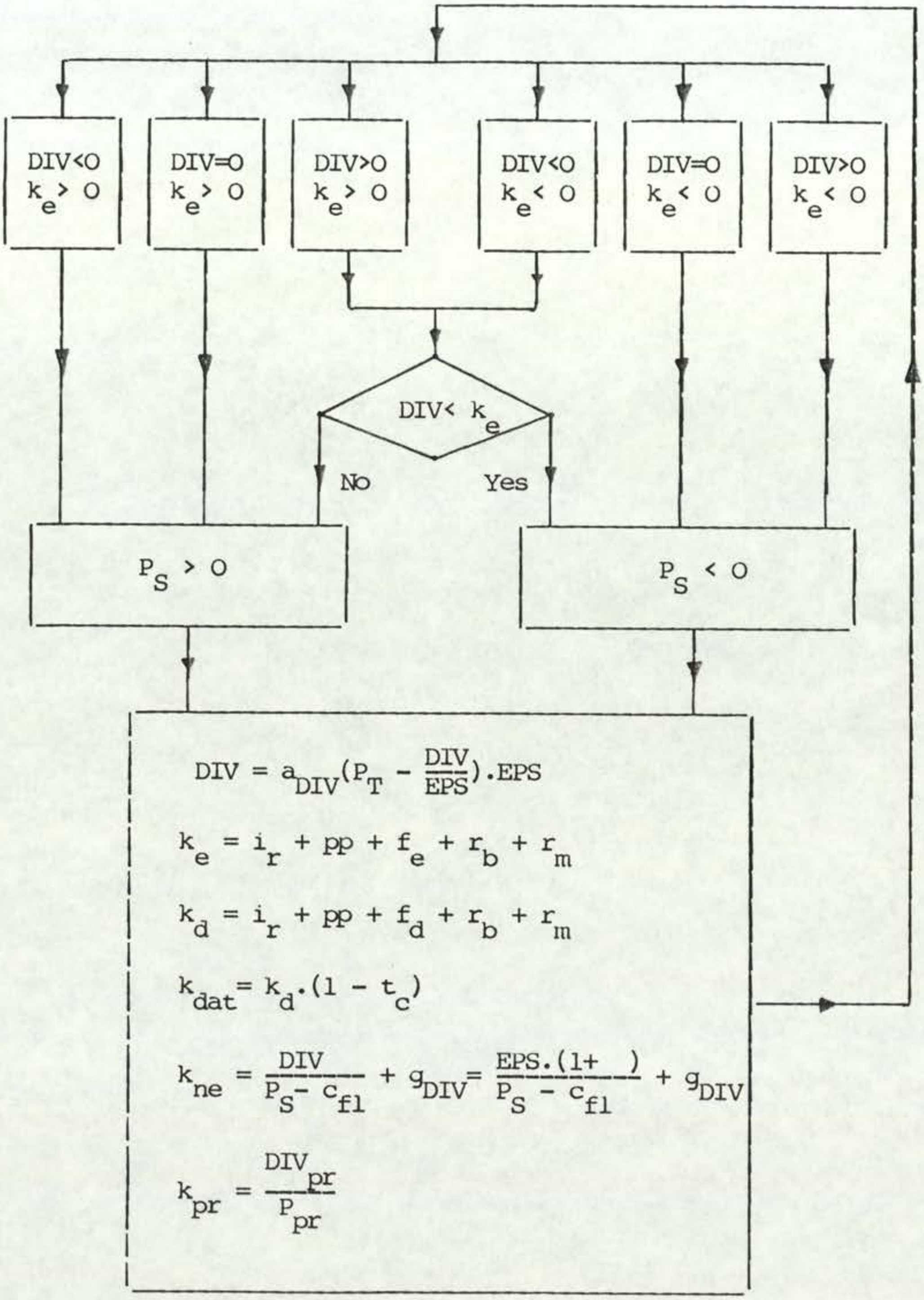
$$CC = I_g \cdot \frac{1 - k_{GC}}{1 - t_c} + I_g \cdot \sum_{i=1}^{N_Y} \frac{Y_{GEi} - Y_{MIi}}{Y_{GEi} - Y_{BEi}} \cdot \left(1 + \frac{Y_{GIi} - Y_{\emptyset i}}{Y_{GIi} - Y_{BIi}}\right) \cdot W_{Yi} +$$

$$+ \ (I_g - EPR_{\emptyset}) + \frac{(N_{SEC.FL} - N_{SEC.SOLD}) \cdot P_{MKT}}{N_{SEC.FL} \cdot P_{TARGETED} - C_{FL}}$$

With the above considerations in mind, it can be realised that individual securities essentially differ in the associated marketability risk. It must also be pointed out that the financial risk for debt differs slightly from the financial risk for equity, since the former takes priority over the latter in the distribution of an organisation's earnings. The financial risk for debt depends, to a great extent, on the variability of the interest coverage and fixed charges earned, while the financial risk of equity depends, also to a great extent, on the variability of the earnings per share.

Generally, in order to appropriately evaluate the costs of individual securities of any organisation, it is essential to analyse the interaction between dividend expectations from the organisation, its implied cost of equity capital, and the market price of its equity. The flow diagram (Fig. 3.1) is a representation of this interaction which essentially involves only the financial environment (that is, the 'fund parties') of the organisation.

Fig. 3.1 Flow diagram of possible objectives in analysing organisational growth



Note: Notation for this flow diagram is on the following page.

Notation for the flow diagram of Fig. 3.1

DIV, EPS - prevailing dividend and earnings per share, respectively, for the period under consideration

a_{DIV} - adjustment cushion for dividends

P_T - target payout ratio for dividends

P_S - stock price in capital market

k_e - cost of equity capital

k_d, k_{dat} - costs of debt capital before and after tax, respectively

t_c, i_r, pp - corporate tax rate, real interest rate and purchasing power risk, respectively

f_e, f_d - financial risks of equity and debt, respectively

r_b, r_m - business and marketability risks, respectively

k_{ne}, k_{pr} - costs of new and preferred equity, respectively

c_{fl} - flotation costs for new equity

g_{DIV} - anticipated dividend growth rate

λ - assumed retention rate for earnings per share during the period under consideration

P_{pr} - prevailing price of preferred-stock

DIV_{pr} - prevailing dividend (usually fixed) for preferred-stock.

Using such a flow diagram, the coefficients of the decision variables which correspond to the capital inputs and outputs parameters in the viability planning model can be obtained. This type of flow diagram is particularly useful in that it helps to make much more realistic the structuring of possible objectives for valuation and growth analysis. This is the subject of discussion in the following section.

3.3 Possible Growth Strategies and Valuation Relationships

In order to bring into focus the different aspects to consider for strategic financial decision-making, it is necessary to conduct an in-depth analysis of an appropriate valuation relationship.

3.3.1 Basic Growth Strategies

The value of new investments depends on the amount of investment made and also on the difference between the average rate of return on the investments and the market-required rate of return. Although the overall assets of a firm may grow, they will really add nothing to the firm's value unless they earn a rate of return greater than what the market requires for assets of equivalent risk. This is essentially why the total capitalised cost of an organisation is the absolute minimum firm-value acceptable in order to avoid becoming technically insolvent unexpectedly. Copeland & Weston (1979) emphasise that for an organisation to actually grow, it needs to maintain a 'supernormal' rate of return on investments for at least a finite period of time while in other periods, it maintains at least a normal rate of return on the average. The average rate of return on investments (AROI) would then be the average of the supernormal and the normal rates of returns within the horizon concerned.

Usually, the rate of growth can be taken as the product of the investment rate and the AROI within the horizon concerned. In order to analyse growth therefore, it is vital to monitor the three parameters - RETR, CAPIR and AROI. The first two of these determine the investment rate, INVR.

Earnings after interest and taxes (EAIT) for a geared firm can be obtained (Copeland & Weston, 1979) as:

$$\begin{aligned} EAIT &= [R - VC - (F_C + F_{NC}) - r_d.D].(1 - t_c) + F_{NC} \\ &= (R - VC - F_C - r_d.D)(1 - t_c) + F_{NC}.t_c \\ &= NCI + F_{NC}.t_c \end{aligned}$$

where R represents sales revenue,

VC - variable cost of operations,

t_c - corporate tax,

F_C - cash fixed costs (such as admin. expenses, etc.),

F_{NC} - non-cash fixed costs (e.g. depreciation, etc.); and

NCI - net cash income.

The retention rate, $RETR = \frac{NCI - DIV}{NCI}$

where DIV represents payable dividend;

the capital intervention rate, $CAPIR = \frac{\text{New Capital}}{NCI + F_{NC} \cdot t_c}$ and

the investment rate, $INVR = RETR + CAPIR$

From the table of desirable scenarios (Table 3.1) presented below, it can be seen that for growth to be assured, an organisation has a choice among 13 different basic strategies:

Table 3.1 Table of feasible scenarios for basic growth strategies

PARAMETER CHANGES		BASIC GROWTH SCENARIOS 1	2	3	4	5	6	7	8	9	10	11	12	13
RETR	> 0	1	1	1	1	1	0	0	0	0	0	0	0	0
	= 0	0	0	0	0	0	1	1	1	0	0	0	0	0
	< 0	0	0	0	0	0	0	0	0	1	1	1	1	1
CAPIR	> 0	1	0	0	0	0	1	0	0	1	1	1	0	0
	= 0	0	1	0	0	0	0	1	0	0	0	0	1	0
	< 0	0	0	1	1	1	0	0	1	0	0	0	0	1
INVR	> 0	1	1	0	0	1	1	0	0	1	0	0	0	0
	= 0	0	0	0	1	0	0	1	0	0	1	0	0	0
	< 0	0	0	1	0	0	0	0	1	0	0	1	1	1

It can be observed in Table 3.1 that each of the growth strategies is essentially determined by a particular combination of changes in the sustainable levels of the RETR and CAPIR. The point is that any of these strategies could result in either of the three feasible states of the AROI (that is, supernormal, normal or subnormal), thereby indicating that there are 39 options altogether. However, since subnormal AROI is not desirable at any time, only 26 of the options are acceptable for growth to be assured. Reflecting decision-makers' perception of even these reduced number of options is an onerous task for any modeller. The proposal in this study is to elicit the decision-makers' optimism or pessimism regarding those parameters which constitute the root cause of the basic 26 desirable options. This can be done by putting to the decision-makers the following typical questions:

- What are the chances of $\substack{\text{RETR} \\ \text{CAPIR} \\ \text{AROI}}$ increasing?

- Given there is an increase in RETR,

  what are the chances of having an increase in $\substack{\text{CAPIR} \\ \text{AROI}}$?

From the decision-makers' responses to such questions, it is not difficult (with the aid of multi-criteria decision-making modelling techniques) to determine what the preferences of management appear to be. The application of 'decision analysis' in a goal-programming formulation should be of significant help in this. Hence this aspect will be examined in Chapters Six and Seven. It must also be pointed out that the questions pertaining to conditional increases of the CAPIR and AROI actually relate directly to the decision-makers' perception of the degrees of attainable levels of the 'total capitalisation value' and the 'new investment decision-criterion' - two of the constituent parameters in the synergic package, which will be discussed in Chapter Five.

The strategies in the table are referred to as 'basic' in the sense that a closer examination of earnings after interest and taxes, EAIT (which is a parameter comprising both the 'net cash income' and part of the 'non-cash fixed costs'), could yield many more strategies. For example, each of these constituent elements of the EAIT may have 'economic' and/or 'translation' exposures, which are usually neglected either due to the fact that many managers are not aware of it until crisis occurs or due to the fact that the market of such exposures is perhaps the least understood of all the areas of the international money market. Heywood (1978) emphasizes that many companies usually have losses (attributable to these exposures) which exceed all the incomes gained through the many cost-minimisation and/or profit-maximisation programmes into which relentless efforts are always put. 'Economic exposure' is the term normally used to describe the economic effect on an organisation that would result from a movement in a particular currency. It is sometimes referred to as 'cash-flow or transaction risk' since it arises from transactions done and committed in foreign currencies. This exposure will not necessarily show up in the financial accounts at the time it arises since after all, the balance sheet shows where funds are today and not where they will be in the future. 'Translation exposure', on the other hand, arises from the translation of the currency balance sheets of the organisation's foreign subsidiaries - hence, it is sometimes referred to as 'balance sheet risk'. In fact, it is the only other way in which foreign exchange movements can have an impact upon an organisation.

3.3.2 Valuation Considerations

The 'capital asset pricing model' (CAPM) considers the total risk of any individual asset to be made up of two components - systematic, which is a measure of how the asset covaries with the economy, and unsystematic, which is independent of the economy. Usually investors can diversify away the unsystematic risks from any organisation if the composition of their individual portfolio is carefully selected. This diversification treatment however, will not work with systematic risks. In other words, investors can diversify away all risks except the risk of the economy as a whole - which is inescapable and almost undiversifiable.

For any organisation, the systematic risk is of major concern since on it is dependent the required rate of return on the assets. Using the CAPM in a continuous time version (Copeland and Weston, 1979),

$$E(R_i) = R_f + [E(R_m) - R_f].\frac{\sigma_{im}}{\sigma_m^2}$$

where $E(R_i)$ is the instantaneous expected rate of return on asset i;

R_f - the deterministic instantaneous rate of return on the risk-free asset;

$E(R_m)$ - the expected instantaneous rate of return on the market portfolio;

$\sigma_{im} = COV(R_i, R_m)$; $\sigma_m^2 = VAR(R_m)$; and

$\frac{\sigma_{im}}{\sigma_m^2} = \beta_i$, the instantaneous systematic risk of asset i.

The cost of capital from transactions with any particular fund party can then be represented as: $k = R_f + (R_m - R_f).\ \beta_S$

where β_S is the systematic risk of common stock as perceived by that particular fund party.

Using the 'options pricing model' of Black and Scholes (1972), shareholders' wealth in any organisation may be written in the form of a European call option. Thus,

$$W = V.N(d_1) - e^{-r_f.T}.D.N(d_2) - w_{IM}.q + w_{OM}(1 - q)$$

where q is a binary-valued parameter having the value 1, Ø for 'in-the-money' and 'out-of-the-money' options, respectively

w_{IM}, w_{OM} - the corresponding undervaluing and overvaluing error terms, respectively,

V - market value of the organisation's assets,

r_f - the risk-free rate ,

T - time to option maturity,

D - face value of debt (book value),

N(.) - cumulative normal probability of the unit normal variate in brackets, and

$$d_1 = \frac{\ln(V/D) + r_f.T}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2} \text{ and } d_2 = d_1 - \sigma\sqrt{T}$$

Given continuous trading, a prudent investor will form risk-free hedges by each time using only two securities - a call option and the underlying asset. Such an equilibrium relationship takes the form:

$\frac{dW}{W} = r_f.dt$ where W represents the shareholder's wealth. In order for the equilibrium to be maintained, each purchase of 1 share of stock has to be accompanied by a sale of $\frac{1}{(\delta W/\delta V)}$ calls.

Thus, although the CAPM and OPM both view all financial assets as contingent claims, they still base the valuation of organisations on pure arbitrage conditions available to the investor, and hence both rely on the existence of diversification opportunities and usually on the existence of a large market portfolio.

At this stage, it is worth pointing out that the traditional view has been that through judicious use of the proportion of debt to equity in a firm's capital structure, the overall cost of capital can be minimised. It will appear however that the CAPM and OPM have been the tools for leading a dissenting school of thought in opposition to the traditional approach. A major implication underlying both models is that the overall cost of capital can remain virtually unchanged regardless of the proportion of debt to equity since, it is argued (Modigliani & Miller, 1961), that investors will adjust their own holdings of a firm's securities in order to ensure a virtually constant overall cost of capital. The assumptions of perfect capital market, perfect investor-rationality, nil transaction costs, nil taxes, etc. only serve to compound the practicality of such models. Infact, there is a prepondrance of evidence through empirical studies (for example, Barges 1963, Wippern 1966, Brigham & Gordon 1968) which indicate that the overall cost of capital function is saucer-shaped (as is expected in the traditional approach) when regressed with various financial ratios for different industries. Thus, much as the CAPM and OPM go a long way in helping theorists to understand the nature of financial markets, there is little doubt that most decision-makers are either ignorant of the (albeit limited) applicability of the models, or just not able to make use of the models in their particular operating environments.

Organisational viability requires that the decision-makers give more weight to that component of the capitalisation structure which makes the capital market desire the participation in it of the organisation rather than to that component which is much dependent on pure arbitrage conditions of the capital market.
In order to enhance organisational viability, the flow of possible objectives (presented in Fig. 3.1) can be expressed through some of the parameters in a valuation relationship which reflects the logical preferences of the three main parties involved - the potential shareholders, the bondholders and the company itself. Each of these parties has a particular value attached to the wealth which the organisation is capable of creating. The value will depend on the 'remunerations' received (by the parties within any specified horizon) and will also depend on the characteristics of capital-generation capability left within the organisation to assure future remunerations.

Let E_S be the earnings receivable by potential shareholders in any specific period,

E_B - interest earnings for bondholders, etc

$r_d.D$ - interest rate on debt multiplied by debt principal

k_e, k_d - cost of equity and bond capitals, respectively

k_o - the organisation's implied cost of capital

IVOL - investment volume which the organisation should be certain of obtaining,

C_{pv} - total equivalent uniform cost for all the organisation's assets

t_{pS} - average personal tax rate for the shareholders,

t_{pC} - average capital-gains tax rate for shareholders,

t_{pB} - average personal tax rate for bondholders, etc

k_{DIV}, k_{CG} - proportions of earnings anticipated in dividend and stock forms, respectively.

Then, $E_S = NCI.(1 - RETR).[k_{DIV}(1 - t_{pS}) + k_{CG}(1 - t_{pC})]$

$E_B = r_d.D(1 - t_{pB})$

and $IVOL = NCI.RETR + CAPIR.(NCI + F_{NC}.t_c) + C_{pv}$

$$= NCI.(RETR + CAPIR) + CAPIR.F_{NC}.t_c + C_{pv}$$

Obviously, $k_{DIV} + k_{CG} = 1$ where $0 < k_{DIV}, k_{CG} < 1$

That is, $k_{CG}(1 - t_{pC}) = (1 - k_{DIV}).(1 - t_{pC})$

The value of the assured investment volume (IVOL), to any party, has to be evaluated on the basis that the organisation's implied cost of capital is the required rate of return on that proportion of the IVOL which is attributable to the particular party concerned. The earnings, on the other hand, have to be evaluated relative to the cost of the individual securities.

Therefore,

The value of the organisation to potential shareholders:

$$V_S = \frac{E_S}{k_e} + \frac{IVOL}{k_o}.\frac{S}{B + S}.[k_{DIV}(1 - t_{pS}) + (1 - k_{DIV})(1 - t_{pC})]$$

The value of the organisation to potential bondholders:

$$V_B = \frac{E_B}{k_d} + \frac{IVOL}{k_o}.\frac{B}{B + S}.(1 - t_{pB})$$

The value of the organisation to itself:

$V_C = V_S + V_B$

$$= \frac{K_{pDIV}}{k_e}.NCI(1 - RETR) + \frac{IVOL}{k_o}.\frac{S}{B + S}.K_{pDIV} +$$

$$+ \quad \frac{r_d.D}{k_d}.(1 - t_{pB}) + \frac{IVOL}{k_o}.\frac{B}{B + S}.(1 - t_{pB})$$

$$= NCI(1 - RETR).\frac{K_{pDIV}}{k_e} + D(1 - t_{pB}).\frac{r_d}{k_d} +$$

$$+ \quad \frac{S.K_{pDIV} + B(1 - t_{pB})}{B + S} . \frac{IVOL}{k_o}$$

where,

K_{pDIV} represents $[k_{DIV}(1 - t_{pS}) + (1 - k_{DIV})(1 - t_{pC})]$

The implication underlying this valuation relationship is that as far as viability is concerned, an organisation itself gains little benefit from historic accounting data or any sophistication in the analysis of arbitrage conditions in the capital market. This is why right from the start of this study, the assumption was considered appropriate that most capital markets are efficient at most in the semi-strong form. Furthermore, although the annual report may serve as a useful device for monitoring the performance of management, it has little value to the investment community. What investors would like to know is what the management estimates future performance to be and the degree to which the management is accounting for all the risks involved. In particular, all the three parties concerned would benefit from unbiased estimates of the rate of return on future investments, the cash amount of new investments, the characteristics of productive capability and anticipated growth, and the percentage of new capital which will be provided from equity sources.

3.4 Connective Summary

In this chapter, the emphasis has been on developing the requisite form of evaluation considerations for ensuring organisational viability. In particular, these considerations have been shown to necessitate (for every organisation) the derivation of the cost of capital from an economic rather than merely an accounting viewpoint. The considerations have been used to reinforce the necessity for the implementation of that growth strategy which mostly satisfies a valuation relationship which is based on the value of the organisation to itself.

In the following chapter, the discussion of applicable current financial planning models will be aimed at giving an appropriate 'closure' to the contextual framework of the 'total investment system' from the viewpoint of organisational viability.

CHAPTER FOUR

THE CONTEXTUAL FRAMEWORK OF VIABILITY PLANNING

4.1 Introduction

The interface between the considerations discussed in Chapter Three and financial management practice can be developed in the form of the organisation's wealth matrix. In this research, such a matrix is called the Interaction Tableau. Its major components are the capitalised-cost structure and the synergic package of the organisation. The relevance of developing an interaction tableau can be realised from various problems associated with the application of logico-mathematical models in financial management. These problems pertain to formulation as well as implementation, and they arise perhaps mostly because financial management is still being recognised as the subject of concern or responsibility only of accountants even though, in reality, many non-financial people are also very much involved in management decision-making in general. All problems involve the selection of means to desired outcomes, but many take the desired outcomes as given or granted. To the extent that they do, they are tactical, since implicit in them is a major constraint, which imposes the definition of an 'a priori' precise boundary separating the possible or considered from the impossible or non-considered. Hence, for example, corporate planning (which must establish organisational goals and objectives) is more strategic than is a problem involving the minimisation of, say, transportation costs in which such minimisation is taken as being a desired outcome. In the same way, a problem involving the selection of an accounting convention is likely to be more tactical than, say, corporate budgeting.

Ackoff and Sasieni (1968) identified the three major characteristics of any problem as the range, scope and ends-orientation. They define the form of a problem as the way in which the properties of the problem are related to each other, while the content of the problem is the nature of these properties. Much as this type of classification aids better understanding of problems, it is usually almost impossible to identify clear cut-off points which distinguish tactical from strategic problems without making many contentious assumptions in the associated decision-making modelling. In most cases, these assumptions have been among the significant factors that limit the acceptability of logico-mathematical models by management in practice.

This chapter will present a close examination of the assumptions underlying applicable current financial planning models and their implications on financial management practice. Chapter Seven will then go further to the development of the Interaction Tableau and will subsequently discuss the manner in which the shortcomings of presently available models are tackled by the proposed viability planning framework.

4.2 Logico-Mathematical Models and Viability Planning

An integral part of the strategic planning process of any organisation is financial planning, which itself is essentially a formalised programme of interrelated actions to achieve desired results. It therefore rests upon the implicit assumption that the imposition of a predetermined programme of action upon the future development of the organisation will favourably influence the outcome of future operations. Even the success of tactical plans is, to a considerable extent, determined by the quality of the organisation's strategic planning efforts. This makes financial planning the central issue in order to establish organisational goals, which are the pre-requisites that determine the priorities, policies and procedures.

The most important problems for strategic planners in any organisation pertain to planning the cash flow to ensure growth, helping the organisation to see itself explicitly as an entity and assisting the development of that entity. A diversified and multi-disciplinary outlook is essential in order to appropriately tackle these problems. One reason for this is that whichever economy is considered, technological, competitive, social, financial and temporal factors typically interact in a very complicated fashion. Another reason is that organisations inevitably pursue inconsistent goals, since the responsibility and authority for making the required decisions are greatly diffused within each organisation and the economic environment in which the organisations operate is usually very uncertain. Every single industrial activity nowadays has to be viewed in terms of improved decision-making and improved performance not only within the boundaries of the particular organisation, but also in terms of the flexibility of the operational feasibility vis-a-vis the dynamic state of the environment within which the implementation of any decision taken is to be effected. In as much as there appears no limit to the factors worth considering in any decision-making process, the sheer number of variables as well as possible influences to take into account is itself a very worrying aspect of decision-making. Perhaps it is the challenge posed by this problem alone that is motivating the application of logico-mathematical models in decision-making generally.

Logico-mathematical models have come to be accepted essentially as scientific management techniques to aid management in its planning, controlling and decision-making functions. However, there is still not enough confidence in decision-makers that the factors concentrated upon for any possible situation form a collectively exhaustive set in such a way as to adequately reflect desirable courses of action at any time when unanticipated pressures are exerted on the particular organisation. Thus, the problem of uncertainty remains - which in turn serves as a major 'recipe' for inconsistent decision-making.

There is no 'fool-proof' means of knowing the totality of variables which form the appropriate collectively exhaustive set.

Indeed, the importance of each particular variable depends on which criterion answers the question of degree, which answers the question of judgement and which criterion is perhaps based on convention. Moreover, the importance that any chosen set of variables has - by any of these criteria - will change from time to time not only in nature, but also (and more importantly) in its structural relevance for each particular organisation. Most logico-mathematical models - for example, those of Weingartner (1963), Baumol & Quandt (1965), Chambers (1967 & 1971), etc., which have become popular in financial management - do not seem to allow for a close examination of the above-mentioned criteria. They have tended to be mostly applicable to preformulated problems in which the satisfaction of such criteria is usually taken for granted.

Weingartner (1963) has presented a firm-valuation model by analysing capital rationing in terms of situations imposed from within the firm and those imposed by the capital market. He has used a linear programming formulation to select a sequence of investments over a number of periods allowing for interactions between projects, in that they may require the same scarce facilities.

A simple representation of this model may be presented as:

$$\text{Maximise NPV} = \sum_{j=1}^{n} p_j X_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} c_{tj} X_j \leqslant F_t$$

$$t=1, \ldots\ldots, T \quad \emptyset \leqslant X_j \leqslant 1$$

where p_j = net present value of project j

X_j = the proportion of project j undertaken

c_{tj} = net outlay for project j in time t

F_t = total funds available in period t.

Other possible constraints can be incorporated in addition to the available-funds constraint. These might be to consider the production function, etc. or even situations of projects being mutually exclusive and/or collectively exhaustive. The very restrictive assumptions of Weingartner's model are the conditions of certainty and the imposition of constrained capital budgeting. More often than not, self-imposed expenditure limits are set to preserve corporate control, while externally imposed capital rationing usually results from an attitude of the capital markets that providing funds beyond a specific amount would lead to increased risks of high bankruptcy costs, which could be so high that feasible interest rates would not be adequate compensation. However, many companies in practice set expenditure limits merely to define more clearly the hierarchical structure of the organisation, especially when subsidiaries are in quite separate geographical locations. Also, most economists would agree that as long as capital markets are reasonably efficient, it will always be possible for an organisation to raise an indefinite amount of funds so long as the projects are expected to have positive net present values and the investors' confidence in the organisation is reasonably well maintained. Nevertheless, what should be the appropriate objective function for models of this sort is far from agreed. Models of the NPV type may be criticised for considering projects' cash flows as net figures rather than separating the cash inflows and the cash outflows, since the net figures do not allow actual optimisation if reinvestment opportunities have to be taken into consideration. Also there is the problem of the cost of capital used in these models - the cost of capital to get the net present values of each project has to be externally derived before applying linear programming to determine which projects maximise the organisation's net present value, yet the cost of capital is internal to the model solution (where it in fact appears in the dual as the implied marginal return to any additional funds).

Weingartner's horizon model (1963) has an objective function which maximises the firm's value at some future terminal point, rather than the net present value. This model is represented as follows:

$$\text{Maximise} \quad \sum_{j=1}^{T} a_j X_j + V_T - W_T$$

subject to

$$\sum_{j=1}^{T} a_{1} X_j + V_1 - W_1 \leqslant E_1$$

$$\sum_{j=1}^{T} a_{tj} X_j - (1+r)V_{t-1} + V_t + (1+r)W_{t-1} - W_t \leqslant E_t$$

where $\quad t=2, \ldots\ldots, T; \quad \emptyset \leqslant X_j \leqslant 1; \quad V_t, W_t \geqslant \emptyset;$

X_j = the proportion of project j undertaken

a_j = the value of all subsequent future flows to the horizon, T

a_{tj} = the inflow from project j undertaken in period t

E_t = the expected funds generated from operations in period t

W_t = borrowed funds in period t

V_t = lent funds over a particular period t

r = average borrowing and lending rate of interest

This model clearly recognises the intertemporal effects between periods, taking into consideration such things as the reinvestment of the inflows of prior periods and also incorporating the financial transactions of lending and borrowing funds over the multi-period horizon. However, this model lacks a utility function, thereby implying that investors' utility is independent of time. Also, the goal is to maximise only the cash returns on available projects at the horizon, T, and the opportunity cost of funds for the investors may not be known prior to the investment decision. Moreover, it still does not resolve the conflict between the external and internal determination of the cost of funds.

Baumol & Quandt's model (1965) is based on the maximisation of shareholders' wealth as measured by their utility for dividends. The model can be represented as:

$$\text{Maximise} \quad \sum_{t=0}^{T} U_t D_t$$

$$\text{subject to} \quad - \sum_{j=1}^{j} a_{jt} X_j + D_t \leqslant M_t$$

$$X_j \geqslant 0 \qquad D_t \geqslant 0 \qquad U_t = \frac{U_{t-1}}{1 + k_t}$$

where D_t, U_t = dividend & investors' utility, respectively

a_{jt} = fund generation from project j in period t

M_t = funds from external sources

X_j = amount of jth. project implemented

k_t = the discount rate to equate stockholders' utilities of consecutive periods t, t-1.

Much as this model goes a step further by solving the problems of NPV-based models, and much as it also achieves appropriate integration of the capital budgeting and the dividend policy, the 'a priori' derivation of stockholders' utility in consecutive periods remains problematic due to the high degree of judgemental issues involved. Also market understanding generally breeds the expectation that investors' utility depends not only on the dividends received but also on the share price at the end of the period under consideration, since any capital gain is also part of the investors' return and increases their expected utility. This model does not account for this, and moreover, there is the complication in practice that in order to derive the dividend policy before applying the model, one has to know the cash configuration of every project the organisation can undertake during the planning horizon, T.

With the types of model described until now, a closer look will reveal that unless the last planning period in the considered horizon coincides with the terminal date of the last project to be completed, there is no guarantee that the models will maximise the cash accumulation during the period over which the investors' utility is being considered. Rather, it is possible that most of the benefits may accrue after the end of this period and leave the investor at a lower utility for the period, unless (as pointed out above), the corporate planning period and the investors' utility period coincide. This horizon valuation problem has been quite worrying for most planners. Perhaps the most helpful attempts so far has been the work of Chambers (1967, 1971).

Chambers's model (1967) on allocation of funds seems to bridge the gap between Weingartner's horizon model and Baumol & Quandt's model. The model can be represented as follows:

Maximise $$\sum_{t=0}^{T} \frac{D_t}{(1+i)^t} + \frac{P_T}{(1+i)^T}$$

subject to

$$\sum_{t=0}^{T} \sum_{h=0}^{t} \sum_{j=1}^{n} (Kw_{tjh} - v_{tjh}) X_{jh} \leqslant V_T - KW_T$$

$$R . \sum_{t=0}^{T} \sum_{j=1}^{m} X_{jt} + R \sum_{t=0}^{T} \sum_{h=0}^{t} \sum_{j=1}^{n} (v_{tjh} - w_{tjh}) X_{jh} - \sum_{t=0}^{T} \sum_{j=1}^{n} c_{Tjt} X_{jt} \leqslant C_T - RA_T$$

$$\sum_{t=0}^{T} \sum_{j=1}^{n} e_{Tjt} X_{jt} \geqslant E_T^* - E_T$$

$$\sum_{j=1}^{n} X_{jT} + \sum_{t=\emptyset}^{T-1} \sum_{j=1}^{n} c_{Tjt} X_{jt} + D_T \leq F_T + \sum_{t=\emptyset}^{T} \sum_{j=1}^{n} f_{Tjt} X_{jt} + M_T$$

$$X_{jt} \leq X_{jt}^{*}$$

The above inequalities represent, respectively, the current ratio constraint, the constraint for return on gross assets, the earnings constraint, the period-linking requirement and the constraint for project scale control.

In this model,

X_{jt} = outlay at end of period t on the jth available project

V_T, W_T = level of 'old' current assets and liabilities, respectively, of period T (that is, resulting from the decisions taken before the end of period Ø)

v_{tjh}, w_{tjh} = increase in current assets and liabilities, respectively, between the end of period t-1 and the end of period t (that is, expected to result from the jth project started in period h)

K = current ratio stated by management

n = number of projects whose initial outlay is charged to capital account

$(n-m)$ = number of projects whose initial outlay is charged immediately to expense

A_T = value of gross assets at end of period T (that is, acquired before the end of period Ø but not yet scrapped by the end of period T)

c_{Tjh}, e_{Tjh} = contributions, respectively, to gross and net earnings in period T (that is, expected to result from project j started in period t)

C_T, E_T = contributions, respectively, to gross and net earnings in period T from projects started before the end of period Ø

R = stipulated return on gross assets ratio

E^*_T = minimum net earnings desired by management

D_T = dividends declared at the end of period T

F_T = contributions to cash flow in period T from projects started before the end of period Ø

f_{Tjt} = contributions to cash flow in period T expected from project j started in period t

M_T = new long-term finance (equity or bond) available at the end of period T

X^*_{jt} = upper limit on outlays (on the range of reasonable scales acceptable to management) for the jth project started in period t.

In this model, Chambers has concentrated on more specific financial considerations. He has laid much emphasis on making more flexible the constrained capital budgeting imposed in most other models. This model is aimed at shareholder-wealth maximisation within a specified horizon. As such, it is taking for granted that all the parties concerned have this goal as the overriding one. Moreover, the problems of horizon valuation and integration of financing with investments remain unsolved, as is the Hirshleifer paradox (that is, the problem of external versus internal determination of the cost of capital). Chambers (1971) has tackled the second problematic issue in another model - that is, the joint problem of investment and financing. However, the context of this model is not different from the previous one and moreover, the approach to the issue has been to impose some specific states of the firm's market activities (for example, government securities' purchase, rights issues, debentures status, equity in other firms, etcetera), rather than allowing the choice of states to be determined within the model.

Merville and Tavis (1973) have tried to resolve the Hirshleifer paradox by incorporating in their model a specific desire by stockholders for dividends over each period. Their model can be represented as follows:

$$\text{Maximise } U(D) = \sum_{t=1}^{T} U_t D_t + U_{t+1}\left(\sum_{j=1}^{n} p_{j(t+1)} X_j\right)$$

subject to

$$- \sum_{j=1}^{n} f_{j1} X_j + V_1 - W_1 + D_1 \leqslant E_1$$

$$- \sum_{j=1}^{n} f_{jt} X_j - (1 + r_L)V_{t-1} + (1 + r_B)W_{t-1} + D_t \leqslant E_t$$

$t= 2, \ldots\ldots, T \qquad \emptyset \leqslant X_j \leqslant 1 \qquad j= 1, \ldots\ldots, n$

$V_1 \geqslant \emptyset \qquad W_1 \geqslant \emptyset \qquad D_t \geqslant \emptyset \qquad t= 1, \ldots\ldots, T$; and

V_1, W_1 are compounded throughout period $t=2, \ldots., T$.

In this model,

U_t = the constant utility per monetary unit (pound) for all returns in period t

D_t = consumed dividends in period t

X_j = proportion of project j undertaken

f_{jt} = cash inflow of project j in period t

V_t, W_t = amount loaned and borrowed, respectively, in period t

r_L, r_B = average lending and borrowing rates, respectively

E_t = potential cash disbursement level from current operations in period t

$p_{j(t+1)}$ = present value of all cash flows of project j past period (t+1) and discounted back to period (t+1) at the cost of capital.

Merville and Tavis have, in addition, attempted to resolve the cash accumulation problem of Weingartner's model by specifically incorporating borrowing and lending at interest rates expected to prevail over the planning period. Financial transactions of borrowing and lending and also the utility trade-off of dividends have been imposed against consumption (in one or some of the constraints) to form a single period model. The other constraints in the model are simply linking constraints for consecutive periods. Perhaps the most questionable aspects of this model are the derivation of utility-links between consecutive periods and the assumption that simply stipulating the expected borrowing and lending rates should reflect major financial interactions.

The model of Lerner and Rappaport (1968) is concentrated on the problem of erratic reported earnings per share which may result in any linear programming application due to the variations in cash inflows under the maximising objective function. This model can be represented as:

$$\text{Maximise} \quad \sum_{j=1}^{n} \sum_{t=1}^{n+1} \frac{f_{jt}}{(1+k)^{t}} X_j$$

subject to

$$\sum_{j=1}^{n} E_{jt} X_j - (1+g) \sum_{j=1}^{n} E_{j1} X_j \geqslant 0$$

$$X_j + q_j = 1 \qquad j = 1, \ldots\ldots, n \qquad X_j,\ q_j \geqslant 0$$

where

f_{jt} = cash flow from project j

X_j = proportion of project j undertaken

q_j = proportion of project j not undertaken

E_{jt} = earnings per share from project j in period t

g = stipulated growth rate in earnings per share.

This model addresses situations where the solution undertakes a highly profitable project which has a substantial amount of start-up costs and thus temporarily depresses earnings per share. The earnings variability is tackled by additional constraints whereby reported earnings per share rise at a stipulated annual rate. The approach in this model may be taken as identical to the introduction of a cushion factor in the organisation's dividend policy. What is obvious about this model, as well as that of Mervis and Tavis, is that they are both maximising project cash-inflows. As such, they are attempts at sub-optimisation in a manner that would be a credit only to the conventional wisdom of financial accountants.

The types of models discussed so far have concentrated on specific aspects of financial management, in each case isolating the problem on hand and introducing a set of assumptions which makes reality seem simple to comprehend. Apart from the distinctive characteristics of each model which have been highlighted during the discussion, an observation worth making is about a strong implication, common to and underlying all such models - the totality of transactions of any organisation has to be viewed in the form of projects. This being so, it is the sum of benefits attributable to each project which is being used to develop the objective function rather than a measure of the consolidated benefit attributable to the joint-effort of all projects and all other organisational operations. Furthermore, the interactions (of the various productive sub-systems) which reflect the effect of each project on the organisation's cost-structure and also the interactions (of such sub-systems) activated by the influence of other projects have been virtually neglected. It has been assumed that the projects' contribution to total net present value, owners' utility, etc. is enough to reflect the results of all such relevant interactions.

Orgler's model (1970) seems to be in a totally different league. The model is aimed at optimising cash management using constraints which are introduced as production constraints, cash constraints and capital constraints - the latter being based on various financial ratios, desired by the management. Orgler's model can be represented as follows:

Maximise $\sum_{i=1}^{n} U_i X_i$

subject to

$$p_i X_i \leqslant P_i$$

$$\sum_{i=1}^{n} c_i X_i \leqslant C_T$$

$$\sum_{i=1}^{n} (s_i - q_i - v_i) X_i \geqslant K.L_c + COL - (MB+AC+BAR+BAI+NS)$$

where

X_i = units of products i being manufactured

U_i = profit per unit of product i

p_i = production requirements (time, materials, etc.) per unit of product i

P_i = potential capacity for making product i

c_i = cash requirement per unit of product i

C_T = total cash available

q_i, s_i, v_i = labour cost, sales on accounts receivable, and inventory sold, respectively, per unit of product i

K = current ratio as stated by management

L_c = current liabilities as given by management

MB = minimum cash balance

AC = accounts receivable collections

BAR = accounts receivable at start of planning period

BAI = average inventory at start of planning period

NS = new stock expected during the planning period.

The objective function here is to minimise the horizon value of the net revenues from the cash budget over the entire planning period. However, using the assumptions that all revenue generated is immediately reinvested and that any cost is immediately financed, the objective function is being made to represent the value of the net income from the cash budget at the horizon by adding the net returns over the planning period - hence, it becomes a maximising program. Orgler goes further by distinguishing two types of constraints - institutional and policy. Institutional constraints are defined as those imposed upon the organisation by external forces such as a bank-required compensating balance. Policy constraints are taken to be those imposed upon the organisation's cash management by the organisation itself - for example, an internally imposed constraint might prohibit credit sale of a particular product below or above a certain range in monetary terms. Thus, Orgler's model can be viewed as an attempt at aggregate planning as far as organisational operations are concerned. The formulation however needs a lot of modification when investments and financing have to be considered.

The 'FIRM' model of Deam et al (1975) is perhaps one of the most comprehensive attempts at resolving all the deficiencies of the types of model discussed up till now. A representation of the model is not given here since, to some extent, it is similar to Chambers's (1967) model. The distinctive characteristics, and perhaps the most positive contributions, are that:

- the dividend component of shareholders' wealth is reduced by the capital 'subscriptions' into the firm by its shareholders
- a series of financial matrices provides the links between successive periods, and

- the discounted sum of the dividend component of shareholders' wealth extends to infinity after correction for income tax and capital-gains tax effects.

The model of Deam et al solves the problem of horizon selection by 'time-phasing' interactions of different periods. The financial matrices used however are based on conventional accounting 'rules of thumb', while the problem of uncertainties is not given much consideration. It must be said also that the model seems to be more oriented towards validating the implications of many assumptions underlying developments in financial theory than it is towards enhancing the acceptability of such models by management who are the intended end-users.

All the types of model discussed above have one common characteristic - any problem on the hand of management has to be introduced as one of the constraints (institutional or policy), while the objective function remains basically the same. This is indeed far from reality in management decision-making, since the aim of any model-application is essentially to introduce a conscious intent of management in directing the interactions between the constituent sub-systems towards resolution of the problem on hand to the best possible capability.

Thus, it is conceivable that all the models discussed above (and many other logico-mathematical decision-making models) have had disappointingly low responses for analysts simply because the models' identification of the range, scope, characteristic, content and form of organisational problems does not coincide with the realities faced by the planners and decison-makers for whom the models were meant. Ashton (1978) appears to have seen this mainly as a problem of 'search' improvement in the mathematical techniques used. The author believes that this is not entirely so. The real core is that a new modelling approach is needed, especially now that there is increasing recognition of the practical limitations of linear programming, the need for more capital market understanding and the need for much improved management information systems. These are the reasons for considering this research worth undertaking.

The limitations of linear programming applications have centred around the practicability of multi-criteria considerations and situations of project indivisibility, economies of scale, mutual exclusiveness and/or collective exhaustiveness of projects. The development of integer and goal programming techniques have been significant theoretical improvements in these aspects. However, most planners and decision-makers have not been able to put these developments into practice since existing software packages are not widely available nor are most of them appropriately tailored to the needs of the end-users. Many commercial and/or academic developments in this area - for example, Moskowitz's goal programming code, PAGP (Moskowitz and Wright, 1979) - have been based on linear programming only and the multi-criteria modelling has not been appropriately developed to take a full advantage of the versatilty of goal programming.

A goal programming model essentially permits performance of three types of analysis:

- it determines the input requirements for a set of goals,
- it determines the degree of attainment of defined goals with given resources, and
- it provides the optimum solution under varying inputs and goal structure.

Thus, if the relationship between defined goals is poor or if consistency is not maintained in the choice of variables, the solution (when used in practice) may deviate from the optimum upon which satisficing recommendations should be based. Therefore if goal programming is to give acceptable and convincing satisficing models, the strength of the applications should be in the monitoring of consistency. This is more so when the developed tableaux are intended to reflect the relevant aspects of the judgemental issues of strategic decision-making.

Decision-making consistency in any organisation depends to a great extent upon the organisational goal and the specification of objectives. These objectives, in today's multi-criteria world, have to ensure the most benefit for some acceptable cost within the framework of maintaining long-term viability. Organisational goals are the pre-requisites that determine the organisation's priorities, policies and procedures - they define the organisation's general direction and its specific strategies.

The decision-making process in organisations therefore needs in-depth analysis in order to identify the requisite goal for viability planning and to enhance the specification of objectives. This is the topic of discussion in the following section.

4.3 Organisational Goals and Specification of Objectives

The measurement system for growth and stability in any organisation has to be viewed from three angles:

- the organisation in isolation from its environment,
- the organisation relative to its environment, and finally
- the degree of mismatch between the first two aspects.

These three aspects depend on management's philosophy, attitudes, focus and purpose. They all revolve around organisational goals, which serve not only as a reference point and a device for coordinating the efforts of all concerned, but also serve as targets against which the particular organisation's operating performance can be measured. The first aspect mentioned above concerns the types of organisational goal in current management practice. The second concerns what organisational goal should be maintained (given that the management clearly understand which developmental needs offer the best chances to adapt to the prevailing environment). The third essentially concerns how best to minimise any perceived mismatch between the practised and the requisite goals.

Organisational goals are generally accepted to be in five main categories:

- shareholder wealth maximisation,
- profit maximisation,
- rate of return maximisation,
- growth maximisation,
- behavioural objectives.

When operating under a shareholder wealth maximisation goal, management has to coordinate its profit plan so that stockholders receive the highest combination of dividends and increase in share-value or share-price for any given period. In other words, a shareholder's proportional ownership of the organisation should be as valuable as possible. This organisational goal directly affects the policy decisions of what to invest in and how to finance the investments. Although this goal appears to be highly compatible with the concept of the perpetual life of the organisation, it is actually something more to strive for than to achieve. Foremost is the fact that share price is subject to outside influences beyond management's control. Secondly, stockholders are very different from each other - partly because the only pre-requisite to be one is usually simply having enough funds to purchase the stock (without any character evaluation whatsoever), and partly because stockholders (being human) usually adapt faster to changes in the environment than any organisation could ever hope to. These have accounted for most situations where management have felt frustrated and disillusioned by the stock price performance not seeming to reflect what they consider to be a good effort.

The profit maximisation goal implies that management favours maximum profitable investments regardless of the associated risks - operational and/or financial. This goal tends to aggravate the existing separation between the shareholders and management. Since management is not really relating its decisions to any measure of stockholder benefit, its investments and financing policies tend to become self-centred and usually fail to satisfy the organisation's commitment to its owners and/or, in most cases, the environment. Furthermore, with this goal, management may never pay a dividend as long as there are investment opportunities which assure rates of return higher than zero (whether or not such rates of return are less than the market-required rate of return on investments).

The rate of return maximisation goal, on the other hand, implies that an organisation may embark on only the investment with the highest rate of return. In such a situation, uneconomically large dividends can be declared (which is surely not in the best interest of the stockholders, and moreover cannot be sustained in the long-run). Indeed, as has been pointed out by Deam et al (1975), " .... Both maximisation of profits and maximisation of rate of return would result in a conscious distortion of the social preferences of the shareholding community .... "

The growth maximisation goal is generally understood to mean the maximisation of growth in earnings or cashflows. Management, implementing this goal, tend to accept only those investments which yield large cashflows regardless of the original outlay and, even much more damaging, regardless of the rate of return on the investments. The fact is that not only do large original outlays create a heavy burden on the organisation which could jeopardise relationships with stockholders unless they are well justified, but also such outlays indicate that few investments have to be undertaken (thereby offering fewer chances of minimising the business risk). Furthermore, the organisation would be worse off if the rate of return on investment is less than the market-required rate of return. A justified criticism of this goal is to liken it to what has been termed 'managerial utility maximisation'. Bolten (1976) describes this as the situation when management tend to base their decisions on what would give them higher salaries and expense accounts. Such maximisation of managers' welfare and benefits may be done through maximising the organisation's size in such a way that there is slack in operations above that which satisfies the stockholders and therefore can be drained off for the benefit of the managers themselves. Of course, such a goal will hardly ever be expressed publicly by management, but it may always be lurking in the back of their decisions, especially in situations where the stockholders exercise little control through the elected directors of the organisation. What is perhaps more obvious with this goal is the fact that there is bound to be increasing inefficiency in the allocation of resources since the larger (perhaps less attractive) investments tend to have the most slack and are, therefore, frequently chosen over the more attractive (if smaller) projects.

The goal pertaining to behavioural objectives contrasts all the four mentioned above in that it is not focused towards maximising any single objective whatsoever. It essentially emphasizes the reasonable level of achievement that suffices to satisfy stockholders and managemet alike. Management theorists - for example, Drucker (1954), March and Simon (1958) - have called this type of goal 'satisficing'. They assert that perhaps the justification for adopting this goal is the fact that it is the only goal that can be used by management without exerting undue strain upon the organisation and its ability to work as a cohesive team. A sceptical view however may be that satisficing is the best that can be expected from managers who must make decisions within the constraints of risk - they cannot maximise in the face of uncertainties because the penalties for failure, such as being fired, are severe, whereas the penalty for doing a mediocre job is practically non-existent! Nevertheless, it must be said that what seems to be the main justification is that this is the only goal which ensures optimum flexibility and negotiating power for the organisation in any given situation, while retaining the ability to monitor decision-making consistency of ensuring that the long-run return on equity shareholders' investment is sufficient to continuously uphold a high prestige for the organisation as an investment channel from the viewpoint of investors, and as a credit-worthy entity from the viewpoint of the bond-security parties. Furthermore, this satisficing goal is the only one which tends to resolve the conflicts usually encountered among the various operational goals in any organisation. For example, the production department may want to make standardised products while the sales department may be propagating specialised customer-tailored ones; similarly, the marketing department may want to increase sales at the expense of return on investment.

4.4 Connective Summary

From the above discussion about various organisational goals, it is clear that the requisite goal for viability planning has to be the one pertaining to behavioural objectives. The ensuing model therefore has to incorporate multiple criteria, which continuously ensure (as emphasized by Sizer, 1979) that:

- the equity-security parties are assured of a fair return on their investments,
- the normal expansion of the organisation is sustained through a modicum of forward progress and with no deterioration relative to other organisations within the industry,
- adequate reserves are maintained for sustaining the business potential (especially in times of inflation and general economic recession),

- new external capital can be attracted, when required, without excessive pledging of assets or similar unduly straining commitments,
- the employees maintain their identification with the organisation by working as a cohesive team, and finally,
- the creditors as well as employees are satisfied of the likelihood of the continued existence of the organisation.

In the following two chapters, the 'state of the art' of multiple criteria decision-making modelling is discussed with emphasis on its applicability to viability planning. This will help to put in the right perspective the necessity for a transition stage between understanding the underlying concept of viability planning and the modelling process.

CHAPTER FIVE

MULTIPLE CRITERIA DECISION-MAKING MODELLING USING MULTI-OBJECTIVE LINEAR PROGRAMMING TECHNIQUES

5.1 Introduction

Model-building, the essence of Operational Research, helps to put the complexities of a problem into a logical framework amenable to comprehensive analysis. This became perhaps more apparent than ever in the 1950s when Operational Research started to be widely applied in industries especially in Britain and the United States of America.

In terms of economic impact, linear optimisation models (usually called linear programming models) are perhaps the most successful applications of Operational Research. Since the introduction (by Dantzig in the late 1940s) of the 'simplex algorithm' as a systematic procedure for solving linear programming problems, models using the procedure have received wide application in various aspects of industrial, social and economic activities.

There have been considerable difficulties however, in applying such models to some decision-making problems. This is a consequence of the realisation that many such problems necessarily involve multiple objectives which cannot be simultaneously optimised due to inherent conflict between the objectives. In other words, such problems necessitate a thorough evaluation (of the multiple criteria perceived) aimed at the proper development of a criterion function, which when optimised should yield a solution constituting the most desirable compromise strategy among the several different (usually incommensurable) objectives. Such problems are hence referred to as multiple criteria decision-making (MCDM) problems, and model-building for tackling such problems will be referred to, in this study, as MCDM modelling.

In the following sections, first, a broad categorisation of the current 'state of the art' of MCDM modelling using multi-objective linear programming (MOLP) techniques will be made, and then the emphasis will be upon how to develop a practical tool utilising the concept of MCDM in the context of Viability Planning.

A detailed study of MCDM models was conducted by Johnsen (1968) based on his empirical investigations about the 'goal catalogues' of Danish firms. The more analytical interest in the optimal solution of MCDM problems however, was perhaps first aroused by Charnes and Cooper (1961) who emphasized that such problems are formally equivalent to the mathematical vector maximisation problem - in which case, alternatives which are dominated with respect to the pursued goals may be dropped right from the start of problem analysis. This has been one of the two basic strategies that have emerged for analysing MCDM problems. It is usually referred to as vector optimisation - Fandel and Gal (1980) - since the objective function is viewed as a vector-valued rather than a scalar-valued function (as in conventional linear programming) and the strategy attempts to develop the corresponding vector maximum model. This strategy thus attempts to view each objective as a separate criterion function defined on the set of alternatives and to determine the set of efficient alternatives - that is, alternatives that remain non-dominated with respect to the set of criteria imposed.

The second strategy attempts to order the alternatives by developing a utility function which incorporates in some way all the decision criteria applicable to the multiple objectives. This strategy is related to multi-attribute utility theory (Keeney and Raiffa, 1976) and so will be referred to, in this study, as MAUS modelling - Multi Attribute Utility Strategy modelling.

The performance of extensive sensitivity analyses on optimal solutions of linear programming problems may have led to those techniques usually referred to as multi-objective linear programming (MOLP) techniques. The simplex method is still fundamental to these MOLP techniques. The formulation of tableaux however, takes the form of parametric programming cases, where the focus is on ranges of desired levels (goals) expressible through deviational variables and/or additional constraints, both of which are used to indicate the way the ordering of the different objectives ought to be achieved. In MOLP, goals may be implicitly or explicitly given. In the first case, the desired level is defined by the maximum of an objective function thereby becoming manifest as far as it exists after the maximisation procedure. In the second case, the desired level is given as a particular value specified by the decision-maker himself or by his environment before the "solution" is found.

MOLP techniques are therefore more suited to the vector optimisation strategy than to the multi-attribute utility strategy. However, goal programming (GP) - perhaps the most versatile MOLP technique - is also well adapted for MAUS modelling. GP involves establishing some form of goal structure for the MCDM problem by expressing each objective function in the form of a goal constraint and then, instead of trying to maximise/minimise the objective criterion directly (as in linear programming), the deviations between goals and achievable limits dictated by the set of system constraints are minimised.
Goal Programming (GP) has been appropriately described as

" .... an approach for dealing with managerial decision
problems that involve multiple, incommensurable
goals, according to the attached importance of the
goals .... " - Moskowitz and Wright (1978).

Deviational variables (equivalent to 'slack' variables in linear programming) have a different meaning in GP. They are divided into positive and negative deviations from each goal and the objective then becomes the minimisation of a function of these deviations within the pre-emptive priority structure assigned to the deviations, or the maximisation of any multi-attribute utility function that is considered approriate in the case of MAUS modelling.

A general formulation of a multi-objective linear program is as follows:

$$\text{Maximise } \{ \Psi_i(x), i=1, \ldots, r \mid x \in X \}$$

where $\{ \Psi_i(x)\}$ is a set of objective functions of order r, and X is a non-empty and closed feasible region.

This formulation is usually expressed in the context of (linear) goal programming as:

$$\text{Minimise } \Sigma_i[\alpha_i d_i^- + \beta_i d_i^+]$$

$$\text{where } F_i(x) + d_i^- - d_i^+ = G_i$$

$$f_m(x) = g_m, \quad x \geqslant \emptyset$$

$$d_i^-, d_i^+ \geqslant \emptyset \quad i=1, \ldots, r \quad m=1, \ldots, M$$

r being the number of linear objective functions $F_i(x)$, each with a specified goal G_i, M - the number of 'hard' constraints in the problem;

d_i^-, d_i^+ are deviational variables on goal G_i's achievement; and

α_i, β_i are differential weights assigned to each priority group.

Using the above formulation, GP is capable of handling multiple goals in multiple dimensions. Since the multiple goals are often achieved only to the detriment of one another, a hierarchy of importance among the goals is required which allows consideration of low-order goals only after higher-order goals are satisfied or have reached points beyond which they cannot be improved. Rank-equivalent weights, which ensure that the hierachical order (priority structure) of the objectives is maintained, can be introduced in developing the overall objective function. Furthermore, within the same priority group, differential weights can be attached to the deviational variables in order to ensure that the relative importance of each is maintained. For example, if shortages of one resource are considered more critical than others, larger weights are attached to the resource's deviational variables. Thus in GP, deviations are real variables and the objective function is expressed only in terms of these variables.

Due to the complications that are associated with the development and usage of utility functions - Keeney and Raiffa (1976), de Neufville and Stafford (1971) - problem-solving techniques tend to have been swayed more towards the vector optimisation strategy. Nevertheless, considerable theoretical development on MCDM modelling in general has been made. This is evident in the works of, for example, Charnes and Cooper (1961), Eckenrode (1965), Yu and Zeleny (1975), Ignizio (1976) and Fandel and Gal (1980). Some of the theoretical developments have focused on generating all efficient extreme point solutions to the problem - for example, Evans and Steuer (1973), Kornbluth (1973), Zeleny (1974), Gal (1976), Isermann (1977) and Ecker and Kouada (1978). Other developments have gone further by focusing on guiding the decision-maker to his/her most preferred solution - for example, Benayoun et al (1971), Belenson and Kapur (1973), Ozernoi (1980), Keeney and Raiffa (1976) and Zionts and Wallenius (1976).

It can be observed that there has been about a one decade gap between the earliest developments and the large number of contributions in the seventies. It could be that, as is usual with many theoretical developments, it did take some time for a framework to be established which then motivated further research and development. It could also be that decision-making problems in the sixties were not realised to be complicated enough to necessitate further in-depth study of mathematical programming spanning such problems (for example, it has taken a further decade for 'group decision-making' to be considered in such developments). Nevertheless, what is undoubtedly true is that efficient computer programs to solve MCDM problems were not developed until the late seventies, and this could have been a major impediment faced by analysts in the sixties. Further elaboration of the above issue is not intended in this thesis. What is intended however, is a close look at the already developed framework of MCDM modelling and how it matches decision-making problems of today.

Developments in MOLP techniques have tended to recognise the inherent problem of MCDM as two-fold. Firstly, the question of how best to transform different outcome scales into one effectiveness scale, and secondly, how best to improve 'satisficing' decision-making. Before embarking on a categorisation of the various MOLP techniques for MCDM modelling, it is necessary at this point to discuss 'satisficing' in order to put it into the correct perspective.

5.2 On The Issue Of Satisficing

Many management theorists, including March and Simon (1958), have held the view that satisficing is a process of sub-optimising. This, of course, gives the connotation that satisficing is irrational in the classical sense. However, it remains arguable whether or not it is unimpressive as good management practice, considering the sheer number of factors usually affecting decisions which places substantial informational and computational requirements upon the decision-maker often under considerable time pressure.

There are two main dimensions of management decision-making problem, each of which helps to highlight that satisficing is a much wider concept than merely sub-optimising. One dimension pertains to inadequacy of information which seems to be encountered more often than not in decision-making. The other dimension pertains to the increasing recognition of a multiple rather than single goal structure of decision-making. Drucker (1954) was one of the first to contend that organisations do and should undertake the achievement of multiple rather than single goals. The concept of satisficing is motivated essentially here as the search for 'balance among areas'. Thus, while one aspect of satisficing is related to inadequate data availability, preparation and/or reliability, the other aspect relates specifically to the vastness of desirable outcomes, thereby indicating that satisficing has to be concerned with determining a combination of desirable outcomes which maximises overall utility for the decision-maker.

Ackoff and Sasieni (1968) have highlighted some assumptions about utility (in the context of MCDM modelling), which make the results of using satisficing models equivalent to maximising utility. These are as follows:

- a less-than-targeted value of a higher priority objective has no utility and all values equal to or greater than the targeted value have equal utility;
- any value of a lower priority objective has less utility than any target-satisfied value of a higher priority objective;

- even if target-satisfied values of a higher priority objective have different utilities, the dispersion of the values around the expected can be ignored.

How valid are these assumptions? Firstly, it is not difficult to realise that they can be made redundant or at least considerably weakened where recent developments in MOLP techniques are concerned. Also, the second assumption will not necessarily hold if there is a stage of problem analysis when the aim is to derive the most appropriate trade-off weights that make an obtained compromise solution most acceptable in comparison with other efficient (non-dominated) solutions. Finally, the third assumption will also not hold if the derived trade-off weights are introduced into an overall objective function, the optimal value of which is expected to be associated with the best compromise plan achievable. Furthermore, if preference or rank-equivalent weights are obtained and combined with the derived trade-off weights, and if the combination of such weights is introduced into the overall objective function, the first assumption will be considerably weakened, especially on the issues of no-utility for less-than-targeted values of any higher priority objective. Thus, even without these assumptions, satisficing can still be seen in the context of utility maximisation, especially in any situation with inherent conflict.

Satisficing, therefore, can be appropriately defined as optimising the structure of the decision-maker's environment by striving to achieve a satisfactory balance of all desirable outcomes while maintaining optimum availability, dissemination and reliability of information. In other words, contrary to earlier interpretations by management theorists, satisficing has to be viewed precisely as effecting an approximate attainment of an optimal plan in an almost impossible situation, rather than an exact attainment of an inferior one.

5.3 Broad classification of MCDM models

In this broad classification, attention will first be focused on that part of MCDM modelling problem concerned with transforming different outcome scales into one effectiveness scale. In many models tackling this problem - for example, those considered by Yu and Zeleny (1971) and Yu (1975) - the tendency is simply to avoid it by optimising with respect to one objective and satisficing with respect to the other objectives. The basic aim in doing this has been to determine an optimal (or near-optimal) solution to a specific problem, starting with some presumption about the decision-maker's preferences but avoiding having to determine any value function precisely in reaching the requisite solution. This may be viewed as an indication that the modellers concerned implicitly recognise some form of multi-dimensionality in MCDM modelling. In these models, the objective functions are ranked according to some subjective priority scheme so that a marginal improvement for a particular objective preempts arbitrarily large improvements in lower-ranked objectives. Models with this approach are thus classified as the 'pre-emptive' group. Goal programming has tended to be identified with this group since MCDM problems in the context of GP have usually been resolved as pre-emptive programs with objective priority rankings.

5.3.1 The Pre-emptive Group

There are two categories in this group, distinguishable by the nature of their approach to problem-solving. In this study, the two categories are referred to as 'direct' lexicographic ordering and 'indirect' lexicographic ordering approaches.

5.3.1.1 The Direct Lexicographic Ordering Approach

This approach is basically hierarchical optimisation and it may be done with or without interaction with the decision-maker. Hence, the two sub-groups here are called the 'sequential method' and 'interactive sequential method'.

The Sequential Method

This method - considered by, for example, Fishburn (1974) and Starr and Zeleny (1977) - advocates:

(i) Maximise $\psi_1(x) \mid x \in X$

determining an optimal solution set $\{x^* \mid \psi_1(x^*) = \alpha_1\}$;

then,

(ii) Maximise $\psi_2(x) \mid \psi_1(x) = \alpha_1;\ x \in X$

In general, the procedure is:

Maximise $\psi_k(x) \mid \psi_i(x) = \alpha_i;\ i=1, \ldots, k-1;\ x \in X$

where, $2 \leqslant k \leqslant r$, r being the number of objective functions. If the optimal solution set consists of a single element x^* such that $\psi_k(x^*) = \alpha_k$, then α_k is a pre-emptive optimum and x^* is 'the' solution. Otherwise, the procedure is continued until k=r.

A problematic issue in the usage of this method is that the decision-maker has to give subjective priority rankings based usually on inadequate information, the consequence of which is that 'rank-switching' (that is, rational or irrational changes in the priority assignments of the various objectives) becomes highly probable. While the effect of 'rank-switching' can be investigated by solving all such permutations of prioroty structures, this would be highly inefficient especially since it would typically produce a large number of solutions, many of which would be highly similar and overlapping in nature. This indicates that in practice, the decision-maker may end up with a solution which may be worse than that of one or more other solutions in terms of the achievement of objectives. This issue has therefore led to the decreasing usage of the sequential method.

The Interactive Sequential Method

This approach - considered by, for example, Dyer (1972), Price (1976), Zionts (1976) and Nijkamp and Spronk (1978) - relies on the progressive definition of the decision-maker's preferences, with simultaneous exploration of the bounds on the range of values taken by the objective functions and within which a compromise solution is expected to be found. In this approach, the decision-maker gives trade-offs on preference information based upon the set of current solutions in order for the analyst to obtain a new optimal solution using the model. The procedure, as used by Masud and Hwang (1981), is as follows:

(i) Maximise $\psi_i(x) \mid x \in X$ where $i=1, \ldots, r$

thereby obtaining a set of optimal objective function values $\{ \psi_1(x^{*1}), \psi_2(x^{*2}), \ldots, \psi_r(x^{*r}) \}$ and corresponding sets of objective function values $\{ \psi_i(x^{*j}) \}$ $\forall_{i=j}$ $j=1, \ldots, r$ where x^{*j} denotes the optimal solution when the jth objective function is optimised.

(ii) Select $\alpha_{i1} = \text{Min}_{i,j} \psi_i(x^{*j})$ and $\beta_{i1} = \text{Max}_{i,j} \psi_i(x^{*j})$

thereby the initial goals G_i are chosen such that

$\alpha_{i1} \leq G_i \leq \beta_{i1}$ for all i

(iii) Derive initial weights for deviational variables as

$W_i = G_i - \alpha_{i1}$ whereby a normalising scheme makes the variation between α_{i1} and G_i equal to 1 thereby

representing the (current) maximum value of d_i^-.

Thus, the goal constraint constituting the ith objective takes the form:

$$\psi_i(x) + W_i d_i^- - W_i d_i^+ = G_i \quad \text{for all } i$$

(iv) Minimise $\Sigma_i(d_i^+ + d_i^-) \mid \psi_i(x) + W_i d_i^- - W_i d_i^+ = G_i;$

$$d_i^- \leqslant 1; \quad d_i^-, d_i^+ \geqslant \emptyset; \quad x \in X$$

where, at every stage, α_i and β_i are presented to the decision-maker for him to indicate G_i for all i.

The interactive sequential method thus comprises three major stages. The first stage determines the bounds within which the decision-maker has to set the desired goals, the second derives the appropriate weights which ensure that the deviational variables are measured in commensurable units (since they are automatically adjusted during iterations as well as in response to variations in the specified goals), while the third minimises the distance function which represents the mismatch between the obtained optimal values of the objectives and the set of goals specified by the decision-maker. It is conceivable that the initial range of values of the objective function might not be satisfactory to the decision-maker. This would signify that either the objective functions are mis-specified or the targets set in the constraints of the problem need to be modified. Such target modification would not be a problem since results from the previous analyses could be used to have a feel for the whole situation. Indeed, this is the first interactive stage of this method and it constitutes the advantage of obviating the necessity for 'a priori' specification of the goals G_i.

A major drawback of the interactive sequential method however, is that the decision-maker not only has to spend considerable time with the analyst as well as be responsible for considerable computer costs, but he is also expected to be rational and consistent in providing the information required from him/her at every stage. This is bound to increase the pressure on the decision-maker, bearing in mind the limited time within which he has to arrive at a decision and also the vast amount of information he has to analyse before being confident of remaining rational and consistent in satisfying the informational requirements of this approach.

5.3.1.2 The Indirect Lexicographic Ordering Approach

This approach - considered by, for example, Srinivasan and Shocker (1973 & 1974) and Zionts (1976) - is based on the assumption that the decision-maker is able to choose between a limited number of options offered to him and that his choice behaviour is compatible with a weighted overall (usually linear) objective function. The weighted overall objective function can be stated as:

$$F(x) = \Sigma_i \gamma_i^* \psi_i(x) \quad \text{where } \gamma_i^* \geqslant 0; \ \Sigma_i \gamma_i^* = 1 \quad \text{and}$$

$$i=1, \ldots., r$$

The initial preemptive model is thus transformed into a non-preemptive one with the utility function being a weighted sum of the original objective functions. The crux of the issue then, is to derive a set of equivalent weights γ_i^*, for all i, such that the optimal solution set of the resulting non-preemptive model (with the derived utility function) is accepted as the set of optimal solutions for the initial preemptive model.

There are two model sub-groups utilising this approach. Typical of one sub-group is Wallenius and Zionts's (1977) model, while typical of the other is Sherali's (1981) model.

Wallenius and Zionts's model does the transformation (preemptive-nonpreemptive) after having obtained an initial non-dominated solution. The following procedure characterises this sub-group.

(i) Arbitrary weights γ_i^O are assigned to the objective functions $\psi_i(x)$; then the overall function

$\Sigma_i \gamma_i^{\emptyset} \psi_i(x)$; $i=1, \ldots, r$ is optimised, thereby obtaining a set of solutions $\{x^{*\emptyset}\}$ as well as the corresponding set of optimal values $\{\psi_i(x^{*\emptyset})\}$

(ii) The next stage is the efficient-improvement vertex (EIV) search. This is a search done, to investigate desirable improvements in the solution set $\{x^{*\emptyset}\}$, as follows:

Let $x_j^{*\emptyset}$ denote the jth element of the solution set $\{x^{*\emptyset}\}$, the latter having been obtained after optimising the overall objective function $F(x)$;

where,

$$F(x) = \Sigma_i \gamma_i^{\emptyset} \psi_i(x); \qquad \Sigma_i \gamma_i^{\emptyset} = 1; \qquad \gamma_i^{\emptyset} \geqslant \emptyset$$

Suppose an increase is considered desirable (by the decision-maker) and possible (by the analyst) for the kth element $x_k^{*\emptyset}$. If this new element is denoted by $x_k^{*\emptyset'}$ and the corresponding value of the overall objective function (when $x_k^{*\emptyset}$ is substituted by $x_k^{*\emptyset'}$) is denoted by $\gamma^*.f(x_{j\neq k}^{*\emptyset}, x_k^{*\emptyset'})$;
$j=1, \ldots, n$ (number of variables in the problem), then a constraint of the form:

$$\gamma^*[f(x_{j\neq k}^{*\emptyset}, x_k^{*\emptyset'}) - f(x^{*\emptyset})] \geqslant \delta \quad \text{can be obtained}$$

where, δ is some small number representing the minimum desirable change in the overall objective function value due to the change in the kth element of the solution set $\{x^{*\emptyset}\}$

Such a constraint is added to the original problem, and the corresponding element-change is introduced into the set of admissible weights. Consequently, the value of the overall multiplier γ^{*} changes. Thus, for each vertex improvement considered desirable and possible, such a constraint is formed which in turn introduces a new set of weights. If no improvement is possible or considered necessary, the whole process is terminated and the current set of weights with the current efficient solution set and optimal objective function values are accepted as final. Otherwise, after all the improvement vertices have been considered, an arbitrary set of weights $\{\gamma_i'\}$ is chosen among all the ones obtained so far.

(iii) Maximise$_{x \in X}$ $\Sigma_i \gamma_i' \psi_i(x)$

where,

$$\Sigma_i \gamma_i' = 1; \quad \gamma_i' \geqslant 0; \quad i=1, \ldots, r$$

(iv) The process is looped from step (ii), comparing at each stage new optimal values with the previous ones. The whole procedure is terminated when no further EIV search is possible or considered necessary.

It is evident that the main problems here are those of estimating and choosing the admissible set γ_i'.

White's (1980) approach (within the same sub-group) focuses upon eliminating these problems by doing the EIV search in a different way. The following procedure highlights his approach.

(i) An initial set $\{\gamma_i^{\emptyset}\} = \{\frac{1}{r}, \frac{1}{r}, \ldots, \frac{1}{r}\}$ is assumed and on maximising $\Sigma_i \gamma_i^{\emptyset} \psi_i(x)$, a solution set $\{x^{*\emptyset}\}$ is obtained, yielding an optimal overall objective value $V^{\emptyset\emptyset}$.

(ii) Assuming a prior knowledge that

$\gamma_1^* \geqslant \gamma_2^* \geqslant \gamma_3^* \geqslant \ldots \geqslant \gamma_r^* > \emptyset$,

r sets of the form $\{\gamma_i^{\emptyset k}\} = \{\frac{1}{k} \ \forall_{i=k}, \emptyset \ \forall_{i>k}\}$

$i=1, \ldots, r \qquad 1 \leqslant k \leqslant r$ are obtained. Obviously, $\gamma_i^{\emptyset r} = \gamma_i^{\emptyset}$.

(iii) One of these sets, the one which maximises $\sum_i \gamma^{\emptyset i} \psi_i(x)$, is chosen - thus obtaining a solution set $\{x^{*n}\}$ which yields an optimal overall objective value $V^{\emptyset n}$ where n is the number of solution sets obtained after having obtained the solution set $\{x^{*\emptyset}\}$

(iv) If $V^{\emptyset n} = V^{\emptyset, n-1}$, then the final solution set is taken as $\{x^{*,n-1}\}$. Otherwise, the previous solution set is augmented with the current solution set, thus constituting a consolidated solution set $\{x^{*n}, x^{*,n-1}, x^{*,n-2}, \ldots, x^{*\emptyset}\}$ from which the decision-maker is asked to choose a preferred element.

(v) From this preference knowledge, a relationship of the form $\sum_i a_i \gamma_i^* \geqslant \emptyset$ is obtained as follows:

Let $\underline{U}(x)$ be the matrix of objective functions,

$\underline{x}^{*n}$, $\underline{x}^{*,n-1}$ be the nth and (n-1)th solution column vectors, respectively,

Then, if $\underline{x}^{*n}$ is declared preferable to $\underline{x}^{*,n-1}$,

$$(\underline{x}^{*n} - \underline{x}^{*,n-1})\underline{U}(x) \cdot (\gamma_1^* \quad \gamma_2^* \quad \ldots \quad \gamma_r^*) \geqslant \emptyset$$

(vi) Based on the above relationship and also upon the assumption in step (ii), admissible sets of the form $\{\gamma^{ni}\}$ are obtained. One of these sets is chosen to maximise $\Sigma_i \gamma^{ni} \psi_i(x)$, thus obtaining a solution set $\{x^{*n}\}$ with an optimal overall objective value V^{ni}

(vii) The whole process is looped from step (iv) until further development of solution sets is considered unnecessary.

White's usage of 'new preference knowledge' can be considered an improvement over Wallenius and Zionts's approach, especially from the viewpoint of information requirements from the decision-maker. The main problem however, is bound to be two-fold. One aspect is that the decision-maker can easily lose consistency when faced with a 'barage' (considerable amount) of solution sets. He may also get the analyst confused if he decides at a later stage to pick a previously non-preferred solution, especially since his hypothesized operative weights may not necessarily be fixed and stable in his mind. The other aspect is in the underlying assumption that

$$\gamma_1 \geqslant \gamma_2 \geqslant \gamma_3 \geqslant \cdots \geqslant \gamma_r$$

which may not necessarily be valid in real-life situations.

An important point to emphasize here is that this approach is an evidence of the trend to minimise information-demand on the decision-maker even though it is the response to such demand that the analyst still has to use as a guide in choosing the appropriate cluster of non-dominated (Pareto-optimal) solutions, within which to search for the final acceptable compromise plan. This, of course, means that modelling in this manner has to be more sophisticated than the sequential methods discussed earlier. Nevertheless, it is a progressive trend from the viewpoint of model adaptability to the situations encountered by intended end-users.

The other sub-group utilising the indirect lexicographic ordering approach embarks upon the preemptive-nonpreemptive transformation before obtaining any non-dominated solutions. This sub-group focuses on how to develop an effective and appropriate rank structure of the multiple objectives in a non-preemptive framework while preserving the initial preemptive structure of the problem. Thus the emphasis here is on priority ranks rather than trade-off weights. As mentioned earlier, Sherali's (1981) approach is typical of this sub-group.

His approach is based upon determining a set of upper bounds on the range of values taken by the different objective functions.

Such upper bounds can be derived as:

$$UB_i(V) > \text{Maximum}_{x \in X_e} \psi_i(x) - \text{Minimum}_{x \in X_e} \psi_i(x)$$

where, $UB_i(V)$ denotes the upper bound on the range of optimal objective function values for $\psi_i(x)$, i=1, ..., r

and $X_e = \{x \mid x \text{ is an extreme point of } X\}$.

If $C = \{C_j\}$ is the set of coefficients in an objective function, another form of the above inequality can be:

$$UB(V) = \Sigma_{j \in P(C)} U_j C_j - \Sigma_{j \in N(C)} U_j C_j \equiv \Sigma_j U_j |C_j|$$

where, j=1, ..., n (number of decision variables),

$\emptyset \leqslant x \leqslant U$ for some finite $U = (U_1, U_2, \ldots, U_n)$,

and P(C), N(C) denote the sets of positive and negative coefficients, respectively, of the decision variables in the objective function being considered

Another alternative - as demonstrated by Sherali (1981) in an assignment problem - is that for every goal constraint constituting the ith-rank objective function $\psi_i(x)$, the difference between the maximum and minimum coefficients of the decision variables is calculated, and the sum of these differences then represents the required upper bound $UB_i(V)$.

Finally, using the obtained upper bounds, the required non-preemptive overall objective function is represented as:

$$F(x) = (1 + \Pi_2^r.UB_2).\ \psi_1(x) + (1 + \Pi_3^r.UB_3).\ \psi_2(x) + \ldots.$$

$$\ldots. + (1 + UB_r).\ \psi_{r-1}(x) + \psi_r(x)$$

That is,

$$F(x) = [1 + \Pi_{k=i+1}^r.UB_k].\ \psi_i(x)$$

where, r is the least-priority rank of the objective functions.

It must be said that the similarity of this approach to Masud and Hwang's method is merely in the use of the range of optimal objective function values as the basis for model formulation. In Masud and Hwang's method, it is used to guide the trial and error choice of constraints' targets. In Sherali's approach however, the aim is to develop the rank-equivalent weights in the overall objective function.

The general implications of Sherali's approach can be easily realised. A striking and useful one, for example, is that it elevates the unit potential 'gain' of every higher-order objective by whichever value of the immediate lower-order objective is considered acceptable. Thus, while ensuring the simultaneous consideration of all the objective functions, this approach offers the opportunity to effectuate some leverage or flexibility in the exercising of the desired priority orderings.

The major drawback here is that the method can fall flat in situations where the objective functions cannot be expressed in commensurable units. Such situations can be tackled however, by an adept use of goal-programming at the initial stage of problem formulation. Another drawback, according to Sherali, is the possibility of overflow in the weights - which is highly probable if r is large. Nonetheless, the advantages of this conversion (preemptive-nonpreemptive) technique should outweigh any suspected drawbacks. In fact, apart from the preservation of the initial preemptive structure, another of the most attractive aspects of the technique is the way it makes 'rank-equivalence' a requisite characteristic to reflect in the weights. Thus, it makes more distinct the separate issues of preference rankings and trade-off weightings which have until now been confounded in most multiple objective decision-making models, based on the use of a weighted sum of the objectives.

5.3.2 The Non-preemptive Group

The non-preemptive group of MOLP models is based on the use of a multiple criterion utility function to be maximised which, in some way, incorporates all the decision criteria (the fulfilment of which are desired by the decision-maker). In goal programming, these criteria are expressed in the form of ranked priorities. Indeed the analysis of the resulting overall objective function represents the phase during which the second part of the problem of MODM modelling - that is, satisficing - is concentrated upon.

The main modelling approaches in this group can be categorised into (a) the explicit utility approach and (b) the implicit utility approach.

5.3.2.1 The Explicit Utility Approach

This approach involves the usage of explicit utility functions, formulated for the application of techniques such as maximin/maximax programming, fuzzy linear programming, and so on.

Maximin programming involves maximising the minimum criterion value of the function. This implies the expectation of the worst possible situation. The maximax decision rule, on the other hand, maximises the maximum criterion value thus implying the expectation of the best possible world. This indicates that both decision rules are based on extreme utility functions. The former assumes that the decision-maker is very risk-averse, and has essentially no utility for any return above the minimum, while the latter presumes that he is insensitive to levels of achievement below the maximum. Further, the maximin or maximax approaches, even when combined as proposed by Hurwicz (1957), discard all information about outcomes with intermediate values, and these may be the most useful ones. Finally, these approaches have been shown - de Neufville and Stafford (1971) - to ignore all subjective estimates of the probabilities of the outcomes.

Fuzzy linear programming involves defining the intersection of all introduced fuzzy sets and any 'hard' constraints of the problem on hand. However, since it essentially seeks the solution having the highest degree of membership of the decision set, it is based on a set of assumptions which are equivalent to those of maximin programming, and hence there are still many unresolved controversial aspects in this approach.

In general, models with explicit utility functions tend to be simple, easily controllable and adaptive. However, the controversial aspects are in the underlying assumptions - for example, that the decision-maker is equally concerned with all the criteria. Owing to such assumptions, this approach has not been of much practical use in multiple criteria decision-making.

5.3.2.2 <u>The Implicit Utility Approach</u>

This approach is more or less the same as the explicit utility approach except for the fact that it recognises not only that the violation of certain constraints is probable, but also that the effectiveness of the overall objective function may be very much dependent on the degree of any such violation.

The approach was pioneered by Charnes and Cooper (1959, 1961 and 1963), and has been termed 'chance-constrained' goal programming. It has been widely applied especially in situations such as that of capital budgeting where product demand uncertainty can prove quite a nuisance (Keown and Taylor III, 1980). As the name suggests, the approach is based on goal programming but with some of the constraints written in the form:

$$\text{Prob} \left(\Sigma_j \, a_{ij} \, x_j \leqslant b_i \right) \geqslant p_i \qquad 0 \leqslant p_i \leqslant 1$$

where, p_i is the probability of satisfying the ith constraint;

a_{ij} - the coefficient of the jth decision variable in the ith constraint; and

b_i - the associated 'bound' on the constraint.

Such constraints then need to be converted into their deterministic equivalents before continuing with the usual procedure for solving goal programming problems. This conversion is really the aspect which limits the practical application of this approach, since it necessitates obtaining information regarding the expected values and variances for each of the specified chance-constraints. Moreover, in many situations, the a_{ij} elements are stochastic thereby yielding a non-linear form of constraints in the deterministic equivalent, and this can be very troublesome to deal with in goal programming.

5.4 Connective Summary

All the MCDM modelling approaches discussed above have been classified into groups, each of which has some distinctive characteristics, highlighted during the discussion of the various models. However, all the groups do possess certain common characteristics, which reflect perhaps how most analysts would prefer MCDM problems to be tackled rather than how such problems should, in general, be realistically perceived. These common characteristics centre around the fact that, while it is of general accord for the decision- maker to hold the 'trump-card'on the issue of preference weighting, considerable discrepancy can be observed in how the modellers expect that 'trump-card' to be used and also in how the modellers approach the issue of trade-off weighting on specified objectives.

Preemptive models (sometimes termed 'lexicographic models') are built on the premise that decision-makers are capable of complete comprehension of all possible combinations of uncertainties which could affect the situation on hand and therefore are confident about their expressed preferences among the specified objectives. Non-preemptive models (sometimes termed 'Pareto-optimal models'), on the other hand, are built on the premise that the decision-maker's overall utility, if appropriately derived, should reflect the inherent preference and trade-off weights. The relevance of priority specification and evaluation of trade-offs is therefore played down in such models.

The practical implication then is that Lexicographic-optimal models could totally ignore any lower ranked objective which is incommensurate with higher ranked objectives, while Pareto-optimal models could accept an overall utility function which may not necessarily be a weighted consolidation of the specified objectives. In other words, applications of either of the models would perhaps be reasonable only in situations, where the objectives are in commensurable units and also are all non-satiable (that is, more of each is preferred to less or less of each is preferred to more).

The fact is that depicting any problem as an MCDM one is based on the realisation that the organisation itself is a self-adjusting, goal-seeking system for which the inherent interconnectedness of things will necessarily also affect the ability of plans and controls to work as intended. This necessitates that the vital issues - of uncovering the inevitable in order to exploit it and of conscious, deliberate direction of affairs - be decided upon in terms of some larger system for which the organisation is merely a part. This realisation is in harmony with the contention which underlies the Pareto-optimum concept in that the use of an overall utility function is in recognition of the need for consistency of value-judgement relative to that larger system. However, this is not enough, since insufficient emphasis is placed on the evaluation of preference and trade-off weights when this concept is applied. The lexicographic-optimal concept, on the other hand, tends to ignore this important feature of any MCDM problem (since the almost total devotion given to preference weights when using this concept imposes more of the individual characteristics of high_priority objectives than of those features which would ensure stronger consistency with the larger system behaviour and performance). The trade-off weights are normally introduced as cut-off points beyond which any value of a higher-priority objective is acceptable even though that point might not be the best value obtainable. The fact about lexicographic models is that lower-priority objectives are not considered at all unless the higher-priority ones have been fulfilled. Thus, with such models, there is no logic supporting the contention that what is sought is a compromise plan since after all, a compromise plan is one which is supposed to ensure a satisfactory balance between the fulfillment of the various objectives - in which case, there should be some rationale in seeking an optimal set of the trade-off weights involved.

In summarising the above discussion about the broad classification of MCDM models, one can say that there is a need for a new approach which improves not only the manner of obtaining preference weights, but also the evaluation of trade-offs among specified objectives.

If analysts accept that decision_makers, as all human beings, have to operate within the confines of 'bounded rationality' as emphasised by Simon (1957), then the evaluation of preferences and trade-offs has to be of primary concern if the decision-maker is to understand fully all the salient features of the MCDM problem on hand. Furthermore, the elicitation of preferences needs to be done not directly on those objectives that are a consequence of the problem on hand, but indirectly through those basic viability factors which serve as the `reference for normality' - that is, those factors which are generally used by the management to perceive the organisation's problems and to specify accordingly the objectives considered necessary.

The usage of basic viability factors in tackling any MCDM problem would considerably help the decision maker and the analyst not only to understand the nature of priorities before seeking any compromise solution, but also to guard appropriately against any mis-specification of objectives.

CHAPTER SIX

MCDM MODELLING IN THE CONTEXT OF VIABILITY PLANNING

6.1 Introduction

The practical focus being proposed in this study is based on the concept of Viability Planning (VP), which is essentially planning for structural stability through the maintenance and improvement of synergy in the continuing process of organisational adaptation.

It must be pointed out that structure stability does not necessarily mean just the maintenance of the organisation's given structure within pre-established limits. In as much as any given structure involves feedback loops with the organisation's environment, interactions among the organisation's components may result in significant changes in the nature of the components themselves with important consequences for the organisation as a whole. Thus, structural stabilisation encompasses homeostatic, mediative and proactive processes which necessitate a change or elaboration of the organisation's structure as a condition of survival or viability. It is these self-regulation and self-direction aspects of structure stabilisation which require (as a necessary condition for ensuring their efficiency and effectiveness) the identification of, and concentration on, the factors for synergy maintenance and improvement.

Synergy is a term frequently used to describe the joint effect of different system components resulting in greater utility for the whole system than the sum of the different effects from each separate component. In other words, if a system's value is appreciated through the various types of gains or economies achievable by it, then synergy attainment implies that the value, say V_{AB}, attributable to the combination of the system components A and B exceeds the sum of values ($V_A + V_B$) of the isolated individual components. That is, $V_{AB} > V_A + V_B$
In the context of viability planning, synergy is concerned with the desired characteristics of fit between a system and every feasible field of activity open to that system. Since every field of activity necessitates a particular combination of collectively exhaustive system variables, synergy has to address itself not only to the extent to which any such combination of system variables offers the possibility of desirable achievement in the system's critical areas of performance, but also to how well the capabilities of the system as a whole match the requirements for success in that field.

In conformity with the concept of viability planning therefore, it is necessary to view multiple criteria decision-making as a two-stage process which essentially recognises, and is hence centred around, the multi-dimensional aspect of structure stabilisation in the manner discussed above.

The two stages of this process are:

- enhancement of decision-making strategies by minimising any mismatch between the decision-maker's perceptions and reality; evidently, this should help to minimise any mismatch between the decision-maker's aspirations and operational feasibility;
- enhancement of value judgements in decision-making by minimising any inconsistency in the development and ranking of priorities intended for analysis.

It is clear that the current 'state of the art' of MCDM modelling is more or less concentrated on the second stage mentioned above. An exception worth mentioning is that chance-constrained goal programming does involve some matching of the decision-maker's risk-taking or risk-aversion with operational feasibility. However, this has been focused on how well the chance-constraints maintain their individual characteristics without jeopardising the effectiveness of the overall objective function.

Viability Planning, on the other hand, essentially focuses upon how best to derive an overall objective function which recognises that the component elements of the constraint set may be random variables but at the same time maximises the efficiency of any selected effectiveness scale in order to aid satisficing.
Figure 6.1 is an illustration of how the methodology proposed in this research relates to the current 'state of the art' of modelling for multiple criteria decision-making.

Notes on Fig. 6.1

1. Problem state can be obtained from the following table: in which "1" denotes "known" and "0" denotes "unknown":

	States			
	A	B	C	D
Ranks	0	0	1	1
Utilities	0	1	0	1

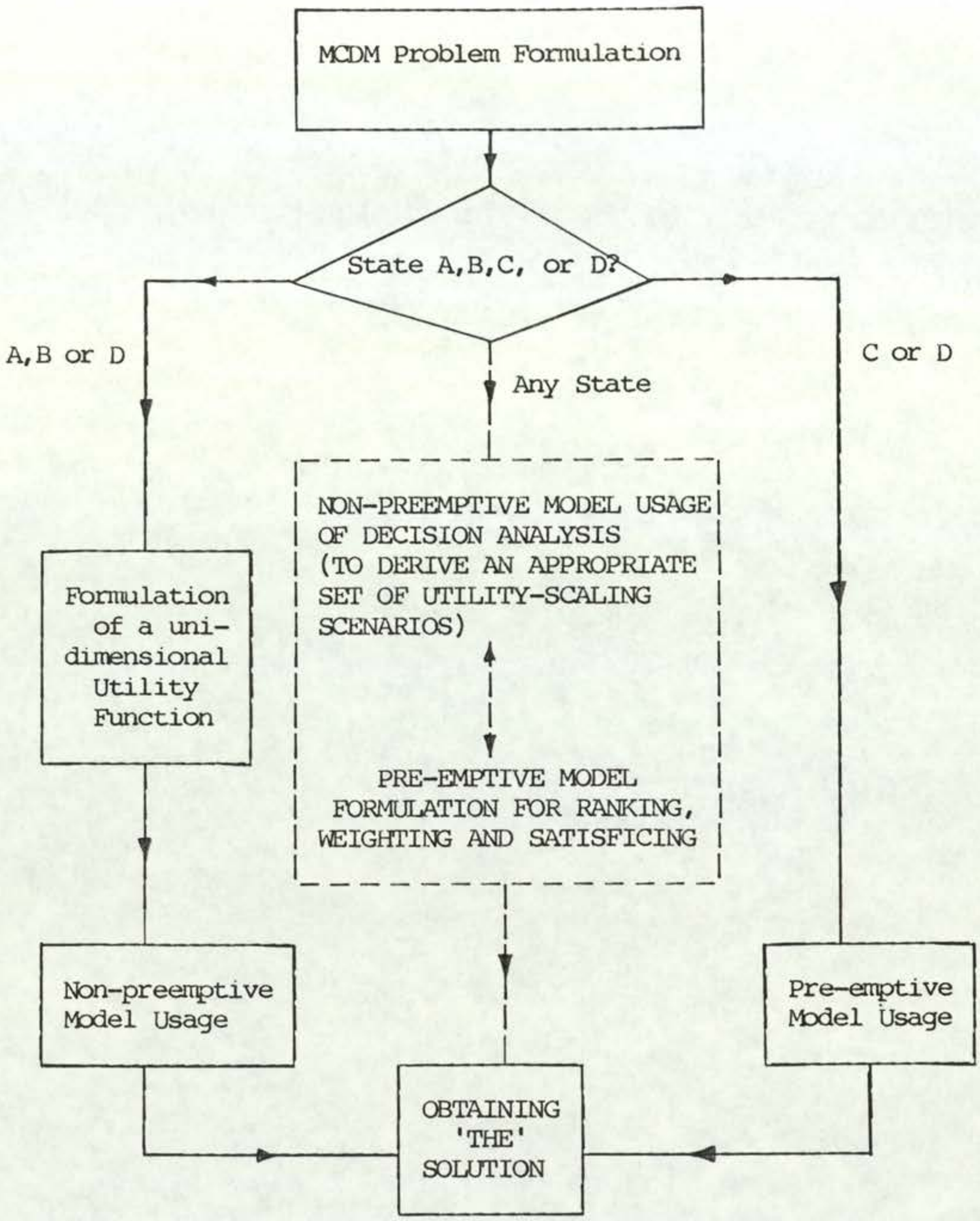
2. State B is infeasible since a knowledge of weightings implies a knowledge of ranks. That is, State B implies inconsistency - a violation of the transitivity axiom which is one of the axioms of cardinal utility.

3. Preemptive models make use only of State C while non-preemptive models only State A.

4. ______ Present 'state of the art' of MCDM modelling;

_ _ _ Proposed 'state of the art' of MCDM modelling.

Figure 6.1: THE VIABILITY PLANNING APPROACH IN RELATION TO CURRENT MODELLING PRACTICE FOR MULTIPLE CRITERIA DECISION-MAKING



State A: Both Ranks and Utilities are Unknown.
B: Ranks Unknown, Utilities Known (infeasible since a knowledge of weightings implies a knowledge of ranks).
C: Ranks Known, Utilities Unknown.
D: Both Ranks and Utilities are Known.
——— Present 'state of the art' of MCDM modelling.
-------- Proposed 'state of the art' of MCDM modelling.

Note: Preemptive models make use only of State C while non-preemptive models only State A.

6.2 The Relevance of a Decision Analysis Approach

Viability planning proposes an elevation of the level of problem formulation in MCDM modelling to the consideration of scenario probabilities, whereby the focus is on possible combinations of the states of certain constraints which define the factors for synergy maintenance and improvement while resolving the problem on hand.

The contention here is that no organisational problem can be realistically detached from the survivability objective, the non-fulfillment of which could easily lead the organisation to more complicated problems and eventually, total collapse. Evaluating the state of fulfilment of such an objective is paramount in the concept of viability planning, and the constraints which help to structure that objective are the mathematical representations of those factors for sustaining a high level of synergy.

If the states of fulfillment of every selected synergy-defining constraint are designated as binary events, signifying target-satisfaction or the contrary, then a synergy-evaluating scenario is one of all the possible combinations of such binary events for all the selected synergy-defining constraints.

An important characteristic of such constraints is that they usually form the basis for policy decisions and as such, decision-makers do not normally find it difficult to relate to the underlying factors the effect of uncertainties in the particular decision-making environment. Thus, any marginal and pair-wise conditional probability judgement given by the decision-maker can be used as a reference element which any proposed model ought to use in evaluating the meaningfulness of feasible probability assessments.

Decision Analysis is an area of modelling in which various techniques have been developed to tackle such issues. A recent outstanding contribution is the development, by Moskowitz and Kluyver (1981), of a goal programming approach to decision analysis. Their approach is focused on the assessment of scenario probabilities on the basis of marginal and pair-wise (first-order) conditional probability judgements of the factors or events constituting the scenarios. They emphasize that in their model,

" .... Meaningfulness of probability assessments is analysed in terms of their imputed informational content. Assessments which are not meaningful are defined as judgements that either imply that two events are statistically independent or uninformative or for which the imputed informativeness is contrary to the data when such is not intended by the assessor. .... "

The main aspects of their approach are described below:

(i) For n binary events, $N = 2^n$ mutually exclusive and collectively exhaustive scenarios can be identified and the entire system of scenario probabilities can be described in terms of 2^n linear equations. The latter can be replaced by a corresponding set of equations and inequalities which define the feasibility of the scenario probability estimates in terms of consistency conditions on all possible joint-probabilities. The resulting set of equations contains a considerable amount of redundancy which can be reduced to a relatively small set of conditions involving only those equations corresponding to the marginal event probabilities, the sum constraint on the scenario probabilities, and the consistency conditions for highest-order joint-probabilities.

Thus, the first step of this approach is to develop the reduced system of equations and inequalities which comprise:

- n equations corresponding to marginal event probabilities,
- a sum constraint on the scenario probabilities,
- lower-bound consistency conditions on all highest-order joint-probability terms, and
- non-negativity conditions on all scenario probabilities.

(ii) An objective function is then specified which reflects the decision-maker's state of knowledge regarding the interdependence among the likelihood of occurrence of the various events, and also regarding the link between first-order probability assessments and elicited second-order probability assessments. Since the objective function comprises deviational variables with their attached weights reflecting the intended pre-emptive structure, the aim is to evaluate whether or not the goals specified at all priority levels can be satisfied in the optimisation program. If an acceptable feasible solution exists, then consistency is assured.

(iii) Finally, by interactively revising assessments of pair-wise conditional probability relationships, convergence towards a set of scenario probability estimates (which are consistent with the decision-maker's marginal and first-order conditional probability assessments of the events constituting the scenarios) is achieved.

The above steps suggest a different dimension of interaction - that involving likelihoods rather than preferences or ranks. Further, this method does not have the burdensome management involvement of the usual interactive sequential method since the issues being analysed here not only are relatively few, but also are issues of policy formulation which can be structured in a manner compatible with day-to-day management 'language'.

Consequently, the thrust of this model would be very useful in tackling the problem of matching management perception and aspirations with reality. Management nowadays have developed considerable expertise in recognising the relevant factors which enhance adaptation in organisations, and which levels of these factors to aim for as progressive policy decisions. If such factors were used as the basis for certain binary events upon which scenario probability assessments could be exercised, the results of the model usage in this way could be made the reference in investigating the degree of leverage during satisficing among priorities since management would be certain of consistency in their policy decisions and subsequently feel considerably less burdened by the degree of uncertainties involved.

An important fact to note at this point is that utility functions are specific to individuals. Furthermore, this personal attribute of decision-making 'power' underlies every decision-maker's vulnerability to irrational and/or non-objective behaviour. Consequently, even though it is of general accord (in organisations today) that the multifarious aspects of any decision-making process have to be strongly affected by the analytical or institutional mechanism used to generate alternative courses of action, nevertheless, the greater the complexity of issues, the less the chance for purely rational weightings between different outcomes of available courses of action. Indeed, the ultimate selection is judgemental.

Thus, if a decision-maker, in utilising a model, is convinced of a considerable reduction in the levels of uncertainty involved, he will be quite likely to accept objective ranking (by the model) of his specified priorities, especially when he is satisfied with the consistency as regards already accepted policy decision rules.

6.3 The proposed Viability Planning Approach

The main aspects of this approach are the derivation of rank-equivalent or preference weights and the derivation of trade-off weights both of which are needed to make up the required overall objective function. These aspects will now be evaluated in turn.

6.3.1 Derivation of Rank-equivalent or Preference Weights

(1) From the set of specified goal constraints, a subset is chosen which constitutes the multi-plane structure of the MCDM problem. This is done through interaction with the decision-maker about the factors relevant to maintain synergy in adaptation for the particular organisation concerned.

(2) Having selected n relevant events, 2^n scenarios constitute a set of collectively exhaustive and mutually exclusive options for each of which the probability of occurrence needs to be determined. If the vector of scenario probabilities is represented by

$$y = (y_1, y_2, \ldots, y_N); \quad N = 2^n; \quad \Sigma_1^N y_i = 1 \qquad \text{(I)}$$

then a system of 2^n linear equations can be obtained of the form:

$$y'.C_i = p_i \quad i=1, \ldots, n \qquad \text{(II)}$$

$$y'(C_i \wedge C_j) = p_{ij} \quad j=i+1, \ldots, n \qquad \text{(III)}$$

$$\vdots \qquad \vdots$$

$$y'(C_1 \wedge \ldots \wedge C_n) = p_{1,\ldots,n} \qquad \text{(IV)}$$

$\emptyset \leqslant p_i \leqslant 1$ and $\emptyset \leqslant p_{ij} \leqslant 1$

where,

C_i denotes the components of the ith column vector of Øs and 1s for non-occurrences and occurrences, respectively, of event i in the scenarios;

$\wedge$ denotes component by component multiplication of the n column-vectors involved;

y' denotes the transpose of vector y;

$p_i, p_{ij}, \ldots\ldots, p_{1,..,n}$ respectively denote

marginal probability, pair-wise, triple, ..., nth order joint-probabilities of occurrence for the n events.

The scenario-probabilities' feasibility conditions thus comprise

- n marginal probability equations of type II,
- a sum constraint of type I, and
- $\Sigma_{k \leqslant (1/2)n} \binom{n}{k}$ bounds of type IV on the highest-order joint-probability.

It has been shown (Moskowitz and Kluyver, 1981) that equations of the type III (which define the first-order conditional probabilities) and type IV can be converted into inequalities which build into the system necessary and sufficient conditions for any pairwise, triple, ..., nth order joint-probabilities to be consistent.

Thus, for a joint-probability $p_{1,..,n}$,

$$p_{1,..,n} \leqslant \mathrm{Min}(p_1;\ p_2;\ p_3;\ \ldots;\ p_n)$$

$$p_{1,..,n} \geqslant \mathrm{Max}[(p_1 + p_{2,..,n} - 1);\ (p_2 + p_{1,3,..,n} - 1);\ \ldots\ ]$$

i.e. the maximum of all sums of the probabilities corresponding to all possible composite 2-event splits minus 1

$$\emptyset \leqslant p_{1,..,n} \leqslant 1 \qquad \text{(V)}$$

For example:

$$p_{12345} \leqslant \mathrm{Min}[p_{1234}; p_{1235}; p_{1245}; p_{1345}; p_{2345}] \qquad \text{(VI)}$$

$$\begin{aligned} p_{12345} \geqslant \mathrm{Max}[&(p_1 + p_{2345} - 1); (p_2 + p_{3451} - 1); \\ &(p_3 + p_{4512} - 1); (p_4 + p_{5123} - 1); \\ &(p_5 + p_{1234} - 1); (p_{12} + p_{345} - 1); \\ &(p_{13} + p_{452} - 1); (p_{14} + p_{523} - 1); \\ &(p_{15} + p_{234} - 1); (p_{23} + p_{451} - 1); \\ &(p_{24} + p_{513} - 1); (p_{25} + p_{134} - 1); \\ &(p_{34} + p_{512} - 1); (p_{35} + p_{124} - 1); \\ &(p_{45} + p_{123} - 1)] \end{aligned} \qquad \text{(VII)}$$

Furthermore, Moskowitz and Kluyver (1981) have shown that equations of types V & VI are redundant while equations of type VII can be expressed in the form:

$$\Omega_{1,..,n} < 1 \qquad \text{(VIII)}$$

where, Ω is the union of the scenarios spanned by the joint probabilities defining the 2-event split for the consistency condition of type VII.

Using Moskowitz & Kluyver's approach, the decision-maker is asked to give specific estimates of pairwise conditional probabilities according to a priority structure which reflects the degree of confidence in the accuracy of the given estimates. This suggests the necessity of a pre-emptive goal programming method of solution. The accuracy of the estimates then has to be evaluated on the basis of non-violation of all the goals (specified for the first-order conditional probability estimates) at <u>all</u> priority levels.

It needs pointing out here that both the usage of pre-emptive GP and the method of accuracy evaluation in this approach lay emphasis on the appropriateness of the ranking of priorities. For the purposes of this research however, what is preferable at this stage is that emphasis be put on precisely how realistic the resulting scenario probabilities are from the decision-maker's viewpoint. Otherwise there would be no way of knowing whether the scenario probabilities obtained from the model would be due to the ranking or to the earlier-specified marginal and conditional probability inputs.

Using a non-preemptive GP obviates this problem since the accuracy of specified inputs can be evaluated on the basis of whether or not the obtained scenarios are perceived to be operationally feasible by the decision-maker and whether or not the corresponding scenario probability estimates are viewed to be realistic. With this consideration, a non-preemptive GP is proposed by the researcher for this stage of the methodology.

Continuing with the earlier example of a 5-event situation, Table 6.1 shows part of the system of equations which is used to express marginal probability equations of type II.
Such a table can be used to build up the parts of column vectors C_i which collectively define the necessary equations, the sum constraints, and the other feasibility conditions.
For example,

p_{123} pertains to the occurrence of events 1, 2 & 3 (irrespective of events 4 & 5), thereby indicating the set of scenarios $\{y_1, y_2, y_3, y_4\}$ while,

p_{45} pertains to the occurrence of events 4 & 5 (irrespective of events 1, 2 & 3), thereby indicating the set of scenarios

$\{y_5, y_9, y_{13}, y_{17}, y_{21}, y_{25}, y_{29}\}$

That is, in this case,

$$\Omega = \{y_1, y_2, y_3, y_4, y_5, y_9, y_{13}, y_{17}, y_{21}, y_{25}, y_{29}\}$$

In order to determine the size of the required problem-solving tableau for this stage, it is necessary to know the total number, M, of required equations including those of type VIII.

TABLE 6.1: TABLEAU FOR EXPRESSING MARGINAL PROBABILITY EQUATIONS

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
P1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
P3	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
P4	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
P5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
P1/2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P1/3	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P1/4	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P1/5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2/3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P2/4	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
P2/5	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
P3/4	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
P3/5	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
P4/5	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
P1/2345	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2/3451	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
P3/4512	1	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
P4/5123	1	1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
P5/1234	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
P12/345	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
P13/452	1	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P14/523	1	1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
P15/234	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P23/451	1	1	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P24/513	1	1	1	0	1	1	0	0	1	0	1	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
P25/134	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
P34/512	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
P35/124	1	1	1	0	1	1	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
P45/123	1	1	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0

Note: Columns represent the 32 Scenario Probabilities, while Rows represent the various Event Probabilities & Feasibility Conditions for Scenario Probabilities

For $n = 2$, $\quad M = M_{\emptyset} + 1 + [\frac{1}{2}\binom{n}{n/2}] = M_{\emptyset} + 2$

For $n > 2$ & odd, $\quad M = M_{\emptyset} + 1 + [\,\Sigma_{k=1}^{n/2-1/2}\binom{n}{k}]$

For $n > 2$ & even, $\quad M = M_{\emptyset} + 1 + [\frac{1}{2}.\binom{n}{n/2} +$

$$+ \quad \Sigma_{k=1}^{n/2\,-\,1}\binom{n}{k}]$$

where, $M_{\emptyset} = n + \binom{n}{2}$

$n > 1$ is the number of events

k is the order of joint probabilities defining a particular 2-event split, and

$$\binom{n}{k} = \frac{n!}{(n-k)!k!}$$

$M_{\emptyset}$ represents the number of specific probability estimates to be elicited from the decision-maker. Using the above formulae, values of M and n can be tabulated as presented in Table 6.2. From the table, it can be seen that the realistic upper bound (even though arbitrary) of n is equal to 5, which corresponds to a value of 15 for $M_{\emptyset}$. Any value above this could make coping with the input requirements practically very taxing indeed, especially since the sheer number of estimates to be elicited from the decision-maker would not only discourage him but would also make the interactive process for reviewing the estimates considerably lengthy and burdensome.

Table 6.2 Input Requirements from the decision-maker

n	$\binom{n}{2}$	$\frac{1}{2}\binom{n}{n/2}$	k_{max}		$\binom{n}{k=1,\ldots,k_{max}}$				$M_{\emptyset}$	M
			$(n-1)/2$	$(n/2)-1$	$k=1$	2	3	4		
2	1	1	–	–	2	–	–	–	3	5
3	3	–	1	–	3	–	–	–	6	10
4	6	3	–	1	4	–	–	–	10	18
5	10	–	2	–	5	10	–	–	15	31
6	15	10	–	2	6	15	–	–	21	53
7	21	–	3	–	7	21	35	–	28	92
8	28	70	–	3	8	28	56	–	36	199
9	36	–	4	–	9	36	84	126	45	301
10	45	126	–	4	10	45	120	210	55	567

Augmenting the system of M necessary and sufficient equations with deviational variables d_m^-, d_m^+ which respectively denote under and over-achievement of the estimate p_i or $p_{i|j}$ given for the mth condition, the proposed objective function should then be of the form:

$$\text{Minimise} \quad \Sigma_{m=1}^{M} (d_m^- + d_m^+)$$

The resulting set of scenarios, understandably, has to be analysed interactively with the decision-maker from the viewpoint of

(a) the operational feasibility of the particular event-combination constituting each scenario; and

(b) how acceptable the obtained scenario probability estimates are.

The major hurdle is centred around operational feasibility. If the decision-maker does not perceive a scenario to be operationally feasible, then the events constituting that scenario have to be reviewed as regards the earlier-specified marginal probability estimates in which they are involved. This is where sensitivity analysis can be done with the decision-maker's attention focused on the most pertinent issues - especially those pertaining to the judgemental bounds attached to the pairwise conditional probability estimates. This is the main advantage of using a non-preemptive GP for scenario probability assessments. The model may then be rerun and the interactive process continued until operational feasibility is perceived to be achieved.

The appropriateness of the obtained scenario probability estimates is mainly dependent on the optimism or pessimism reflected in the decision-maker's earlier-specified marginal probability estimates. Hence, the deviational variables corresponding to these estimates should provide valuable insight into the degree of leverage for further optimism or pessimism.

It must be emphasized however that, although the obtained set of scenarios represent feasible hyper-planes (in a solution space representation) to be used later for analysing the original problem, it may happen that none of them appears in conformity with the solutions obtained during subsequent analysis of the specified priorities. This would indicate that either the decision-maker's perception of operationally feasible scenarios is merely aspirations rather than realistically achievable with the present resources, or the factors chosen to be relevant are not the appropriate ones for sustaining synergy in the resolution of the particular problem on hand.

(3) When the result of the non-preemptive GP is considered acceptable, the procedure for ranking and weighting of the priorities is as follows:

(i) Maximise $\psi_i(x) \mid [f_m(x) + d_m^- - d_m^+ = V_m;$

$$d_m^-, d_m^+ \geqslant \emptyset] \ \forall_m \forall_i$$

where,

$\{\psi_i(x)\}$ is the set of specified objectives,

$\{f_m(x)\}$ is the set of M required constraints,

d_m^-, d_m^+ are the deviational variables denoting, respectively, the under and over-achievement as regards value V_m of $f_m(x)$

Further, there is a particular set

$$\{f_n(x)\} \subseteq \{f_m(x)\} \qquad 3 \leqslant n \leqslant M$$

such that the subset $\{d_n^-, d_n^+\}$ corresponds to those events for which scenario probability assessment was done in the previous stage - that is, step (2) - of the analysis.

(ii) For each element of the set $\{\psi_i(x)\}$ maximised, an optimal constraint value subset $\{f_n(x^{*i})\}$ is obtained, as well as a subset of the corresponding optimal deviational variables' values $\{d_n^-, d_n^+\}$. On the basis that occurrence of a selected event are indicated through achievement of a specified satisfactory level of whichever of deviational variables (that is, d_n^- or d_n^+) is desired when optimality is attained, the states of the (say, n_s) selected events are matched with any of the optimal synergy-defining scenarios earlier obtained.

Let the corresponding scenario probability = y_{ik} where, k denotes the scenario number. Then, the expected utility value, $EUV_i = y_{ik}.UV_i$

where, utility value $UV_i = 1 - \sum_n \frac{d_n^{-/+}}{V_n}; \quad n \leqslant n_s.$

Further, the set of optimal values $\{ \psi_i(x^{*k})\}$, which denote the values of $\psi_i(x)$ when objective function $\psi_k(x)$ is optimised, can be used to obtain the set of admissible bounds $\{UB(\psi_i(x))\}$, for the linear objective functions $\psi_i(x)$, i = 1, ..,r.

That is,

$$UB(\psi_i(x)) = Max[\psi_i(x^{*1}); \; ....; \; \psi_i(x^{*r})] - Min[\psi_i(x^{*1}); \; ....; \; \psi_i(x^{*r})].$$

(iii) The set $\{EUV_i\}$ is used to rank the specified r objective functions - that is, in order of decreasing EUV.

(iv) Following Sherali's (1981) approach, the preference or rank-equivalent weights, ω_i, for the objective functions, $\psi_i(x)$, are obtained as:

$$\omega_i = 1 + UB(\psi_{i+1}(x)) \ \forall_{i=r}; \quad \omega_r = 1$$

where r is the least-priority rank.

6.3.2 Derivation of Trade-off Weights

The contention here is that from the information content of the original problem, a set of trade-off weights can be derived, which is independent of the priority orderings and maximises the achievable compromise between the specified objectives. Two different methodologies are proposed in this study. The first is focused on the relationship between deviational variables in satisfying the specified goal constraints, while the second is focused on trade-off values between the different non-dominated solutions obtained from the various objectives.

(1) For each element of the set $\{\psi_i(x)\}$ optimised, a subset of optimal distance function values $\{d_m^{i-}, d_m^{i+}\}$ is obtained where, m=1, ..., M (the total number of required constraints).

Let the variable $d_m^i = d_m^{i+} + d_m^{i-}$ represent the absolute distance from the targeted goal in constraint m while optimising the objective function $\psi_i(x)$. Before this variable can reasonably be used, it is necessary to convert its values into an equivalent form, usable on a uniform scale with all other such deviational variables of the constraints in the problem. In order to do this, one of the constraints (say, q) is chosen (on the basis that the constraint is defined by all or most of the decision variables under consideration) and its deviational variable, d_q, is used as the basis for the uniform scale. All other such variables are then equivalently expressed in terms of d_q, irrespective of which objective function is being optimised by the following process.

Let

$d_{c \to q}$ denote d_c equivalently expressed in terms of d_q, and

$C_c = \{C_{c1}, \ldots, C_{cn}\}$ denote the set of coefficients of the n decision variables for constraint c.

Then, for the non-zero coefficients, a set of ratios

$$C_{\Pi} = \{\frac{C_{qk}}{C_{ck}} \mid C_{qk}, C_{ck} \in C_q \otimes C_c\}; \quad 1 \leq k \leq n$$

can be obtained from which a conversion factor can be derived as the average of all the non-zero non-infinite ratios. Thus,

$\Pi_{c \to q} = \frac{1}{|C_{\Pi}|} \Sigma_j C_{\Pi j}$ where $C_{\Pi j}$ is the jth element of set C_{Π}; $j=1, \ldots, |C_{\Pi}|$, the latter denoting the order of set C_{Π} which may not necessarily be n

Using this conversion factor, $d_{c \to q} = d_c \cdot \Pi_{c \to q}$

The weakness here is when $\{C_q \cap C_a\} = \emptyset$ (that is, the empty set), while $\{C_b \cap C_a\}$ and $\{C_b \cap C_q\}$ are not.

For such a situation, an approximate solution may be:

$$\Pi_{a \to q} = \text{Mean } [(\Pi_{a \to m} + \Pi_{q \to m}) \mid m \neq q]_{m=1,..,b,..M}$$

where M is the number of constraints with deviational variables.

Having converted all deviational variables into their equivalent forms in terms of d_q, the main assumption to be made is that the trade-off value of any of the different objective functions is dependent, to a large extent, upon the the sum of all the deviations (uniformly scaled) obtained in the optimisation of that function. This is expressed as the relative measure of non-achievement of desired goals, since afterall trade-off values of any objective function should indicate the extent to which non-achievement of desired goals (during its optimisation) would be acceptable as a price to be paid in improving the optimal value of another and/or of all the other objective functions. Thus, the trade-off weight is taken in this study as the complement of the 'Average Loss Of Goal-Achievement (ALGA)'.

For the objective function, $\psi_i(x)$, let,

$$\hat{d}_i = \frac{1}{M} \cdot \Sigma_m d^i_{m+q}; \quad m=1, \ldots., M$$

The trade-off weights, γ_i, for the objective functions, $\psi_i(x)$, can then be obtained as:

$$\gamma_i = 1 - \frac{\hat{d}_i}{\Sigma_i \hat{d}_i} = 1 - d^*_i ; \qquad i=1, \ldots., r$$

where r is the number of objective functions specified.

In this study, this proposed method of deriving trade-off weights is termed 'structured-indifference response'. This is because it emphasises structuring through uniformly-scaled fulfilment of problem-constraints rather than structuring through comparison of potential gains attributable to the various goals.

A point worth mentioning is that in cases where M (the number of constraints) is greater than r (the number of specified objective functions), an improvement of this method could be an application of multiple regression, whereby an estimating model is developed in the form:

$$d_k^* = a + \hat{\gamma}_1 \psi_1(x^{*k}) + \ldots\ldots + \hat{\gamma}_r \psi_r(x^{*k}) + u_k$$

where d_k^* denotes the ALGA obtained in optimising the objective function $\psi_k(x)$,

$\hat{\gamma}_i$ is the ith estimator,

a is the constant term, and

u_k is the residual error term.

Thus, the values, $\psi_i(x^{*k})$, of the objective functions become the obtained observations of the regressors while the ALGA values obtained become the observations of the regressand. The constant term, a, is needed since even if at any stage an optimal solution x^{*k} yields values of zero for all $\psi_i(x^{*k})$, the estimated ALGA from the regression may not necessarily be zero - which could be an indication of mis-specified objectives. Such a multiple regression analysis would yield appropriate trade-off weights that could be used in the final overall objective function.

The derivation of trade-off weights in this manner would be particularly useful since valuable information (usually extractable from regression models) could be obtained regarding the relationships between particular objective functions and/or constraints of the original problem.

(2) This method is concentrated upon minimising total trade-off values between the different efficient solutions obtained from the various objectives.

In any linear programming problem, the usage of weights, γ_i, introduces a reduction of $100(1 - \gamma_i)\%$ in the value of the unit potential gain from every final non-slack variable in the objective function, $\psi_i(x)$.

Let C_{ij} represent the coefficient of the jth basic decision variable for objective function $\psi_i(x)$.

Then, δ_{ij} represents the change in C_{ij}, that is, $\delta_{ij} = C_{ij}(1 - \gamma_i)$.

The objective function having this changed coefficient becomes a modified version of $\psi_i(x)$.

Let it be denoted by $\psi_i^{'}(x)$.

Since the final solution set $\{x^{*i}\}$ remains optimal after introducing δ_{ij}, then,

$$\psi_i^{'}(x^{*i}) = \psi_i(x^{*i}) - \Sigma_j x_j^{*i} \delta_{ij}$$

$$= \psi_i(x^{*i}) - (1 - \gamma_i) \Sigma_j C_{ij} x_j^{*i}$$

where, $\psi_i^{'}(x^{*i})$ is the optimal value of the modified version of objective function $\psi_i(x)$,

and x_j^{*i} is the value of the jth basic decision variable in the optimal solution set $\{x^{*i}\}$.

Since $\{x^{*i}\}$, $\{x^{*k}\}$ represent sets of optimal solutions from optimising $\psi_i(x)$, $\psi_k(x)$ respectively, the trade-off between both solution sets with respect to objective function $\psi_i(x)$ can be taken as equal to

$$\psi_i'(x^{*i}) - \psi_i'(x^{*k})$$

where, $\psi_i'(x^{*k})$ is the value of modified $\psi_i(x)$ using the optimal solution set $\{x^{*k}\}$.

Denoting this trade-off by Δ_{ik} for $i \neq k$,

$$\Delta_{ik} = \psi_i'(x^{*i}) - \psi_i'(x^{*k})$$

$$\psi_i'(x^{*i}) = \psi_i(x^{*i}) - \Sigma_j x_j^{*i} \delta_{ij}$$

$$\psi_i'(x^{*k}) = \psi_i(x^{*k}) - \Sigma_j x_j^{*k} \delta_{ij}$$

Thus,

$$\Delta_{ik} = \psi_i(x^{*i}) - \psi_i(x^{*k}) - (1 - \gamma_i)(\Sigma_j C_{ij} x_j^{*i} - \Sigma_j C_{ij} x_j^{*k})$$

It should be noted that when i=k, $\Delta_{ik} = \emptyset$.

A useful trade-off tableau can then be developed as:

$$
\begin{array}{ccccc}
\emptyset & \Delta_{12} & \Delta_{13} & \cdots & \Delta_{1r} \\
\Delta_{21} & \emptyset & . & & . \\
. & . & . & & . \\
. & . & . & & . \\
\Delta_{r1} & \Delta_{r2} & \Delta_{r3} & \cdots & \emptyset
\end{array}
$$

In such a tableau, the zero element corresponds to the objective function value for which trading-off is not possible since it is its own solution set that is being used to evaluate trade-offs of the other objective functions.

The opportunity cost of selecting an objective function $\psi_i(x)$ can be measured as a proportion of $\psi_k(x^{*k})$ which would be lost due to the non-selection of objective function $\psi_k(x)$.

Further, since trade-offs indicate 'losses' with respect to particular objectives, 'gains' for say $\psi_i(x)$ are the differences between $\psi_i(x^{*i})$ and values of $\psi_i(x^{*k})|_{k=1,\ldots,r;\ k \neq i}$

'Losses' for $\psi_i(x)$ on the other hand are the differences between $\psi_k(x^{*k})$ and values of $\psi_k(x^{*i})$.

Thus the problem of finding the appropriate trade-off weights takes the form:

Optimise : Σ Relative Trade-offs

Subject to:

Weighted Average Obj. Function Values $\leqslant$ Max. Obj. F. Values

Σ Weights = 1

Individual weights $\geqslant$ Ø

The problem can be expressed as:

Optimise $\Sigma_i \gamma_i \Sigma_{k=i} \Delta_{ki} / \psi_k(x^{*k})$

where, i,k = 1, ..., r   r - being the number of objective functions in the problem.

Subject to:

$$\gamma_i \psi_i(x^{*i}) + \Sigma_{k \neq i} \Delta_{ik} \gamma_k < \text{Max } (\psi_i(x^{*i})) \quad \text{for } \psi_i(x^{*i}) > Ø$$

$$\gamma_i \psi_i(x^{*i}) + \Sigma_{k \neq i} \Delta_{ik} \gamma_k > \text{Min } (\psi_i(x^{*i})) \quad \text{for } \psi_i(x^{*i}) < Ø$$

$$\gamma_1 + \gamma_2 + \ldots\ldots + \gamma_r = 1$$

$$\gamma_1, \gamma_2, \ldots\ldots, \gamma_r \geqslant \emptyset$$

Finally, from the minimisation program elaborated above, the optimal solution set $\{\gamma_i^*\}$ represents the set of appropriate trade-off weights to be used in the overall objective function.

In this study, the above method is termed 'controlled-flexibility response', since the emphasis here is essentially on achieving a balance between the potential gains/losses attributable to the various goals.

The advantages of this proposed method are obvious. Not only is the method applicable to any size of problem, but also it obviates the necessity for any assumptions beyond those which underlie conventional linear programming applications.

6.3.3 The Overall Objective Function

Using the methods detailed above (Sections 6.3.1 & 6.3.2), the following steps are taken:

- a set of preference weights $\{ \omega_i \}$ are derived;
- a set of trade-off weights $\{ \gamma_i \}$ is derived which are aimed at a 'controlled-flexibility response' to the problem on hand;
- if desired (or when no optimal 'controlled-flexibility response' can be achieved), a set of trade-off weights is derived for a 'structured-indifference response'.

Finally, the required overall objective function can be formulated with a non-preemptive structure as:

$$F_\emptyset(x) = \gamma_1 \omega_1 \psi_1(x) + \gamma_2 \omega_2 \psi_2(x) + \ldots\ldots + \gamma_{r-1} \omega_{r-1} \psi_{r-1}(x) + \gamma_r \psi_r(x)$$

That is,

$$F_\emptyset(x) = [\Sigma_{i=1}^{r-1} \gamma_i \omega_i \psi_i(x)] + \gamma_r \psi_r(x)$$

The result from optimising this derived non-preemptive programme with objective function, $F_\emptyset(x)$, represents the compromise solution, consistent with operationally feasible policy decisions, earlier accepted by the decision-maker.

An improvement to the introduction of the preference and trade-off weights can be made by using the products of the trade-off weights and the UB_i of the objective functions as the upper bounds needed in the calculation of a set of compromise weights Γ_i.

In this case, the overall objective function becomes:

$$F_{\emptyset}(x) = \Gamma_1 \psi_1(x) + \Gamma_2 \psi_2(x) + .. + \Gamma_{r-1} \psi_{r-1}(x) + \psi_r(x)$$

That is,

$$F_{\emptyset}(x) = [\Sigma_{i=1}^{r-1} \Gamma_i \psi_i(x)] + \psi_r(x)$$

The above additive utility model, used in either form, tackles the problems associated with uncertainties by recognising that the latter mainly influence the preference characteristics of the decision-maker. The model structure thus takes care of situations where multiple decision-makers have to be considered - in which case, compromise has to be sought first in the selection of synergy-defining scenarios at the early stage of model-building when the preference structure is being analysed.

The proposed model also tackles the problems associated with value judgements by recognising that they are mainly influenced by uncertainties and by the information content of the problem on hand. This suggests that the uncertainties here are essentially reflected by the specified targets for the goal constraints of the problem. The interaction between the model parameters therefore not only possesses a vast information content beyond human capabilities, but also ensures the consideration of some uncertainties which may otherwise colour the value judgement of the decision-maker in the evaluation of trade-offs. This is indeed the justification for the contention of deriving the set of appropriate trade-off weights from the information content of the problem irrespective of the priority orderings.

Further, it must be emphasized that the multiplicative introduction of both preference and trade-off weights into the overall objective function (or into the range of uppper bounds of objective functions) offers the opportunity to exercise the desired rigidity-flexibility balance in the decision-making process. Rigidity is exercised through the optimism or pessimism of the decision-maker which is reflected in the selection of optimal synergy-defining scenarios, while flexibility is exercised by the decision-maker through the specified targets for the goal constraints which in fact define the bounds of the interaction between the parameters of the proposed model.

6.4 Connective Summary

A key difference between this study and much of existing development on multiple criteria decision-making (MCDM) modelling lies in the emphasis placed on how to tackle the problems associated with uncertainties and value judgements.

Most studies have been essentially directed towards tackling these issues by directly obtaining from the decision-maker the preference and/or trade-off weights to be used either in a sequential priority-ordered optimisation structure or in an overall objective function. This study, on the other hand, is focused upon how these issues of uncertainties and inconsistencies exert their influences on the decision-maker and, therefore, how best to elicit from the latter subjective information about such influences so that the preference and trade-off weights can be derived from such information as well as from the information content of the original problem.

It must be emphasized however, that the author is not claiming that the proposed methodology is applicable to all types of problems encountered in multiple criteria decision-making. The essential point is that the concept of viability planning can be used in most cases in directing the modelling activity towards aiding decision-makers to exercise their judgemental duty with monitored consistency and in an intuitively appealing way.

On the basis of the methodology proposed in this Chapter, a computer program has been prepared (written in FORTRAN) and run on the University's Harris 800 Computer System.

CHAPTER SEVEN

THE INTERACTION TABLEAU AND THE VIABILITY PLANNING MODEL

7.1 Introduction

Real growth comes from the ability of management to successfully employ additional capital at a satisfactory rate of return for all relevant parties in the capital and money markets. This is the final criterion of the soundness and strength of an organisation - because in a competitive economy, capital gravitates towards the more environmentally responsive and profitable enterprises. Before formulating organisational objectives therefore, what matters above all is to obtain a true picture of the totality of considerations - by representing all cash outlays and inflows on a scale that enhances coordination, control and awareness of the interaction with the environment. In this way, the true value of any transfer and effect of resource deployment is related to the conditions accompanying the involvement. This is the relevance of the Interaction Tableau discussed below.

TABLE 7.1: A TYPICAL INTERACTION TABLEAU FOR VIABILITY PLANNING

RESOURCE PARAMETERS & EFFICIENCY INDICATORS			CAPITAL INPUTS						PRODUCT ACTIVITY PARAMETERS			CAPITAL OUTPUTS					TARGET VALUES
			EQUITY	BONDS: LONG	BONDS: MEDIUM	BONDS: SHORT	CASH BALANCE	SECUR-S SALE	TRANSFORMA-TION OUTFLOWS	MARKET LINKING OUTFLOWS	TRADING INFLOWS	RETENTION	STOCK DIV-D	CASH DIV-D	SECUR-S ACQ.	STOCKS ACQ.	
CONVENTION-L COST-STRUCT.		OPERAT. COST	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		WORK-G CAP-L	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		VARIAB. COST	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
TRANSFORM-N CHARACTER-S		PRODUC. MGT.	0	0	0	0	0	0	1 . . . 1	0 . . 0	0 . . . 0	0	0	0	0	0	1
		INVENT. MGT.	0	0	0	0	0	0	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	0	0	1
		WORKLD. BAL.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
CAPITALISATION MODEL PARAMETERS	HUMAN RESOURCES	PUPIL APPREN.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		LINE SEMI-SK.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		LINE SKILLED	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		GRADUATE TRN.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		LOWER MANAGT.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		CONTRACTUAL	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		MIDDLE MGT.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		SENIOR MGT.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		TOP MANAGEMT.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
	PHYSICAL ASSETS	IN ECON. LIFE	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		IN SERV. LIFE	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		IN EXTRA LIFE	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		OTHERS	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
	MATERIALS	RAW MATERIALS	0	0	0	0	0	0	1 . . . 1	0 . . 0	0 . . . 0	0	0	0	0	0	1
		INTERM. CONS.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		NORMAL CONSU.	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		ENERGY INPUTS	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
		OTHERS	0	0	0	0	0	0	1 . . . 1	1 . . 1	0 . . . 0	0	0	0	0	0	1
SYNERGIC PACKAGE PARAMETERS	OPER-L EFFIC-Y	DEG. OP. LEV.	0	0	0	0	0	0	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	0	0	1
		BASIC DEF.INT	0	0	0	0	1	1	1 . . . 1	1 . . 1	1 . . . 1	1	0	0	1	0	1
		ACC. REC.TURN	0	0	0	0	1	0	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	0	0	1
		ASSET UTIL.	0	0	0	0	0	0	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	0	0	1
	CAPITAL EFFICIENCY	RTN. ON CAP.	0	0	0	0	0	0	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	0	0	1
		NEW CAPITAL-N	0	0	0	0	0	0	1 . . . 1	1 . . 1	1 . . . 1	1	0	0	1	1	1
		NEW INV. DEC.	1	1	1	1	1	1	1 . . . 1	1 . . 1	1 . . . 1	0	0	0	1	1	1
		FXD.CHGS.EARN	0	0	0	0	0	0	0 . . . 0	0 . . 0	1 . . . 1	0	0	0	0	0	1
		TOT.CAP-N VAL	0	0	0	0	1	1	1 . . . 1	1 . . 1	1 . . . 1	1	1	1	1	1	1

7.2 The Interaction Tableau

Table 7.1 represents a typical interaction tableau for viability planning in any organisation.

The columns of such a tableau have three basic categories of parameter - capital inputs, product activity parameters and capital outputs. The capital inputs category comprises parameters which reflect the influence of the various fund parties on the organisation and also reflect the organisation's potential for maintaining liquidity without additional pressure on the sales activity. The capital outputs category, on the other hand, comprises parameters which reflect the organisation's influence on the various fund parties. For both categories, the relevant fund parties are of course the shareholders, the debenture holders, the securities market, the bankers and the trade creditors and debtors. The product activity parameters constitute the category around which are centred the not-entirely-financial interactions among the organisation's constituent sub-systems and also between the organisation and its relevant environment. The decision variables which correspond to the capital inputs and outputs categories are chosen to provide answers to a specific type of management query - how much of a particular type of capital to use? For the capital inputs category, the usage referred to is essentially within the organisation. For the capital outputs category however, the usage is essentially outside the organisation since it is aimed at elevating the organisation's reputation on the issue of capital efficiency - for example, consistency of the organisation's growth, dividend declaration and portfolio management. The decision variables which correspond to the product activity parameters are chosen to provide answers to another specific type of management query - how many of a particular type of product to manufacture, retain in a particular market-linking state or sell? These variables are the ones upon which the entire cost-structure of the organisation depends and without which no realistic appreciation of the level of operational efficiency can be obtained.

The rows of the Interaction Tableau have four basic categories of parameter - conventional cost-structure parameters, parameters relating to transformation characteristics, capitalisation model parameters and synergic package parameters.

The conventional cost-structure parameters are those which pertain to the budgetary planning and control system of the organisation. In such a system, it is traditional to have all the individual budgets integrated into a master budget. However, for the purpose of the interaction tableau, perhaps the most relevant budgets to be monitored are the operating or production budget, the working capital budget and what might be called the variable cost budget. This is mainly because, as shall be explained later in this section, these individual budgets help derive a measure of operational efficiency in terms of the degree of operating leverage, which is one of the synergic package parameters. The operating budget, understandably, looks at the requirements for materials, labour and manufacturing facilities while the working capital budget focuses on the changes in raw material stocks, work-in-progress, finished stocks, trade debtors and creditors. The variable cost budget looks at those costs which tend to vary directly with the volume of output but which cannot be allocated directly to any cost unit in particular. It must be said that the issue of variable costs is not as straightforward as those of the other two budgets referred to above. The use of prime costs plus variable overhead classification to calculate marginal costs - together with the frequent use of standard costing - tends to lead cost-accountants to assume that the cost of the marginal unit is constant over a wide range of output. However, while marginal cost and variable cost per unit may be the same at a given level of output, economists clearly distinguish between marginal costs and average variable cost per unit. Accountants, on the other hand, frequently do not distinguish between the two - if they recognise a distinction in concept, they tend to assume that average variable cost is equal to marginal cost at all levels of output and that both are constant for the relevant portions of the output range in which they are operating. In fact the validity of this assumption has been a worrying aspect of marginal costing as indicated by Sizer (1965). For the purpose of the Interaction Tableau however, the economists' viewpoint seems to be much more realistic.

The transformation characteristics category are those which pertain to production management, inventory management and workload balancing. The production management aspect can usually be represented in two forms - oriented towards demand satisfaction, and oriented towards enhancement of active productive capacity. The inventory management aspect can also usually be represented in two forms - oriented towards the maintenance of an economic order quantity while at the same time satisfying the average demand for inventory, and oriented towards enhancement of active storage capacity. Workload balancing, on the other hand, is usually in the form of balancing of idle capacities of the different productive sub-systems concerned. Thus the parameter relating to this transformation characteristic becomes relevant in situations where production processes have to be balanced among various responsibility centres, where job distribution needs to be more equitably planned or where, for example, demand satisfaction needs to be balanced among different consumer-categories.

The capitalisation model parameters reflect the cost-structure of the organisation in terms of the capitalisation value (to the organisation) of individual resource clusters which should be sustained as long as solvency is maintained. These parameters are focused on the worth to the organisation of the human resources, physical assets and materials in a manner by which the 'capital employed base' of the organisation can be determined while at the same time obviating the problems usually associated with valuation of fixed assets. The problems being referred to here are centred around the issues of gross versus net book values versus assumed current cost valuation of assets. The fact is that the use of gross book values has an inconsistent effect on the capital employed base when fixed assets are replaced (since the gross book value will increase only by the difference between the cost of new equipment and the original cost of the old). Also, the use of net book values causes an automatic reduction in the capital employed base as the assets age thereby distorting asset replacement policies - since, for example, a rising return on capital employed may very well be accompanied by stagnant or falling absolute profits. On the other hand, the use of assumed current cost valuation is not reliable when, as is usually the case, assets are not replaced by the same ones due to technological changes. What the capitalised-cost model does however, is to focus not on which type of valuation technique to use among the conventional ones discussed above, but on the fact that the capitalisation commitment which accompanies the acquisition of any asset or resource can itself be taken as the subjective, economic value of the asset to the organisation.

The synergic package parameters constitute the indicators of operational efficiency and also the indicators of capital efficiency. For the Interaction Tableau, the four selected indicators of operational efficiency (degree of operating leverage, basic defensive interval, accounts receivable turnover, and asset utilisation) and the five selected ones of capital efficiency (return on capital invested, new capitalisation volume, new investment decision-criterion, fixed charges earned, and total capitalisation value) are considered by the author to be a collectively exhaustive set. This is because while the four indicators of operational efficiency sufficiently cover interactions within an organisation as well as between the latter and its product market, the five indicators of capital efficiency sufficiently cover interactions between the organisation and all the fund parties relevant to it.

Operating leverage arises whenever an organisation can expand output and sales without a proportionate increase in costs. Under such circumstances, operating profits increase proportionately more than sales increase. Conversely, if output decreases without an accompanying proportionate decrease in costs, the organisation's operating profits shrink proportionately more than the decrease in sales. Thus, the degree of operating leverage (DOL) at any particular level of production or service is a measure of the percentage change in operating profits per unit percentage change in output.

Let the proportional change in profit be $\dfrac{q(sp - vc)}{Q(sp - vc) - FC}$

where q = increase in output

Q = output level at which DOL is being calculated

sp = unit selling price

vc = unit variable cost

FC = total fixed cost

Thus, VC = Q.vc and S = Q.sp where VC is the total variable cost and S - the total sales revenue.

$$\text{Therefore, } DOL = \frac{q(sp - vc)}{S - VC - FC} \cdot \frac{Q}{q} = \frac{S - VC}{S - VC - FC}$$

Since FC = TC - VC, where TC is the total cost, then

$$DOL = \frac{S - VC}{S - VC - (TC - VC)} = \frac{S - VC}{S - TC}$$

Thus the representation of DOL in the Interaction Tableau can be done in terms of the conventional cost-structure parameters (operating cost and variable cost) and also in terms of the product-activity parameters pertaining to sales. The degree of operating leverage reveals an important insight to decision-makers concerning the operating risks of the organisation. A high DOL implies that there will be more fluctuation in operating earnings than a lower DOL. This alerts the decision-makers to the necessity for faster and more accurate economic forecasts and also the need to search for investment opportunities which might offset the operating risk. Thus as DOL increases, dependence on debt as a means of financing has to decrease in order to reduce the chances of insolvency. Consequently, DOL can also be useful in the determination of the appropriate capital structure for the organisation.

The 'basic defensive interval' is the period, the duration of which gives the organisation the chance to minimise the inconveniences of any immediate cash requirement without sales or other sources. The basic defensive interval (BDI) is measured as the number of days the organisation's defensive assets (cash, market securities and accounts receivable) can be used to offset, if needed, projected operating expenditures (production costs of sold outputs, selling expenses and general administrative expenses).

$$BDI = \frac{\text{(Total Defensive Assets).(Total Work-days per annum)}}{\text{Projected Operating Expenditure per annum}}$$

A closer examination of this indicator will reveal that it helps to monitor the degree of synchronisation of the cash inflows and outflows, the costs associated with a shortfall in the organisation's cash needs, the costs associated with maintaining excess idle cash, the costs associated with managing the organisation's cash balances and marketable securities, and associated uncertainties. In order to synchronise the cashflows, there is the need to understand not only such cash inflow characteristics as the seasonal and cyclical pattern of the organisation's sales, its collection of accounts receivable and its borrowings, but also such cash outflow characteristics as the organisation's payroll, raw material costs, accounts payable pattern, interest payments, loan repayments and taxes. In order to monitor the costs associated with a shortfall in cash needs, there is the need to examine the organisation's transaction costs of raising cash, its borrowing costs, the forfeiture of trade discounts and other valuable opportunities, the deterioration of the organisation's credit rating, and the increased banking charges. Excess idle cash, on the other hand, leads to missed opportunities - particularly the interest passed up on marketable securities - from which the organisation could have profited if it had invested those funds.

Thus, the usage of the BDI is really to monitor the transaction, precautionary and speculative motives underlying the cash management policy of the organisation. It can therefore be said that this indicator is particularly focused on the operational efficiency of the financial sub-system of the organisation - unlike the 'degree of operating leverage', which seems to be a 'feed-forward' indicator that the financial sub-system can use in matching the realities of prevailing productive capabilities with the business potential (in the form of capital structure) of the organisation.

The 'accounts receivable turnover' is a measure of liquidity of the organisation's accounts receivable as the number of times annual credit sales are in reality turned liquid. It is usually estimated as the ratio of the annual credit sales to average annual accounts receivable. It can be converted into the average collection period by simply dividing it into 360 days thereby giving how many days it takes the average account to be collected. A closer examination of this indicator will reveal that it actually focuses on how many times in a year the volume of credit sales can really be relied upon to support the organisation's basic defensive assets. The higher this indicator, the more realistic the estimated 'basic defensive assets interval'. It must be said however, that a very high accounts receivable turnover or very low collection period might indicate an overly restrictive credit policy which could limit profits by denying credit to potential customers who will then go elsewhere. The fact is that there is an inherent cost-structure to be monitored in the implementation of any accounts receivable policy. There are collection costs - which pertain to the maintenance of the credit responsibility centre of the organisation, and there are capital costs, delinquency costs and default costs - all of which pertain to the fund-raising and insurance aspects of any credit policy. Thus, any return on investment in additional accounts receivable which is less than the cost of funds raised to finance that additional credit cannot be acceptable. In other words, the cut-off point is that where the return on investment in any further funding of receivables is less than the cost of capital. It can therefore be said that the relevance of this indicator in the synergic package is two fold:

- it serves as a complement to the 'basic defensive interval' parameter, and
- it helps to appropriately understand the nature of the return on capital invested.

The 'asset utilisation' indicator focuses on the efficiency with which management utilises the organisation's assets to generate sales and profit. There are three different financial ratios usually used as measures of asset utilisation. These are the asset turnover ratio, the earning power ratio, and various physical ratios - an example of the latter is the 'load factor' usually used by airlines. The asset turnover ratio is different from the earning power ratio in the sense that the former is the ratio of net sales to total tangible assets while the latter is the ratio of net profit to total assets. For the purpose of the Interaction Tableau, the earning power ratio seems the most appropriate since it is applicable to most organisations (asset turnover can be distorted, for example, in organisations which heavily depend on intangible assets such as patents, copyrights, etcetera to generate their sales). The relevance of this indicator is essentially to have a common measure of comparison between an organisation's investment success and alternative investment opportunities. This indicator also reinforces the view that an organisation's productivity is perhaps best measured in terms of 'value added' - the wealth which the organisation has been able to create by its own and by its employees' efforts.

From the discussion so far, it is not difficult to realise that operational efficiency indicators tend to be concerned with liquidity and short-term solvency problems - that is, problems which are closely associated with the internal operating risks of an organisation. The usage of operational efficiency indicators reinforces the view that every management has its own particular internal operating risks to contend with and that the sustained degree of minimisation of such risks reflects the reliability that investors should attach to the operating skills of the organisation's decision-makers. In other words, these indicators inform the environment about the ability of the organisation's decision-makers to retain valuable and competent employees, to keep abreast of technology, to patent properly the organisation's products and processes, to instil consumer loyalty and to always fulfil desired satisficing objectives in the progressive sense.

The indicators of capital efficiency, on the other hand, tend to be concerned - as shall shortly be explained - with profitability and long-term solvency problems (that is, problems closely associated with external operating risks). Operating risks are, in general, those factors which are peculiar to the particular industry or type of organisation and which introduce uncertainty into the investment and financing processes of the organisation because such factors increase the variability in projects' income and the chance that the profitability projections for any particular investment may not be realised. Thus, operating risks which are imposed on the organisation by industry forces outside its control have to be tackled with adept consideration of the business cycle, the quality of sales and the capital market. Consequently, indicators such as the return on capital invested, the fixed charges earned, the new investment decision-criterion, and subjective economic valuation become absolutely essential.

The 'return on capital invested' focuses on profitability as a reflection of management's efficiency in using the amount borrowed from creditors and the amount invested by stockholders. It is measured by the ratio of net profit to total capital (long-term debt plus stockholders' equity). As this indicator increases, management is considered increasingly efficient in selecting projects in which to invest the organisation's capital. Although there are many profitability indicators usually used in financial ratio analysis, this particular indicator is perhaps the most suitable for the purpose of the Interaction Tableau since it can be expressed in terms of the product-activity parameters and also since it excludes current liabilities from the denominator (on the grounds that such liabilities are offset by current assets and are, therefore, not really part of the organisation's debt from the viewpoint of long-term solvency).

The 'fixed charges earned' is measured by the ratio of earnings before interest and taxes to interest, principal repayments and other fixed charges such as lease payments, etc. This indicator focuses on how the organisation manages and maintains its debt - hence, it partly reflects the effectiveness of the cushion provided by the stockholders' equity and partly reflects the effectiveness of the organisation's activities for generating sufficient funds to meet interest and repayment schedules. In estimating this indicator of capital efficiency, earnings before interest and taxes are used because interest payments have prior claim on the earnings before taxes - the interest payments themselves are available to meet the interest obligation, and so deducting them would be double counting. Also, any principal repayment (which is paid out of after-tax income) has to be adjusted to a pre-tax basis to make it comparable with the other terms in the ratio.

The 'new investment decision-criterion' is an indicator which reflects the rule or standard by which the organisation judges the qualifications and desirability of any new investment. The criteria frequently applied in most organisations fall into two broad categories - present discounted value techniques and internal rate of return techniques. Approaches in the first category are discounted cash flow (DCF), net present value (NPV), benefit/cost (BC) and terminal value (TV). In the second category, the approaches are the internal rate of return (IRR) and the average rate of return (ARR). There are, however, other criteria - for example, the payback and the retension - which do not fit into either of the two broad categories and are more limited in their application. The selection, in an organisation, of any of these decision criteria normally depends on the specific circumstances surrounding the capital budgeting process - an organisation may find one decision criterion easier to relate to its chosen objective than another; the organisation may even choose to use more than one of the decision criteria in its capital budget planning in order to view proposed investments from several different angles.

For the purpose of the Interaction Tableau however, the major consideration is to devise a criterion which best relates successful investment selection to whichever organisational goal management intends to implement. The DCF decision criterion, for example, typically works best for an organisation which has a shareholder-wealth maximisation goal and which recognises that the present value of the organisation is enhanced by investments with DCFs in excess of the investments' cost. The DCF approach lends itself to situations in which there is little concern about ranking projects according to their relative attractiveness and little need to give specific consideration to cash outflows subsequent to the original capital outlay. The NPV tends to suit the same organisations as the DCF but it is particularly appropriate for situations where it is necessary to rank the projects by how much each adds to the organisation's present value. In fact, the NPV is best applied in situations where there is no concern with netting cash outflows and inflows in any one period and no need for an indication of the absolute amount of the cost of each project. The IRR decision criterion, on the other hand, most readily relates to organisations with profit-maximising goals - because of this criterion's direct comparison of cost versus return. It is best applied in situations in which there is no need to worry specifically about the absolute size of the project or of cash outflows subsequent to the original outlay. All the other decision criteria in the broad categories mentioned above can similarly be somehow related to specific organisational goals.

The payback criterion, however, is hard to relate to any particular organisational goal, but it can be appropriately used for any organisation especially when there is an overriding consideration for liquidity or a very short-term spurt in earnings. The flaw in this criterion is that it ignores the time value of money, the timing of the cash flows, the life expectancy of the projects, and the value of the inflows beyond the acceptance year.

The criterion suggested for use in the Interaction Tableau is the 'time-adjusted payback'. It is a modification of the payback by the incorporation of considerations which obviate the severity of the flaws associated with all the other criteria discussed above. If the management are able to supply information about the expected growth rate of income attributable to an investment, the desired time-adjusted payback period (TAPB) for the investment, and also the cost of capital for the organisation, then it will not be difficult to represent all such new investments as one of the rows for the capital efficiency indicators. Thus, this criterion will still be measuring the rapidity with which projects will return the original capital outlays without the risk of emphasizing short-run earning performance over sound long-run budgeting procedures. In order to use this criterion in any viability planning model, it is assumed that every new investment has a known annual rate of growth of the net profit contribution from its associated individual products or services. Also, the organisation is assumed to have an average time-adjusted payback period, acceptable to management, and that every new investment has an estimated time-adjusted payback period of its own. The decision rule then is to ensure that a level of product activity is sustained which does not make the time-adjusted payback period for the entire organisation to go beyond the acceptable maximum, specified by management.

The capital efficiency indicators expressed as the parameters, 'new capitalisation' and 'total capitalisation' values, focus on the valuation of the present state of affairs of the organisation from the viewpoint of engineering economics. This viewpoint considers every resource of the organisation as a wealth-creating source which (as long as solvency is maintained) goes through a continual acquisition-operation-retirement cycle. As such, a subjective economic valuation can be derived for the resources based on their capital recovery costs, operation and maintenance costs, the profits attributable to them, and the salvage settlement anticipated to be associated with their retirement. The concept behind capital recovery derivation is to incorporate a compounding factor on the capital recovered and reinvested, while at the same time discounting for the time value of money lost while waiting, as it were, for the capital recovery. Thus, using the concept of compound annuity for each resource, an equivalent annual cost of capital recovery, operation and maintenance can be derived if the organisation's cost of capital and the resource's expected service life are known. From the equivalent annual cost, the capitalised amount can be obtained (as demonstrated in

Section 2.5). This is the single amount in the present whose return at the given cost of capital would yield the equivalent annual cost. The capitalised amount can further be spread over the various product-activity parameters which pertain to outflows and through which the amount is being dispensed. Thus, the 'new capitalisation' row in the Interaction Tableau is the summation of such capitalised amounts for all contemplated new investments during the planning period, while the 'total capitalisation' row is similarly the summation for the entire resources of the organisation. In as much as the capitalisation model has considered only costs, the valuation estimate has to include (over and above the total capitalisation costs) the anticipated profits, total cash balance, total net trade credit, marketable securities of the organisation, the organisation's retention, and finally, the organisation's percentage increase in dividends. It should be pointed out that dividends per se are not included in this valuation since the value of the organisation depends only on the distribution of future cash-flows provided by investment decisions. Pettit (1972) and Watts (1973) have shown that dividends as such do not contribute to the organisation's value, although the percentage increase in dividends may have a 'signalling' effect on investors about future cash-flows.

The valuation estimate, obtained as described above, represents the target value below which management cannot afford the market valuation of the organisation to be sustained. The leverage associated with this valuation is, of course, the value attached to the organisation's intangible assets, which are not represented in the Interaction Tableau. In order to estimate the magnitude of this leverage, another valuation of the organisation can be made (based on considerations for profits, financing, investment decisions and the implied cost of capital for investors) as indicated in the model formulation below. This formulation draws on a quantitative framework such as Peterson's (1969) and also draws on the concept of shareholder-wealth-maximisation.

$$V = \frac{(1 - r_{RET}) . C_{INV} . r_{ROC}[1 + G(1 - \frac{r_d}{r_{ROC}})]}{k_{EQ} - r_{RET} . r_{ROC}[1 + G(1 - \frac{r_d}{r_{ROC}})]} . N_{EQ}$$

where,

$r_{RET} . r_{ROC}[1 + G(1 + \frac{r_d}{r_{ROC}})]$ represents the estimated growth rate of the organisation;

N_{EQ} - total number of issued shares less treasury stock;

V - estimated market value of the organisation;

G - gearing in the organisation's capital structure;

r_{RET} - retention rate;

C_{INV} - total capital allocated for new investments;

r_{ROC} - expected rate of return on all investments during the period under consideration;

k_{EQ} - the implied cost of capital for the organisation's investors;

r_d - the weighted average interest on short, medium and long term debts of the organisation.

Such a valuation as the one indicated above and the capitalisation value then represent the maximum and minimum bounds, respectively, within which management has to set the target value during any planning period.

7.3 The Viability Planning Model

The problem of viability planning in any organisation is centred around the problems usually associated with multi-criteria decision-making situations. These problems necessitate that some degree of flexibility has to be maintained since the target values will most probably represent what the decision-makers deem desirable but not necessarily attainable. Furthermore, not only are many of the objectives specified likely to be incommensurate and/or conflicting, but also the priority setting specified by the decision-makers may not necessarily have to be sacrosanct. Consequently, any logico-mathematical model to be used for viability planning has to include a considerable number of 'soft' constraints, and detailed consideration has to be given to the problems of uncertainty which usually aggravate the inconsistency of the decision-making process.

A mathematical representation of such a model (resulting from the above discussion and developed on the basis of the Interaction Tableau) is given below.

Objective Function:

$$\text{Minimise } \{\ P_1(w_{11}d^-_{ROC}) +$$

$$P_2(w_{21}d^-_{TAPB} + w_{22}d^+_{TAPB} + w_{23}d^-_{NEWC} + w_{24}d^+_{NEWC}) +$$

$$P_3(w_{31}d^-_{DOL} + w_{32}d^+_{DOL} + w_{33}d^-_{BDI} + w_{34}d^+_{BDI}) +$$

$$P_4(w_{41}d^-_{EPR} + w_{42}d^+_{EPR} + w_{43}d^-_{FCER} + w_{44}d^+_{FCER}) +$$

$$P_5(w_{51}d^-_{WK} + w_{52}d^+_{WK} + w_{53}d^-_{PRD} + w_{54}d^+_{PRD} +$$

$$w_{55}d^-_{INVE} + w_{56}d^+_{INVE}) +$$

$$P_6(w_{61}d^-_{CAPV} + w_{62}d^+_{CAPV})\ \}$$

Subject to

Operating Cost Constraint:

$$\sum_{j=1}^{n} c_{(OPER)j} \cdot X_{(PRD)j} + d^-_{OPER} - d^+_{OPER} = C_{OPER}$$

Working Capital Constraint:

$$\sum_{j=1}^{n} c_{(WKCAP)j} \cdot X_{(PRD)j} + d^-_{WKCAP} - d^+_{WKCAP} = C_{WKCAP}$$

Variable Cost Constraint:

$$\sum_{j=1}^{n} c_{(VARC)j} \cdot X_{(PRD)j} + d^-_{VARC} - d^+_{VARC} = C_{VARC}$$

Production Management Constraint:

$$\sum_{j=1}^{n} X_{(PRD)j} + d^-_{PRD} - d^+_{PRD} = Q_{PRD}$$

Inventory Management Constraints:

$$\sum_{j=1}^{n} q_{(INVE)j} [X_{(PRD)j} + X_{(INVE)j} + X_{(SALE)j}] + \\ + d^-_{INVE} - d^+_{INVE} = Q_{(INVE)}$$

$$\sum_{j=1}^{n} (TC_{(INVE)j} - q_{(INVE)j} \cdot c_{(INVE)j}) \cdot \\ [X_{(PRD)j} + X_{(INVE)j} - X_{(SALE)j}] + \\ + d^-_{EOQ} - d^+_{EOQ} = \sum_{j=1}^{n} REQ_{(INVE)j} \cdot P_{(INVE)j}$$

Workload Balance Constraint:

$$W_b \cdot \sum_{j=1}^{n} X_{(PRD)jm} - W_m \cdot \sum_{j=1}^{n} X_{(PRD)jb} + d^-_{(WK)bm} - d^+_{(WK)bm} = 0$$

(for each m, while b remains the base-centre)

Capitalisation Model Constraint:

$$\sum_{j=1}^{n} cc_{Rj} \cdot X_{(PRD)j} \qquad + d^-_{CC(R)} - d^+_{CC(R)} = CC_R$$

Synergic Package Constraints:

Degree of Operating Leverage

$$\sum_{j=1}^{n} \{ [1 - (1\text{-tax})(DOL\text{-}1)].c_{(OPER)j} - c_{(VARC)j} \}.X_{(PRD)j} +$$

$$(1\text{-tax})(DOL\text{-}1).X_{(SALE)j} + d^-_{DOL} - d^+_{DOL} = 0$$

Basic Defensive Interval

$$\sum_{j=1}^{n} (BDI.c_{(PDOE)j} + c_{(OPER)j}).X_{(PRD)j} -$$

$$CB - SEC_{(SALE)} - SEC_{(ACQ)} - \sum_{j=1}^{n} sp_j.X_{(SALE)j} +$$

$$+ d^-_{BDI} - d^+_{BDI} = 0$$

Accounts Receivable Turnover

$$\sum_{j=1}^{n} (sp_j - ARTR.AR_j).X_{(SALE)j} \quad + d^-_{ARTR} - d^+_{ARTR} = \emptyset$$

Asset Utilisation

$$(1 - tax) \sum_{j=1}^{n} gp_j.X_{(SALE)j} + d^-_{EPR} - d^+_{EPR} = EPR.TASS$$

Return on Capital

$$2(1-tax).\sum_{j=1}^{n} gp_j.X_{(SALE)j} - (1+c_{RET}).RET -$$

$$(1+c_{CDIV}).CDIV - (1+c_{SDIV}).SDIV +$$

$$+ d^-_{ROC} - d^+_{ROC} = ROC.(LB_{\emptyset} + EQ_{\emptyset})$$

New Capitalisation

$$\sum_{j=1}^{n} cc_{(NEW)j}.X_{(PRD)j} - RET - SEC_{(ACQ)} - SACQ +$$

$$+ d^-_{NEWC} - d^+_{NEWC} = \emptyset$$

New Investment Decision-Criterion

$$
\begin{aligned}
&- (1+c_{EQ}).EQ - (1+c_{LB}).LB - (1+c_{MB}).MB - (1+c_{SB}).SB - \\
&(1+c_{CB}).CB - (1+c_{SEC-}).SEC_{(SALE)} - (1+c_{RET}).RET + \\
&(1+c_{SEC+}).SEC_{(ACQ)} + (1+c_{SACQ}).SACQ + \\
&TAPB(1-tax).\sum_{j=1}^{n} gp_j \frac{(1+r_{gj})^{TAPB_j}}{TAPB_j} . X_{(SALE)j} + \\
&\qquad\qquad d^-_{TAPB} - d^+_{TAPB} = 0
\end{aligned}
$$

Fixed Charges Earned

$$
\begin{aligned}
&\sum_{j=1}^{n} gp_{(less\ interest)j} . X_{(SALE)j} + \\
&\qquad d^-_{FCER} - d^+_{FCER} = FCER.[INT + RPAYM.(\frac{1}{1-tax})]
\end{aligned}
$$

Total Capitalisation Value

$$
\begin{aligned}
&CB + SEC_{(SALE)} + \sum_{R=1}^{NRC} \sum_{j=1}^{n} cc_{Rj}.X_{(PRD)j} + \\
&(1-tax).\sum_{j=1}^{n} gp_j.X_{(SALE)j} + RET + SDIV + \\
&\qquad + SEC_{(ACQ)} + SACQ + d^-_{VCAP} - d^+_{VCAP} = VCAP
\end{aligned}
$$

where

$X_{(\ldots)j} \geqslant \emptyset$ $\qquad\qquad d^+, d^- \geqslant \emptyset$

n - number of product variants

$X_{(..)j}$ - quantity of product j to manufacture, to sell, or to hold in inventory

$c_{(..)j}$ - unit cost incurred for product output j

$C_{(..)}$ - target value of total cost

$Q_{(..)}$ - target value of, or maximum capacity for, product outputs during activity (..)

$REQ_{(INVE)j}$ - average annual requirement (demand) for item j in inventory

$q_{(INVE)j}$ - average annual volume of item j held as stock

$TC_{(INVE)j}$ - unit total holding cost for item j in stock

$P_{(INVE)j}$ - ordering cost (per order) of item j

W_b, W_m - idle capacity of product activity centres b and m, respectively, where b is the base centre (that is, upon which workload balancing is based) and m is any other centre

cc_{Rj} - capitalised cost of resource R per unit of weighted potential capacity for item j in the organisation as a whole

CC_R - target capitalisation cost for resource R

DOL - specified degree of operating leverage

BDI - specified basic defensive-assets interval

$c_{(PDOE)j}$ - projected daily operating expenditure per unit output of item j

CB - required cash balance

$SEC_{(SALE)}$, $SEC_{(ACQ)}$ - number of security units to sell, and to acquire, respectively

sp_j - unit selling price of item j

ARTR - accounts receivable turnover ratio, specified by management, for the organisation as a whole

AR_j - average annual accounts receivable per unit of item j

gp_j - gross profit per unit of item j

EPR - earning power ratio desired by management

TASS - current worth of total assets

RET - amount of capital to retain for internal use

CDIV, SDIV - cash and stock dividends payable, respectively

ROC - desired rate of return on capital

$cc_{(NEW)j}$ - capitalised cost of new investments per unit of their weighted potential capacity for item j

SACQ - number of outside stocks to acquire

c_{EQ}, $c_{.B}$ - cost of equity and bond capitals, respectively

EQ, ..B - amount of equity and bond capitals to seek

$EQ_{\emptyset}$, $..B_{\emptyset}$ - amounts of equity and bond capitals, respectively, that are already in the capital structure

TAPB - specified time-adjusted payback period for the organisation's investments in general

$TAPB_j$ - time-adjusted payback for individual project j

r_{gj} - expected rate of earnings-growth for project j

FCER - desired fixed charges earned ratio

INT - total interest payable

RPAYM - tota principal repayment

NRC - total number of resource-clusters (parameters) in the rows of the Interaction Tableau

VCAP - capitalisation value of the organisation

d^-, d^+ - under & over-achievement deviational variables for the goal constraints

w_{zk} - differential weights for the kth deviational variable in priority z

P_z - priority z with the associated weight of 1.

The above formulation highlights the necessity of an in-depth consideration of logico-mathematical modelling for multi-criteria decision-making which was the subject of detailed discussion in Chapters Five and Six. Presently, it is necessary to point out how such a formulation tackles the main problems associated with the usage of the types of model discussed earlier in Section 4.2

The horizon problem is tackled in that the capitalisation model necessitates that the mean time between model-runs be equal to the interval between capital budget submissions or the interval between new major project considerations - whichever is shorter. However, a more realistic way to tackle this problem is to derive the viability planning horizon (VPH) through an analysis of those factors that normally influence the organisation's long-term plans. The process of estimating the desirable VPH for any organisation involves the development of a table of possible long-term horizon factors, covering various aspects (for example, political, social, economical, legal, geographical, demographic, technological advancement, etcetera). Such a table is presented below as Table 7.2

Table 7.2: Desirable Viability Planning Horizon Estimation

HEF_f	p_f	HAB_f	$p_f.HAB_f$
Political:			
Social:			
Economic:			
Legal:			
Geographical:			
Demographic:			
Industrial:			

In the above table, the following notation is used:

HEF_f denotes the f-th Horizon Estimation Factor

p_f - the factor relevance (as perceived by management)

HAB_f - the perceived Horizon of Acceptable Bias

$p_f.HAB_f$ - the required Horizon, solely due to factor f.

In order to further elaborate the above table, the following sub-group of factors may be used:

Political	- political stability,
	- constitutional changes
Social	- gross domestic product,
	- physical quality of life (PQLI),
	- consumer characteristics
Economic	- energy policy,
	- government fiscal policy,
	- currency strength,
	- foreign exchange control
Legal	- union strategy,
	- government policy on foreign investments,
	- profit repatriation policy,
	- customs protection,
	- inland revenue policy
Geographical	- township development,
	- transportation network,
	- telecommunications development
Demographic	- dependence ratio,
	- ageing index
Industrial	- mechanisation,
	- automation,
	- technology

For each factor, anticipated durations within which deviations of the factor from expected trend are acceptable (and/or are expected to be relatively low), have to be obtained and also the perceived significance of each factor's effect on the organisation's long-term planning horizon. Thus, the required maximum planning horizon (RMPH) can be obtained as follows:

$$RMPH = \sum_{f=1}^{N_f} p_f . HAB_f; \qquad \sum_{f=1}^{N_f} p_f = 1$$

where, N_f represents the number of horizon estimation factors (usually less than 20) considered to be an exhaustive set, and

p_f - the weighting, reflecting the anticipated importance of factor f.

The viability planning horizon (VPH) has to be taken as:

$$RMPH \geqslant VPH \geqslant \frac{1}{2} RMPH$$

The reason for this is that since short-term plans usually cover involvements of up to 1 year, and medium-term plans pertain to involvements within 1-3 years, restricting the VPH not to be less than half the horizon estimate (derived in the above formulation) implies the assurance of a period of not less than 18 months. This allows the organisation not only to be in a position of experiencing complete behavioural cycles of most short and medium term environmental factors, but also to guarantee adequate coverage of all obligations at least in the short and medium-terms, thereby obviating any dissolution risks. In many organisations, attempts to tackle these risks have been only through consideration of indicators such as the basic defensive interval ratio and the interest coverage ratio. However, each of these indicators has its shortcomings since all of them are based only on quantitative responses exercised through physical resources within the organisation. The introduction of the VPH, on the other hand, brings into focus the necessity to complement quantitative responses with qualitative ones (exercised to determine the scope of anticipated long-term problems and to give direction to resource utilisation within as well as outside the organisation). The use of VPH may be argued to be inappropriate especially when the financially acceptable life durations of the different sub-systems do not correspond with the considered long-term planning horizon for the organisation. However, the introduction of the capitalisation model nullifies this argument since each resource group considered has its service life contributions to the cost-structure incorporated on an equivalent scale into the present state of affairs of the organisation. Moreover, such arguments mostly apply to cases where the organisation's chosen horizon is dependent more upon political considerations than upon socio-economic or consumer market interactions and/or intra-sectoral development considerations. Even then, the usage of factor relevance during VPH estimation takes care of such cases.

It should be emphasized that what is of most concern for VPH estimation is not the set of particular levels of specific horizon estimation factors (HEF), but the expectation of significant changes in them. Hence, this approach essentially serves as a means of identifying certain changes in the environment which should make the organisation aware of the need to change the planning horizons and update plans accordingly.

The Hirshleifer paradox is tackled here by emphasizing the desirability of using the external cost of capital.
Firstly, the implied cost of capital is derived for the organisation's shareholders and this is then used to estimate the expected value of the organisation that ought to be used as the target value for the total capitalisation constraint within the synergic package.
Secondly, the organisation's weighted average cost of capital is derived and then used in the capitalisation model.
Finally, the cost of capital for each capital category (input or output) is derived and then used as the coefficient for the corresponding parameter in the viability planning model.

The above procedure for resolving the Hirshleifer paradox is in conformity with Elton's (1970) viewpoint, which maintains that under capital rationing (a common situation), the financial market (lending-borrowing) curve does not exist because the firm cannot reach it - and hence, the interest rate representing the trade-off of consumption between any two periods has to be determined by the stockholders' desires, which are based on their time-preference utility of receiving dividends at any particular time.

Of course, the derivation of the costs of capital for the various capital input and output categories has to be looked at in the context of viability planning. This is why a detailed consideration has been given to this aspect in Chapter Three.

The problem of consistency relates to the specification of the objectives but, more importantly, to the setting of priorities and evaluation of trade-offs between them. These are problems which are the consequence of the existence of multiple objectives and, hence, are reserved for consideration during the discussion of multiple criteria decision-making modelling in the next chapter.

5.4 Connective Summary

Conventional financial planning models are based on a type of organisational valuation which is in conformity with the organisation's need of the capital market (that is, market share price) rather than the total environment's need of the organisation (that is, the value of the organisation to itself). This has been discussed in detail in Chapter Four. In this Chapter, however, a major point is that none of the models discussed earlier has been directed towards the fulfilment of the behavioural-considerations-goal, whose emphasis is essentially on satisficing rather than optimising.

Further, the problems of project interdependencies and horizon valuations, and also the Hirshleifer paradox have been highlighted to be a consequence of the impracticality of the results that would arise from using such models. The viability planning model has been shown not only to be capable of tackling all these problematic issues, but also to essentially bring into focus the relevance of the capitalisation model (sometimes called the capitalised-cost model in this research) and those parameters which constitute the core of survivability of any organisation (that is, the synergic package).

The problems of uncertainties and inconsistencies of decision-making however, are not so much a consequence of the limited understanding of economic and systems concepts in organisational planning as they are a consequence of man's 'bounded rationality', limited pace of response to environmental influences, non-objective behaviour, and finally, the temporal heterogeneity of individual utility characteristics. These aspects of decision-making are bound to have the most profound effect on any organisation through its decision-makers' perception of the synergic package characteristics, since the latter form the basis for policy formulation and implementation in the organisation. This has been shown, in this chapter, as the major reason why organisational viability has to be recognised as a multi-dimensional problematic issue. The detailed consideration given to the 'state of the art' of multiple criteria decision-making modelling was essentially to study how best any viability planning model can be made to adequately enhance management's capability to cope with such complexities, thereby making such models more acceptable to the intended end-users.

CHAPTER EIGHT

A CASE STUDY:

VIABILITY PLANNING FOR A HOLDING COMPANY

8.1 General Information

8.1.1 Brief Information on the Holding Company

Rubery Owen Holdings Limited is the central Holding Company, based in the West Midlands, for a large group of privately-owned engineering companies in the United Kingdom. The organisational structure of ROH Ltd., indicating the entire group of companies, is presented in Appendix 2.1. The companies are split into groups, depending on product-type and market supplied. The groups, in most cases, hold the whole of the issued share capital of the individual companies, and the latter are in most cases comprised of operationally-autonomous subsidiary works. The individual companies range from fewer than 100 employees in size to nearly 2000. The total number of employees (in 1980/81) was about 6000 in U.K. and about 2000 overseas. The average annual turnover is about £130M, 1980 estimates being about £120M for U.K. and about £10M overseas. Major ROH Ltd. customers belong to the automotive, agricultural and general engineering industries - in fact, about 30-40% of ROH Ltd.'s products go to the automotive industry.

8.1.2 Aston Management Centre's Involvement

Early in May, 1980, an introductory meeting was arranged between the University of Aston Management Centre and the Planning and Financial Departments of ROH Ltd. This was initiated through the Management Centre's scheme for promoting project opportunities with decision-makers in various organisations. In the course of the discussion, the ROH team indicated that they felt the need for an Operational Research study of the system of project appraisal and review within the organisation. There was a definite desire to develop a system such that subsequent feed-back information could improve the chances of optimising the benefits from investments made and also improve the chances of keeping the implementation of plans well under control. A particular project suggested was the investment to be made on new automatic boltmakers for RO (Moxley) Ltd., since the ROH team felt that there was sufficient relevant data to make such an exercise worthwhile.

8.1.3 Aim and Outline of the Study

The study had two major aims. In the first instance, the bolt-making project had to be appraised on the basis of its potential value to the subsidiary concerned and also to the holding company as a whole. Secondly, a system had to be developed to guide the appraisal of future projects before final approval, and also to guide subsequent reviews after the approval. Such a system would, hence, ensure optimum co-ordination and control during as well as after project implementation.

In this chapter, the first aspect of the study is focused on the relevant environment of RO Fasteners Ltd., which holds the whole of the issued share capital of RO (Moxley). This includes a study of the investors' requirements for RO (Moxley) and the degree of conformity with the pre-requisite for viability within the environment. It is envisaged that this first aspect should be of considerable help in understanding background details of the bolt-makers' project and the prevailing practice on project development within ROH. Another identifiable aspect of the study is that which concerns 'designing' a desirable future for RO (Moxley) through an analysis of the company's performance especially for the few years up to 1978/79 (around which time the implementation of the bolt-makers' project started). Finally, there is the multiple criteria decision-making aspect of the study. This aspect has to be initiated as an interactive plan not only for approximating the design as closely as possible to reality, but also for establishing the basis for policy formulation on investments by the holding company.

8.2 Total Environment Considerations

8.2.1 Product Identification and Market Supplied

The major products of industrial fasteners companies are of the screw family. These products differ in length, diameter, type of head, number of threads per unit length, type of thread, type of finish, and type of material. Any plant manufacturing them therefore usually has a large number of fairly similar machines, turning out different kinds of screws, bolts, etc. For products that are commonly used, several machines are usually kept busy continuously, but for others, the production rates may exceed the sales rates, and it will be necessary to manufacture in batches, with several such products sharing a group of machines so that the machines and their operators have more work to do when each batch is finished.

Depending on the size range as well as on the quality required, manufacturing plants may be grouped (for organisational purposes) such that it is not difficult to specify the potential plant capacity and the market segment each manufacturing plant may concentrate upon. An example of such grouping was Nuts and Bolts (Darlaston) Ltd. as distinct from RO (Moxley). Both companies were in the Fasteners Group of ROH, but while the first manufactured mainly hot formed bolts and nuts, especially in large sizes up to M48, the second manufactured mainly cold formed smaller sized screws and bolts.

Products of the screw family are usually manufactured by means of a series of operations on a length of wire-rod, usually purchased in coiled or bale forms from steel producers. The wire-rod is cut into short pieces with a head stamped on one head of every piece by machines called headers. The heads are trimmed at the trimming machines and some slot or other fitting may be made for ease of product use later. On the opposite end, threads are formed at the threading machines, and pointed at the pointing machines. The processes of general machining, heat treatment, etc., follow after the pointing. There is some flexibility in the choice of the type of machines used, and in the sequence of these operations, but at any one time, each machine in the same technological flow must be set accurately for the same given size and type of screw, bolt, etc as all the other active resources in the particular technological flow.

Generally, the market supplied by the Fasteners Group of ROH involves passenger car manufacturers, commercial vehicle manufacturers, manufacturers of agricultural and construction equipment, and various stockholders. All these manufacturers belong to the metal processing and engineering industries, although product specialisation has led to their attainment of somewhat different identities.

8.2.2 Matching Marketing Strategy with Demand Estimation

Having pointed out the particular industries involved, a better understanding of the situation can be achieved by analysing the nature of stock control accorded the screw family in these user-industries. In order to establish a comprehensive overall stocking policy, most organisations group items using some measure or criterion of importance. A general practice - elaborated by Lewis, 1970 - is to group stocked items on the basis of their relative importance (for example, annual usage value and turnover share) into three categories A, B and C. Category A items are usually valuable items, making up about 20% of total items but representing up to 80% of the turnover. For these items, a high degree of stock control is vital and the tendency is therefore to implement inventory control policies that involve fairly sophisticated methods of forecasting with some form of demand monitoring - Harrison & Davies (1964), Trigg (1964). Category B items are medium-cost items, making up about 15% of the total items and representing about 15% of the turnover. The inventory control policy here is most likely to be slightly less strict and therefore may be combined with adaptive response techniques for forecast monitoring. Category C, on the other hand, are the large majority of items representing relatively little value. The screw family belongs to this category, and usually one of the simplest forms of stock control (such as the 'two-bin' method) is used for them in the user-industries, thereby ensuring a reasonable degree of control with a minimum of record-keeping. In fact, if space allows, a degree of overstocking can generally be acceptable, simply because of the relative cheapness of the items and also in order to reduce the probability of stockouts. For screws, bolts, etc., therefore, the user-industries do not usually update stock control parameters in line with forecasts, since forecasts are not generally made for them. Simple annual updating is therefore more usual, and in fact, even the user-industries' auditors generally accept limited sampling as a method of assessing the 'C' items for audit purposes.

The simplicity of stock control of screw-family products in the user-industries is undoubtedly a great contrast to the complexities of demand estimation by fasteners manufacturers such as RO (Moxley). Furthermore, these manufacturers experience considerable market segmentation due to product specialisation - which may, indeed, not be beneficial on a long term basis in a highly competitive market.

RO (Moxley) had been practising concentrated marketing in order to keep costs moderate. Promotional activities were based on personal selling, with the sales force kept low to such an extent that the market exposure of the products had remained selective rather than intensive. Coupled with all these was the fact that demand estimation in the company had always been done on a 'soft' forecasting basis - a practice developed through, and relying on, years of experience but not without considerable degrees of bias. All these had perhaps been the main causes of serious handicaps such as high risks due to the company's future being tied to a few segments.

A notable aspect was that the products of RO (Moxley) were not entirely homogeneous - the relevant market was only homogeneous on the standard products but heterogeneous on the 'specials'. Further, the company carried its marketing responsibilities itself and did not hold stocks, due to limited resources. This had made the production function directly (and almost bufferlessly) tied to marketing performance. Hence at this stage, a fair suspicion (from the researcher's viewpoint) was that investments in production machinery (such as the bolt-makers project) were more likely to be based on sub-optimisation (that is, optimisation of the marketing function) rather than overall optimisation in the interest of the organisation as a business entity.

8.2.3 Performance Statistics and Investors' Requirements

The investors' requirements for all the constituent companies were laid down by ROH's Board, and were in the form of financial performance statistics which reflected the corporate policy of the whole organisation. For RO (Moxley), the requirements were grouped into operating and working capital statistics. The specified desirable levels were as follows:

- Operating Statistics

Return on Capital	25%
Return on Sales	8%
Sales per Capital Employed	3.1

- Working Capital Statistics

External Debtors to Sales	2.2 monthly sales
Stock to Sales	2.0 monthly sales

There was also the directive that unless an acceptable return on invested capital was achieved, capital expenditure had to be limited to the amount of the annual depreciation.

The investors' requirements mentioned above are indicative of ROH's policy of profit maximisation. However, most of the factors were based on the sales turnover, and this would not necessarily give good indications of desirable performance levels. Sizer (1976) emphasizes that increased sales volume, rising absolute profits, and a satisfactory profit/sales ratio are at best short-term indicators of successful growth, and without additional information must be viewed as such. This viewpoint would be supported by most business analysts. Thus, it should be said that the effects of any projects implemented by RO (Moxley) could not be evaluated realistically merely through changes in the above statistics. In the long run, increased sales volume might prove a deceptive indicator of success if there was not a proper return (with a rate higher than that required by the market) on the capital necessary to support the sales.

8.3 The Holding Company's Project Considerations

8.3.1 Project Types and Information Flow

The types of project of relevance to the subsidiaries were categorised by ROH as follows:

- replacement of equipment
- modernisation of plant
- expansion of existing facilities, land and equipment
- change of technology due to obsolescence or high running costs
- upgrading of technological processes in conformity with either government directive or industrial standards
- purchase of facilities in order to obviate the opportunity costs of the same being utilised by competitors
- re-siting of facilities.

The information flow for consideration of projects in ROH is shown in Appendix 2.2. The situation was that the preparation of capital budgets for the various subsidiary groups was usually completed by early June so that by September they would have been accepted or amended. For any project to be included in the budget therefore, the proposal would have been initiated by the Works Committee of the sub-subsidiary company. If considered necessary, the proposals were passed on to the subsidiary group board, which included all worthy proposals in the capital budget submissions, having already classified them 'must' or 'desirable'. At the capital budget submissions (CBS), the projects were either approved in principle or were declined and classified as 'deferrable' projects. Generally, projects costing below £10,000 were completely handled at the subsidiary group level, while any projects above that amount were forwarded to ROH. These projects were presented to ROH on 'capital expenditure authorisation' (CEA) forms. If the cost of any project was within the range £10,000-50,000, approval of the ROH Special Sub-Committee would have to be obtained. For projects above £50,000 however, this committee only had to appraise the proposals and give recommendations, while final approval had to be obtained on presenting the project to the ROH Board. Undoubtedly, the sole responsibility for the appraisal of projects for approval rested with the Group Financial Director, who was the ROH Executive on the Special Sub-Committee. He had to take decisions on whether or not it was actually necessary to consult the Commercial Department (mainly involved with marketing), the RO Site Services (mainly involved with engineering responsibilities) or any other department.

8.3.2 Details of the bolt-making project

In early 1977, among the list of deferrable projects of ROH was the replacement of the ageing plant machinery at RO (Moxley), a company within the group of RO Fasteners Ltd. The problems here had been linked with consistently low demand to such an extent that the Moxley plant was being rendered almost profitless. In fact, the plant had only been keeping its viability by its being kept self-contained as far as processing is concerned - that is, processes such as phosphating, electro-plating, wire drawing and heat treatment had made the plant almost totally integrated (unlike its competitors) in satisfying the demand especially from the major user-industry, automotive. Another problem was that the environment was one of recession, and this is not usually a favourable climate for implementing any policy for purchase of new plant especially when demand is not encouraging.

The British government, in September 1977, announced an initial allocation of £100M to a new Selective Investment Scheme (SIS) to promote investment projects (worth not less than £0.5M) which would, through improved performance, yield significant benefits to the nation's economy. Another scheme was the Products and Process Development Scheme (PPDS), which offered support for projects costing between £0.25-1M for the development of new products and processes in manufacturing industries within the U.K. The SIS was in the form of interest-relief grants which would usually be rather lower than the grants under the industry schemes normally available. The PPDS grants could be as much as 25% of eligible costs or, as an alternative, a shared cost contract where the government could provide up to 50% of costs in return for a levy (that could be up to 10%) on the commercial sales. These two schemes, together with the modernisation policies of competitors such as GKN, and also Ford's construction of a new engine plant at Bridgend in South Wales, offered sufficient incentive for ROH to approve the implementation of the bolt-makers project for RO (Moxley) before the end of that year.

By early 1978, the modernisation project was embarked upon, and the new machinery required comprised two boltmakers (each being a combined bolt-making unit), a wire drawing bull block with coil-carrier and one hardening and tempering furnace. This equipment was anticipated to guarantee additional output through increased productivity, fewer maintenance problems, better customer-service (which had slumped for the past three years) and, finally, through higher machine utilisation on production of special products not totally covered by competitors. The total cost, including working capital increase, was about £703,000 which therefore made it eligible for the SIS and PPDS grants. The schemes were followed up, and by May 1978, the Department of Industry had approved an interest-relief grant of £129,150 for the Moxley project. The project implementation had been one of parallel utilisation of both old and new facilities such that the old ones could be gradually phased out.

The whole range of new plant machinery had not been completely installed by early 1980, since the wire drawing bull block and the hardening and tempering furnace still had to be acquired. However, the bolt-makers had been commissioned. The lease details are presented in Appendix 2.6.

Although the total amount spent on the project by early 1980 was about £0.6M (which was not yet the total capital requirement), the financing of the project could be considered successful, since all the SIS-granted amount had been received by then. However, the project had been poorly implemented since the boltmakers were being grossly underutilised. This could be attributed to the highly uncertain market situation, prevailing strength of pound sterling, high interest rates, and also increasing lack of enthusiasm in new investments generally. The problem could also be attributed to inappropriate workload distribution which would otherwise have ensured that the new technology boltmakers gradually phased out the old technology throughout the plant.

8.3.3 Operational Considerations at the Subsidiary Company

A list of relevant cost centres and a Machine-Hours Rates Report, prepared for RO (Moxley), is presented in Appendix 2.3. The cost distribution indicated therein was typical of the focus of operational considerations in the company.

However, capacity planning recommendations from the ROH Group Planning Director had considerable weight in the setting of production targets. At that time, the recommendations for RO (Moxley) were that in relation to a sales/production target of 26 tons per day, the following load distribution had to be aimed at:

- 18 tons per day from 2-blow headers (about 10.3 tpd of PL5 standard preferred items, about 2.5 tpd of PL5 standard non-preferred items, and about 5.2 tpd of other various non-standard items - especially on length)
- 4 tons per day from the Malmedie QPB-20 for simple specials such as drilled bolts, patched bolts, ground bolts, etc.

- 4 tons per day from the proposed bolt-makers (BMV3 and BMV4) for complex specials of the 'Perkins/GKN' type such as flange bolts, 12-point-place bolts, special head form, Con Rod bolts, main bearing bolts, wheel bolts, etc.

In general, machines were restricted either due to length limitations or die specifications. Nevertheless, apart from the above-mentioned specified operating targets, it was also desirable to stress the production of bolts in alloy steels and the high-quality heat treatment of type 10 Boron bolts. These additional operating objectives were to reduce the dependence on standard preferred items since these specially treated bolts were not usually readily available in the general stockholders' market, where an average of 7-8% of Moxley Works' sales was usually covered.

8.4 Problem Analysis and Results for the Subsidiary Company

Concentrating on RO (Moxley), the management expected a re-appraisal of the bolt-making project through the application of the viability planning concept.

Financial management theory (Bolten, 1976) asserts that the first decision criterion in any project appraisal system should involve whether or not the projects fall within an acceptable 'frontier level' on the 'indifference curve' of the particular company concerned. In particular, if the risk-values of anticipated projects were plotted against the expected returns, the resulting curve would be the 'efficiency frontier', while if the utility values were plotted against the frequency of expected returns, the 'indifference curve' would be obtained. However, for the bolt-making project, using such a criterion was irrelevant since the Holding Company had the essential motive of seizing the opportunity of a good business-financing scheme introduced by the Government and on which there was a time limit as well as scale and time-advancement requirements.

The application of the viability planning concept to the modernisation situation in RO (Moxley) therefore had to start with the identification of the capital and operational efficiency parameters, the salient features of which were explained in Chapters Four and Seven. During a previously arranged preliminary study (Adeogba, 1980), operating and working capital statistics of

RO (Moxley) were collected for the period 1969-78, and conventional appraisal parameters were analysed for the bolt-making project. Taking 1978 as the base year (since the first bolt-maker, BMV4, was acquired that year), deviations of performance statistics from the desired levels were derived for the other years. The analysis was done through a simple program, prepared for use with the PROSPER (PROfit Simulation, Planning and Evaluation of Risk) software package on the University's ICL 1904S computer. The operation-tree flowchart of the program is given in Appendix 2.4. The result of the preliminary study was used in the present study to determine the desirable levels of the performance statistics required in the viability planning application.

For cost of capital and valuation considerations, it was considered more appropriate to use a combination of five performance statistics of relevance to RO (Moxley)'s management, and which had to be selected from those analysed with the PROSPER software package. Of particular concern to the management of RO (Moxley) were the parameters in Table 8.1 below, since each one of them was perceived to reflect an element of business risk in a specific way. For example, the operating profit margin was perceived to be indicative of the efficiency with which management not only manufactured the product but also sold and distributed it, while the return on capital was perceived to be indicative of how effectively management had selected rewarding investments for the funds available to the organisation. The data obtained are presented in Table 8.1 below.

Table 8.1

Cost of Capital and Valuation Considerations for RO (Moxley)

	W_{Yi}	Y_{GEi}	Y_{BEi}	Y_{GIi}	Y_{MIi}	Y_{BIi}	Y_{Oi}	K_{BRi}
DOL	0.15	4.0	8.0	5.0	6.0	10.0	10.02	1.0020
IC	0.2	10.0	2.5	6.0	5.5	2.5	4.42	0.8709
OPM	0.2	0.6	0.1	0.4	0.2	0.1	0.04	1.7600
ROC	0.3	0.35	0.15	0.25	0.15	0.2	0.19	1.2000
BDI	0.15	28	56	35	42	70	46.10	0.6586

DOL denotes the Degree of Operating Leverage,

IC - Interest Coverage Ratio,

OPM - Operating Profit Margin,

ROC - Return On Capital, and

BDI - Basic Defensive Interval, in days

Y_{GEi}, Y_{BEi} denote good and bad levels, respectively, of indicator i as they were perceived to apply for the economy as a whole during the period 1974-79

Y_{GIi}, Y_{MIi}, Y_{BIi} denote good, mean and bad levels, respectively, of indicator i as they were perceived to apply to the Industrial Fasteners sector of the economy during the same period

Y_{Oi} denotes average levels of indicator i obtained for RO (Moxley) for the period 1977-79, around which time the bolt-making project was embarked upon

W_{Yi} denotes the differential weights, $\Sigma W_{Yi}=1$, elicited from management as applicable to the efficiency parameters, and

the business risk coefficient, $K_{BRi} = \frac{Y_{GEi} - Y_{MIi}}{Y_{GEi} - Y_{BEi}} . (1 + \frac{Y_{GIi} - Y_{Oi}}{Y_{GIi} - Y_{BIi}})$

The prevailing corporation tax, t_c was taken as 0.52

The risk-free rate, R_f, assumed to be generally applicable during the period considered was 0.12, while the proportion of funds taken for investment by the government was assumed to be 0.5 (being an average of 0.35 for a conservative government, and 0.65 for a more liberal government). The assumption was based on the premise that governments usually finance investments either as a major component of public sector borrowing requirement (PSBR) or at the expense of the PSBR. The first case would normally be the liberal approach and so the real proportion would be less than 0.65, the reduction ensuing especially from the multiplier effect of new capital-intensive public projects. The second case, the conservative approach, would be to consider the PSBR and investments as direct competitors for funds - this would inadvertently increase the proportion of funds taken by the government for investments. Thus while the conservative approach would in theory be attached to an average of 0.35, in practice this proportion is higher. On the other hand, while the more liberal approach would in theory be attached to an average of 0.65, in practice the applicable proportion should be lower. Furthermore, since the proportion of funds taken for investment by the government is generally within the range (0,1), the sensitivity that can be associated with the choice of any particular value for this proportion is, in the final analysis, dependent on the width of the range $(1, \frac{1}{1-t_c})$, where t_c denotes the corporate tax. That is, the bigger the corporate tax, the wider the sensitivity range for attaching a particular value to the proportion of funds taken for investment by the government. With the above considerations in mind, it became reasonable to assume a value of 0.5 for this proportion.

The results obtained (Adeogba, 1980) from using the PROSPER package to analyse conventional project appraisal parameters for RO (Moxley) Ltd are elaborated below:

1) The Internal Rate of Return (IRR) was about 29-30% with a standard deviation of 3-4%. This was obtained from a simulation of 200 runs, and was considerably lower than the 49.5% estimated on the Capital Expenditure Authorisation (CEA) Forms for the bolt-making project.

2) The Net Present Value (NPV), obtained within a period of 15 years, was £973,197. The interest-free project cost was taken as the cost of the bolt-making machines plus working capital increase. The expected NPV became: £973,197-£474,968 = £498,229

Thus, the standardised value of the expected NPV

$$= \frac{\text{Zero - Expected NPV}}{\text{Standard Deviation of the Mean NPV}} = \frac{0 - 498229}{362960}$$

$$= -1.3727$$

On normal distribution tables, the percentage risk = 8.53

This means that based on the data available on the CEA Forms with some adjustments for inflation, wage-rise, price-rise and production volume-rise, the basic decision for approving the bolt-making project was to consider whether or not an expected NPV of £498,229 was worth 8.53% risk over a period of 15 years.

3) The Pay-back Period (PbP) obtained was between 6 and 7 years rather than the 3.6 years specified on the CEA Forms. The computer output (Adeogba, 1980) indicates that the cumulative profit-after-tax should become positive only in 1984. The

graphs of the cashflows and the cumulatives also give this indication.

The Time-adjusted Pay-back Period (TPbP) was not calculated since it was not considered necessary in this case, sufficient information having been obtained from the Pay-back period estimate. The basic principle however, would be to calculate the present value of the cashflows and use their cumulative value (rather than the cumulative value of the normal cashflows), which would result in a slightly longer period than the normal Pay-back Period.

4) The Marginal Rate (MR) obtained was an average of 26-27% with a standard deviation of 5-6%. This was obtained from a simulation of only 50 runs, since more runs would have meant more computer time than was available. This percentage obtained indicates what should be the targetted yearly average earning and/or paying rate for the desired IRR to be eventually achieved within the considered horizon.

In conformity with the viability planning concept,
the nominal interest rate, NIR (as explained in chapter three) = the social discount rate, SDR

$$= I_g.\frac{1 - k_{GC}.t_c}{1 - t_c} = 0.12\frac{1 - (.5)(.52)}{1 - (.52)} = (.12)(1.5417) = 0.185$$

The 'business risk', $BR = R_f \sum_{1}^{N_{Yi}} K_{BRi} \cdot W_{Yi}$

where $N_{Yi} = 5$, being the number of indicators selected.

That is,

$BR = (.12)[0.1503 + 0.1742 + 0.3520 + 0.3600 + 0.0988]$

$= (.12)(1.1353) = 0.1362$

The 'financial risk', $FR = R_f - EPR_{\emptyset}$

where $EPR_{\emptyset} = 0.08$, the average earning power ratio maintained by

RO (Moxley) during the period under consideration

That is,

$FR = 0.12 - 0.08 = 0.04$

The 'marketability risk' had to be taken as zero, since none of the shares of RO (Moxley) had ever been, or was ever anticipated to be, floated (all being 100% owned by ROH).

Therefore, the cost of capital for RO (Moxley):

$CC = NIR + BR + FR + MR$

$= 0.185 + 0.1362 + 0.04 + 0 = 0.3612 = 36.12\%$

This is within 1 standard deviation of the IRR (29-30%) obtained from the analysis done with the PROSPER package. Such a value for the cost of capital indicates that the bolt-making project had a poor chance of success even if the anticipated average demand could be satisfied. The value of any investment normally depends on the amount of investment made and the difference between the project's IRR and the market-required rate of return. It can therefore be said that apart from the amount of the government grant, the boltmakers really added nothing to the value of ROH, since the difference between the cost of capital and the IRR was negligible (only about 2%). With such a result, the rather high average DOL of 10.02 in 1977-79 would have made the project undesirable had it not been for the substantial government grant and the decision to lease instead of purchase. Indeed, the lease decision meant that if adequate operating earnings could not be maintained, the major concern should be whether or not the cost of lease-cancellation before the end of the primary period would be higher than the income already earned in the form of government grants.

It must also be mentioned that the zero marketability risk implied that bankruptcy costs were trivial for ROH, and hence, that no targetted optimal capital structure existed - that is, there was no targetted weighted average cost of capital that could be considered to be superimposed on projects by a debt-equity ratio acceptable to the shareholders. This would suggest that the investment and financing decisions for the bolt-maker project could be handled as if they were independent. However, the lease-decision would contradict this, since after all in a world of corporate taxes and VAT, the optimal capital structure would be 100% debt.

The Capitalised-cost Model of RO (Moxley) is presented in Appendix 2.7. The model was obtained by using a program, developed to extract, organise and convert the conventional cost-structure in the Machine-hours Rates report (Appendix 2.3), in the Summarised Trading Accounts and other management reports of the company. The program organised the data in the form of a preparatory table for subsequent use in the final capitalised-cost structure model. Twenty-four activity centres and six resource groups were identified.

During discussions about the major objectives for RO (Moxley), the aims expressed by the management were as follows in preference order:

- to stabilise the human capital of the company at a level which minimises the opportunity cost of retaining already developed skills within the company
- to strengthen and stabilise the asset base of the company so that after the recession bottomed out, the rate of earnings growth could be considerably elevated mainly through increase in the working capital rather than through substantial new capital investment

- to stabilise the level of consumables, since this has a direct effect on the level of profits
- to minimise operating costs, and
- to keep company operations at a level that conformed with ROH Ltd's long term plans.

From the above-specified aims, five priority functions were formulated for the viability planning model. They were in the form of minimisation of deviations from the desirable levels of the company's human resource, physical assets, capitalised-cost of consumables, operating costs and total machine-hours. In transforming the Interaction Tableau into a goal programming formulation, the decision variables were taken as the human resource requirements (in man-hours) at the different activity centres. This was mainly to enable running the model without having to impose any integer restrictions.

The management's priority preferences were not directly fed into the model. This was because the model normally commences with synergy-scenario probability assessment, the result of which serves as the basis for ranking the priorities - depending on the expected achievement level for synergy attributable to each priority. The model output is presented in Appendix 2.9.
The result of the decision-analysis aspect indicates that the logical conclusion from the management's understanding of environmental realities could only be to rank the priorities as follows:

Rank No.	Priority
1	Minimisation of operating costs
2	Stabilisation of physical asset base
3	Stabilisation of human capital
4	Stabilisation of consumable resources
5	Conformity with ROH Ltd's long term plans

From the above ranking, it is not difficult to realise the disparity between the aspirations and realistic expectations of the management in RO (Moxley). For example, while the management would ideally aim for human-capital stabilisation as the first priority, the model output indicated that management's feared expectations about the depressing market situation should compel them to aim at operating cost minimisation as the first priority. The model output however agreed with the least rank given to the objective of conforming with ROH's long-term plans. Indeed, the model output seemed to suggest that RO (Moxley) should be better-off in a much more autonomous relationship with ROH. This suggestion of encouraging a more decentralised structure for policy formulation within ROH would be perfectly logical since the subsidiary companies were too diversified for any coherent policy implementation to be achieved. However, the implications of this strategy on the capital structure of the holding company could lead to the selling-off of the majority shareholding of subsidiaries such as RO(M) if ROH was to remain a 'close' company.

The result of the multi-criteria decision-making aspect comprised compromise plans for the following two different situations:

(i) 'controlled-flexibility response' by the decision-maker, and

(ii) 'structured-indifference response'.

The first case was the plan in which the trade-offs between priorities were maximised or minimised (that is, the second method proposed in Chapter Six for deriving trade-off weights). The other case had the trade-offs on a uniform scale but equivalent to the extent to which each priority allowed all the goal-constraints to be satisfied (that is, the first method proposed in Chapter Six for deriving trade-off weights). A summary of the results obtained is presented in Table 8.2

In analysing Table 8.2, the implications for staffing were of utmost importance to the management - perhaps because of the expectation of continued recession. In order to study these implications, it was essential to consider the nature of staffing for the different activity centres in RO (Moxley). The company operated on single and double-shift bases for an annual average of 260 days, out of which an average of 30 days was assumed for holidays. Consequently, single-shift activity centres necessitated (260-30)x7=1610 man-hours per staff annually, while double-shift activity centres necessitated 3220 man-hours per staff annually. With this consideration in mind, Table 8.3 was prepared as a representation of Table 8.2 in terms of staffing requirement.

Table 8.2 Optimal man-hours from analysis of priorities

Activity Centres	Specified Objectives: Stabilisation of Human Capital	Stabilisation of Physical Asset-base	Stabilisation of Consumable Resources	Minimi-sation of Oper.Cost	Conform with ROH plans
3&4 BMV	12845.58	13854.37	13219.97	12792.21	13809.43
Finance	-	-	-	-	74019.72
Admin.	-	-	-	44731.54	-
Carriage	-	235.05	-	-	-
Maintenan.	22265.72	-	-	-	-
General	-	79922.77	80481.01	81476.85	80270.94
5/16 BMS	-	-	22774.59	-	-
QPB-20	5051.72	5051.72	2314.52	3764.06	-
Oth. Heads	136.32	-	-	136.32	136.32
Trimming	-	152496.51	-	-	28255.45
Threading	-	-	1103.51	-	-
Auto-Point	136587.58	-	-	-	-
Plating	15725.33	-	10209.84	17713.47	-
Wire Draw	-	15980.59	-	19114.84	-

Table 8.2 (continued)

Activity Centres	Compromise Plans		
	Controlled-flexibility Response		Structured-Indifference Response
	(Minimisation)	(Maximisation)	
3&4 BMV	13219.97	12792.21	12792.34
Finance	-	-	-
Admin.	-	44731.54	-
Carriage	-	-	-
Maintenan.	-	-	-
General	80481.01	81476.85	81563.85
5/16 BMS	22774.59	-	17138.20
QPB-20	2314.52	3764.06	2991.94
Oth. Heads	-	136.32	136.32
Trimming	-	-	-
Threading	1103.51	-	-
Auto-Point	-	-	-
Plating	10209.84	17713.47	17713.47
Wire Draw	-	19114.84	19114.84

Table 8.3 Optimal staffing requirement from analysis of priorities

Activity Centres	Specified Objectives: Stabilisation of Human Capital	Stabilisation of Physical Asset-base	Stabilisation of Consumable Resources	Minimisation of Oper.Cost	Conform with ROH plans
3&4 BMV	4	5	5	4	5
Finance	-	-	-	-	48
Admin.	-	-	-	29	-
Carriage	-	1	-	-	-
Maintenan.	7	-	-	-	-
General	-	25	25	26	25
5/16 BMS	-	-	7	-	-
QPB-20	2	2	1	1	-
Oth. Heads	1	-	-	1	1
Trimming	-	48	-	-	9
Threading	-	-	1	-	-
Auto-Point	43	-	-	-	-
Plating	5	-	3	6	-
Wire Draw	-	5	-	6	-

Table 8.3 (continued)

Activity Centres	Compromise Plans		
	Controlled-flexibility Response		Structured-Indifference Response
	(Minimisation)	(Maximisation)	
3&4 BMV	5	4	4
Finance	-	-	-
Admin.	-	29	-
Carriage	-	-	-
Maintenan.	-	-	-
General	25	26	26
5/16 BMS	7	-	6
QPB-20	1	1	1
Oth. Heads	-	1	1
Trimming	-	-	-
Threading	1	-	-
Auto-Point	-	-	-
Plating	3	6	6
Wire Draw	-	6	6

The following observations emerged from the model output illustrated in Tables 8.2 & 8.3:

- A distinctive feature of human capital stabilisation was the insistence on keeping maintenance staff, even if at a moderate level of 7. It was ROH's policy that major maintenance be carried out by RO Technical Services especially during the summer break, while other maintenance activities were usually scheduled within the available annual man-hours and carried out by skilled operating personnel at the subsidiaries. Thus it would seem that the objective of human capital stabilisation favoured the recruitment of the staff of RO Technical Services for major maintenance activities at RO (Moxley). However, the other objectives (and, indeed, the compromise plans) would not favour such an action - it would seem that the implication here would be to subcontract such services within or outside ROH.
- Another distinctive feature of human capital stabilisation was the upsurge in staffing for the auto-pointing activity centre. Since trimming, threading and auto-pointing could be done in a flowline with an equal spread of the capitalised cost, the upsurge could actually be spread over the three activity centres at an average staffing level of 15. Nevertheless, since these activities would only be needed as in the flowline for 'other headers', such a staffing level would still be too high for the 136.32 man-hours obtained for the 'other headers' activity centre. Consequently, it would be more appropriate to utilise these activity centres for outside sub-contracts,

perhaps even from other subsidiaries of ROH such as RO (Darlaston) - another member of the Fasteners Group of ROH.

- The objective of stabilising the physical asset-base would lead to operating plans, similar to those mentioned above for the trimming, threading and auto-pointing activity centres.
- The objective of stabilising the consumable resources had the common feature (with all the other objectives except human capital stabilisation) of increased staffing level for general works on single shift. This activity centre was for management services such as work study, operational planning, etc. Consequently, the increased staffing level indicated here would suggest a need for more efficient management services, perhaps through computerisation.
- The distinctive feature of operating cost minimisation was the upsurge in administrative activities. This would suggest the need for more effective information handling and hence, this objective seemed to indicate a widened scope for computerisation. The same could be said about the objective of conforming with ROH's long-term plans, which indicated an increased staffing level for financial activities.
- The 'controlled-flexibility response' compromise plan (with trade-off minimisation) was to stick to a single objective of stabilising the consumable resources. With trade-off maximisation, the compromise plan obtained was to uphold a single objective of operating cost minimisation. The compromise plan constituting a 'structured-indifference response' however, was to strike a balance between the other two compromise plans

by keeping the preparatory activities of wire-drawing and plating at the average staffing level of 6 while rendering non-optimal the administrative staffing level suggested in the 'controlled-flexibility response' compromise plan.

It should be pointed out that all the compromise plans favoured the bolt-making project. They also favoured a staffing level of 1 for the QPB-20 specials and an increase in general activities. Indeed, it should be emphasized that the model output seemed to indicate the need for:

(i) a total stoppage of the inch-products flowline,

(ii) a gradual phasing-out of the conventional flowline for metric products and

(iii) a cautious operating plan for the QPB-20.

The relevance of increased general activities could be seen in the fact that these activities were previously undertaken by ROH and RO (Fasteners) - that is, at the holding company level and the subsidiary group level. Consequently, the model output would seem to indicate the necessity to uphold a more autonomous status for RO (Moxley).

For determining the viability planning horizon (VPH) as explained in chapter three, the data and the results obtained are presented in Table 8.4

Table 8.4: Viability Planning Horizons for ROH and RO(Moxley)

Factors considered by the researcher as relevant and accepted by the management	Data for ROH		Data for RO(M)	
	Anticipated Significance p_f	Horizon of acceptable bias HAB_f	Anticipated Significance p_f	Horizon of acceptable bias HAB_f
Consumer Characteristics	0.2	4	0.3	2
Govt. Fiscal Policy	0.25	4	0.15	4
Currency Strength	0.25	2	0.15	5
Foreign Exchange Control	0.1	4	-	-
Automation	-	-	0.1	8
Technology	0.2	5	0.3	10
Required Max. Planning Horizon (RMPH)		3.7		5.75
Viability Planning Horizon, VPH		2		3

The VPH values obtained for ROH and RO(M) are suprising since they indicate that the Holding Company was planning for 2 years while the Subsidiary was planning for 3 years. It can be argued however that these values are reasonably matched, since they indicate that the holding company (which is closer to the financial market than the subsidiary) has a lead time of at least one year within which to modify the strategic plans of the organisation accordingly. This lead time is indeed the period for 'high-level tactical' planning at ROH in order to ensure strategic flexibility of long-term plans for the organisation. It should also be noted however, that the set of weights attached to the relevant factors for the subsidiary company is characteristically different from that for the holding company. For example, while government fiscal policy and the strength of £-sterling had the highest weights for ROH, consumer characteristics and technology had the highest weights for RO(M).

A point worth noting was that RO(M) management did not perceive any significant deviations from expected trends in automation and technology within the next eight and ten years respectively. This could be because it was felt that the cost of such changes for bolt-making processes would be unjustifiably high unless a consistent and considerably large demand could be assured - a situation which could not be realistically expected in a recessionary period.

It should also be mentioned that the implication of effectuating a more autonomous RO (Moxley) could be that the management would attach a zero weight to a factor like currency strength. The management of RO (Moxley) could also consider as relevant two types of technology instead of one - that is, technology pertaining to information handling and technology pertaining to manufacturing processes.

8.5 Problem Analysis and Results for the Holding Company

Concentrating on the Holding Company, the problems considered to be of interest were the development of the project-evaluation system and the application of the viability planning concept to the organisation's strategic decision-making.

On the issue of project evaluation, assuming that the bolt-making project was typical of projects from all ROH subsidiaries, it was considered that a simulation program should reveal whether or not complete and/or sufficient information was being communicated to ROH on projects, and which aspects of the present appraisal system needed modification or total reorganising. Such a program would need to be fed with the information on the Capital Expenditure Authorisation (CEA) Forms about the bolt-making project and also with information obtained from the management of RO (Moxley) about economic influences on the plant's operation.

In Appendix 2.2 is presented the information-flow normally used for projects in the organisation. A major problem, noticeable from the chart, was the absence of feed-back information about post-approval situations from the subsidiary group level upwards. Another major problem suspected was the possible 'bottleneck' at the Capital Budget Submissions, since the latter took place only once or twice a year and they were between different parties attempting to decide, within a limited period of time, enormously complex issues having wide ramifications for ROH.

The only data usually available for pre-approval appraisal were those in the CEA Forms, a sample of which is presented in Appendix 2.5 It can be seen that the relevant pages for appraisal purposes are 3 and 9 which are comprised of sections titled "justification summary", "evaluation" and "capital investment appraisal". Another sheet which could be of some relevance is sheet 8, titled "production/operation cost data". However, this was not usually completely filled in, perhaps because its relevance in post-approval review had never been stressed. Further, the only appraisal parameters used were the DCF rate of return, the Pay-back Period and the Added Output expressed as a percentage of the present capacity. These parameters, without doubt, are appropriate for organisations with profit-maximisation policies, but unless rightly determined and analysed, they may be very misleading - thereby making more likely either the implementation of projects that would otherwise be rejected or the rejection of policies that would otherwise be implemented. Furthermore, the organisation should not be expected to implement profit-maximisation policies all the time. Finally, it can be noticed that the CEA Form does not really have sufficient data that could help to appraise any project without the latter's isolation from the particular company's realities.

On the issue of viability planning, the accounting system at ROH had the capability to make readily available all the data required for developing those areas of the Interaction Tableau pertaining to the conventional cost-structure, the transformation characteristics and the synergic package. However, a major reorganisation of the accounting and administrative systems would be necessary in order to be able to rely on the system to provide the data required for developing the capitalised-cost structure model. Further, the organisation of the interface between ROH and its constituent companies was such that a realistic evaluation of the implied cost of capital for the Holding Company itself was virtually impossible with the existing system.

The reasons for the problems mentioned above are as follows:

- The heterogeneity of the constituent companies made the business risk so diverse that even an indicator such as Altman's Z-index (Bolten, 1976 and as explained in chapter three) would need to be used differently for each group of companies, each subsidiary company and even, in certain cases, each sub-subsidiary plant. To evaluate the business risk for the ROH from this, a weighted average should probably be the most realistic parameter to use - in which case, the management would have to give weights reflecting which industrial category they perceived each constituent company to belong to, and also reflecting the relevance of the constituent company to ROH as a whole. This itself was a task which the management would not necessarily be able to do without consultation with the 'pioneers' of the Holding Company - that is, the 'owner-family' of ROH.

- Evaluating the financial risk of ROH would involve considerable problems associated with economic and translation exposures since many of the constituent companies were outside the United Kingdom. Further, if the same procedure (as for the business risk) were to be used, weighting problems would similarly be encountered.
- The marketability risk could not be realistically evaluated with the prevailing equity capital composition. Being a 'close' company, although a legal status as a business entity was maintained, stock marketability was really dependent on the capital-mobility status of the 'owner-family' within the community rather than on the capital worth and dividend policy of the business entity.
- The problems about developing the capitalised-cost structure model of ROH were associated partly with the difficulties of evaluating the cost of capital, and partly - perhaps more importantly - with the problems of information handling. This was because more and better structured information about the resources was required to be transmitted between ROH and its constituent companies. Unfortunately however, the management information system being used was not capable of ensuring this, even with the leased UNIVAC computer operating at ROH headquarters at that time.

Notwithstanding the problems mentioned above, the problem of inconsistency in decision-making could still be tackled. From the discussion held with management staff at RO (Moxley) and ROH offices, relevant data on general organisational policy were elicited for use in testing the decision-analysis aspect of the viability planning modelling. The synergic package considered by the researcher to be relevant and sufficient consists of the 'basic defensive interval', the asset utilisation, the return on capital, the new-investment decision criterion, and the total capitalised value.

Due to the cost minimisation problem faced by management in ROH, the feeling was that maximising the BDI through minimising the daily operating expenditure was paramount to survival. The BDI was therefore used as the basis for eliciting the perception of management about the other synergic package parameters considered relevant.

" .... Using a scale of 0-100, how many points would you attach to the belief that:

(a) say, the BDI would reach the desired level?

(b) if the BDI's desired level was maintained, the desired level for say, Asset Utilisation would be maintained? .... "

These are the typical questions put to management during various discussions about the project-evaluation system development aspect of this study. Variants of the first question were developed by substituting the other selected parameters for BDI. Variants of the second question however, only involved substituting any of the other parameters (except BDI) for Asset Utilisation. The responses obtained on the average for each question were categorised as conservative, normal or optimistic. These were used (assuming a beta-distribution for the responses to determine the mean value to use) as input to the decision-analysis procedure of the viability planning model. The data file used is presented in Appendix 2.8, while the program flowchart is presented in Appendices 1.1

The computer output, presented in Appendix 2.9, includes the table upon which management reports on the decision analysis aspect should be based. The table, entitled 'status of optimal synergy-defining scenarios', indicates that according to ROH management's perception of operational and environmental realities, the only optimal scenarios that should be considered are as follows:

- p[BDI, AU, ROC, NINV, TCV]= 0.3167 (that is, the occurrence of a situation in which all the desired levels for the synergic package parameters could be achieved).
- p[$\overline{BDI}$, $\overline{AU}$, $\overline{ROC}$, $\overline{NINV}$, $\overline{TCV}$]= 0.2417 (none of the levels achieved).
- p[BDI, AU, $\overline{ROC}$, NINV, TCV]= 0.2000 (only the desired level of Return On Capital <u>not</u> achieved).
- p[$\overline{BDI}$, AU, $\overline{ROC}$, $\overline{NINV}$, $\overline{TCV}$]= 0.1083 (only the desired level of Asset Utilisation achieved).

- $p[B\bar{D}I, AU, R\bar{O}C, NINV, TCV]= 0.0750$

  (the desired levels of Basic Defensive Interval and Return On Capital <u>not</u> achieved).

- $p[B\bar{D}I, AU, R\bar{O}C, NINV, T\bar{C}V]= 0.0583$

  (the desired levels of Basic Defensive Interval, Return On Capital and Total Capitalised Value <u>not</u> achieved).

For the consideration of uncertainties, the probability assessment given by the model (for that optimal scenario having the maximum number of elements in its decision-set) was used to determine the robustness of the particular set of objectives being analysed. This probability assessment was taken as the most likely estimate in a beta-distribution, having at one extreme the optimistic occurrence certainty situation with probability estimate $p(.)=1$, while at the other extreme the pessimistic non-occurrence situation with probability estimate $p(\bar{.})=0$.
For both situations, (.) denotes the achievement of the desired levels of the elements in the synergy-scenario, while $(\bar{.})$ denotes the complement of (.)

Thus the expected robustness ROB_e of any considered set of objectives could be calculated as: $\frac{1 + 4(\text{prob. assessment}) + 0}{6}$

For RO (Moxley), the consideration of uncertainties yielded:

$$ROB_e = \frac{1 + 4(0.3167) + 0}{6} = 0.3778$$

For the operational feasibility considerations however, the model indicated that the objectives of labour stabilisation, asset-base stabilisation and operating cost minimisation would each achieve the desired level of only the New Investment parameter in the synergic package. This was not one of the optimal scenarios obtained during the consideration of uncertainties. Consequently, the associated robustness would be $\frac{1 + 0 + 0}{6} = 0.1667$

On the other hand, the other objectives (that is, stabilisation of consumables and conformity with ROH's plans) would each achieve none of the desired levels of the synergic package parameters. The associated robustness of this scenario would be

$$\frac{1 + 4(0.2417) + 0}{6} = 0.3278$$

Flexibility is generally obtained only at the expense of some deterioration in performance, or of some extra outlay of resources. In this case study, it would seem that the 'controlled-flexibility response' compromise plan favoured maximising the robustness of an optimal scenario even if the scenario had the least associated synergy achievement. If the robustness was minimised, this compromise plan favoured maximising synergy even if it would be at the expense of scenario optimality. The 'structured-indifference response' compromise plan favoured having an optimal scenario (in order to maximise achievable robustness) but also tried to achieve some synergy by minimising the underachievement of the desired level of New Investment in the synergic package parameters. In this way, the 'structured-indifference response' plan achieved a balance between the two variants of the 'controlled-flexibility response' compromise plan (that is, between maximisation and minimisation of trade-offs).

The above result ought to be verified as to its acceptability by management. Unfortunately however, this has not been possible, because major reorganisation has since been going on in ROH due to the prevailing economic recession which warranted the closure of many of the constituent companies. This is why the earlier results were not fed back. In fact, this had also contributed to the non-completion of the validation process of the viability planning model for ROH - which should have completed the project-evaluation system development. Nevertheless, it can be said that the model output on the decision-analysis aspect appears to be realistic. This is because events which, since then, have overtaken ROH confirm that none of the desired levels for the synergic package parameters has been achieved. Also, the compromise plan, involving minimisation of trade-offs, seemed to have been the one adhered to since no new investment was embarked upon and most of the old flow-lines (for standard inch and metric bolts) had been stopped. At that time, such a situation had a probability of only 0.2417 (a rather low figure but comparatively high if considered that it was quite close to the 0.3167 probability of occurrence for the reverse situation in which all the desired levels might be achieved).

The lesson that could be learnt from the model validation exercise is that it is vital to watch the probability assessments given by the model for any two directly contradicting scenarios. If the assessments are very close (as had happened in the ROH case), then it is fair to suggest that either the decision-makers have been too optimistic in their given estimates or the desired levels set for all the synergic package parameters have been, in reality, too tight for any 'robustness' to be expected of the decision-making process in the organisation concerned.

In choosing among the compromise plans, it could be learnt that robustness is associated with synergy scenario optimality from the viewpoint of how the management perceives uncertainties. On the other hand, from the viewpoint of operational feasibility, synergy achievement is dependent on the characteristic features of the organisation and the targets set by the management for the different resource groups.

A notable feature of the analysis is that robustness is, operationally, a relative rather than an absolute quantity. Thus a robustness score of a decision-set says little about whether or not that decision-set should be recommended by the analyst. What is meaningful is whether or not the particular decision-set asserts its superiority over an alternative decision-set with a different robustness score. Another feature of the analysis is that robustness is concerned as much with mixed-scanning, contextuating decisions as it is with flexibility. It is concerned with strategic flexibility - that is, the ability to take a variety of subsequent decisions which define different resource configurations for the organisation as a whole. This is quite different from tactical flexibility, which is the ability of the organisation (in its resource configurations at a point in time) to operate in a number of different modes. Indeed, strategic flexibility is the essence of achieving robustness in any decision-making for viability planning.

Finally, from the analysis of viability plannning in ROH and RO(M), it was realised that in general the more autonomous a company is, the more applicable the viability planning procedure. Since the autonomy of any business depends to a large extent on the nature of policy formulation, which in turn is usually dictated by the organisation's capital structure, the question of capital leverage has to be in the forefront. The issue is not just whether or not the economic value of equity of an organisation can be changed by changing its long-run capital structure. What is also involved is the effect of such changes on the organisation's decision-makers, whose expectations and aspirations about the organisation have to be fed into the viability planning model. Perhaps most important are the effects of such changes on the degree of homogeneity of the services rendered or products made by the organisation and also on the degree to which the perception of the policy implementers (about the organisation's characteristics and its environment) matches that of the policy formulators.

CHAPTER NINE

GENERAL CONCLUSIONS

The inadequacy of conventional appraisal techniques in organisational planning and in the monitoring of organisational performance cannot be over-emphasized. The tendency has always been to appraise individual projects in isolation from the normal flow of resources in the organisation, and/or to apply mathematical programming or simulation techniques for the tactical 'tuning' of projects with the flow of resources. This has led, on the one hand, to problems of business heterogeneity and sub-optimisation, and on the other hand, to problems of unjustifiable economy of scale and considerable insensitivity to dynamic environmental pressures. Many analysts and management theorists - for example, Drucker (1954), Sizer (1979), Weingartner (1963), Chambers (1971) - have been aware of this. However, attempts made so far to help decision-makers have been to develop models tackling specific functional areas rather than developing a framework for pragmatic analyses of decision-sets in an organisation as a whole. Such a framework is developed in this research as a planning concept termed 'viability planning'. It comprises a multi-objective decision-making modelling methodology which analyses not only apparent organisational characteristics but also the inherent capitalised-cost structure (termed the 'capitalisation model'), which serves as the basis for sustaining synergy and strategic flexibility in any organisation.

In developing the conceptual framework therefore, this research has been focused on financial management modelling and its integration with logico-mathematical models for organisational decision-making in general.

On the issue of financial management modelling, the simultaneous incorporation of investment and financing policies into a planning model had to be based not only on the assumptions underlying financial theoretical models (such as the capital asset pricing model, CAPM), but essentially on the relaxation of the assumptions by eliciting and assessing management perception of uncertainties in a decision-analysis framework. By using systems concepts to elaborate the inherent homeostatic, mediative and proactive processes of an organisation, it became apparent for example that the incorporation of uncertainty principally via a risk adjusted discount rate coupled with restrictions on the level of debt is, in fact, a simplification of the unanimity principle and which contradicts many of the assumptions of capital market theory. Such conventional practices place severe limitations on the validity of the conclusions to be drawn from current model-applications. This brought into focus the relevance of identifying in an organisation a synergic package, through which every encountered problem should always be related to the organisation's inherent objective, that of survival. It was shown that the cost of capital could be expressed in terms of the social discount rate, the risk-free rate (rate on gilt-edge securities), the earning power ratio, the prevailing stock market price and the Altman's Z-index (or any appropriate combination of performance statistics acceptable to relevant fund-parties). This derivation considered the nominal interest rate as a composite opportunity cost from the government's major sources of capital, and considered the systematic risk of securities as a function of the business, financial and marketability risks of the organisation relative to its environment (national or international).

In examining conventional financial planning models, it was understood that the bias of such models towards either a profit-maximisation or shareholder-wealth maximisation goal had been a consequence of the interpretation given to firm-viability by accountants, management and modellers alike. It was argued that the biased approach has made conventional financial planning models inadequate for tackling problems such as the limitations imposed by horizon truncation, the Hirshleifer paradox, the non-resolution of conflicts between organisational goals, the non-objective behaviour of decision-makers, and finally, the aggravation of inconsistencies in the decision-making process. These problems were tackled by the development of the Interaction Tableau, which (apart from the conventional cost-structure and transformation characteristics) essentially comprises the capitalised-cost structure and the synergic package. The 'interaction tableau' was used to develop the viability planning model, characterising the organisation and for which a viability planning horizon (VPH) has to be derived. The problem of inconsistencies however, could not be reflected in the Interaction

Tableau, nor could it be directly reflected in the viability planning model itself. This was considered to be a problem requiring the development of a methodology (for using the Interaction Tableau, and hence, for the model-application) based on multiple criteria decision-making techniques.

In examining the current 'state of the art' of multiple criteria decision-making modelling, it was argued that two extreme approaches have been the main solution concepts in the theory of multiple criteria decision-making, and that both of these approaches necessitate direct elicitation of preference and/or trade-off weights from the decision-maker. One extreme - the 'lexicographic optimum' concept - is the approach whereby the ranks and/or trade-off weights are taken to be sancrosant, while the other extreme - the 'Pareto optimum' concept - is the approach whereby the rank and trade-off weights become secondary issues after the primary concern of developing an appropriate utility function, incorporating all the decision criteria involved. Lexicographic optimisation can be seen in the context of those practical situations where policies are determined by making and refining decisions successively. Models in the 'pre-emptive' group were based on this concept - in that first, the most important objective is met, and then among the solutions which meet this objective, smaller sets are chosen, one at a time, to satisfy the other objectives in order of decreasing importance. Thus, this can be seen in the context of a 'top-down' approach in organisational decision-making whereby there is not much room for flexibility once the priority ranks have been established. Pareto-optimisation, on the other hand, is essentially to ensure maximum levels of benefits in any situation of competitive equilibrium. Consequently, what underlies this concept is the intention to find all non-dominated extreme point solutions in the quantitative analysis of any problem. In as much as, for each such solution, there exists a convex cone in the space that can be generated by a vector of weights ascribed to the different objectives, this concept is essentially to identify and characterise all the convex cones of this space. A filtering procedure is then needed in order to obtain the smallest number of convex cones which are necessary and sufficient to define an appropriate compromise solution. In this research, it was shown that models using this concept comprise the 'non-preemptive' group and essentially differ from each other in the weighted-vector cone contraction method. Since non-domination is itself a qualitative concept (meaning that a preferred group of solutions has been found in which to search for a decision), there is not much room for considering any alternative, albeit less-preferred, group of solutions when applying such models with directly specified preference and/or trade-off weights for the different objective functions.

On the issue of MCDM modelling, it was shown that three distinct phases of problem structuring have to be recognised. One phase is the situation when, at the early stages of problem analysis, the constraints are implicit while the outcomes of any analysis at that stage are stochastic. This is the phase when a decision analysis problem has to be tackled in order to determine the scenarios which constitute the appropriate criteria upon which further evaluation has to be based. The second phase is the situation when the constraints are explicit while the outcomes are stochastic. This is the phase during which not only are the criteria reviewed (in that goals may become objectives, and vice versa), but also ranks and trade-off weights are ascribed to the different objectives. The completion of this phase signifies that a proxy utility function has been obtained through which satisficing can be subsequently effectuated. The third and final phase is the situation when the constraints are explicit and the outcomes are relatively deterministic. This is the phase for satisficing to obtain desirable compromise solutions, constituting the 'controlled-flexibility response' and 'structured-indifference response' compromise plans. This phase is also, and perhaps more importantly, for robustness analysis in selecting which compromise plan to recommend and in assessing the appropriateness of the goals initially specified.

The concept of viability planning (VP) is particularly relevant in this framework, since VP addresses the pertinent issues faced by any decision-maker by identifying the core factors through which the decision-maker's intuition (about the levels of uncertainties as well as possible inconsistencies) can be analysed. The analysis is done in such a way that the outcome not only ensures consistency and makes manageable the uncertainty aspects, but also essentially constitutes the policy framework within which to work out compromise plans. After identifying the core factors, they are used in the form of synergy-defining constraints to determine optimal scenarios (one of which has to be selected as the basis for utility maximisation in ranking the different objectives). Subsequent derivation and usage of the preference and trade-off weights in the manner proposed (in the VP methodology) ensures that the desirable extent of flexibility or rigidity is exercised - either as a universal criterion which can yield a partial ordering of the points in the non-dominated set, or as the inverse concept which has the potential of ordering the non-dominated set itself. Thus, the proposed approach effectuates the implementation of a wide concept of satisficing with minimum pressure on the decision-maker. Indeed, the approach uses the same rationale of expected utility maximisation coupled with total trade-off optimisation which most decision-makers attempt to implement when faced with any MCDM problem.

The viability planning methodology was partly demonstrated in a case study of a holding company, faced with a modernisation project of one of its subsidiary engineering companies. The general conclusions to be drawn from the case study are two-fold:

- Strategic, rather than tactical, flexibility is the essence of achieving robustness in any decision-making for viability planning.

- The applicability of viability planning in any organisation is dependent on the potential of the organisation for autonomy, business homogeneity and coherency of perception between the organisation's policy formulators and its policy implementers. In particular, without an appropriate lead time for the policy formulators to conduct 'high-level tactical' planning, the applicability of viability planning would be limited.

Having given a global overview of the work done, it would be inappropriate to conclude without drawing attention to certain aspects where further work through future research might be directed.

Viability planning concerns analysing the factors which need to be taken into account in making certain economic choices for an organisation. For financial decision-making, viability planning assumes that the capital market is efficient in one form or the other - that is, the market is more or less Pareto-optimum. However, departures from Pareto-optimum situations arise when monopolistic elements or other imperfections in the market for resources are such as to twist relative outputs away from those which would prevail under competitive conditions. In situations of this kind, management judgement of environmental pressures may not be reliable since failure of the market to correct such distortions may lead to maldevelopment of investment projects between different industries - which in turn could colour considerably management perception of the problematic situation on hand. Thus a worthwhile study could be the determination of the prevailing level of market efficiency, and how the viability planning methodology should take into consideration non-Pareto optimum situations of the market.

Another area of interest for future work on the viability planning methodology pertains to cost of capital considerations. In this research, it has been assumed that the social discount rate and all the risk factor components have equal weights in the cost of capital. However, when there is an excess supply (at the current market price) of any input, that price overstates the social cost of using that input. Furthermore, if that input is labour (such as in periods of high unemployment), increased government or public projects are bound to create (as a multiplier effect) additional real incomes in the rest of the economy concerned. This suggests the near-certainty of social costs being overstated and total benefits being underestimated. In situations like this, it could be inappropriate to assign equal weights to the cost of capital components, the nominal part of which is considered in viability planning as the social discount rate. Consequently, a study to determine the appropriate weights to apply would be desirable.

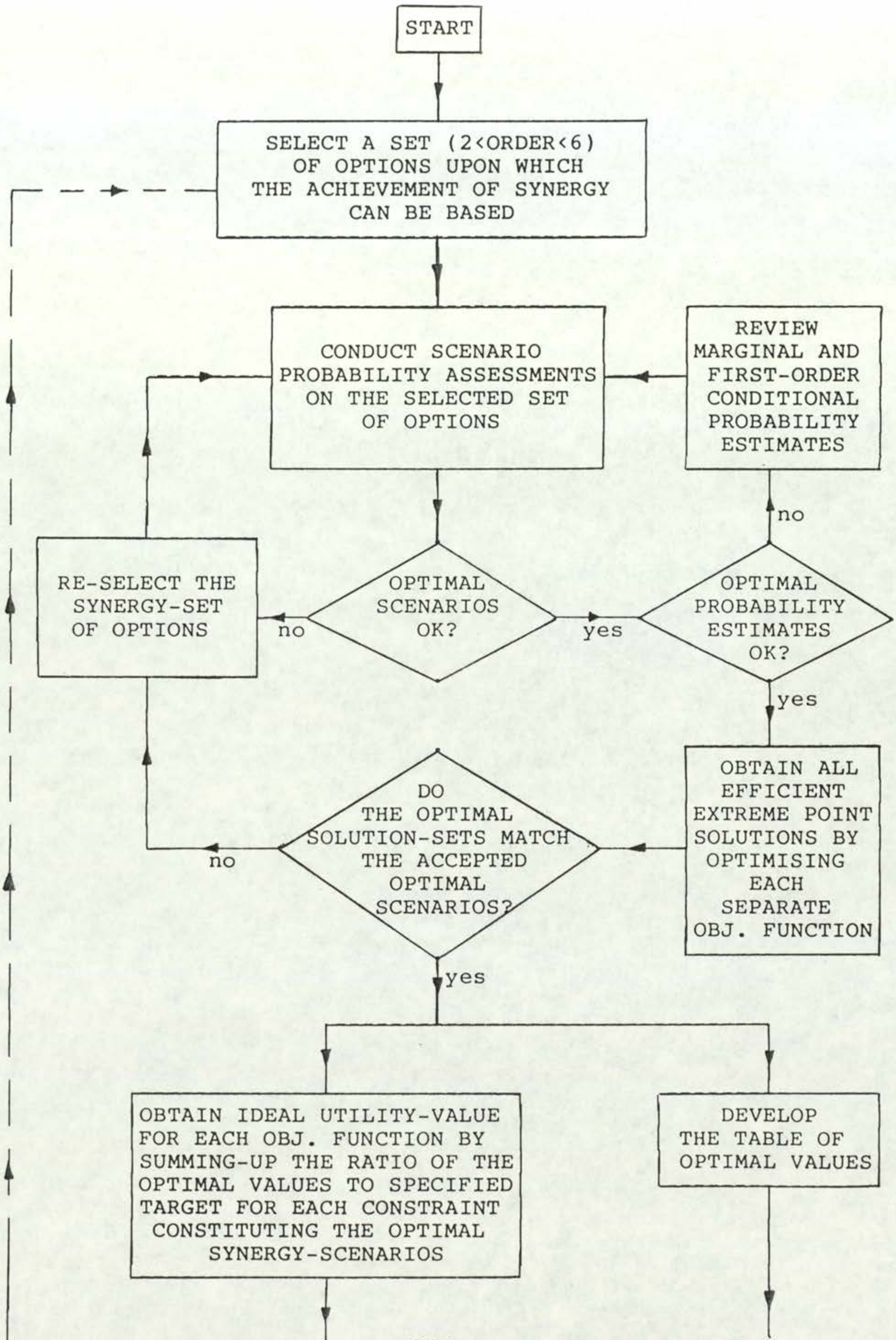
Finally, considerable challenge could be faced in certain viability planning application areas such as project management (where various subcontractors are involved) or project planning involving consortium formation. In these cases, the firms concerned would presumably be investing in a common activity (the contract) but with different objectives. A viability planning study could be to analyse the process of finding an adequate distribution of investment and resources with respect to the objectives of each participating firm. These are cases of group decision-making, which is an aspect that has not been specifically considered in this research.

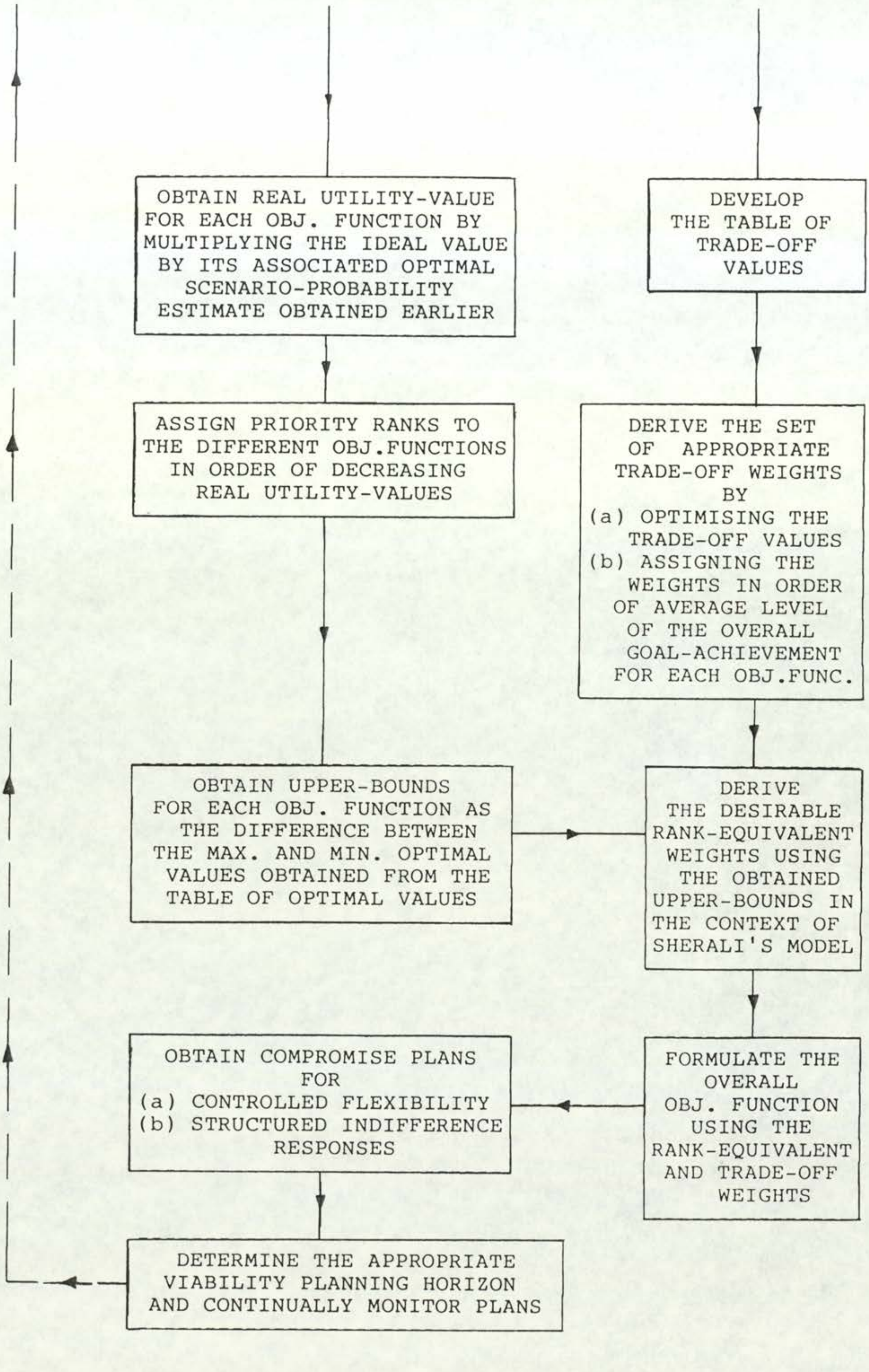
The scope for future work highlighted above suggests that there are still certain limitations in any attempt at a universal application of the viability planning methodology. Nevertheless, the latter is sufficiently robust as a decision-aid modelling technique to obviate any hindrance to further progress. It would thus seem an appropriate point at which to formally present the developments so far and to submit this thesis.

APPENDICES

APPENDIX 1.1

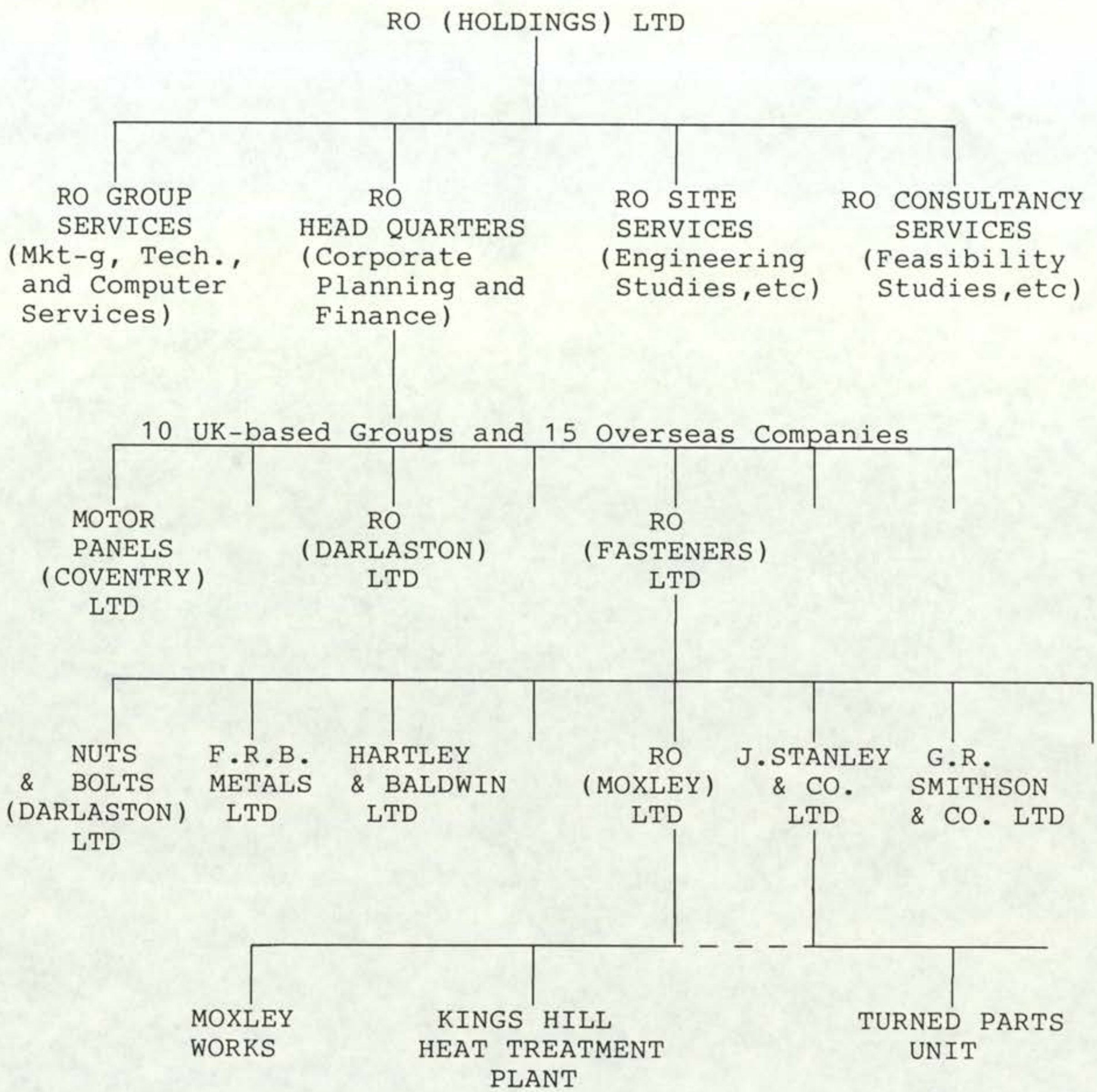
VIABILITY PLANNING MODELLING FLOWCHART



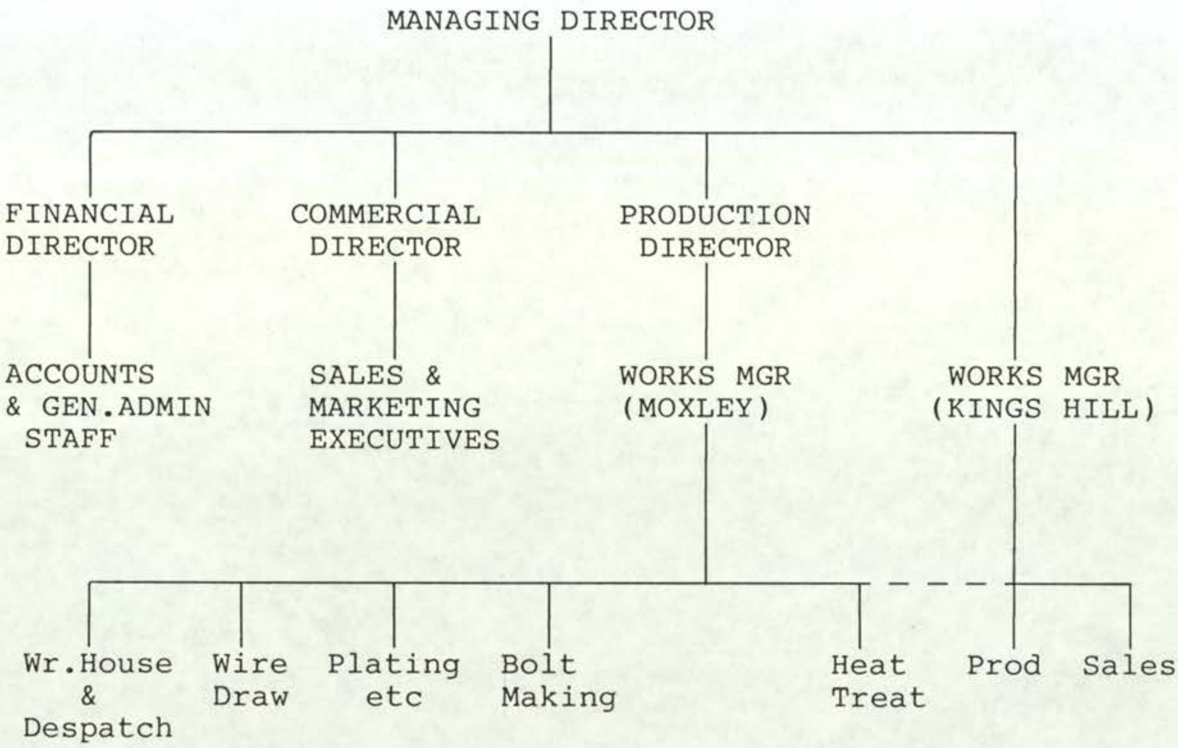

OBTAIN REAL UTILITY-VALUE FOR EACH OBJ. FUNCTION BY MULTIPLYING THE IDEAL VALUE BY ITS ASSOCIATED OPTIMAL SCENARIO-PROBABILITY ESTIMATE OBTAINED EARLIER
DEVELOP THE TABLE OF TRADE-OFF VALUES
ASSIGN PRIORITY RANKS TO THE DIFFERENT OBJ.FUNCTIONS IN ORDER OF DECREASING REAL UTILITY-VALUES
DERIVE THE SET OF APPROPRIATE TRADE-OFF WEIGHTS BY
(a) OPTIMISING THE TRADE-OFF VALUES
(b) ASSIGNING THE WEIGHTS IN ORDER OF AVERAGE LEVEL OF THE OVERALL GOAL-ACHIEVEMENT FOR EACH OBJ.FUNC.
OBTAIN UPPER-BOUNDS FOR EACH OBJ. FUNCTION AS THE DIFFERENCE BETWEEN THE MAX. AND MIN. OPTIMAL VALUES OBTAINED FROM THE TABLE OF OPTIMAL VALUES
DERIVE THE DESIRABLE RANK-EQUIVALENT WEIGHTS USING THE OBTAINED UPPER-BOUNDS IN THE CONTEXT OF SHERALI'S MODEL
OBTAIN COMPROMISE PLANS FOR
(a) CONTROLLED FLEXIBILITY
(b) STRUCTURED INDIFFERENCE RESPONSES
FORMULATE THE OVERALL OBJ. FUNCTION USING THE RANK-EQUIVALENT AND TRADE-OFF WEIGHTS
DETERMINE THE APPROPRIATE VIABILITY PLANNING HORIZON AND CONTINUALLY MONITOR PLANS

APPENDIX 2.1

THE ORGANISATIONAL CHARTS OF ROH LTD AND RO (MOXLEY) LTD

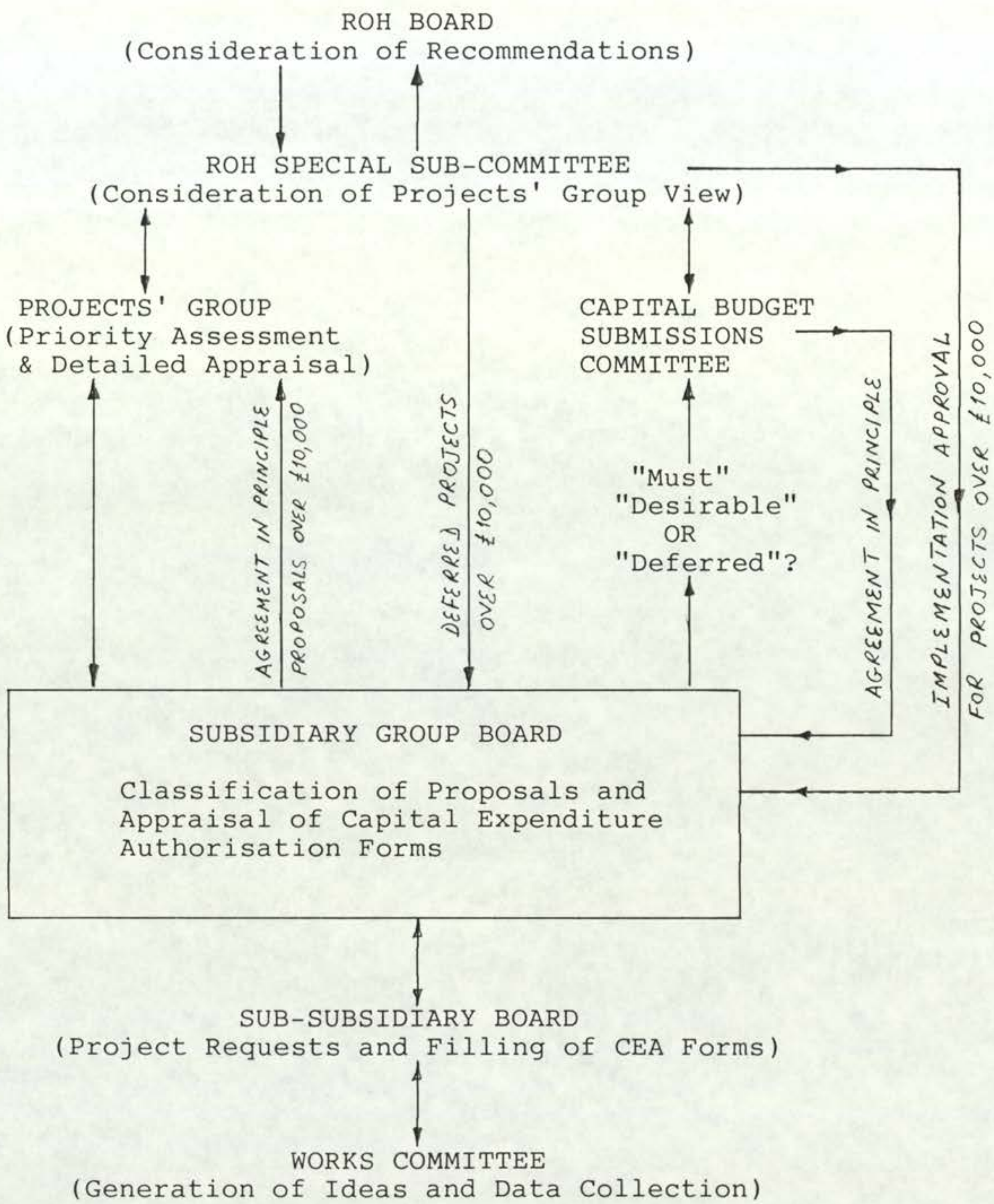


RO (MOXLEY) LTD



APPENDIX 2.2:

INFORMATION FLOW FOR CONSIDERATION OF PROJECTS IN ROH LTD



NOTE: ⟷ Continuous Information Flow
⟶ Project-dependent Information Flow

APPENDIX 2.3: A MACHINE-HOURS RATES REPORT

R.O. (MOXLEY) LIMITED. COST CENTRE CODES.

COST CENTRES.	No.
BMV 3. BOLTMAKER.	01.
1/2" BOLTMAKERS (INCLUDES BMV 4)	02.
5/16" BOLTMAKERS.	03.
Q.P.B. 20.	04.
3/4" HEADERS.	05.
1/2" HEADERS.	06.
OTHER HEADERS.	07.
TRIMMING.	08.
THREAD ROLLING.	09.
AUTO POINTING.	10.
GRINDING.	11.
GENERAL MACHINING.	12.
HEAT TREATMENT.	13.
PLATING.	14.
WIRE DRAWING.	15.
INSPECTION.	16.
INTERNAL TRANSPORT.	17.
WAREHOUSE/DESPATCH.	18.
TOOLROOM.	19.
MAINTENANCE.	20.
STORES.	21.
GENERAL.	22.
PERSONNEL APPORTIONED (WAGES ONLY)	23.
SICKNESS BENEFIT (WAGES ONLY)	24.
TRAINEES. (WAGES ONLY)	25.

AY AUG 7, 1978 14:13

RUBERY OWEN MOXLEY - MACHINE HOUR RATES REPORT

COST CENTRE	TOTAL	NUTFORM 1.02	1/2 BMS 2.02	5/16 BM 3.02	QPB 20 4.02	3/4 HDS 5.02
DIRECT WAGES	395982	-	18423	11018	20916	16807
IND WAGES	394686	-	-	-	4032	1604
WKSADMINSALS	109000	-	1485	900	2524	3644
HOLIDAY PAY	117219	-	1973	1315	3750	2631
N H I	145823	-	3138	1898	4477	3540
TRAINING	21411	-	-	-	-	-
COMP PENSION	3214	-	44	27	74	107
WKS PENSION	13205	-	308	184	417	307
CONS STORES	100800	-	1512	706	3427	1008
CONS TOOLS	107600	-	250	13200	2367	224
REPS & RENS	130600	-	3787	1437	9534	2220
REPS&REN EXC	22600	-	-	-	-	-
GAS PROCESS	17200	-	-	-	-	-
GAS HEATING	43300	-	1559	1559	1559	1559
GAS NITROGEN	37700	-	-	-	-	-
POWER KVA	18200	-	382	164	619	491
POWER UNITS	88900	-	4000	1689	6401	5067
RENT	33190	-	1693	631	4282	1095
RATES	32612	-	1663	620	4207	1076
INSURANCES	18875	-	963	359	2435	623
CANTEEN	15895	-	240	160	479	319
SUND WKS EXP	31005	-	467	312	935	623
TECH SERVICE	10300	-	-	-	-	-
PLANT LEASES	85200	-	-	-	-	-
DEPN BUILDGS	1100	-	-	-	-	-
DEP CARS&TKS	5057	-	-	-	-	-
DEP PLT& M/C	42730	-	1600	11318	2062	169
PLANT REPRES	233310	-	32040	5508	43574	13170
TOTAL	2276714	-	75527	53005	118071	56284
MAINTENANCE	-	-	2737	1108	847	1890
TOOLROOM	-	-	30572	14861	25901	20806
INT TPT	-	-	964	642	1927	1285
WKS GENERAL	-	-	6643	3034	15795	5603
AUTO POINT	-	-	-	-	-	-
TOTAL COST	2276714	-	116443	72650	162541	85868
HOURS			3605	1730	1385	1615
RATE/HOUR			32.300	41.994	117.358	53.169
TONNES						
RATE/TONNE						

DAY AUG 7, 1978 14:15

RUBERY OWEN MOXLEY - MACHINE HOUR RATES REPORT

1/2 HDS, OTH HDS, TRIM NG, THRD RL, AUTOPTG, GRINDG ,

COST CENTRE	6.02	7.02	8.02	9.02	10.02	11.02
DIRECT WAGES	14935	43716	41671	25654	5413	11549
IND WAGES	-	-	-	30483	4095	6034
WKSADMINSALS	1297	4058	8149	5663	692	1189
HOLIDAY PAY	2090	5926	5261	9209	1742	3553
N H I	2614	7701	7899	10183	1712	3201
TRAINING	-	-	-	-	-	-
COMP PENSION	38	120	240	167	20	35
WKS PENSION	249	730	696	937	159	294
CONS STORES	806	3226	1210	5947	302	604
CONS TOOLS	3650	1506	14096	39597	108	4089
REPS & RENS	2351	8750	3134	3396	1828	914
REPS&REN EXC	-	-	-	-	-	-
GAS PROCESS	-	-	-	-	-	-
GAS HEATING	1559	1559	1559	4590	433	433
GAS NITROGEN	-	-	-	-	-	-
POWER KVA	419	1310	983	1401	127	200
POWER UNITS	4356	13513	9957	14313	1245	2045
RENT	1062	4182	1560	1593	431	431
RATES	1044	4109	1533	1565	424	424
INSURANCES	604	2378	887	906	245	245
CANTEEN	240	719	639	1238	240	439
SUND WKS EXP	467	1402	1246	2415	467	857
TECH SERVICE	-	-	-	-	-	-
PLANT LEASES	-	-	-	-	-	-
DEPN BUILDGS	-	-	-	-	-	-
DEP CARS&TKS	-	-	-	-	-	-
DEP PLT& M/C	-	3504	1678	4428	-	-
PLANT REPRES	11600	21726	12822	10553	967	1933
TOTAL	49291	130135	115220	174238	20650	38469
MAINTENANCE	1629	18702	1890	4561	782	521
TOOLROOM	18046	43947	30997	12951	1274	1274
INT TPT	964	2891	2570	4979	964	1767
WKS GENERAL	4876	17418	9440	14288	3110	4695
AUTO POINT	3040	8659	6506	8575	-26780	-
TOTAL COST	77846	221752	166623	219592	-	46726
HOURS	4710	28380	31370	29985	1645	5915
RATE/HOUR	16.528	7.814	5.312	7.323		7.900
TONNES						
RATE/TONNE						

RUBERY OWEN MOXLEY - MACHINE HOUR RATES REPORT

		GEN MAC,	HEAT T ,	PLATING,	WIRE DW,	INSPN ,	INT TPT,
	COST CENTRE	12.02	13.02	14.02	15.02	16.02	17.02
10	DIRECT WAGES	46009	49959	55367	34546	-	-
1	IND WAGES	12093	13080	-	-	58470	17097
2	WKSADMINSALS	5845	13932	9869	2594	12393	124
3	HOLIDAY PAY	11160	7930	6156	3660	10649	3050
4	N H I	10770	12175	10238	5851	11689	2907
5	TRAINING	-	-	-	-	-	-
6	COMP PENSION	172	411	291	77	366	4
7	WKS PENSION	970	1053	925	577	976	286
8	CONS STORES	1008	21773	49795	1613	1411	-
9	CONS TOOLS	1399	261	608	1183	1399	-
20	REPS & RENS	2351	36568	15280	3134	3265	5485
1	REPS&REN EXC	-	-	-	-	-	-
2	GAS PROCESS	516	13588	2236	-	-	-
3	GAS HEATING	3031	2814	1559	3031	-	-
4	GAS NITROGEN	-	37700	-	-	-	-
5	POWER KVA	473	9119	819	983	-	-
6	POWER UNITS	4889	3289	978	9957	-	-
7	RENT	1195	4082	1659	830	1626	-
8	RATES	1174	4011	1631	815	1598	-
9	INSURANCES	679	2322	944	472	925	-
0	CANTEEN	1558	1038	799	479	1438	399
1	SUND WKS EXP	3038	2025	1558	935	2804	779
2	TECH SERVICE	-	1751	8034	-	515	-
3	PLANT LEASES	-	12000	732	-	-	-
5	DEPN BUILDGS	-	-	-	-	-	-
6	DEP CARS&TKS	-	-	-	-	-	92
7	DEP PLT& M/C	575	4035	7000	2170	-	-
0	PLANT REPRES	4143	22687	12650	6119	-	7521
	TOTAL	113047	277603	189120	79026	109524	37744
5	MAINTENANCE	847	21699	2476	3323	-	-
5	TOOLROOM	2548	1274	1274	6581	-	-
7	INT TPT	6264	4176	3212	1927	-	-37744
8	WKS GENERAL	15708	19675	10987	6127	15965	-
1	AUTO POINT	-	-	-	-	-	-
	TOTAL COST	138414	324427	207069	96984	125489	-
	HOURS	30490					
	RATE/HOUR	4.540					
	TONNES		5000	5100	3465		
	RATE/TONNE		64.885	40.602	27.990		

RUBERY OWEN MOXLEY - MACHINE HOUR RATES REPORT

WH&DESP, TOOLRM , MAINT , GENERAL, BMV4&3 ,

	COST CENTRE	18.02	19.02	20.02	22.02	25.02
0	DIRECT WAGES	-	-	-	-	-
1	IND WAGES	36789	101322	35899	73688	-
2	WKSADMINSALS	25504	2584	3230	3324	-
3	HOLIDAY PAY	5899	14421	4604	12330	-
4	N H I	9779	16968	6271	12812	-
5	TRAINING	-	-	-	21411	-
6	COMP PENSION	752	76	95	98	-
7	WKS PENSION	614	1692	600	1231	-
8	CONS STORES	4334	2016	102	-	-
9	CONS TOOLS	107	21520	215	1829	-
0	REPS & RENS	8881	8359	9926	-	-
1	REPS&REN EXC	11600	-	-	11600	-
2	GAS PROCESS	-	860	-	-	-
3	GAS HEATING	10824	1559	-	4113	-
4	GAS NITROGEN	-	-	-	-	-
5	POWER KVA	-	710	-	-	-
6	POWER UNITS	-	7201	-	-	-
7	RENT	4315	2423	100	-	-
8	RATES	4239	2381	98	-	-
9	INSURANCES	2453	1378	57	-	-
0	CANTEEN	799	1757	559	2356	-
1	SUND WKS EXP	1558	3428	1091	4598	-
2	TECH SERVICE	-	-	-	-	-
2	PLANT LEASES	-	-	-	10468	62000
5	DEPN BUILDGS	-	-	-	1100	-
6	DEP CARS&TKS	-	-	-	4965	-
7	DEP PLT& M/C	225	418	5	3543	-
0	PLANT REPRES	2579	21233	161	2324	-
	TOTAL	130651	212306	63013	171790	62000
5	MAINTENANCE	-	-	-63013	-	-
6	TOOLROOM	-	-212306	-	-	-
7	INT TPT	3212	-	-	-	-
8	WKS GENERAL	18424	-	-	-171790	-
	AUTO POINT	-	-	-	-	-
	TOTAL COST	152287	-	-	-	62000
	HOURS					
	RATE/HOUR					
	TONNES					
	RATE/TONNE					

APPENDIX 2.4

EXPENDITURE AUTHORISATION	DATE	AUTHORISATION No.
COMPANY: RUBERY OWEN (MOXLEY) LIMITED		PROJECT No.: ROM 41, 54 and 55
DIVISION/DEPT.: MOXLEY WORKS - HOLYHEAD ROAD		LOCATION
PREPARED BY: W. W. G. STACEY	PROPOSED BY: P. CARTWRIGHT	APPROVED BY: T. H. FOSTER

DESCRIPTION OF PROJECT

1 - BMV 3: Nedschroef Boltmaker
1 - MBV 4 Nedschroef Boltmaker
1 - Bull Block

INVESTMENT SUMMARY

LAND & BUILDINGS		£ -
PLANT & EQUIPMENT		£ 419,000
TOOLING & INSTALLATION OF ADDITIONAL PLANT		£ -
INSTALLATION & MOVEMENT OF EXISTING PLANT		£ -
ADDITIONAL WORKING CAPITAL REQUIREMENTS		£ 134,000
TOTAL FOR AUTHORISATION		£ 553,000
AMOUNTS PREVIOUSLY AUTHORISED	AUTH No. -	£ -
ANTICIPATED FUTURE EXPENDITURE	DATE -	£ -
ACHIEVEMENT REPORTS DUE	1 DATE March 1979 2 October 1979	RESPONSIBILITY W.W.G.Stacey.

OTHER QUOTES CONSIDERED (IF YES SEE SHEET 5) YES [X] NO [ ]

ALTERNATIVES CONSIDERED (IF YES SEE SHEET 5) YES [ ] NO [ ]

APPROVAL

[illegible]

DETAILS	SUPPLIER	NEW S/H REBUILD	STD. SPECIAL	COST	DELIVERY	CAP OR REV
BMV 3 Boltmaker	Nedschroef	New	Std.	165,000	April 1978	CAP
BMV 4 Boltmaker	Nedschroef	New	Std.	204,000	Feb. 1979	CAP
Bull Block	Malmedie	New	Std.	50,000	Aug. 1978	CAP
				419,000		

Item 1 and 2 @ B.Frs. 63.2 = £1.00
Item 3 @ D.M. 4.01 = £1.00

ADDITIONAL WORKING CAPITAL REQUIREMENTS

STOCKS	64,000
DEBTORS	157,000
CREDITORS	87,000
NET	134,000

USTIFICATION SUMMARY

EXPECTED PROCESS/MACHINE LIFE, WHICHEVER IS THE SHORTER	....20.......YEARS	
EXPANSION OF EXISTING OPERATION OR PRODUCTS	YES [X]	NO [ ]
EXPANSION - NEW OPERATIONS OR PRODUCTS	YES [ ]	NO [X]
REPLACEMENT TO MAINTAIN EXISTING LEVELS OF OPERATION	YES [ ]	NO [X]
COST REDUCTION	YES [X]	NO [ ]
RESEARCH & DEVELOPMENT	YES [ ]	NO [X]
IMPROVED PRODUCTIVITY	YES [X]	NO [ ]
DOES THE REQUESTED EXPENDITURE INCLUDE ANY NON-YIELDING FACILITIES ?	YES [ ]	NO [X]

IF YES PLEASE SPECIFY ITEM No.......................AND VALUE £.....................

LL ANY EXISTING PLANT BE RELEASED –

FOR PRODUCTION PURPOSES IN YOUR DIVISION/DEPT.	YES [ ]	NO [X]
FOR PRODUCTION PURPOSES IN OTHER AREAS	YES [ ]	NO [X]
FOR DISPOSAL	YES [ ]	NO [ ]

RTHER DETAILS TO BE PROVIDED IN THE PLANT RELEASE REPORT

VALUATION

EXPRESS THE ADDED OUTPUT AS A PERCENTAGE OF THE PRESENT CAPACITY ....19.4...... %

VALUE OF ADDITIONAL OUTPUT £...800,000...........

VALUE OF DIVISIONAL GROSS PROFIT MARGIN AT STAKE BASED ON EITHER :-

1. ADDITIONAL OUTPUT, OR
2. MAINTENANCE OF EXISTING LEVELS £ ....

VALUE OF COST REDUCTIONS £.......................

D.C.F. RETURN AFTER TAXATION ....49.5.... %

PAY BACK BASED ON NET INCOME AFTER TAXATION ....3.6....... YEARS

ORIGINAL CAPITAL BUDGET				PREDICTED CASH REQUIREMENT CALENDARISATION		
ITEM No.	BUDGET REF.	BUDGET PAYMENT DATE	BUDGET £	19..78.... £	19..79.... £	REMARKS
1	ROM 54	March 1978	150,000	165,000		
2	ROM 41	1978/79	190,000		204,000	
3	ROM 55	1978/79	30,000	50,000		

DETAILS OF OTHER QUOTES CONSIDERED

MALMEDIE	8 - 10 M	£229,000
	10 - 16 M	£293,000
NATIONAL	10 - 12 M	£293,000
	10 - 16 M	£396,000

DETAILS OF ALTERNATIVES CONSIDERED	REASON FOR REJECTION

REPORT ON PLANT TO BE RELEASED

PLANT No.	DESCRIPTION	RECOMM. ACTION	YEAR OF PURCHASE	COST £	BOOK W.D.V. £	REALISABLE VALUE £

PLANT RECOMMENDED FOR RETENTION

PLANT No.	DETAILS OF ALTERNATIVE USE	EST. REMAINING LIFE

CHIEF ENGINEERS REPORT

PLANT No.	YEAR OF PURCHASE	NEW ☐ SECONDHAND ☐
DESCRIPTION		
ORIGINAL COST £	BOOK VALUE £	SALE/SCRAP VALUE £

	CURRENT MACHINE	IF CURRENT M/C RECONDITIONED	IF REPLACED BY NEW MACHINE
ESTIMATED REMAINING LIFE	YRS	YRS	Y
ANNUAL TURNOVER UNITS			
A VALUE	£	£	£
COST OF SALES	£	£	£
MATERIALS			
DIRECT LABOUR			
RECTIFICATION & INSPECTION			
OVERHEADS (EXC. DEPRECIATION) (& MAINTENANCE)			
MAINTENANCE			
OTHERS			
B TOTAL COST OF SALES EXCLUDING DEPRECIATION			
CASH FLOW A-B	£	£	£
CAPITAL INVESTMENT			
[illegible] OF PRODUCT	YRS	YRS	

PRODUCTION OPERATING COST DATA

ANNUAL TURNOVER		QUANTITATIVE DATA PRESENT	QUANTITATIVE DATA PROPOSED	COST DATA PRESENT	COST DATA PROPOSED
ODUCING HOURS					
TPUT	A		[illegible] per 7 mm.	£ 262,000	£ 800,000
COST OF SALES					
ECT MATERIALS					339,000
ECT CHARGES					121,000
RRIAGE					4,500
ECT LABOUR					15,000
ALITY OF PRODUCT					
RECTIFICATION					
SCRAP					
INSPECTION					
PENSES					
TOOL SETTING					1,500
SERVICE LABOUR					
TOOL CONSUMPTION } TOOL MAINTENANCE }					18,500
PLANT MAINTENANCE					2,500
POWER					8,000
HEAT					
PROCESS MATERIALS					3,500
NAT. INSURANCE, HOL. PAY					
OTHER					20,500
TOTAL COST OF SALES EXCLUDING DEPRECIATION					534,000
CASH FLOW	A - B				266,000

CAPITAL INVESTMENT APPRAISAL

PERCENTAGE OF WORKING CAPITAL RECOVERABLE AT END OF LIFE %

EAR		CAPITAL EXPENDITURE		WORKING CAPITAL EXPENDITURE	SALES	COSTS	PROFIT BEFORE DEPRECIATION & TAX	TAX RATES
		PLANT & EQUIPMENT £	BUILDINGS £	£	£	£	£	
8	1	215,000	–	(20,000)	58,000	54,000	4,000	
9	2	204,000	–	(60,000)	419,000	309,000	110,000	
0	3	–	–	(54,000)	800,000	534,000	266,000	
1	4	–	–	–	800,000	534,000	266,000	
2	5	–	–	–	800,000	534,000	266,000	
3	6	–	–	–	800,000	534,000	266,000	
4	7	–	–	–	800,000	534,000	266,000	
5	8	–	–	–	800,000	534,000	266,000	
6	9	–	–	–	800,000	534,000	266,000	
7	10	–	–	–	800,000	534,000	266,000	
8	11	–	–	–	800,000	534,000	266,000	
9	12	–	–	134,000	800,000	534,000	266,000	
	13							
	14							
	15							
	16							
	17							
	18							
	19							

APPENDIX 2.5:

Lease details for the bolt-makers, BMV3 & BMV4

Type	BMV3
Normal purchase price	£168,145
Primary Period (PP) of Lease	5 years
Rental frequency in PP	Quarterly
Rental in PP	£9,986.14
Start date of PP	27.09.1979
End date of PP	26.09.1984
VAT rate at start date	15%
Further Period (FP), if any	10 years
Rental frequency in FP	Annually
Rental in FP	£1,681.45
Start date of FP	27.09.1984
End date of FP	26.09.1994
VAT	Prevailing rates added to rentals due, and tax invoice issued each time.

APPENDIX 2.5: (Contd)

Type	BMV4
Normal purchase price	£172,900
Primary Period (PP) of Lease	5 years
Rental frequency in PP	Quarterly
Rental in PP	£10,436.81
Start date of PP	29.09.1978
End date of PP	28.09.1983
VAT rate at start date	8%
Further Period (FP), if any	10 years
Rental frequency in FP	Annually
Rental in FP	£1,729.00
Start date of FP	29.09.1983
End date of FP	28.09.1993
VAT	Prevailing rates added to rentals due, and tax invoice issued each time.

LISTING OF 5099GA *OWENDATA LAST UPDATED ON 18-SEP-85 AT 19:59:13

PREPARATORY TABLE FOR DEVELOPING THE CAPITALISATION-STRUCTURE MODEL
****

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
1	0.0000	17166.0000	28.0000	0.1000	0.0000	9043.1847
2	0.0000	18182.0000	28.0000	0.1000	0.0000	6794.2785
3	0.0000	180990.0000	28.0000	0.1000	0.0000	61484.8233
4	0.0000	116674.0000	28.0000	0.1000	0.0000	41031.3273
5	0.0000	0.0000	28.0000	0.1000	0.0000	19863.0000
6	0.0000	0.0000	28.0000	0.1000	0.0000	5808.0000
7	0.0000	0.0000	28.0000	0.1000	0.0000	12498.0000
8	0.0000	0.0000	28.0000	0.1000	0.0000	34420.0000
9	0.0000	0.0000	28.0000	0.1000	0.0000	12195.0000
10	0.0000	0.0000	28.0000	0.1000	0.0000	25033.0000
11	0.0000	23886.0000	28.0000	0.1000	0.0000	3605.0000
12	0.0000	14442.0000	28.0000	0.1000	0.0000	1730.0000
13	0.0000	28225.0303	28.0000	0.1000	0.0000	1385.0000
14	0.0000	22818.3028	28.0000	0.1000	0.0000	1615.0000
15	0.0000	19836.0000	28.0000	0.1000	0.0000	4710.0000
16	0.0000	58193.0000	28.0000	0.1000	0.0000	28380.0000
17	0.0000	55767.0000	28.0000	0.1000	0.0000	31370.0000
18	0.0000	35020.4496	28.0000	0.1000	0.0000	29985.0000
19	0.0000	7481.3034	28.0000	0.1000	0.0000	3230.0000
20	0.0000	16201.3100	28.0000	0.1000	0.0000	5915.0000
21	0.0000	64277.8504	28.0000	0.1000	0.0000	30490.0000
22	0.0000	67052.6352	28.0000	0.1000	0.0000	21415.0000
23	0.0000	72977.0000	28.0000	0.1000	0.0000	18809.0000
24	0.0000	44711.0000	28.0000	0.1000	0.0000	11736.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
1	0.0000	9454.0000	23.0000	0.1000	0.0000	9043.1847
2	0.0000	1818.0000	23.0000	0.1000	0.0000	6794.2785
3	0.0000	0.0000	23.0000	0.1000	0.0000	61484.8233
4	0.0000	4108.0000	23.0000	0.1000	0.0000	41031.3273
5	0.0000	82150.0000	23.0000	0.1000	0.0000	19863.0000
6	0.0000	23344.0000	23.0000	0.1000	0.0000	5808.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
9	0.0000	47489.0000	23.0000	0.1000	0.0000	12195.0000
10	0.0000	100159.0000	23.0000	0.1000	0.0000	25033.0000
11	0.0000	0.0000	23.0000	0.1000	0.0000	3605.0000
12	0.0000	0.0000	23.0000	0.1000	0.0000	1730.0000
13	0.0000	5440.9697	23.0000	0.1000	0.0000	1385.0000
14	0.0000	2177.6972	23.0000	0.1000	0.0000	1615.0000
15	0.0000	0.0000	23.0000	0.1000	0.0000	4710.0000
16	0.0000	0.0000	23.0000	0.1000	0.0000	28380.0000
17	0.0000	0.0000	23.0000	0.1000	0.0000	31370.0000
18	0.0000	41612.5503	23.0000	0.1000	0.0000	29985.0000
19	0.0000	5659.6966	23.0000	0.1000	0.0000	3230.0000
20	0.0000	8464.6900	23.0000	0.1000	0.0000	5915.0000
21	0.0000	16895.1496	23.0000	0.1000	0.0000	30490.0000
22	0.0000	17555.3648	23.0000	0.1000	0.0000	21415.0000
23	0.0000	0.0000	23.0000	0.1000	0.0000	18809.0000
24	0.0000	0.0000	23.0000	0.1000	0.0000	11736.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
1	87000.0000	23240.0000	15.0000	0.0500	8700.0000	9043.1847
2	446000.0000	84520.0000	15.0000	0.0500	22300.0000	6794.2785
3	0.0000	219604.0000	10.0000	0.0500	0.0000	61484.8233
4	0.0000	61790.0000	10.0000	0.0500	0.0000	41031.3273
5	0.0000	0.0000	10.0000	0.0500	0.0000	19863.0000
6	0.0000	0.0000	10.0000	0.0500	0.0000	5808.0000
7	0.0000	0.0000	10.0000	0.0500	0.0000	12498.0000
8	0.0000	0.0000	10.0000	0.0500	0.0000	34420.0000
9	0.0000	0.0000	10.0000	0.0500	0.0000	12195.0000
10	0.0000	0.0000	10.0000	0.0500	0.0000	25033.0000
11	0.0000	45235.0000	10.0000	0.0500	0.0000	3605.0000
12	0.0000	10880.0000	10.0000	0.0500	0.0000	1730.0000
13	0.0000	72466.0000	10.0000	0.0500	0.0000	1385.0000
14	0.0000	0.0000	10.0000	0.0500	0.0000	1615.0000
15	0.0000	0.0000	10.0000	0.0500	0.0000	4710.0000
16	0.0000	0.0000	10.0000	0.0500	0.0000	28380.0000
17	0.0000	0.0000	10.0000	0.0500	0.0000	31370.0000
18	0.0000	0.0000	10.0000	0.0500	0.0000	29985.0000
19	0.0000	0.0000	10.0000	0.0500	0.0000	3230.0000
20	0.0000	0.0000	10.0000	0.0500	0.0000	5915.0000
21	0.0000	0.0000	10.0000	0.0500	0.0000	30490.0000
22	0.0000	0.0000	10.0000	0.0500	0.0000	21415.0000
23	0.0000	0.0000	10.0000	0.0500	0.0000	18809.0000
24	0.0000	0.0000	10.0000	0.0500	0.0000	11736.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS

5	0.0000	12171.0000	5.0000	0.0500	0.0000	19863.0000
6	0.0000	14184.0000	5.0000	0.0500	0.0000	5808.0000
7	0.0000	35824.0000	5.0000	0.0500	0.0000	12498.0000
8	0.0000	48870.0000	5.0000	0.0500	0.0000	34420.0000
9	0.0000	11992.0000	5.0000	0.0500	0.0000	12195.0000
10	0.0000	31346.0000	5.0000	0.0500	0.0000	25033.0000
11	0.0000	0.0000	5.0000	0.0500	0.0000	3605.0000
12	0.0000	0.0000	5.0000	0.0500	0.0000	1730.0000
13	0.0000	0.0000	5.0000	0.0500	0.0000	1385.0000
14	0.0000	24684.0000	5.0000	0.0500	0.0000	1615.0000
15	0.0000	22143.0000	5.0000	0.0500	0.0000	4710.0000
16	0.0000	58089.0000	5.0000	0.0500	0.0000	28380.0000
17	0.0000	32761.0000	5.0000	0.0500	0.0000	31370.0000
18	0.0000	37380.0000	5.0000	0.0500	0.0000	29985.0000
19	0.0000	5974.0000	5.0000	0.0500	0.0000	3230.0000
20	0.0000	7488.0000	5.0000	0.0500	0.0000	5915.0000
21	0.0000	19500.0000	5.0000	0.0500	0.0000	30490.0000
22	0.0000	98892.0000	5.0000	0.0500	0.0000	21415.0000
23	0.0000	45084.0000	5.0000	0.0500	0.0000	18809.0000
24	0.0000	23724.0000	5.0000	0.0500	0.0000	11736.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
1	0.0000	8500.0000	15.0000	0.0800	0.0000	9043.1847
2	0.0000	339000.0000	15.0000	0.0800	0.0000	6794.2785
3	0.0000	0.0000	15.0000	0.0800	0.0000	61484.8233
4	0.0000	16608.0000	15.0000	0.0800	0.0000	41031.3273
5	0.0000	1411.0000	15.0000	0.0800	0.0000	19863.0000
6	0.0000	0.0000	15.0000	0.0800	0.0000	5808.0000
7	0.0000	4334.0000	15.0000	0.0800	0.0000	12498.0000
8	0.0000	2016.0000	15.0000	0.0800	0.0000	34420.0000
9	0.0000	102.0000	15.0000	0.0800	0.0000	12195.0000
10	0.0000	0.0000	15.0000	0.0800	0.0000	25033.0000
11	0.0000	1512.0000	15.0000	0.0800	0.0000	3605.0000
12	0.0000	706.0000	15.0000	0.0800	0.0000	1730.0000
13	0.0000	3427.0000	15.0000	0.0800	0.0000	1385.0000
14	0.0000	1008.0000	15.0000	0.0800	0.0000	1615.0000
15	0.0000	806.0000	15.0000	0.0800	0.0000	4710.0000
16	0.0000	3226.0000	15.0000	0.0800	0.0000	28380.0000
17	0.0000	1210.0000	15.0000	0.0800	0.0000	31370.0000
18	0.0000	5947.0000	15.0000	0.0800	0.0000	29985.0000
19	0.0000	302.0000	15.0000	0.0800	0.0000	3230.0000
20	0.0000	604.0000	15.0000	0.0800	0.0000	5915.0000
21	0.0000	1008.0000	15.0000	0.0800	0.0000	30490.0000
22	0.0000	21773.0000	15.0000	0.0800	0.0000	21415.0000
23	0.0000	49795.0000	15.0000	0.0800	0.0000	18809.0000
24	0.0000	1613.0000	15.0000	0.0800	0.0000	11736.0000

CENTRE No.	ACQ. COST	RUN. COST	YEARS	GROWTH	SAL. VALUE	MAN-HOURS
1	0.0000	0.0000	15.0000	0.0800	0.0000	9043.1847
2	0.0000	18500.0000	15.0000	0.0800	0.0000	6794.2785
3	0.0000	0.0000	15.0000	0.0800	0.0000	61484.8233
4	0.0000	0.0000	15.0000	0.0800	0.0000	41031.3273
5	0.0000	1399.0000	15.0000	0.0800	0.0000	19863.0000
6	0.0000	0.0000	15.0000	0.0800	0.0000	5808.0000
7	0.0000	10931.0000	15.0000	0.0800	0.0000	12498.0000
8	0.0000	23939.0000	15.0000	0.0800	0.0000	34420.0000
9	0.0000	215.0000	15.0000	0.0800	0.0000	12195.0000
10	0.0000	5942.0000	15.0000	0.0800	0.0000	25033.0000
11	0.0000	1809.0000	15.0000	0.0800	0.0000	3605.0000
12	0.0000	14759.0000	15.0000	0.0800	0.0000	1730.0000
13	0.0000	3926.0000	15.0000	0.0800	0.0000	1385.0000
14	0.0000	1783.0000	15.0000	0.0800	0.0000	1615.0000
15	0.0000	5209.0000	15.0000	0.0800	0.0000	4710.0000
16	0.0000	3065.0000	15.0000	0.0800	0.0000	28380.0000
17	0.0000	15655.0000	15.0000	0.0800	0.0000	31370.0000
18	0.0000	44187.0000	15.0000	0.0800	0.0000	29985.0000
19	0.0000	541.0000	15.0000	0.0800	0.0000	3230.0000
20	0.0000	4522.0000	15.0000	0.0800	0.0000	5915.0000
21	0.0000	4946.0000	15.0000	0.0800	0.0000	30490.0000
22	0.0000	54363.0000	15.0000	0.0800	0.0000	21415.0000
23	0.0000	4395.0000	15.0000	0.0800	0.0000	18809.0000
24	0.0000	4214.0000	15.0000	0.0800	0.0000	11736.0000

AVERAGE IDLE CAPACITY OF PRODUCT-ACTIVITY CENTRES =   2788.9333 Units

WORKLOAD BALANCING CAN BE BASED ON BMV3 & BMV4 ACTIVITY,
WITH TARGET VALUE OF   772.5000 Units

**   **

CAPITALISATION-COST STRUCTURE FOR R.O.(MOXLEY) LTD. (in $s/man-hour)

Market-required Rate of Return, given, is 15.00%
Applicable Cost of Capital, also given, is 36.12%

	TOT.CAPnCOST	% of TOTAL	NEW HEATTR-T	NEW 3&4 BMV	SYS. FINANCE	SYS. ADMIN.
LABOUR (DIR)	667.3111	22.2734%	14.5570	20.5155	22.5714	21.8064
LABOUR (IND)	290.6958	9.7028%	8.2363	2.1081	0.0000	0.7888
ECON. ASSETS	865.1485	28.8768%	30.6337	167.5394	31.2478	13.1746
SERV. ASSETS	463.8836	15.4834%	0.0000	0.0000	0.0000	0.0000
CONSUM. MAT.	500.9327	16.7201%	7.8210	415.1716	0.0000	3.3684
CONSUM. TOOL	208.0277	6.9435%	0.0000	22.6569	0.0000	0.0000
TOT.CAPnCOST	2995.9994	-	61.2480	627.9915	53.8192	39.1381
% of TOTAL	-	100.0000%	2.0443	20.9610	1.7964	1.3063

	TOT. CAPnCOST	% of TOTAL	SYS. INSPECT	SYS. CARRIAGE	SYS. STORAGE	SYS. TOOLROOM
LABOUR (DIR)	667. 3111	22. 2734%	0. 0000	0. 0000	0. 0000	0. 0000
LABOUR (IND)	290. 6958	9. 7028%	32. 5881	31. 6595	33. 9269	30. 7852
ECON. ASSETS	865. 1485	28. 8768%	0. 0000	0. 0000	0. 0000	0. 0000
SERV. ASSETS	463. 8836	15. 4834%	6. 0891	24. 2602	28. 4747	14. 1083
CONSUM. MAT.	500. 9327	16. 7201%	0. 5912	0. 0000	2. 8849	0. 4873
CONSUM. TOOL	208. 0277	6. 9435%	0. 5861	0. 0000	7. 2755	5. 7872
TOT. CAPnCOST	2995. 9994	-	39. 8545	55. 9197	72. 5621	51. 1680
% of TOTAL	-	100. 0000%	1. 3303	1. 8665	2. 4220	1. 7079

	TOT. CAPnCOST	% of TOTAL	SYS. MAINTEN.	SYS. GENERAL	1/2BMS ACTIV	5/16BM ACTIV
LABOUR (DIR)	667. 3111	22. 2734%	0. 0000	0. 0000	50. 8071	63. 9933
LABOUR (IND)	290. 6958	9. 7028%	30. 6542	31. 5382	0. 0000	0. 0000
ECON. ASSETS	865. 1485	28. 8768%	0. 0000	0. 0000	109. 7838	55. 0179
SERV. ASSETS	463. 8836	15. 4834%	9. 7657	12. 4457	0. 0000	0. 0000
CONSUM. MAT.	500. 9327	16. 7201%	0. 0696	0. 0000	3. 4898	3. 3956
CONSUM. TOOL	208. 0277	6. 9435%	0. 1466	1. 9753	4. 1753	70. 9894

	TOT. CAPnCOST	% of TOTAL	QPB-20 ACTIV	3/4HDS ACTIV	1/2HDS ACTIV	OthHDS ACTIV
LABOUR (DIR)	667. 3111	22. 2734%	156. 2697	108. 3320	32. 2949	15. 7199
LABOUR (IND)	290. 6958	9. 7028%	30. 9499	10. 6247	0. 0000	0. 0000
ECON. ASSETS	865. 1485	28. 8768%	457. 7512	0. 0000	0. 0000	0. 0000
SERV. ASSETS	463. 8836	15. 4834%	0. 0000	151. 8506	46. 7090	20. 3392
CONSUM. MAT.	500. 9327	16. 7201%	20. 5882	5. 1933	1. 4239	0. 9458
CONSUM. TOOL	208. 0277	6. 9435%	23. 5860	9. 1861	9. 2021	0. 8986
TOT. CAPnCOST	2995. 9994	-	689. 1450	285. 1867	89. 6299	37. 9035
% of TOTAL	-	100. 0000%	23. 0022	9. 5189	2. 9917	1. 2651

	TOT. CAPnCOST	% of TOTAL	TRIM ACTIV	THREAD ACTIV	AUTOPG ACTIV	GRINDG ACTIV
LABOUR (DIR)	667. 3111	22. 2734%	13. 6301	8. 9527	17. 7571	20. 9978
LABOUR (IND)	290. 6958	9. 7028%	0. 0000	10. 9308	13. 8052	11. 2746
ECON. ASSETS	865. 1485	28. 8768%	0. 0000	0. 0000	0. 0000	0. 0000
SERV. ASSETS	463. 8836	15. 4834%	10. 3770	12. 3853	18. 3784	12. 5793
CONSUM. MAT.	500. 9327	16. 7201%	0. 3209	1. 6500	0. 7780	0. 8496

CONSUM. TOOL	208.0277	6.9435%	4.1510	12.2603	1.3936	6.3611
TOT. CAPnCOST	2995.9994	-	28.4791	46.1790	52.1122	52.0624
% of TOTAL	-	100.0000%	0.9506	1.5414	1.7394	1.7377

	TOT. CAPnCOST	% of TOTAL	GENMAC ACTIV	HEATTR ACTIV	PLATIN. ACTIV	WIREDR. ACTIV
LABOUR (DIR)	667.3111	22.2734%	16.1634	23.9990	29.7460	29.1978
LABOUR (IND)	290.6958	9.7028%	4.3668	6.4586	0.0000	0.0000
ECON. ASSETS	865.1485	28.8768%	0.0000	0.0000	0.0000	0.0000
SERV. ASSETS	463.8836	15.4834%	6.3551	45.8751	23.8144	20.0766
CONSUM. MAT.	500.9327	16.7201%	0.2751	8.4565	22.0290	1.1432
CONSUM. TOOL	208.0277	6.9435%	1.3497	21.1161	1.9441	2.9866
TOT. CAPnCOST	2995.9994	-	28.5100	105.9052	77.5335	53.4042
% of TOTAL	-	100.0000%	0.9516	3.5349	2.5879	1.7825

** **

```
************** Pdn = 6    5099-GA    Terminal: 45    18 SEP 85 21:45:17    Vos 3.1 **************
```

```
LISTING OF 5099GA  *PRGOWEN  LAST UPDATED ON 10-OCT-83 AT 10:25:29

AS 11=W1
AS 12=W2
AS 13=W3
AS 14=W4
AS 15=W5
AS 16=W6
AS 17=W7
AS 18=INDATA
AS 19=INDATB
AS 20=OWENDATA
AS 100=PRELIDAT
FO.EMLNWDQ ROMDAT
VU.RA VPOWEN
ALLOCATE S+0
SPALLOCATE S+5
LIB *LIBERY
BEGIN
VPOWEN
```

```
************** No. of pages    1   5099-GA    Terminal: 45    18 SEP 85 21:45:19    Vos 3.1 **************
```

LISTING OF 5099GA *GETREADY

Note: To edit *PRELIDAT into *READYDAT

```
QED PRELIDAT
E GETREADY
          421,$D
          217,396D
          205,216D
          169,180D
          133,144D
          97,108D
          61,72D
          25,36D
          WY READYDAT
QY
```

```
********************************************************************
********************************************************************
************
************   Pdn =    7              5099-GA          Terminal: 67
************
********************************************************************
********************************************************************

1 5
BASIC DEF.   0.5000 0.7000 0.4000
ASSET UTIL.  0.65   0.80   0.50
RET.ON CAP.  0.60   0.75   0.40
NEW INVEST.  0.80   0.85   0.50
FIRM VIAB.   0.30   0.50   0.20
0.65   0.75   0.30
0.75   0.85   0.40
0.80   0.85   0.50
 0.50   0.70   0.25
 0.70   0.80   0.40
 0.85   0.90   0.60
 0.50   0.75   0.30
 0.60   0.85   0.40
 0.50   0.70   0.40
 0.50   0.65   0.25
  0  0  5 18  1
  0  0  0 24 23
 0 0
  0
  1     -1.0000 1
  2      0.2500 1
 11      0.1500 1
 12      0.1500 1
 13      0.4500 0
      96600.0000   1
  2     -0.1000 1
 11     -0.4000 1
 12     -0.4000 1
 13     -0.1000 1
 14     -0.3000 1
 15     -0.4500 1
 16     -0.2500 1
 23      6.5000 0
      96600.0000   1
  2     -0.1500 1
 11     -0.2500 1
 12     -0.1500 1
 13     -0.4500 1
 14     -0.3500 1
 15     -0.3000 1
 16     -0.3500 1
 24      6.5000 0
      96600.0000   1
 11      0.1250 1
 12      0.1250 1
 13      0.2000 1
 14      0.1750 1
 15      0.1750 1
 16      0.2000 1
 21     -1.0000 0
      96600.0000   1
```

```
 14        0.2500 1
 15        0.4000 1
 16        0.3500 1
 22       -1.0000 0
         96600.0000   1
 14        0.3000 1
 15        0.2500 1
 16        0.4500 1
 17       -1.0000 0
         96600.0000   1
 14        0.4500 1
 15        0.3000 1
 16        0.2500 1
 18       -1.0000 0
         96600.0000   1
 14        0.5000 1
 15        0.2000 1
 16        0.3000 1
 19       -1.0000 0
         96600.0000   1
 14        0.2500 1
 15        0.3000 1
 16        0.4500 1
 20       -1.0000 0
         96600.0000   1
 14        0.4500 1
 15        0.2500 1
 16        0.3000 1
 21       -1.0000 0
         96600.0000   1
  2        0.0500 1
  9       -1.0000 1
 11        0.0800 1
 12        0.1200 1
 13        0.1000 1
 14        0.2250 1
 15        0.2150 1
 16        0.2100 2
         96600.0000   1
  1
       4411444.4000   0   0
       2893442.4120   0   0
       4793870.0000   0   0
       3574561.6160   0   0
       6664227.9200   0   0
       5535051.2000   0   0
       3977202.3200   0   0
0          5000000.0000   0   1
1 0.3500         500000.0000
2          1823808.0000   0   2
3 0.2500         750000.0000
4          1487083.0000   0   3
5 0.1000         500000.0000
6           500000.0000   0   4
7 0.1000         500000.0000
8           784627.0320   0   5
9 0.2000          96600.0000
0            1.0000 1 1
1 12          0.5000 1
2 13          0.5000 0
```

113	12	0.5000	1	
114	13	0.5000	0	
115		1.0000	1	1
116	14	0.5000	1	
117	15	0.5000	0	
118	14	0.5000	1	
119	15	0.5000	0	
120		1.0000	1	1
121	16	0.5000	1	
122	17	0.5000	0	
123	16	0.5000	1	
124	17	0.5000	0	
125		1.0000	1	1
126	18	1.0000	0	
127	18	1.0000	0	
128		1.0000	1	1
129	1	0.0910	1	
130	2	0.0910	1	
131	3	0.0910	1	
132	4	0.0910	1	
133	5	0.0910	1	
134	6	0.0910	1	
135	7	0.0910	1	
136	8	0.0910	1	
137	9	0.0910	1	
138	10	0.0910	1	
139	11	0.0910	1	
140	23	1.0000	0	
141	1	0.0910	1	
142	2	0.0910	1	
143	3	0.0910	1	
144	4	0.0910	1	
145	5	0.0910	1	
146	6	0.0910	1	
147	7	0.0910	1	
148	8	0.0910	1	
149	9	0.0910	1	
150	10	0.0910	1	
151	11	0.0910	1	
152	23	1.0000	0	
153	1	NSHEATTR		
154	2	NS3&4BMV		
155	3	OSUBFINA		
156	4	OSUBADMS		
157	5	OSUBINSP		
158	6	OSUBCARR		
159	7	OSUBWRH		
160	8	OSUBTLRM		
161	9	OSUBMTCE		
162	10	OSUBGENL		
163	11	OA1/2BMS		
164	12	OA5/16BM		
165	13	OAQPB20		
166	14	OA3/4HDS		
167	15	OA1/2HDS		
168	16	OAOTHHDS		
169	17	OATRIMME		
170	18	OATHREAD		
171	19	OAAUTOPG		
172	20	OAGRINDG		

```
  21 OAGENMAC
  22 OAHEATTR
  23 OAPLATIN
  24 OAWIREDR
   1 L!NSHEAT
   2 L!PLAWRK
   3 L!PL&WDR
   4 L!WRKGEN
   5 L!HEATTR
   6 L!TRIMME
   7 L!THREAD
   8 L!AUTOPG
   9 L!GRINDG
  10 L!GENMAC
  11 L!MAINTE
  12 LABODIRE
  13 LABOINDI
  14 ASSEECON
  15 ASSESERV
  16 CONSMATE
  17 CONSTOOL
  18 OPERCOST
  19 BASICDEF
  20 ASSETUTI
  21 RETONCAP
  22 NEWINVES
  23 FIRMVIAB
   1 P!LABOUR
   2 P!ASSETS
   3 P!CONSUM
   4 P!OPERCO
   5 P!MANHRS
C**** Total Captn.= $3084.132/man-hour, therefore
C**** Average activity-centre captn.= 3084.132/24 = $128.5055/man-hr.
C**** Total Value/man-hr.= 3084.132 + ROC/man-hr.= 3084.132
C****                                             = $3131.332/man-hr.
C**** Assuming average annual activity-centre working time of 3220 hrs.,
C**** Average annual total man-hours (to sustain required firm-value) =
C****         (3131.332*3220)/128.5055 man-hrs. = 78462.7032 man-hrs.
C****
C**** For New-Investment Considerations, Rate= 5%, TAPB(j)= 10yrs., and
C****                                     TAPB(ROH)= 8yrs.
EOF..

*****************************************************************************************************
*****************************************************************************************************
**************                                                                                    ***
**************   No. of pages     4   5099-GA          Terminal: 67          3 FEB 84 17:44:22   Vos 2.4 ***
**************                                                                                    ***
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******************************************************************************
******************************************************************************
**************
**************   Pdn =   6              5099-GA           Terminal: 45
**************
******************************************************************************
******************************************************************************

LISTING OF 5099GA  *PRGVIAB  LAST UPDATED ON  3-FEB-84 AT 13:56:59

AS 11=W1
AS 22=W2
AS 33=W3
AS 44=W4
AS 55=W5
AS 66=W6
AS 77=W7
AS 88=W8
AS 99=W9
FO. EMLNWDQ PRVIAB
VU. R VPLANA
ALLOCATE S+0
SPALLOCATE S+20
LIB *LIBERY
AS 12=TRYDATB
AS 14=OUTTRYA
AS 15=OUTFLMGT
AS 100=READYDAT
AS 101=ACHANNEL
AS 104=DCHANNEL
AS 106=FCHANNEL
AS 111=AWORK
AS 112=BWORK
AS 113=CWORK
AS 114=DWORK
AS 115=EWORK
AS 116=FWORK
AS 17=HOLDFL
EGIN
PLANA
100
010
000
110
1110000
1001100
0101010
1000000
0100000
0001000
1101010
1101100
1111000
111111100000000
111000011110000
100110011001100
010101010101010
111000000000000
100110000000000
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1010101000000000
11000000011000000
1010000010100000
1000100010001000
1111111110000000
1111100011110000
1110110011001100
1110101010101010
1111100010001000
1110110010100000
1110101011000000
11111111111111110000000000000000
11111111000000001111111100000000
11110000111100001111000011110000
11001100110011001100110011001100
10101010101010101010101010101010
1111111000000000000000000000000
1111000011110000000000000000000
1001100110011000000000000000000
0101010101010100000000000000000
1110000000000001111000000000000
1001100000000001100110000000000
0101010000000001010101000000000
1000000110000001100000011000000
0100000101000001010000010100000
0001000100010001000100010001000
1111111111111111000000000000000
1111111100000000111111110000000
1111000111100001111000011110000
1101100110011001100110011001100
1101010101010101010101010101010
1111111100000001000000010000000
1111000111100001000100000000000
1101100110011001010000000000000
1101010101010101100000000000000
1111000100010001111000000000000
1101100101000001100110000000000
1101010110000001010101000000000
1101010110000001100000011000000
1101100101000001010000010100000
1111000100010001000100010001000
   TION     UNDAOVRABASIS    VALUES   FEASDEFNEXHAUSCN
OBJFUN  MAXVAL  MINVAL  RANGE  DEVIATIONSUMCONS
t01gt02gt03gt04gt05gt06gt07gt08gt09gt10TrdWWgt Sum UpLW

*************************************************************************************
*************************************************************************************
*************
*************    No.  of pages     2    5099-GA              Terminal  45
*************
********************************************************************    *********
********************************************************************    *********
```

STATUS OF OPTIMAL SYNERGY-DEFINING SCENARIOS

SCENARIO PROBABILITY:	0.3167	0.2417	0.2000	0.1083	0.0750
SYNERGY FACTORS	TARGET ACHIEVED [1] or TARGET UNACHIEVED [0]				
BASIC DEF.	1	0	1	0	0
ASSET UTIL.	1	0	1	0	1
RET. ON CAP.	1	0	1	0	1
NEW INVEST.	1	0	1	1	1
FIRM VIAB.	1	0	0	0	0

SCENARIO PROBABILITY:	0.0583
SYNERGY FACTORS	TARGET ACHIEVED [1] or TARGET UNACHIEVED [0]
BASIC DEF.	0
ASSET UTIL.	1
RET. ON CAP.	0
NEW INVEST.	1
FIRM VIAB.	0

STATUS OF PRIORITY VALUES
****

PRIORITY TARGETED	CORRESPONDING OPTIMAL PRIORITY VALUES				
	P!LABOUR	P!ASSETS	P!CONSUM	P!OPERCO	P!MANHRS
P!LABOUR	-874. 9534	3887104. 9698	3370077. 6395	287014. 5091	187629. 1425
P!ASSETS	3255500. 5139	-644. 6796	3715628. 8039	910561. 2959	263268. 5508
P!CONSUM	2599277. 9260	2969145. 1823	1838380. 6139	771856. 4908	135823. 6825
P!OPERCO	2911523. 1536	3222831. 7580	3399303. 2254	2954633. 3990	201650. 2414
P!MANHRS	2520763. 7004	3038228. 4637	3269588. 7725	729156. 9835	550060. 7575
MAXVAL	3255500. 5139	3887104. 9698	3715628. 8039	2954633. 3990	550060. 7575
MINVAL	-874. 9534	-644. 6796	1838380. 6139	287014. 5091	135823. 6825
RANGE	3256375. 4672	3887749. 6494	1877248. 1900	2667618. 8899	414237. 0749

OPTIMISATION PLAN FOR TRADE-OFF WEIGHTS
****

In studying the Record of Results, presented below, the title-terms used have to be interpreted as follows:

ACTIVITY LEVEL - THE DESIRABLE UTILISATION LEVEL FOR WHICH THE PLAN REMAINS OPTIMAL

ACCOUNTING VALUE - THE ASSOCIATED VALUE (or improvement of the objective) IN UTILISING EACH UNIT OF THE RESOURCE CONCERNED

OPPORTUNITY COST - THE ASSOCIATED COST (or worsening of the objective) IN UTILISING EACH UNIT OF THE COMMODITY CONCERNED

BIAS PERMITs - THE RANGE WITHIN WHICH THE INITIAL CONTRIBUTION TOWARDS THE OBJECTIVE COULD BE CHANGED FOR THE CONCERNED COMMODITY OR RESOURCE WITHOUT RENDERING THE PLAN NON-OPTIMAL.

RECORD OF OPTIMAL VALUES (MINIMISATION)
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
	***************	-	-	-	-
TrdWgt01	-	-	1247364.3360	0.0000	1247364.3360
TrdWgt02	0.0445	-	-	-8525212.6229	-8525212.6229
TrdWgt03	0.0918	-	-	***************	-9303563.7417
TrdWgt04	-	-	5492222.4807	0.0000	5492222.4807
TrdWgt05	-	-	4000211.6566	0.0000	4000211.6566
Wgt Sum	-	9810868194.9000	-	-12.7070	0.0000
UpLWgt01	-	8840.8437	-	-14080894.6910	0.0000
UpLWgt02	***************	-	-	-2.1184	-2.1184
UpLWgt03	***************	-	-	-2.2970	0.0000
UpLWgt04	2721356.7372	-	-	-3267.4126	-1.0006
UpLW OBJ	16948601.8620	-	-	0.0000	0.0000

In studying the Record of Results, presented below, the title-terms used have to be interpreted as follows:

ACTIVITY LEVEL - THE DESIRABLE UTILISATION LEVEL FOR WHICH THE PLAN REMAINS OPTIMAL

ACCOUNTING VALUE - THE ASSOCIATED VALUE (or improvement of the objective) IN UTILISING EACH UNIT OF THE RESOURCE CONCERNED

OPPORTUNITY COST - THE ASSOCIATED COST (or worsening of the objective) IN UTILISING EACH UNIT OF THE COMMODITY CONCERNED

BIAS PERMITs - THE RANGE WITHIN WHICH THE INITIAL CONTRIBUTION TOWARDS THE OBJECTIVE COULD BE CHANGED FOR THE CONCERNED COMMODITY OR RESOURCE WITHOUT RENDERING THE PLAN NON-OPTIMAL.

RECORD OF OPTIMAL VALUES (MAXIMISATION)
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
	-3032994. 2288	-	-	-	-
TrdWgt01	-	-	327520. 8103	0. 0000	327520. 8103
TrdWgt02	0. 3031	-	-	-548547. 8150	0. 0000
TrdWgt03	-	-	8564398. 1216	0. 0000	8564398. 1216
TrdWgt04	0. 4834	-	-	-5082371. 2562	0. 0000
TrdWgt05	0. 2134	-	-	-3682395. 9236	-3682395. 9236
Wgt Sum	-	2078474. 3555	-	-12. 1367	0. 0000
UpLWgt01	14082093. 0300	-	-	-8840. 8437	-170. 0460
UpLWgt02	15633267. 1960	-	-	-3. 2264	0. 0000
UpLWgt03	-	2. 2947	-	***************	0. 0000
UpLWgt04	-	1. 0006	-	-50409680. 7200	0. 0000
UpLW OBJ	16948601. 8620	-	-	0. 0000	0. 0000

LEVELS OF DESIRED ACHIEVEMENTS FOR SYNERGY CONSTRAINTS
****

In studying the Utility Table, presented below, the terms - Desired Achievement and Utility - have to be interpreted in the following context:

DESIRED ACHIEVEMENT - refers to whichever of the cases ("only over-achievement", "only under-achievement" or "either") has been indicated as acceptable during data-input.

UTILITY - refers to the optimal value of the Desired Achievement, over and above the Zero-Level (for cases of "only ..."), while (for cases of "either"), it refers to the difference between that optimal value and the maximum acceptable deviation given for that case.

ZERO-LEVEL - refers to the Target set for the constraint concerned.

	BASIC DEF.	ASSET UTIL.	RET. ON CAP.	NEW INVEST.	FIRM VIAB.	UTILITY VALUE	EXPECTED UTILITY
Zero-Level:	5000000.0000	1823808.0000	1487083.0000	500000.0000	784627.0320		
OBJ. FUN. USED							
P!LABOUR	0.0000	0.0000	0.0000	108679.1286	0.0000	0.0217	0.0036
P!ASSETS	0.0000	0.0000	0.0000	121643.7942	0.0000	0.0243	0.0041
P!CONSUM	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P!OPERCO	0.0000	0.0000	0.0000	222324.6410	0.0000	0.0445	0.0074
P!MANHRS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

PRESENTED BELOW IS THE APPROPRIATE PRIORITY RANKING,
BEING THE MOST CONSISTENT WITH MANAGEMENT PERCEPTION
OF OPERATIONAL FEASIBILITY AND ENVIRONMENTAL REALITY:

PRIORITY RANK	PRIORITY TITLE	EXPECTED ACHIEVEMENT LEVEL FOR SYNERGY	TRADE-OFF WEIGHTS (BY MINIM. PROGRAM)	TRADE-OFF WEIGHTS (BY MAXIM. PROGRAM)	TRADE-OFF WEIGHTS (BY UNIFORM SCALE)
No. : 1	P!OPERCO	0.0074	0.0000	0.4834	0.1738
No. : 2	P!ASSETS	0.0041	0.0445	0.3031	0.1882
No. : 3	P!LABOUR	0.0036	0.0000	0.0000	0.1832
No. : 4	P!CONSUM	0.0000	0.0918	0.0000	0.1373
No. : 5	P!MANHRS	0.0000	0.0000	0.2134	0.3174

****

PRIORITY No.	RANK	MIN.COMP.WT	MAX.COMP.WT	UNIF.COMP.WT
1	3	0.0000	0.0000	0.0365
2	2	0.0154	0.1046	0.0650
3	4	0.0040	0.0000	0.0060
4	1	0.0000	0.1992	0.0716
5	5	0.0000	0.0000	0.0000

In studying the Record of Results, presented in the following Compromise Plans, the title-terms used have to be interpreted as follows:

ACTIVITY LEVEL	- The desirable utilisation level for which the plan remains optimal;
ACCOUNTING VALUE	- The associated value (or improvement of the objective) in utilising each unit of the resource concerned;
OPPORTUNITY COST	- The associated cost (or worsening of the objective) in utilising each unit of the commodity concerned;
BIAS PERMIT	- The range within which the initial contribution towards the objective could be changed for the concerned commodity or resource without rendering the plan non-optimal.

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USING THE DERIVED PRIORITY RANKING AND TRADE-OFF WEIGHTS,
THE SEARCH FOR AN APPROPRIATE COMPROMISE SOLUTION PROCEEDS

The Trade-off Weights to be used presently have been derived through
a minimisation program of trade-off values between the objectives
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COMPROMISE PLAN No.: 1
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THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!LABOUR], HAS A CORRESPONDING OPTIMAL VALUE:         2599277.9260
                     with associated compromise level of   79.8481%


THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!ASSETS], HAS A CORRESPONDING OPTIMAL VALUE:         2969145.1823
                     with associated compromise level of   76.3884%


THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!CONSUM], HAS A CORRESPONDING OPTIMAL VALUE:         4133038.4500
                     with associated compromise level of  122.2352%


THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!OPERCO], HAS A CORRESPONDING OPTIMAL VALUE:          771856.4908
                     with associated compromise level of  -81.8249%


THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!MANHRS], HAS A CORRESPONDING OPTIMAL VALUE:          135823.6825
                     with associated compromise level of -100.0000%


NOTE: A negative compromise level suggests that
      the degree of commonality of decision-variables between
      the priority concerned and the consolidated objective used
      is very low if not entirely nil.

      This simply indicates that the priority concerned
      is not mutually exclusive with the other priorities, which
      may indeed form a collectively exhaustive set with it.
```

RECORD OF OPTIMAL VALUES
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
CONS OBJFUN	7405.9173	-	-	-	-
NSHEATTR	-	-	0.0233	0.0000	0.0233
NS3&4BMV	13219.9702	-	-	-16767.7598	0.0000
OSUBFINA	-	-	0.0440	0.0000	0.0440
OSUBADMS	-	-	0.0507	0.0000	0.0507
OSUBINSP	-	-	0.0571	0.0000	0.0571
OSUBCARR	-	-	0.0946	0.0000	0.0946
OSUBWRH	-	-	0.1047	0.0000	0.1047
OSUBTLRM	-	-	0.0069	0.0000	0.0069
OSUBMTCE	-	-	0.0222	0.0000	0.0222
OSUBGENL	80481.0129	-	-	-26.0611	0.0000
OA1/2BMS	-	-	0.0518	0.0000	0.0518
OA5/16BM	22774.5878	-	-	-90.8622	0.0000
OAQPB20	2314.5207	-	-	-3.7271	0.0000
OA3/4HDS	-	-	1.1305	0.0000	1.1305
OA1/2HDS	-	-	0.3459	0.0000	0.3459
OAOTHHDS	-	-	0.1583	0.0000	0.1583
OATRIMME	-	-	0.0093	0.0000	0.0093
OATHREAD	1103.5140	-	-	-6.6760	0.0000
OAAUTOPG	-	-	0.0240	0.0000	0.0240
OAGRINDG	-	-	0.0359	0.0000	0.0359

OAPLATIN	10209.8411	-	-	[illegible]	[illegible]
OAWIREDR	-	-	0.0379	0.0000	0.0379
OVRAL!NSHEAT	-	0.0000	-	0.0000	0.0000
OVRAL!PLAWRK	-	0.0000	-	0.0000	0.0000
OVRAL!PL&WDR	-	0.0000	-	0.0000	0.0000
OVRAL!WRKGEN	-	0.0000	-	0.0000	0.0000
OVRAL!HEATTR	-	0.0000	-	0.0000	0.0000
OVRAL!TRIMME	-	0.0000	-	0.0000	0.0000
OVRAL!THREAD	-	0.0000	-	0.0000	0.0000
OVRAL!AUTOPG	-	0.0000	-	0.0000	0.0000
OVRAL!GRINDG	-	0.0000	-	0.0000	0.0000
OVRAL!GENMAC	-	0.0000	-	0.0000	0.0000
OVRAL!MAINTE	-	0.0000	-	0.0000	0.0000
OVRALABODIRE	-	0.0000	-	0.0000	0.0000
OVRALABOINDI	-	0.0000	-	0.0000	0.0000
OVRAASSEECON	-	0.0154	-	0.0000	0.0000
OVRAASSESERV	-	0.0154	-	0.0000	0.0000
OVRACONSMATE	-	0.0040	-	0.0000	0.0000
OVRACONSTOOL	-	0.0040	-	0.0000	0.0000
OVRAOPERCOST	-	0.0000	-	0.0000	0.0000
OVRABASICDEF	-	0.0000	-	-26622343.6660	0.0000
OVRAASSETUTI	-	0.0000	-	0.0000	0.0000
OVRARETONCAP	-	0.0000	-	0.0000	0.0000
OVRANEWINVES	-	0.0000	-	0.0000	0.0000
OVRAFIRMVIAB	-	0.0000	-	0.0000	0.0000
L!NSHEAT	93668.2879	-	-	-1.7243	0.0000
L!PLAWRK	53933.5047	-	-	-0.0418	0.0000
L!PL&WDR	140090.4642	-	-	-437.4238	0.0000

L!WRKGEN	81927.9179	-	-	-942.6789	0.0000
L!HEATTR	59550.2538	-	-	-9484.0818	0.0000
L!TRIMME	48964.6121	-	-	-7376.5080	0.0000
L!THREAD	71239.4096	-	-	-13277.7146	0.0000
L!AUTOPG	64843.0747	-	-	-11064.7621	0.0000
L!GRINDG	48964.6121	-	-	-7376.5081	0.0000
L!GENMAC	74652.0037	-	-	-11064.7620	0.0000
L!MAINTE	70744.7512	-	-	-204.1288	0.0000
LABODIRE	-	0.0031	-	***************	-6555205.8382
LABOINDI	-	0.0032	-	-3002172.6896	0.0000
ASSEECON	-	0.0079	-	***************	-18642768.4310
ASSESERV	-	0.0152	-	***************	0.0000
CONSMATE	-	0.0030	-	***************	0.0000
CONSTOOL	3188855.5039	-	-	0.0000	0.0000
OPERCOST	3113143.0475	-	-	-0.2318	0.0000
BASICDEF	26622343.6660	-	-	-0.2361	0.0000
ASSETUTI	1516382.7683	-	-	-0.1684	0.0000
RETONCAP	954660.3132	-	-	-0.8763	0.0000
NEWINVES	-	0.0019	-	-13677893.4680	0.0000
FIRMVIAB	560258.5388	-	-	-5.0365	0.0000

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THE SEARCH FOR AN APPROPRIATE COMPROMISE SOLUTION PROCEEDS

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The Trade-off Weights to be used presently have been derived through
a maximisation program of trade=off values between the objectives
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COMPROMISE PLAN No. : 2
***********************


THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!LABOUR], HAS A CORRESPONDING OPTIMAL VALUE:        2911523.1536
                     with associated compromise level of   89.4368%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!ASSETS], HAS A CORRESPONDING OPTIMAL VALUE:        3222831.7580
                     with associated compromise level of   82.9137%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!CONSUM], HAS A CORRESPONDING OPTIMAL VALUE:        3399303.2254
                     with associated compromise level of   83.1495%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!OPERCO], HAS A CORRESPONDING OPTIMAL VALUE:         951678.5409
                     with associated compromise level of  -75.0840%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!MANHRS], HAS A CORRESPONDING OPTIMAL VALUE:         201650.2414
                     with associated compromise level of  -84.1090%


NOTE: A negative compromise level suggests that
      the degree of commonality of decision-variables between
      the priority concerned and the consolidated objective used
      is very low if not entirely nil.

      This simply indicates that the priority concerned
      is not mutually exclusive with the other priorities, which
      may indeed form a collectively exhaustive set with it.
```

RECORD OF OPTIMAL VALUES
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
CONS OBJFUN	588513.0271	-	-	-	-
NSHEATTR	-	-	0.4306	0.0000	0.4306
NS3&4BMV	12792.2080	-	-	-7053.3347	0.0000
OSUBFINA	-	-	0.1807	0.0000	0.1807
OSUBADMS	44731.5401	-	-	-2066.5035	0.0000
OSUBINSP	-	-	1.6208	0.0000	1.6208
OSUBCARR	-	-	1.2928	0.0000	1.2928
OSUBWRH	-	-	1.3162	0.0000	1.3162
OSUBTLRM	-	-	1.1936	0.0000	1.1936
OSUBMTCE	-	-	1.3174	0.0000	1.3174
OSUBGENL	81476.8457	-	-	-103.2572	0.0000
OA1/2BMS	-	-	0.1387	0.0000	0.1387
OA5/16BM	-	-	0.3027	0.0000	0.3027
OAQPB20	3764.0620	-	-	-27.0075	0.0000
OA3/4HDS	-	-	0.5065	0.0000	0.5065
OA1/2HDS	-	-	0.0223	0.0000	0.0223
OAOTHHDS	136.3154	-	-	-391.6177	0.0000
OATRIMME	-	-	0.1002	0.0000	0.1002
OATHREAD	-	-	0.3988	0.0000	0.3988
OAAUTOPG	-	-	0.7076	0.0000	0.7076
OAGRINDG	-	-	0.6765	0.0000	0.6765
OAGENMAC	-	-	0.3737	0.0000	0.3737

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OAWIREDR	19114. 8359	–	–	-195238. 0228	0. 0000
OVRAL!NSHEAT	–	0. 0000	–	0. 0000	0. 0000
OVRAL!PLAWRK	–	0. 0000	–	0. 0000	0. 0000
OVRAL!PL&WDR	–	0. 0000	–	0. 0000	0. 0000
OVRAL!WRKGEN	–	0. 0000	–	0. 0000	0. 0000
OVRAL!HEATTR	–	0. 0000	–	0. 0000	0. 0000
OVRAL!TRIMME	–	0. 0000	–	0. 0000	0. 0000
OVRAL!THREAD	–	0. 0000	–	0. 0000	0. 0000
OVRAL!AUTOPG	–	0. 0000	–	0. 0000	0. 0000
OVRAL!GRINDG	–	0. 0000	–	0. 0000	0. 0000
OVRAL!GENMAC	–	0. 0000	–	0. 0000	0. 0000
OVRAL!MAINTE	–	0. 0000	–	0. 0000	0. 0000
OVRALABODIRE	–	0. 0000	–	0. 0000	0. 0000
OVRALABOINDI	–	0. 0000	–	0. 0000	0. 0000
OVRAASSEECON	–	0. 1046	–	0. 0000	0. 0000
OVRAASSESERV	–	0. 1046	–	0. 0000	0. 0000
OVRACONSMATE	–	0. 0000	–	0. 0000	0. 0000
OVRACONSTOOL	–	0. 0000	–	0. 0000	0. 0000
OVRAOPERCOST	–	0. 3984	–	0. 0000	0. 0000
OVRABASICDEF	–	0. 0000	–	-73707644. 9880	0. 0000
OVRAASSETUTI	–	0. 0000	–	0. 0000	0. 0000
OVRARETONCAP	–	0. 0000	–	0. 0000	0. 0000
OVRANEWINVES	–	0. 0000	–	0. 0000	0. 0000
OVRAFIRMVIAB	–	0. 0000	–	0. 0000	0. 0000
L!NSHEAT	98874. 8581	–	–	-153. 7242	0. 0000
L!PLAWRK	–	0. 0116	–	-20132447. 2900	0. 0000
L!PL&WDR	–	0. 2416	–	-74913374. 8460	0. 0000
L!WRKGEN	79641. 1382	–	–	-335782. 2003	0. 0000

L!HEATTR	68239. 4136	–	–	-430573. 8129	0. 0000
L!TRIMME	60721. 4865	–	–	-334890. 7386	0. 0000
L!THREAD	76342. 4383	–	–	-2520. 2529	0. 0000
L!AUTOPG	72290. 9259	–	–	-502336. 1204	0. 0000
L!GRINDG	60136. 3889	–	–	-334890. 7443	0. 0000
L!GENMAC	72290. 9259	–	–	-502336. 1166	0. 0000
L!MAINTE	78567. 6316	–	–	-101. 6381	0. 0000
LABODIRE	–	0. 0189	–	***************	-1553449. 2014
LABOINDI	–	0. 0616	–	-8311930. 8192	0. 0000
ASSEECON	–	0. 0572	–	-640220129. 0600	-18492383. 6300
ASSESERV	–	0. 0595	–	-466818982. 3600	0. 0000
CONSMATE	–	0. 0111	–	***************	0. 0000
CONSTOOL	4805497. 9236	–	–	-3. 7332	0. 0000
OPERCOST	2954633. 3990	–	–	0. 0000	0. 0000
BASICDEF	73707644. 9880	–	–	-0. 3766	0. 0000
ASSETUTI	1495077. 1515	–	–	-7. 0648	0. 0000
RETONCAP	1172490. 3869	–	–	-1. 4783	0. 0000
NEWINVES	277675. 3590	–	–	-4649. 4081	0. 0000
FIRMVIAB	555574. 0408	–	–	-7. 8001	0. 0000

****

USING THE DERIVED PRIORITY RANKING AND TRADE-OFF WEIGHTS,
THE SEARCH FOR AN APPROPRIATE COMPROMISE SOLUTION PROCEEDS

The Trade-off Weights to be used presently have been derived through
weighted=averaging the sums of uniformly scaled optimal deviations
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COMPROMISE PLAN No. : 3
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THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!LABOUR], HAS A CORRESPONDING OPTIMAL VALUE:            2882810.4194
                     with associated compromise level of   88.5551%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!ASSETS], HAS A CORRESPONDING OPTIMAL VALUE:            3223361.9468
                     with associated compromise level of   82.9273%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!CONSUM], HAS A CORRESPONDING OPTIMAL VALUE:            3962292.6635
                     with associated compromise level of  113.1397%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!OPERCO], HAS A CORRESPONDING OPTIMAL VALUE:             925696.4629
                     with associated compromise level of  -76.0580%

THE FUNCTION OF DEVIATIONAL VARIABLES, CONSTITUTING
PRIORITY [P!MANHRS], HAS A CORRESPONDING OPTIMAL VALUE:             173116.3652
                     with associated compromise level of  -90.9973%
```

NOTE: A negative compromise level suggests that
the degree of commonality of decision-variables between
the priority concerned and the consolidated objective used
is very low if not entirely nil.

This simply indicates that the priority concerned
is not mutually exclusive with the other priorities, which
may indeed form a collectively exhaustive set with it.

RECORD OF OPTIMAL VALUES
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
CONS OBJFUN	226737.6975	–	–	–	–
NSHEATTR	–	–	0.1795	0.0000	0.1795
NS3&4BMV	12792.3432	–	–	-3434.8708	0.0000
OSUBFINA	–	–	0.1214	0.0000	0.1214
OSUBADMS	–	–	0.0104	0.0000	0.0104
OSUBINSP	–	–	0.6831	0.0000	0.6831
OSUBCARR	–	–	0.6445	0.0000	0.6445
OSUBWRH	–	–	0.6698	0.0000	0.6698
OSUBTLRM	–	–	0.4444	0.0000	0.4444
OSUBMTCE	–	–	0.5119	0.0000	0.5119
OSUBGENL	81563.8476	–	–	-88.7763	0.0000
OA1/2BMS	–	–	0.1952	0.0000	0.1952
OA5/16BM	17138.1967	–	–	-2095.7593	0.0000
OAQPB20	2991.9382	–	–	-19.7629	0.0000
OA3/4HDS	–	–	0.2898	0.0000	0.2898
OA1/2HDS	–	–	0.0591	0.0000	0.0591
OAOTHHDS	136.3154	–	–	-286.5688	0.0000
OATRIMME	–	–	0.0295	0.0000	0.0295
OATHREAD	–	–	0.1150	0.0000	0.1150
OAAUTOPG	–	–	0.2615	0.0000	0.2615
OAGRINDG	–	–	0.2411	0.0000	0.2411
OAGENMAC	–	–	0.1442	0.0000	0.1442
OAHEATTR	–	–	0.2177	0.0000	0.2177

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RECORD OF OPTIMAL VALUES
****

TARGET	ACTIVITY LEVEL	ACCOUNTING VALUE	OPPORTUNITY COST	MINI. BIAS PERMIT	MAXI. BIAS PERMIT
CONS OBJFUN	226737.6975	–	–	–	–
NSHEATTR	–	–	0.1795	0.0000	0.1795
NS3&4BMV	12792.3432	–	–	-3434.8708	0.0000
OSUBFINA	–	–	0.1214	0.0000	0.1214
OSUBADMS	–	–	0.0104	0.0000	0.0104
OSUBINSP	–	–	0.6831	0.0000	0.6831
OSUBCARR	–	–	0.6445	0.0000	0.6445
OSUBWRH	–	–	0.6698	0.0000	0.6698
OSUBTLRM	–	–	0.4444	0.0000	0.4444
OSUBMTCE	–	–	0.5119	0.0000	0.5119
OSUBGENL	81563.8476	–	–	-88.7763	0.0000
OA1/2BMS	–	–	0.1952	0.0000	0.1952
OA5/16BM	17138.1967	–	–	-2095.7593	0.0000
OAQPB20	2991.9382	–	–	-19.7629	0.0000
OA3/4HDS	–	–	0.2898	0.0000	0.2898
OA1/2HDS	–	–	0.0591	0.0000	0.0591
OAOTHHDS	136.3154	–	–	-286.5688	0.0000
OATRIMME	–	–	0.0295	0.0000	0.0295
OATHREAD	–	–	0.1150	0.0000	0.1150
OAAUTOPG	–	–	0.2615	0.0000	0.2615
OAGRINDG	–	–	0.2411	0.0000	0.2411
OAGENMAC	–	–	0.1442	0.0000	0.1442
OAHEATTR	–	–	0.2177	0.0000	0.2177

OVRAL!NSHEAT	–	0.0000	–	0.0000	0.0000
OVRAL!PLAWRK	–	0.0000	–	0.0000	0.0000
OVRAL!PL&WDR	–	0.0000	–	0.0000	0.0000
OVRAL!WRKGEN	–	0.0000	–	0.0000	0.0000
OVRAL!HEATTR	–	0.0000	–	0.0000	0.0000
OVRAL!TRIMME	–	0.0000	–	0.0000	0.0000
OVRAL!THREAD	–	0.0000	–	0.0000	0.0000
OVRAL!AUTOPG	–	0.0000	–	0.0000	0.0000
OVRAL!GRINDG	–	0.0000	–	0.0000	0.0000
OVRAL!GENMAC	–	0.0000	–	0.0000	0.0000
OVRAL!MAINTE	–	0.0000	–	0.0000	0.0000
OVRALABODIRE	–	0.0365	–	0.0000	0.0000
OVRALABOINDI	–	0.0365	–	0.0000	0.0000
OVRAASSEECON	–	0.0650	–	0.0000	0.0000
OVRAASSESERV	–	0.0650	–	0.0000	0.0000
OVRACONSMATE	–	0.0060	–	0.0000	0.0000
OVRACONSTOOL	–	0.0060	–	0.0000	0.0000
OVRAOPERCOST	–	0.1432	–	0.0000	0.0000
OVRABASICDEF	–	0.0000	–	-36023100.5930	0.0000
OVRAASSETUTI	–	0.0000	–	0.0000	0.0000
OVRARETONCAP	–	0.0000	–	0.0000	0.0000
OVRANEWINVES	–	0.0000	–	0.0000	0.0000
OVRAFIRMVIAB	–	0.0000	–	0.0000	0.0000
L!NSHEAT	96650.8121	–	–	-76.6367	0.0000
L!PLAWRK	–	0.0035	–	-14946334.7120	0.0000
L!PL&WDR	–	0.0875	–	-74914166.7280	0.0000
L!WRKGEN	77663.9381	–	–	-4.3446	0.0000
L!HEATTR	68258.0506	–	–	-113448.1946	0.0000

L!TRIMME	60745. 4484	-	-	-88237. 4841	0. 0000
L!THREAD	76355. 7504	-	-	-158827. 4726	0. 0000
L!AUTOPG	72306. 9005	-	-	-132356. 2267	0. 0000
L!GRINDG	60160. 3508	-	-	-88237. 4845	0. 0000
L!GENMAC	72306. 9005	-	-	-132356. 2250	0. 0000
L!MAINTE	76599. 4358	-	-	-8. 9799	0. 0000
LABODIRE	-	0. 0260	-	***************	-6550484. 2429
LABOINDI	-	0. 0459	-	-4062285. 8059	0. 0000
ASSEECON	-	0. 0419	-	-640220129. 0600	-18634875. 9690
ASSESERV	-	0. 0494	-	-228148208. 5400	0. 0000
CONSMATE	-	0. 0080	-	***************	0. 0000
CONSTOOL	3567603. 0535	-	-	-0. 1494	0. 0000
OPERCOST	2980657. 8238	-	-	-0. 0178	0. 0000
BASICDEF	36023100. 5930	-	-	-0. 3128	0. 0000
ASSETUTI	1454552. 5749	-	-	-3. 5220	0. 0000
RETONCAP	1037675. 8147	-	-	-0. 5352	0. 0000
NEWINVES	101933. 8537	-	-	-0. 4059	0. 0000
FIRMVIAB	559854. 9948	-	-	-2. 0036	0. 0000

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