SIMPLIFIED SYSTEM DYNAMICS:
A METHODOLOGY FOR CORPORATE MODELLING

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To my brother Stuart and his memory

ABSTRACT

This thesis deals with the development and application of a methodology for constructing corporate planning models. The methodology is based on a framework of general systems concepts consisting of elements from the System Dynamics and Input-Output approaches to the modelling of complex systems. These concepts permit the use of explicit and efficient procedures for constructing corporate planning models, which support each of the conceptual, verbal, graphical and mathematical phases of the model abstraction process.

Support for the model programming and computational phases is provided by a system of interactive computer programs, written in the 'BASIC' language, for a Digital PDP 11/70 timesharing computer. The technical details of these programs and their use, are contained in the Appendices.

Discussion of the methodology is preceded by reviews of both management science and corporate planning, which focus on their respective development histories, future development directions, and their interrelationship. These reviews provide a foundation for examining the role of computer-based models in corporate planning. In particular, the importance of modelling in resolving the conflicts and problems of corporate planning is established.

Following appraisal of a selection of systems-based modelling methodologies, including System Dynamics, a simplified version of this methodology is presented. This version permits the construction of more open models in which priority is accorded to representation of the structured, mechanistic relationships of the system being modelled.

Introduction of the matrix algebra concepts of Input-Output Analysis enables systems to be represented as vectorised networks, which in turn facilitate the construction of less aggregated models.

A series of ten applications of the simplified System Dynamics methodology, involving the construction of both financial and non-financial models, is then presented. These applications, together with a comparative study using a typical 'non-systems' approach to the construction of a benchmark financial model, provide the basis for assessment of the methodology. This assessment is made in terms of its strengths and weaknesses, and of some recent technological advances in computing.

As a systems approach to corporate modelling, the methodology is found to meet the needs of corporate planners more closely than any of the existing systems methodologies. The representation of systems as open vectorised networks facilitates model-building and the construction of more flexible, understandable models. These advantages increase markedly as the scale of models constructed with the methodology increases.

The weaknesses of simplified System Dynamics are found to relate directly to the limitations of the current version of the computer software system which supports it. This software system must therefore be upgraded if these weaknesses are to be eliminated. This upgrading should proceed in a manner which takes maximum advantage of the data base management and graphics capabilities of modern time-sharing computers.

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I sincerely thank Professor G.J. Schmitt of the Department of Management Studies, Waikato University and Professor M.S. Rosser of the Department of Theoretical and Applied Mechanics, School of Engineering, Auckland University, for their guidance and constructive criticism offered in the course of the preparation of this thesis.

As a major objective of my research was to apply the methodology presented here, I am particularly grateful to the management of Hallmark International, Caldwell Holdings Ltd., James Aviation Ltd., the N.Z. Livestock Federation, Doug Morris Appliances Ltd., and Trigon Plastics Ltd., for providing me with the opportunity to construct planning models under 'live' conditions. Direct exposure of the methodology and its supporting computer software to a diversity of real-world modelling problems has been essential to the ascertainment of its practical utility as a corporate planning tool. This exposure has also provided insight into likely directions for its future development.

During the early stages of my research considerable time and effort was expended in the design, development and testing of the system of computer programs to support the methodology. I am indebted to Jennifer Fredericksen for her programming efforts in respect of the data entry and report generating programs of the resultant package. I also acknowledge with gratitude the assistance rendered by the Graduate School of Business Administration, University of Washington, in affording me the use of their computing equipment during a period of study leave spent there in 1978.

On completion of development and testing work on the software system, an extensive programme of applications work was embarked upon. In the course of this work, valuable assistance in data collection and model testing was provided by Mark Mathews and Evan Johnson, (in respect of the Livestock Improvement Federation financial and market models) and Yeoh Kok Choon (in respect of the Caldwell Holdings financial model).

Finally, I acknowledge with considerable gratitude the many evening and week-end hours spent by my wife Kay and Wendy Gallie, in typing the early drafts of this thesis. Their efforts provided an excellent foundation for the efficient and skilful completion of the final typescript by Lyn McCarty.

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CHAPTER 1

INTRODUCTION

The research presented in this thesis relates to the development and application of a methodology for constructing corporate planning models. This methodology is based on the use of a framework of general systems concepts which consists of elements from the System Dynamics and Input-Output approaches to the modelling of complex organisations.

Specifically, the methodology seeks to provide model builders with explicit and efficient procedures for model construction which support each phase of a 'conceptual-verbal-graphical-mathematical' sequence for the model abstraction process. Support for the programming and computation of the resultant models is provided by a system of interactive computer programs written in the 'BASIC' language for a Digital PDP 11/70 timesharing computer.

As with conventional System Dynamics modelling, the flow diagram (the graphical form of the model) constitutes an integral part of the model abstraction process, serving both as a communications device and as the vital link between the verbal and mathematical forms of the model. The methodology proposed here, however, is characterised by two important departures from conventional System Dynamics. These are:

(1) The simplification of the conceptual framework to the extent that more open models are constructed in which the focus is on representation of the more highly structured and mechanistic relationships of the system.

being modelled. The less structured relationships associated with the decision processes are in general reflected as exogenous influences, rather than being modelled endogenously using closed information feedback loops. As a consequence, the flow diagrams of the resultant models constitute simpler network representations of the systems which they depict.

(2) The use of the matrix algebra concepts of Input-Output Analysis to permit 'vectorisation' of the networks comprising the model and thus the construction of less aggregated models, within a powerful analytical framework. Nevertheless, the methodology retains much of the capability possessed by conventional System Dynamics for reflecting the dynamic behaviour of real world systems.

These two departures thus consist of a conceptual simplification on the one hand and a conceptual enhancement on the other, which together permit the construction of dynamic input-output models. To the extent that the General Systems Theory view of the real world is that of a dynamic hierarchical system of 'input-transormation-output' sub-systems, these departures give rise to a methodology which is more closely aligned to this view than is either of its parent methodologies.

1.1 Objectives of the Research

The primary objectives of this research were to develop a systems-based modelling methodology for use in corporate planning and to illustrate its application in this context. Of the existing systems approaches to modelling, only System Dynamics can be regarded as offering a serious challenge to the dominance currently exercised by the non-systems approaches to the construction of corporate planning models - approaches which are typically based on the use of the traditional accounting framework and non-rigorous, ill-defined procedures for model construction.

Nevertheless the impact of System Dynamics on corporate planning is still minimal, despite the passing of two decades since its inception and a period of growth in the scale and complexity of organisations which has intensified the need for a systems approach to their management.

1.2 Outline of the Research Approach

Chapters 2 and 3 are devoted to reviews of management science and corporate planning respectively, in terms of their historical development, their inter-relationship and the likely direction of their future development. The need for management science to establish itself as a support discipline for corporate planning and the importance of techniques development in ensuring this is discussed. This is followed by an assessment of the likely nature of this development - given the 'workface' problems being experienced by managers in attempting to bridge the gap between the theory and practice of corporate planning.

These reviews provide the foundation for an examination of the role of computer-based models in the corporate planning process. Modelling is seen as being a key factor in bridging the above-mentioned gap and in resolving the conflict between the need for more comprehensive, pervasive planning and the need for greater flexibility and responsiveness in planning. With this in mind, some important requirements for corporate planning models and some principles for the design of modelling systems are identified, both of which lead to confirmation of the necessity for a systems approach to the problem of modelling complex organisations.

Models and modelling methodologies are discussed in Chapters 5 and 6, with the latter chapter being devoted to an appraisal of a selection of systems methodologies, including System Dynamics.

Chapter 7 provides an introductory treatment of simplified System Dynamics as a methodology for the construction of corporate planning models. The conceptual framework of this approach is presented, along with details of the procedures used in respect of each phase of the model abstraction process. A description of the supporting computer software package is also provided, in general terms, with the technical details of the constituent programs and their functions being contained in Appendices A through to K.

Chapter 8 deals with the detailed practicalities of applying the methodology, and its associated computer software, to two simple but realistic modelling situations. Some important comparative considerations are addressed in Chapter 9, which centre on the matrix algebra features of simplified System Dynamics and their relationship to both Input-Output Analysis and the array capabilities of the DYNAMO III software system.

Full scale applications of simplified System Dynamics are documented in Chapters 10 and 11, while Chapter 12 focuses on some of the managerial aspects of these applications. In Chapter 13 a series of four more financial modelling applications are summarised along with three non-financial models constructed using the methodology.

The extensive programme of applications which has formed an important part of the research presented in this thesis, enables the identification of key strengths and weaknesses of the simplified system Dynamics approach, which are presented in the final chapter. These in turn provide insight into possible improvements to the methodology and to potential for its application in areas other than corporate planning.

PART I

MANAGEMENT SCIENCE AND ITS ROLE IN CORPORATE PLANNING

A review of management science and corporate planning in terms of their respective development histories and their likely directions of development over the next decade. This is followed by an examination of corporate models which focuses on their role in planning and on methodologies for their development.

CHAPTER 2

MANAGEMENT SCIENCE: A REVIEW

Since its World War II beginnings, Operations Research/ Management Science (OR/MS) has undergone a pattern of development which has been the subject of much criticism and comment in recent years. The broad spectrum of contributors to the discussion ranging from the practitioners and academics within the profession to managers and academics without has resulted, not surprisingly, in the emergence of a diversity of viewpoints accentuated inevitably by elements of natural bias and preconception.

The purpose of this chapter is to review this body of opinion and to organise it, as far as possible, into a coherent structure of causes and effects. This is then used as a basis for determining the likely direction of development for OR/MS over the next decade.

2.1 Historical Development of OR/MS

The fundamental concept of OR/MS - the multidisciplinary team use of scientific methodology to solve problems - evolved during World War II. Since that time both the nature of OR/MS in practice and the extent of its application have undergone considerable change in a rapidly changing social, economic and technological environment.

The general nature of the changes in OR/MS over the post-war years is summarised in Table 2.1, in terms of the broad trends

TABLE 2.1: HISTORICAL DEVELOPMENT OF OPERATIONS RESEARCH/MANAGEMENT SCIENCE

TIME PERIOD	SCOPE	DECISION MAKING AREA OF IMPACT	TECHNIQUES USED	EDUCATIONAL BACKGROUND OF OR/MS PRACTITIONERS
1940's	Military Systems	Tactical	Informal Data Collection & Analysis	Scientists from the Physical & Biological Sciences (Physiologists, Biologists, Physicists, Mathematicians)
1950's	Military Systems Industrial Systems (large scale only)	Tactical Tactical (limited)	Analytical Modelling	Ex-wartime Researchers
1960's	Military Systems Industrial Systems (large & medium scale)	Tactical & Strategic Tactical	Analytical & Simulation Modelling	Graduates of the Science & Engineering Schools (Mathematicians, Statisticians & Engineers)
1970's	Military Systems Industrial Systems (full spectrum) Social Systems Economic Systems	Tactical & Strategic Tactical & Strategic (limited) Tactical (limited) Tactical (limited)	Analytical & Simulation Modelling (with Heuristic Optimisation)	Graduates of the Science, Engineering & Business Schools, (Mathematicians, Statisticians, Engineers & Specialists in the Management Disciplines)

in its scope, impact, techniques and practitioners. OR/MS in the 1940's was characterised by its exclusive concern with military systems and tactical decisions within these systems. The techniques used were largely restricted to informal data collection and analysis performed by hastily formed teams, organised to compensate for the inadequate training of service personnel at that time (Zuckerman, 1964).

The transfer of OR/MS from military to industrial systems took place rapidly, particularly in the U.K. (Gratwick, 1979), largely through the efforts of those involved in its wartime beginnings. The first significant postwar applications were in the production operations areas of large scale industrial systems (Phillips et al, 1976) which lent themselves by their nature to Dantzig's recently developed optimising technique of linear programming. Perhaps the two most significant developments of this decade were the emergence of formalised mathematical model-building techniques and concurrently a loss of the 'multi-disciplinarity' of the previous decade.

The 1960's saw the continuation of the diffusion of OR/MS through industry in the private sector and the beginnings of its use in the public sector. The scope of its impact also spread during this period with the emergence of Systems Analysis techniques in the U.S. Department of Defense directed at strategic planning problems (Trost, 1979). In the area of techniques, simulation modelling started to become established as a serious alternative to the still dominant analytical modelling techniques. The educational background of the OR/MS practitioners of this decade was predominantly in the mathematical and engineering disciplines (Schumacher & Smith, 1965;

Cook & Russell, 1977) - undoubtedly a significant factor in the continued emphasis placed on analytical techniques during this decade.

The development of OR/MS during the 1970's benefited significantly from the spectacular growth of computer technology in the previous decade. Large scale models of complex systems became technically and economically feasible, providing further stimulus for techniques development and the capability for addressing more complex problems. Thus OR/MS began to be applied in social and economic systems and to contribute to strategic decision making in both the military and civilian sectors. Also evident in this decade were the beginnings of a broadening in the educational base of OR/MS practitioners, with the emergence of graduates from OR/MS programmes in the business schools, (Graham, 1977) and the completion of its transformation from a results-oriented multidisciplinary activity (Gratwick) to a techniques-oriented discipline in its own right (Phillips et al).

To summarise, it would seem that the overall progress of OR/MS has been substantial as it enters its fifth decade. On closer examination however, much of this progress appears to have been superficial, especially when it is viewed against the immediate post-war prognostications for its future and the totality of management decision-making (Halbrecht, 1972; Woolsey, 1976; Little, 1970; Drucker, 1973; Grayson, 1973; Rivett, 1974). It seems that most successful OR/MS applications are still confined to the operational level of decision making (Lucas, 1976; Gratwick, Simon et al, 1976) with only marginal success being evident at the strategic level (Urban, 1974; Bonini, 1978). Developments in methodology have been slow (Raitt, 1974) during a period of unprecedented increase in the rate of environmental change and the scale and complexity of organisations.

2.2 OR/MS Today

Over the years frequent appraisals of OR/MS have appeared in the literature. In more recent times a sharp division of opinion has become apparent to the extent that two schools of thought can be identified. The first group claims that OR/MS has made a significant impact of managerial decision-making, principally at the operational level, but acknowledges the existence of some problem areas. These problem areas range in severity from poor public relations (Cowie, 1979) to implementation difficulties, albeit for a minority of organisations (Cook & Russell) and more recently to a scarcity of new approaches (Gratwick).

The second group is critical of the present day state of OR/MS to the point, in some cases (e.g. Ackoff, 1979a) of pronouncing it dead. The members of this group perceive as serious at least one of the two related problems in OR/MS:-

(1) a low level of impact on real-world decision-making, and

(2) a high rate of implementation failure.

Regardless of which of the above alleged problems is addressed, the point is invariably made that radical changes in OR/MS are required as a counter-measure. There is, however, a notable lack of agreement as to the nature and extent of the required changes. Some seem little more than cosmetic. Hammond, suggests merely a shift in the role of OR/MS from that of decision maker to 'decision prosthetic' while writers such as Levitt, 1978, and Grayson call for a shift in techniques towards simpler, more workable approaches.

Sagasti and Mitroff, 1973, and Urban both focus on the overall model-building process and the need to improve it, particularly as regards managerial involvement. Wheelwright and Makridakis, 1972, advocate both simpler techniques and an improved model building process, while Raitt calls for innovation in the OR/MS methodology together with the need to establish model utility as a major criterion.

Perhaps the most fundamental change is that proposed by Ackoff. He argues for a complete revision of the OR philosophy, in order to enable development of the ability to formulate and solve problems, then implement and maintain the solutions in a 'turbulent environment'. He also detects a loss of innovativeness and interdisciplinarity in OR, resulting in an obsession with techniques and a consequent reduction in its utility.

As with many instances of polarised opinion in society, there are almost certainly elements of truth in the arguments of both schools. The champions of present-day OR/MS view its development in absolute terms and in a purely historical context, while the detractors view it in relation to the immediate postwar claims for its future and the totality of present-day management decision-making. The important considerations, however, are those pertaining to the future of OR/MS and the need for it to change if it is to achieve maximum utility and maintain its relevance in a climate of rapid change. In as much as the latter school comprises the proponents of change, there is merit in considering its arguments when attempting to assess the likely nature and extent of this change in the immediate future.

2.3 Causes and Effects in OR/MS

In this section an attempt is made to take an holistic view of the arguments presented in the literature by the proponents of change

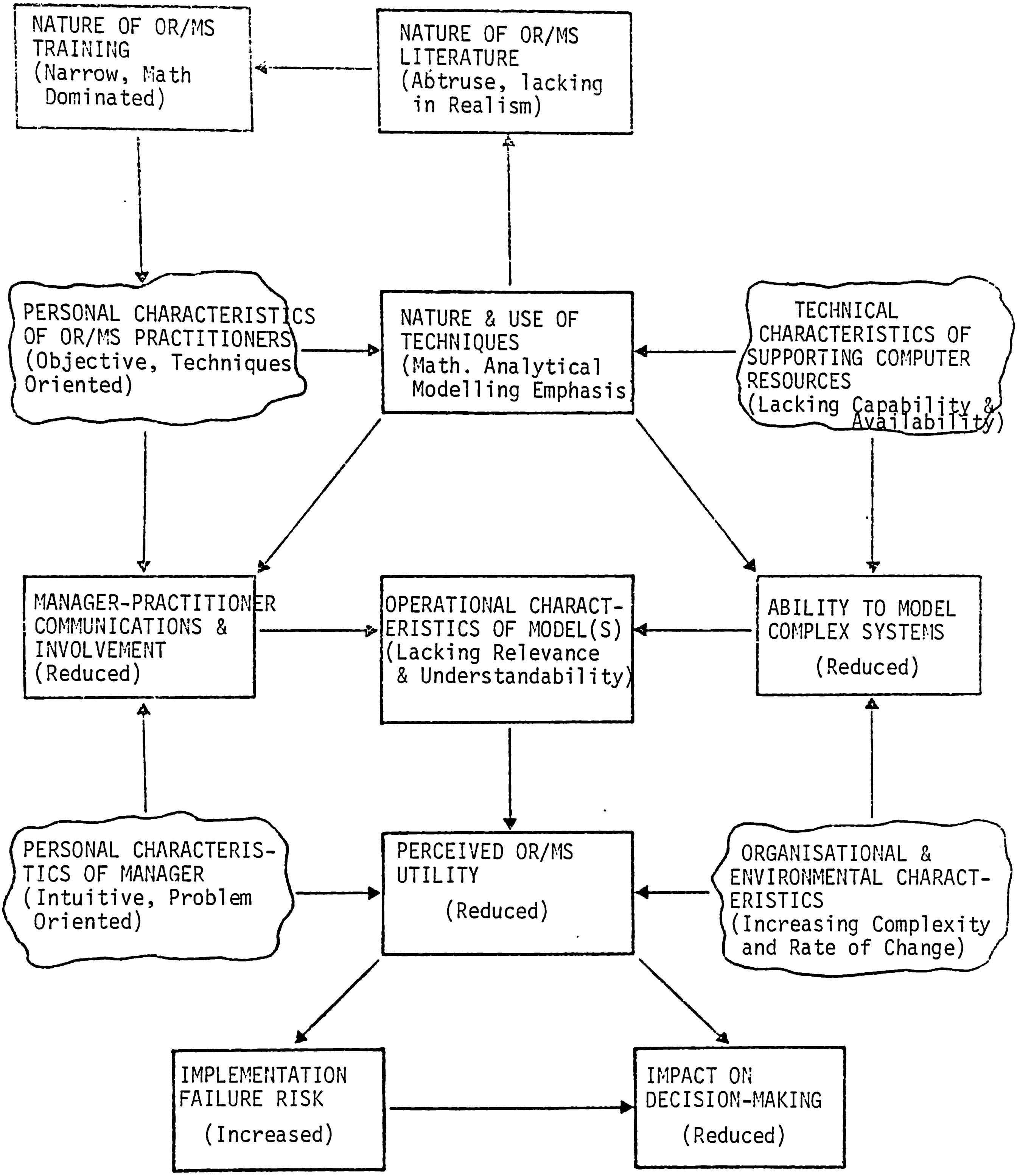

FIGURE 2.1: A CAUSE-EFFECT STRUCTURE FOR OR/MS

in OR/MS. The absence of a common view on how OR/MS should develop has been noted above. Much of this lack of agreement seems to arise from differences in the scope and emphasis of the analyses undertaken by the various writers, rather than any direct conflict of opinion. The wider view taken here is aimed at providing a coherent, integrated cause-effect structure for OR/MS. This is then used as a basis for a broad assessment of the likely pattern of its development if it is to maximise its contribution towards better management decision-making.

A set of thirteen distinct factors is identified in the cause-effect structure depicted in Figure 2.1. The principal negative effects associated with each factor are shown in parentheses on the diagram. Commencing at the top, the <u>nature of OR/MS training</u> is seen to have a two-fold effect. The traditionally narrow training received by most OR/MS practitioners(Cook and Russell[1]) generates an undue preoccupation with objective techniques[2] on the part of practitioners and inhibits technique development and use[3]. This preoccupation has probably been the target of more criticism from the proponents of change than has any other. The essence of this criticism - over-reliance on mathematics and analytical modelling - is supported by the findings of Ledbetter and Cox, 1977, which showed 63% of applications utilising these techniques.

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1. Refer p.441. In a 1964 survey the disciplines of Engineering, Mathematics & Statistics were found to provide 65% of the OR/MS personnel surveyed. Although the 1974 survey shows a broadening in the range of disciplines spawning OR/MS practitioners, the emergence of an OR/MS 'discipline' is contrary to its original concept as an 'ecumenical activity' - a concept generally regarded as being a major factor in its early success (Phillips et al).

2. Described by Ackoff (Ackoff, 1977) as an obsession with optimisation and objectivity.

3. Poole and Szymankiewicz, 1977, assert that simulation has not been fully exploited as a problem-solving technique because training establishment syllabi are 'too academic'.

The nature of OR/MS literature is of significance because of its feedback effects[4] on OR/MS training and to a lesser extent on the public image of OR/MS. Rivett observes that many people look at OR/MS as being synonomous with Linear Programming. The accusations of others (e.g. Gratwick), to the effect that OR/MS literature is abstruse and lacking in relevance to the real world, are supported by the empirical evidence of Urban. This evidence, based on a survey of 150 articles published in the "Management Science Applications" series from January 1971 to June 1973, was that only 15% described real world modelling applications.

To some extent at least, this state of affairs is a reflection of the state of OR/MS techniques and their use (or non-use) and to some extent it in turn reinforces the narrow mathematics-dominated training of practitioners, thus completing the feedback loop. Further evidence of the lack of relevance and balance in the literature is apparent in the results of a survey, conducted by the writer, on a sample of 22 introductory OR/MS texts, (refer p. 20). This survey showed that analytical modelling techniques constituted on average 57% of total page content and that simulation averaged only 7%. This lack of balance is all the more disturbing when viewed in the light of Turban's survey (Turban, 1972), which reports that on average from 25% to 50% of OR team time is spent on simulation.

The technical characteristics of computer resources have undoubtedly had a direct bearing on the nature and use of OR/MS techniques (Cook and Russell). Dekker, 1978, claims that recent hardware

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[4] The importance of this feedback is identified by Hall and Hess, 1978, in their plea for more readable summaries of academic discoveries and more writing up of case studies in the literature.

advances have removed all hardware-related constraints on the use of simulation. However, the lag between technological advances and the use of techniques made possible by these advances is still significant so that analytical techniques remain dominant at the present time.

One consequence of the bias towards mathematical and analytical techniques is described by Ackoff as an inability to handle the critical problems of external change and adaptation. Such problems are of course characteristic of complex, dynamic systems and thus the ability to model these systems is impaired. Further effects are a reduction in understandability (Little) - both in the model and the modelling process. Tocher, 1972, points to a methodological dilemma in that the mathematical complexity of a model bears an inverse relationship to its relevance. Both understandability and relevance are important operational characteristics of models.

These characteristics together with the personal characteristics of managers as intuitive problem-solvers, and the trends in organisational and environmental characteristics constitute the principal determinants of perceived OR/MS utility. The importance of utility in OR/MS is recognised by Lilien, 1975, and by Raitt - who advocates the establishment and application of utility as a fundamental criterion in management science.

The personal characteristics of managers in the form of a diversity of cognitive styles (Dokter and Hamilton, 1973), and the perception of OR/MS as a threat (Bonini) clearly contribute to the fundamental attitudinal differences between OR/MS practitioners and managers which Hammond identifies. These differences manifest themselves in the form of poor communications between the two and a low level of managerial involvement in model development. As far as organisational and environmental characteristics are concerned, Ackoff, 1979a, Gratwick, and Grayson, all see the increasing rate of environmental change as a major cause of the reduced utility of OR/MS, due to its shortening the life of problems and solutions.

The cause-effect relationships between perceived OR/MS utility and the two major 'end effects' of implementation failure risk and impact on decision making are self-evident. The structure of Figure 2.1 can thus be seen to incorporate and integrate most of the cause-effect relationships propounded in the literature. It remains now to discuss the future development of OR/MS in terms of this structure and the need to maximise its impact on decision-making.

2.4 The Future Development of OR/MS

Any assessment of the future direction of OR/MS must take cognisance of broad trends operating in the environment. Cook and Russell postulate the continuation of the following four trends.

(1) The dwindling in supplies of natural resources.
(2) The positive growth in population.
(3) The increasing rate of technological growth.
(4) Greater organisational complexity and rate of change.

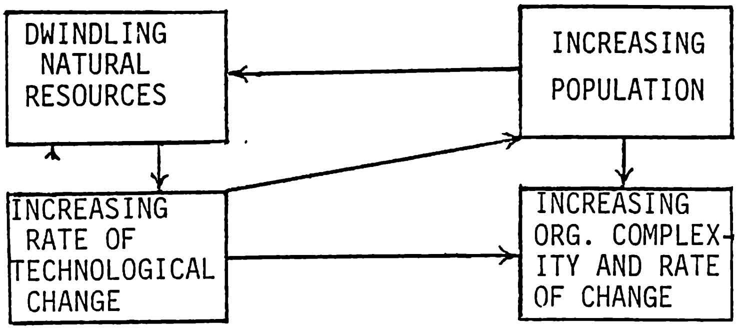

FIGURE 2.2: ENVIRONMENTAL TRENDS AND THEIR INTERDEPENDENCY

To some extent these trends are inter-related as depicted in Figure 2.2. Increasing population reinforces the other three trends while the dwindling of natural resources acts to stimulate technological growth - which in turn adds to organisational complexity, and the rate of environmental change generally. The increasing rate of technological growth, to the extent that it is not directed at resource conservation, also reinforces the trend of dwindling natural resources.

The foregoing observations have significant implications for OR/MS. Increased organisational complexity and rate of change will inevitably place increased pressure on decision makers, forcing an even greater reliance on support resources - in particular those which can facilitate rational decision-making. Thus an increasing need for OR/MS seems assured, and the OR/MS challenge becomes one of how to develop in order to meet this need to the maximum extent possible.

On the basis of the cause-effect structure postulated in the previous section the prescriptions offered by the proponents of change in OR/MS can be organised into a four dimensional framework. Each of these developmental dimensions is discussed below.

(1) OR/MS Training Development

The most commonly identified requirement in this area is for OR/MS practitioners to have a broader educational base, incorporating in particular some exposure to business functions and real-world problem solving (Cook and Russell, Graham). Hall and Hess also suggest greater academic involvement in real-world problem-solving together with academic internships in industry. Similar views are expressed by Grayson.

Broadening of the educational base should also include suitable exposure to related disciplines. McLelland, 1975, advocates multi-disciplinary training, with emphasis on the behaviour of people in organisations and the development of human skills.

An important consideration relating to the need for greater breadth, is that of achieving the best possible balance - between techniques and applications, between techniques and the subject matter of related disciplines and within the techniques themselves. Table 2.2 provides some evidence of the extent to which a techniques imbalance currently exists in introductory OR/MS texts, an imbalance which is almost certainly reflected in the OR/MS training programmes utilising those texts.

Finally, OR/MS training must become more responsive to developments in the remaining three development areas suggested in this section, in view of its importance as a fundamental determinant of OR/MS utility in the long-run. New techniques, new insights into the OR/MS and management processes, and more pragmatism in the literature must all serve to inject more relevance and effectiveness into OR/MS training programmes.

TABLE 2.2: A COMPARISON BETWEEN OR/MS TECHNIQUES USAGE & RELATIVE EMPHASIS IN INTRODUCTORY TEXTS

	Survey of Techniques Most Used[5]	Survey of Relative Emphasis in Texts[6]
Programming	27%	41%
Inventory	6%	9%
PERT/CPM	6%	7%
Queuing	1%	7%
Simulation	25%	7%
Other	35%	29%

(2) OR/MS Literature Development

The problems in the literature of abstruseness, imbalance and lack of realism have, according to Simon et al, generated the view that management scientists are talking largely to themselves. Clearly the literature must develop to overcome these problems if it is to provide adequate support for OR/MS trainees and practitioners, and if effective communications are to be established with a wider audience.

Ideally, this development should include the dissemination of case studies (Hall and Hess) written by and for managers, covering the broad spectrum of techniques and all aspects of the OR/MS process - from problem formulation to post-implementation appraisal. Also the interface between OR/MS and its supporting sciences needs to be discussed more extensively in the literature. Over-riding all of these considerations is the need for the literature to reflect more closely the changing pattern of techniques and those developments in the supporting sciences which are of practical significance to OR/MS.

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[5] Ledbetter and Cox.

[6] Conducted by the writer.

(3) OR/MS Techniques Development

With the advent of recent computer technology developments such as relatively cheap timesharing and powerful user-oriented software, the stage seems to be set for a period of substantial development in the field of OR/MS techniques, as the pressure for this development increases. Managerial decision-making needs point towards two major areas for techniques development. First there is a need for simple techniques to support day-to-day management decisions and widen the scope of OR/MS at the operational level of management (Wagner, 1975, Woolsey and Huntington, 1975). Second, there is a need for flexible, powerful techniques capable of supporting management in complex unstructured decisions, thus extending OR/MS into the strategic level of management (Shannon, 1975) and into complex, less structured systems such as those of the public sector (Rice, 1975).

Both Wagner and Zeleny, 1975, foresee a wider definition of the OR/MS process being accompanied by the need for more effective techniques of both the modelling and non-modelling kind. As far as modelling techniques are concerned, Shannon perceives a need for the ability to incorporate non-quantitative factors such as value judgements into models, while Cook and Russell predict advances in multi-criteria decision tools with the advent of techniques such as goal programming. After some decades as the method of last resort, there is growing support for the view of Emshoff and Sisson, 1970, to the effect that simulation will have a major effect on the way people manage, as it rides the crest of the current wave of computer technology. Van Horn, 1971, for example, sees simulation as offering the most flexible, realistic way of representing complexity, while Dekker proclaims that interactive simulation will eventually become a necessity. This being so, it will qualify as one of the new ways of exploiting the full powers of computers for which Wagner sees a requirement.

Some insight into the likely sources of new techniques is provided by Thierauf and Klekamp, 1975, who suggest that their formation from the combination of existing ones is becoming an important trend[7]. Zeleny, 1975, sees potential for ideas in such areas as fuzzy mathematics, group decision-making and organic systems analysis.

The trend toward hybrid techniques has developed in response to the complexity that derives from a lack of homogeneity in real problems[8]. For example, large complex systems typically display both discrete-event and continuous-flow behaviour which cannot be reflected adequately in models developed using purely discrete-event or purely continuous-flow techniques.

General systems theory offers the possibility of techniques applicable to general classes of problems and the related benefit of quick efficient problem-solving[9], although Raitt advocates a partial and selective use of systems concepts in developing a diversity of specific methodologies. Perhaps both viewpoints could be accommodated with the evolution of a hierarchy of systems-based methodologies incorporating ordered levels of specificity.

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7. An example of this is the use of heuristic 'optimising' algorithms to 'solve' simulation models (Fuller, 1978).

8. Zeleny observes that most problems are neither purely analytical, nor purely intuitive but combinations of the two.

9. Osborne and Watt, 1977, suggest that this arises through enhancement of the ability to recognise and solve problems within a given class.

(4) OR/MS Process Development

This fourth and final dimension to future OR/MS development stems from concern at the inadequacy of the traditional view of OR/MS as a problem-solving process. Sagasti and Mitroff have identified five components in the OR/MS process and argue that both the knowledge and application of this process have been sub-optimised. They consider it to be an advice-generating process and suggest a conceptual model of it based on general systems theory. This model, structured in terms of their five components, is shown in Fig. 2.3. Apart from noting that all components, or sub-systems, are equally critical and that the process of forming analogies to arrive at a conceptual model has been virtually ignored, the authors offer little insight into the practical ramifications of their model. More importantly, however, they do not see the decision-maker as being a component in the process, which is seen as being essentially a model building one. In these respects their model differs little from the traditional view of the process.

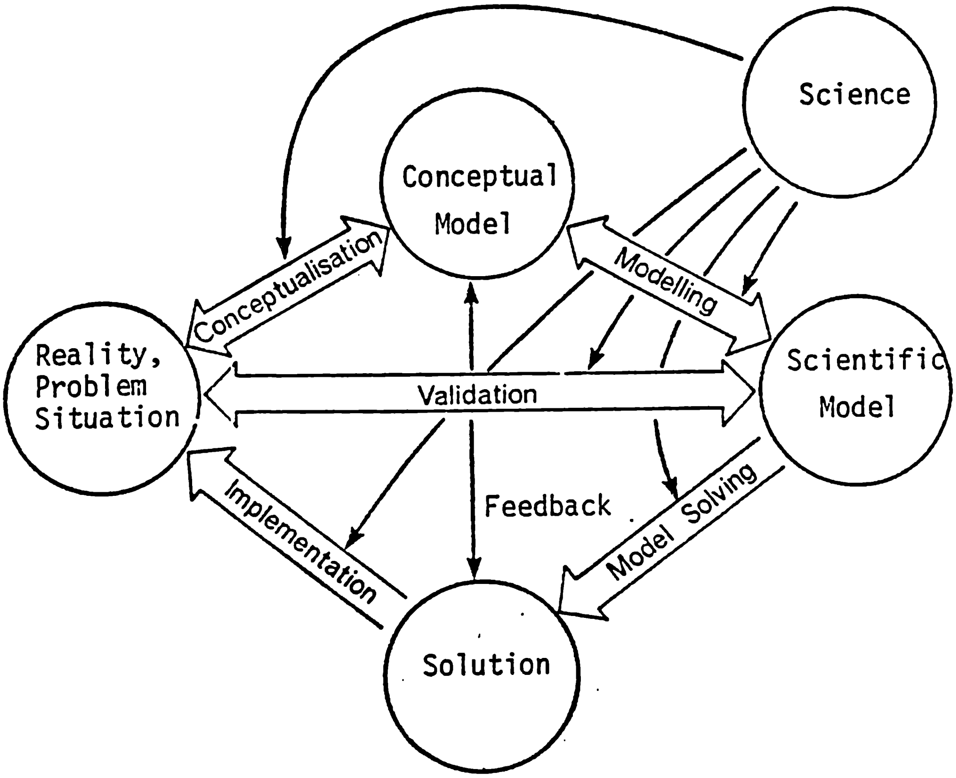
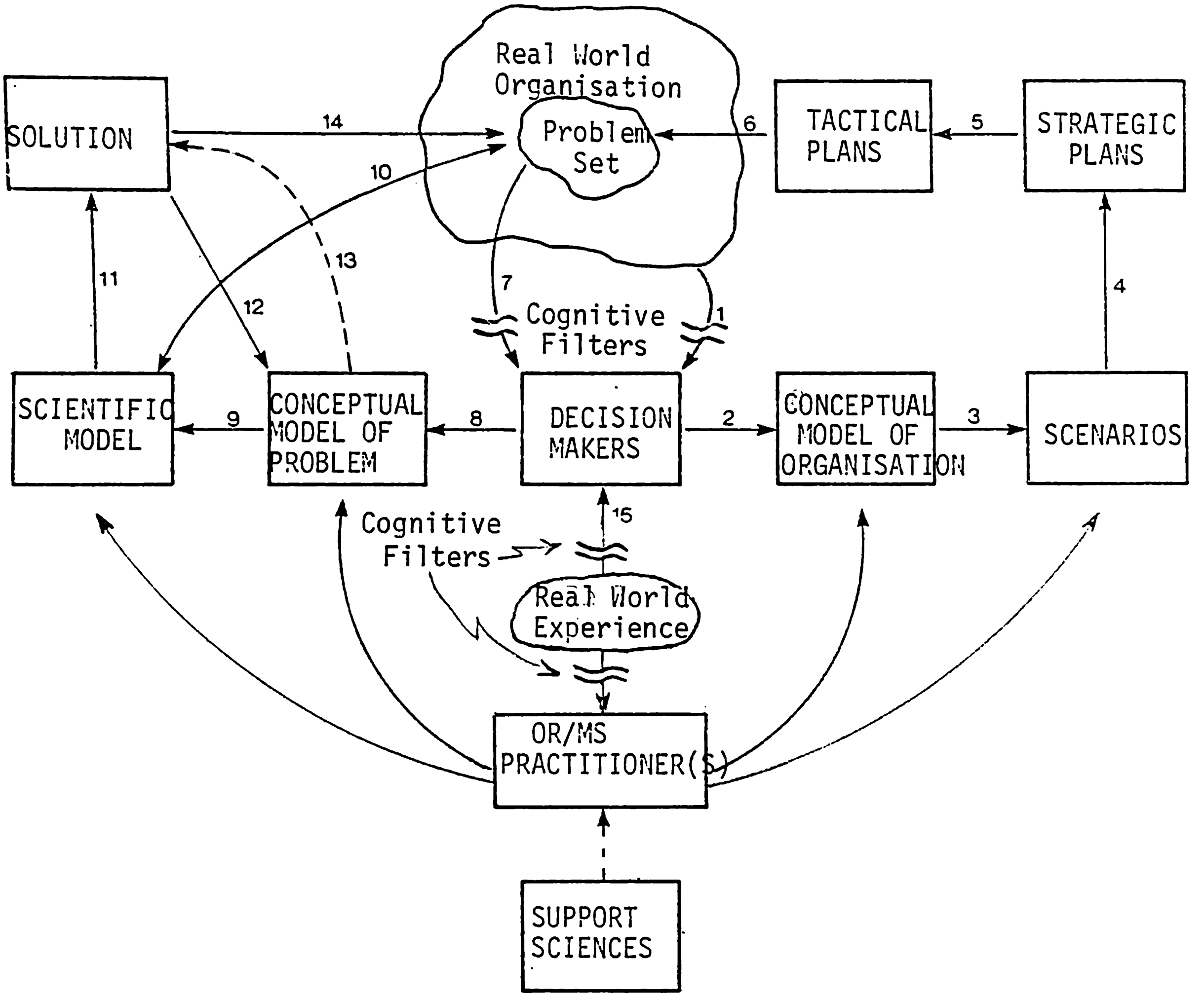


FIGURE 2.3: THE OR/MS PROCESS AS PER SAGASTI AND MITROFF
(see Sagasti and Mitroff, p. 699)

Urban proposes a methodology for the model building process based on viewing it as an organisational change mechanism - an improvement which he sees as necessary to realise the promise of OR/MS. Eight steps are identified in his view of the process, which is distinguished by explicit recognition of the importance of model builders being awake to their natural biases, the supporting role of the formal model and the nature of the model implementation as a continuous process.

The most dramatic development suggested for the OR/MS process however, is that put forward by Ackoff, 1979b, in his call for a change of paradigm - from 'problem solving' to 'ways of designing a desired future and bringing it about'. The implications of this go well beyond the 'advice generating' and 'organisational change' paradigms of the previous two writers, in that the traditional OR/MS process is seen as being an integral part of an overall planning process. Specifically, Ackoff seeks to imbed the traditional OR/MS process in a participative, continuous, multi-level planning process. The adoption of such a paradigm would obviously have profound repercussions for OR/MS techniques and training.

Figure 2.4 constitutes a systems model of the extended OR/MS process based on this paradigm. The model consists of three major sub-systems, viz., the Support sub-system (where the support sciences and the OR/MS practitioners comprise the principal components), the Planning sub-system and the Problem-solving sub-system. The sub-processes of this model, numbering fifteen in total, are as shown in Figure 2.4 and reflect the following important considerations:-



MODEL SUB-PROCESSES:

(1) Organisation Analogy
(2) Conceptual Model Formulation
(3) Scenario Formulation
(4) Strategic Plan Formulation
(5) Tactical Plan Formulation
(6) Problem Set Definition
(7) Problem Analogy
(8) Conceptual Model Formulation
(9) Scientific Model Formulation
(10) Model Validation
(11) Model Solution (Formal)
(12) Solution Validation by Feedback
(13) Model Solution (Informal-alternative to (9) and (11))
(14) Solution Implementation
(15) Utilisation of Experience

FIGURE 2.4: SYSTEMS MODEL OF AN EXTENDED OR/MS PROCESS

(based on the Ackoff paradigm, Ackoff,1979b) reflect and be responsive to the developmental patterns of the other three dimensions. OR/MS literature development must respond to developments in both techniques and the overall OR/MS process itself, while developments in the latter will, if the Ackoff paradigm is adopted, offer new horizons for OR/MS techniques, training and literature, beyond those which have been suggested here.

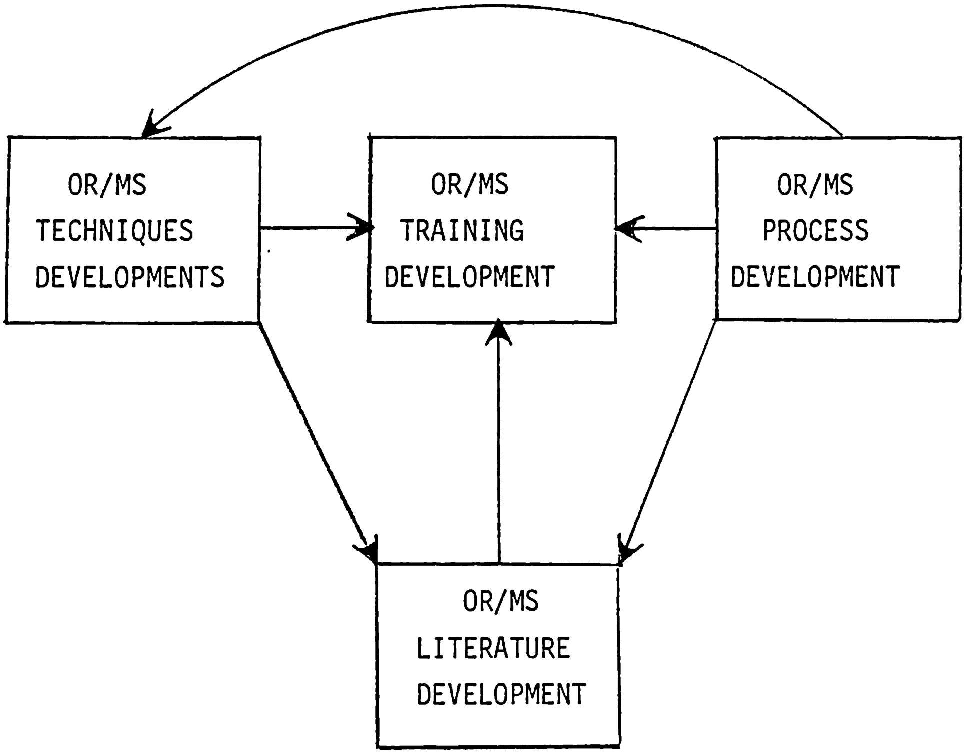


FIGURE 2.5: THE DIMENSIONS OF OR/MS DEVELOPMENT AND THEIR INTERDEPENDENCY

In this Chapter, a perspective on OR/MS has been drawn which establishes, amongst other things, the importance of techniques-development to the continuing relevance of OR/MS in a changing environment. If an acute methodological vacuum is to be avoided, considerable effort should be channelled into the development of new techniques, in a way which secures the best payoff for this effort. It can be reasonably argued that this payoff lies in the expansion of techniques relevant to corporate planning and to realise it OR/MS must be recognised as being primarily a support discipline for this process.

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CHAPTER 3

CORPORATE PLANNING: A REVIEW

Corporate planning in its broadest sense may be defined as the continuing process of

- searching out possible futures for an organisation,
- evaluating them to select the most desirable future,
- developing the means for maximising the chances of attaining the chosen future and for minimising the 'discomfort' in the event of its non-attainment.

Recognition of the importance of this process as a fundamental part of management has been spurred on largely by rapid increases in organisational complexity and the rate of environmental change, which have characterised the last three decades. A rapidly growing body of literature has emerged addressing many aspects of the process at both the conceptual and practical levels. Planning principles and practice, problems and pitfalls, methodologies and techniques have all been and continue to be the subject of lively debate. Consensus appears at present to be limited to agreement on the need for planning - a need which can be reasonably attributed to the fact that decisions must be made and decision-making inevitably implies assumptions about the future. It is reasonably argued (Amara, 1979) that anti-planning sentiments are invariably predicated on some misconception about the meaning of planning - perhaps the most common of which is its confusion with forecasting.

There also seems to be evidence in the literature of agreement (at least among theorists) on the broad phases associated with the corporate planning process, to the extent depicted in Figure 3.1. However this claim cannot be made without some qualification notably as regards the ordering of the 'Scenario' and 'Objectives' phases. Ackoff, 1970, and Perrin, 1971, both advocate the addressing of objectives as the first phase. Katz, 1970, effectively defines scenario formulation as the first phase, while Ansoff, 1965, combines both alternatives in a 'tentative objectives-scenario formulation-final objectives' sequence.

It should be noted at this stage that the meaning attached here to the 'scenario' concept is somewhat broader than that usually found in the literature. It is defined here to encompass the environmental appraisal, the internal appraisal and the constraint, policy and assumption formulation activities - resulting in effectively three scenarios. These can be described as the present environmental scenario, the assumed future environmental scenario and the present organisational scenario.

Further analysis of the current state of affairs with regard to corporate planning should proceed with due recognition of the fact that there exists a significant gap between the theory and practice (Martin 1979).

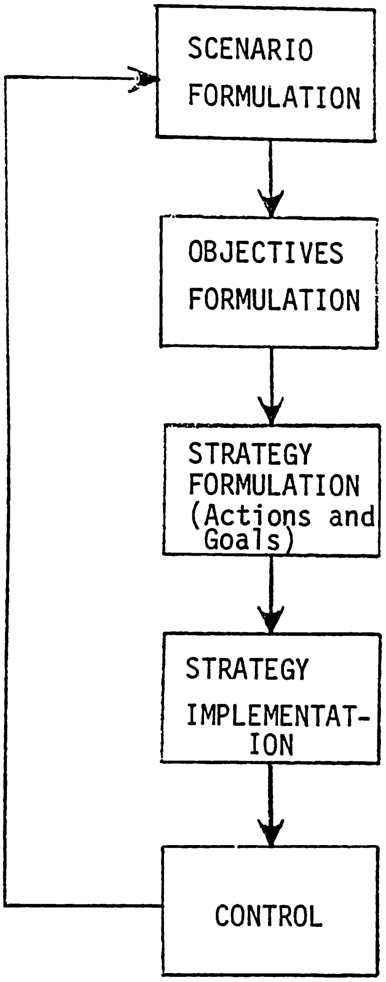

FIGURE 3.1: BROAD PHASES OF THE CORPORATE PLANNING PROCESS

3.1 Corporate Planning - Present Day Practice

Ansoff, 1977, observes that most firms today practice only long range planning, a planning style characterised by the extrapolation of existing trends and the preservation of goal continuity. Kudla, 1978, in his survey into planning in U.S. Corporations established that 84% of 323 responding firms prepare some form of long range plan and that this is usually based on a planning horizon of 3 - 5 years with annual reviews.

Similar findings are reported by Naor, 1978, and Martin, although the latter's results (based on a survey conducted in the U.K. on a sample of almost 100 companies from the 'The Times' top 1000 companies) showed only 50% pursuing this style of planning. The remaining 50% were found to be planning on a far less formal basis, centred on annual budgeting. Martin also asserts that the gap between corporate planning theory and practice is growing, with the styles advocated by the theorists not being practiced in any developed form by the large corporations.

In summary, the evidence indicates that in some organisations there is an unwillingness to plan, while for those organisations which do practice formalised planning, the styles of planning used fall well short of those advocated in the literature, in terms of their scope and effectiveness, measured against the definition of corporate planning provided at the start of this chapter. Planning, if it is done at all, is too often seen as a process separate from management, either through the separation of managers and planners (Taylor, 1979) or the separation of planning in the minds of managers (Amara; Vancil, 1976).

3.2 Corporate Planning - Present-day Theory

The available literature on corporate planning displays a remarkable diversity of forms, concepts and styles with little evidence yet of the emergence of a stable theoretical base. A major obstacle in the path of such a development appears to be profound disagreement at the conceptual level, to the extent that writers such as Holloway & King, 1979, describe corporate planning literature as a 'semantic jungle'.

In order to facilitate some form of comparative analysis of the current literature a framework is proposed here whereby any given planning style can be assessed in terms of four dimensions[1] each of which is described below.

(1) Conceptual Scope

This dimension relates to the nature and extent of the components of corporate planning defined for any given approach. Holloway & King propose a set of six components which they suggest represent a consensus of best contemporary usage. Their definition of strategy, however, as a set of decision rules and guidelines, would receive little support in the literature. A modified set of four components is proposed here (refer Table 3.1).

The term 'scenario' as defined here, embraces the concept of 'mission' identified by Holloway & King and the term 'action plan' embraces their concepts of 'program and project'. As is usually the case, the concept of 'strategy' is seen here as comprising the three key elements of objectives, action plans and goals; which in turn must be formulated within the constraints (i.e. rules) imposed by either the environment, or the organisation itself in the form of policies (i.e. self-imposed rules).

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[1] Holloway & King propose a 3-dimensional framework comprising conceptual, organisational and systems dimensions. This framework is used, however, for the purpose of evaluating alternative planning approaches in terms of their suitability with respect to a particular firm, rather than comparative analysis in the absolute sense.

TABLE 3.1: THE COMPONENTS OF CORPORATE PLANNING

Scenarios:	Descriptions of the Environment (in terms of Threats, Opportunities, Constraints and Assumptions) and of the Organisation (in terms of Strengths, Weaknesses and Policies).
Objectives:	Desired future states for the organisation or aspects of it - both short term and long term.
Action Plans:	The key actions necessary for the attainment of Objectives.
Goals:	Expected outcomes of action plans expressed in quantitative terms, on a time scale.

(2) Organisational Depth

The planning process can be analysed in terms of the various levels in the organisation at which it applies. Four distinct levels can be identified as follows:-

- the corporate or top management level
- the business unit level[2]

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[2] Recognition of this level for planning purposes is only a relatively recent addition to both the theory (Ansoff, 1977; Patel & Younger, 1978) and practice (Vancil). Business units may be defined in terms of corporate divisions, profit centres or product/market groups.

- the functional or activity unit level
- the personal or individual level of key staff and/or managers.

(3) Perceptual Scope

This dimension relates to the extent to which any given approach focuses on and facilitates:-

- The identification and description of multiple futures in terms of scenarios, and
- the identification, description and evaluation of multiple strategies, in terms of objectives, action plans and goals.

(4) Dynamic Responsiveness

In a climate of rapid change, the extent to which a planning approach recognises the need for, and facilitates the revision of, scenarios, objectives, action plans and goals, is an extremely important consideration. In practical terms, the question of how to achieve an acceptable level of response to change in a planning system without sacrificing perceptual scope, conceptual scope or organisational depth, is probably the most challenging problem in corporate planning today.

Analyses, in terms of the above framework, of the planning approaches of four authors of well known texts on the subject (Perrin, Ackoff, Ansoff and Katz) are presented in Tables 3.2, 3.3, 3.4, and 3.5 respectively.

TABLE 3.2: THE PERRIN APPROACH TO CORPORATE PLANNING

CONCEPTUAL SCOPE	ORGANISATIONAL DEPTH	DYNAMIC RESPONSIVENESS	PERCEPTUAL SCOPE
Scenarios defined in terms of Environmental and Position (Company) Audits - focusing on Threats, Opportunities, Strengths and Weaknesses. No explicit recognition of Constraints, Policies or Assumptions. No formal distinction is made between Objectives and Goals. Some attempt is made to take account of interdependencies with an objectives hierarchy but in a limited and vague manner. Action Plans are defined in terms of Strategic, Operational, Project and Contingency Plans. Generally offers a comparitively pragmatic but somewhat confused treatment of concepts.	Recognition of Corporate (Strategic) and Operational (Functional) levels only.	Five year planning with annual reviews.	Limited to those alternatives addressed during Gap Analysis (of the Status Quo vs. Objective projections made in the Position Audit) and Contingency Planning.

TABLE 3.3: THE ACKOFF APPROACH TO CORPORATE PLANNING

CONCEPTUAL SCOPE	ORGANISATIONAL DEPTH	DYNAMIC RESPONSIVENESS	PERCEPTUAL SCOPE
Scenarios defined in terms of a Reference Projection and Wishful Projection. The latter is formulated in terms of Stylistic Objectives, Stylistic Constraints, and Background. Objectives defined in terms of Performance Objectives translated into Goals, which constitute a Planned Projection. No attempt at postulating a goal structure. Interdependency is discussed in terms of conflict resolution through the use of a common scale of measurement. Action Plans defined in terms of actions practices, procedures and programs. Generally a very theoretical treatment of concepts and low level of integration.	Recognition of Corporate Divisional and/or Functional levels only.	Not discussed	Limited to the preparation of two internal scenarios in the form of the Reference and Wishful Projections respectively. Strategy alternatives and their formulation and evaluation is seen as being achieved through the use of explanatory models, but little insight into relevant methodologies is provided.

TABLE 3.4: THE ANSOFF APPROACH TO CORPORATE PLANNING

CONCEPTUAL SCOPE	ORGANISATIONAL DEPTH	DYNAMIC RESPONSIVENESS	PERCEPTUAL SCOPE
Scenarios defined in terms of the Internal Appraisal and the External Appraisal, with the former including the setting of tentative Objectives. Objectives defined in terms of Economic and Social types, with the former organised into a hierarchical system of objectives. No distinction between goals and objectives is made. Action Plans defined in terms of Strategic, Divisional (and/or Functional) and Operational Plans. Generally a rigorous and extensive treatment of concepts but at a very theoretical level.	Up to three levels are recognised: Corporate (Strategic), Divisional (Business Unit) and Functional	Not discussed	Limited to the preparation of two internal scenarios in the form of a set of forecasts and tentative objectives respectively. Strategic alternatives and their evaluation are seen as a problem which can only partially be assisted by OR/MS.

TABLE 3.5: THE KATZ APPROACH TO CORPORATE PLANNING

CONCEPTUAL SCOPE	ORGANISATIONAL DEPTH	DYNAMIC RESPONSIVENESS	PERCEPTUAL SCOPE
Scenarios defined in terms of an Environmental Analysis, Resource Analysis, Competitor Analysis and Scope, to establish the firm's Strategic Posture. Objectives defined as Performance Specifications embracing Stratègic Criteria and Operating Criteria. No distinction is made between objectives and goals and there is no recognition of interdependencies among objectives. A comprehensive treatment of scenario formulation but elsewhere a lack of precision and simplicity in terminology.	Only the Corporate and Operational levels are addressed.	Not discussed at the practical level, other than recognition of the need to 'recycle' plans in the event of major external changes, actual performance differing from planned,or at least annually.	Strictly single future-single strategy planning. No reference to the problems of multiple futures-multiple strategy planning and techniques to support it.

The following points are reinforced by these analyses:-

(1) The lack of agreement in the conceptual area does not preclude some degree of rationalisation in terms of the four basic concepts suggested here (viz. scenarios, objectives, action plans, goals).

(2) All four approaches offer the <u>most</u> precision and detail in the area of scenario formulation although the methodology and techniques suggested for this differ markedly.

(3) Of the four approaches only Ansoff's seriously attempts to systematically organise the multiple objectives of the firm into an objectives hierarchy or system of goals.

(4) All four approaches offer the <u>least</u> precision and detail in the area of strategy formulation, i.e. the search for alternative objectives and/or actions together with their evaluation in terms of goals. More specifically, none of the approaches clearly establishes the link between objectives, actions necessary to achieve them and the expected outcomes of those actions (goals). Also little or no reference is made to supporting methodology and techniques for strategy formulation.

(5) None of the four approaches recognises the lowest planning level, i.e. planning at the level of the individual manager.

(6) All four approaches, in practical terms offer little discussion on the matters of perceptual scope and dynamic responsiveness, nor are these matters perceived as placing limitations on comprehensive planning in terms of the other two dimensions (conceptual scope and organisational depth).

With the exception of Perrin, the approaches discussed above lead the prospective planner deeper into the 'semantic jungle' through the use of extensive vocabularies of terms almost totally removed from everyday managerial usage.

Recent additions to the theory do not offer much prospect of solutions to the shortcomings identified above. Developments appear to be concentrated mainly in the fields of relatively minor variations on existing methodology, and new techniques for facilitating aspects of scenario or objectives formulation. Examples of the former are the concepts of strategic management (Ansoff, 1977) and differential planning (Naor). In the techniques field contributions in objectives formulation have been made by Wiederman, 1979; Carroll, 1978; Bunker & Gupta, 1980; Keeney, 1975; and Morasky, 1977. Also Thomas, 1980, notes a proliferation of environmental scanning techniques in recent years.

One highly important and notable exception to the low impact associated with the above mentioned developments, however, has been the rapid growth in computer-based modelling techniques[3]

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[3] A substantial body of literature exists in support of this and is discussed in Section 3.5.

for supporting strategy formulation. This particular phenomenon has profound implications for overcoming the critical problems of inadequate perceptual scope and dynamic responsiveness referred to above.

3.3 Corporate Planning Theory and Practice - Closing the Gap

As a prelude to discussing the future of corporate planning and how the gap identified in the previous two sections might be bridged, an analysis of cause-effect relationships provides some useful insight into this problem. Fig 3.2 attempts to show, in respect of the two basic end effects noted earlier (of an unwillingness to plan and the separation of planning from management) the principal underlying causal factors and their inter-relationship.

As far as the former effect is concerned three direct causes are suggested, viz., the attitudinal problem of 'status quo' inertia (Taylor), fear of planning through possible loss of power or exposure of weaknesses (Ansoff, 1977), a lack of faith in planning stemming from a failure to understand it (Martin, Ansoff) and a lack of planning effectiveness (Koontz, 1976). This lack of faith in planning is also seen here as the direct cause of the second end effect of the separation of planning from management.

The failure of managers to understand planning can be reasonably attributed to the 'semantic jungle' of poor conceptual definition and to a lesser extent the inadequacy of their planning skills. Both of these factors can be traced back to the inadequate base of current planning theory, which in turn is an inhibiting influence on the development of planning techniques. The inadequacies

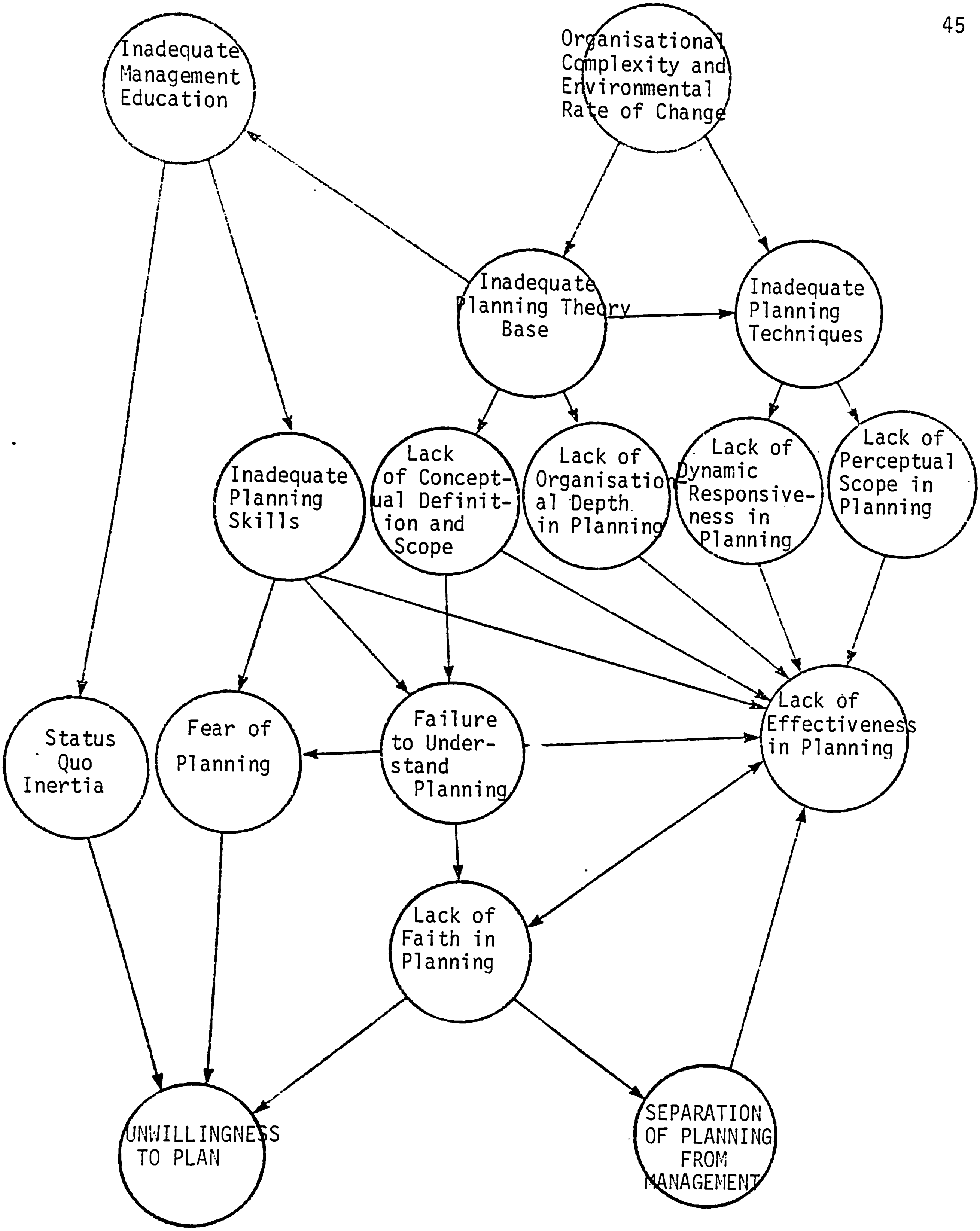


FIGURE 3.2: CAUSES AND EFFECTS IN THE FAILURE OF CORPORATE PLANNING

of both theory and techniques are of course accentuated by the rapid increase in organisational complexity and rate of environmental change which has been a dominant feature of recent decades.

The central problem of poor planning effectiveness while accentuated by the failure of managers to understand planning, is also a result of inadequacies across all four dimensions of the analysis framework postulated in the previous section. These in turn can also be attributed to an inadequate base of planning theory and inadequate planning techniques in the manner shown in Figure 3.2.

On the assumption that the dual phenomena of increasing complexity and rate of change will continue unabated into the foreseeable future, the two root causes to be focused upon are clearly those of inadequate planning theory and techniques respectively.

3.4 Corporate Planning - The Future

Corporate planning theory and techniques must develop to support a more effective style of planning than is supported by any of the systems currently being advocated by the theorists. This increased effectiveness must be achieved by means of simpler and more clearly defined concepts, applied more rigorously at all four organisational levels, in a manner which is fully responsive to change and is based on the scanning of a far more comprehensive range of scenario and strategy alternatives. Table 3.6 represents an attempt to place this fully integrated, comprehensive and responsive style of planning into historical perspective. Thus a pattern of long-term evolution from informal, authoritarian, entrepreneurial planning, through bureaucratic planning, to formal, participative, entrepreneurial

TABLE 3.6: THE EVOLUTION OF FORMALISED CORPORATE PLANNING

PERIOD	PLANNING STYLE & FOCUS	CONCEPTUAL SCOPE	ORGANISATIONAL DEPTH	DYNAMIC RESPONSIVENESS	PERCEPTUAL SCOPE	SUPPORTING TECHNIQUES	UNDERLYING DISCIPLINES
1950's and earlier	Informal entrepreneurial and growth oriented authoritarian style	Limited to scenarios, objectives and actions - intuitively formulated	Corporate level only	Ad Hoc Review	Alternative scenarios & strategies searched and evaluated intuitively	None	None
1960's	Formalised bureaucratic and profit oriented over a 1 year planning horizon Authoritarian style	Limited to formal goal specification via a bottom up accumulation of estimates	Corporate and functional levels	Annual Reviews	Single strategy based on a single scenario	Budgeting MBO Statistical Techniques	Accounting Mathematics
1970's	Formalised bureaucratic and profitability oriented over a 5 year planning horizon Authoritarian style	Formal specification of scenarios, objectives, actions and goals in an essentially top down sequence	Corporate, business unit and functional levels	Annual Reviews	Limited multiple strategies based on single scenario	Financial modelling, statistical, creative thinking & motivational techniques	Accounting OR/MS Mathematics Behavioural Theory
1980's	Formalised entrepreneurial and constrained profitability orientation over a flexible planning horizon Participative style	Formal specification of scenarios, objectives, actions and goals in an integrated, bottom up-top down-bottom up sequence	Corporate, business unit, functional and key staff levels	Annual Reviews interspersed with random reviews as required by circumstances	Multiple strategies based on multiple scenarios	Systems modelling, statistical, creative thinking, motivational, & environmental scanning techniques	Accounting OR/MS Mathematics Behavioural Theory Gen. Systems Theory

planning can be traced.

Fig. 3.3 depicts in more detail the form which this style of planning of the future might take. To some extent this form resembles that suggested by Vancil's strategy formulation process e.g. recognition of the distinction between objectives and goals and their hierarchical nature when the dimension of organisational depth is added. There are, however, significant differences which may be summarised as follows:-

(1) Recognition of a fourth organisational level in the form of the individual manager and his *personal* scenarios, objectives, action plans and goals.

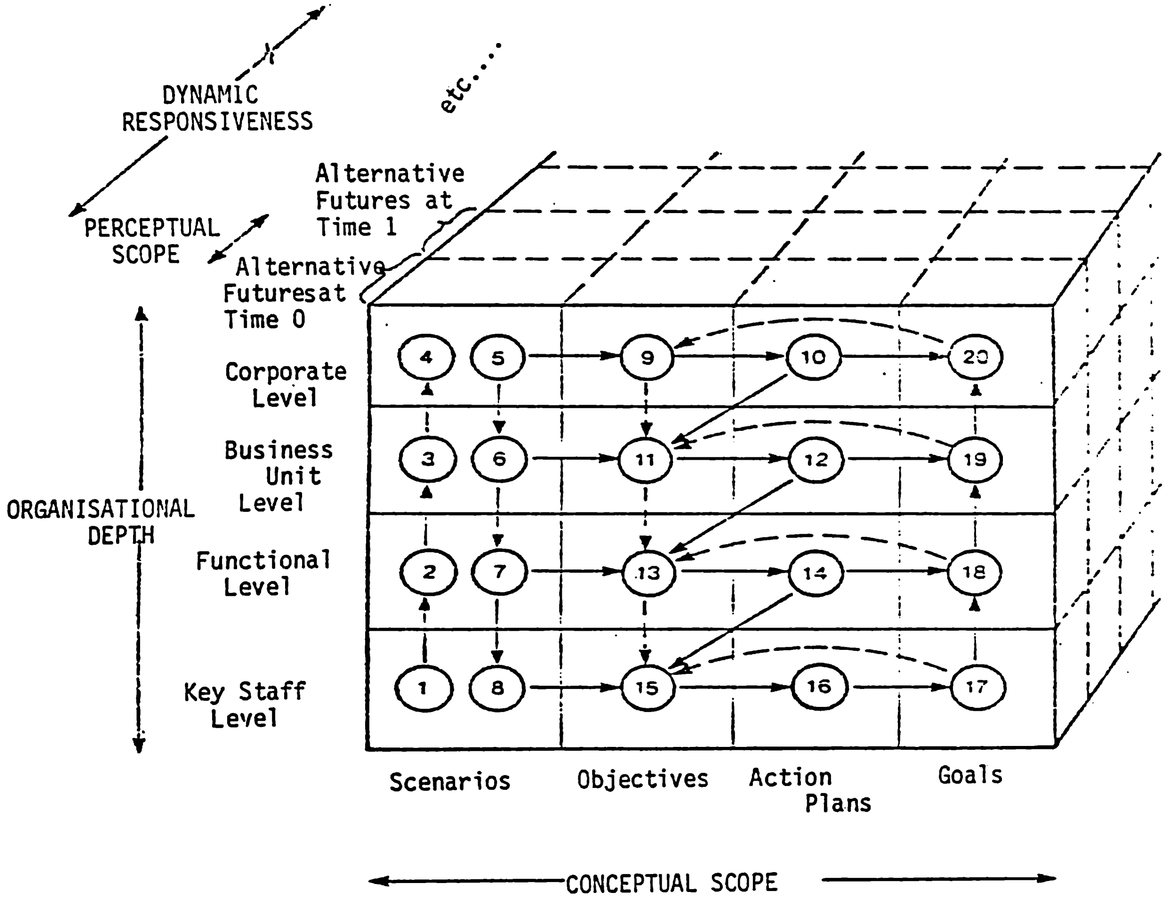
(2) Recognition of *action plans* as an indispensible and fundamentally important bridge between objectives and goals.

(3) Recognition of the concept of *scenarios* as a concept embracing *both* the organisation and its environment, described in terms of strengths, weaknesses and policies (in the case of the former) and threats, opportunities, constraints and assumptions (in the case of the latter).

(4) Recognition of scenarios as the background against which objectives are set in the first instance.

(5) Recognition of the third and fourth dimensions of perceptual scope and dynamic responsiveness, respectively.

(6) Recognition of the 'bottom up-top down' sequence for the



KEY:

——→ Denotes the direction of Feedforward Influence

←- - - Denotes the direction of Feedback Influence

Steps 1 to 4	constitute the formulation of preliminary Scenarios in a 'bottom up' sequence
Steps 5 to 8	constitute the formulation of firm Scenarios in a 'top down' sequence
Steps 9 to 16	constitute the formulation of Objectives and Action Plans in a 'top down' sequence
Steps 17 to 20	constitute the formulation of Goals in a 'bottom up' sequence to achieve an integrated Goal Structure

FIGURE 3.3: A FRAMEWORK FOR PARTICIPATIVE ENTREPRENEURIAL PLANNING (PEP)

formulation of scenarios, followed by the 'top down' sequence for the formulation of objectives and actions, then finally the 'bottom up' sequence for the formulation of goals. These influence flows achieve vertical integration in the process.

(7) Recognition of two other important types of influence flows in the form of feed-forward and feed-back flows which achieve horizontal integration in the process. Thus in the former instance scenarios provide the basis for objective formulation which in turn provide the basis for the formulation of action plans followed by goals. In the latter instance objectives are reconciled against goals at each planning level, with the former also being reconciled between levels.

Three problems are of critical importance as far as the practical implementation of this style of planning is concerned. These are:

(a) The achievement of horizontal integration.
(b) The achievement of vertical integration.
(c) The achievement of (a) and (b) simultaneously with the achievement of an adequate degree of perceptual scope and dynamic responsiveness.

It is for the resolution of these problems that recourse to new techniques and underlying disciplines must be made. As far as horizontal integration is concerned a fundamental prerequisite to success seems to be a clearing of the 'semantic jungle' to the point where only a few key concepts remain. These concepts can then be clearly defined in terms of their practical meaning to managers and their inter-relationship. The 'scenarios-objectives-action plans-goals' set of concepts, organised into the framework of Figure 3.3, seems to permit this clarification.

For both horizontal and vertical integration, perhaps the most meaningful contribution will come from general systems theory[4]. As yet few attempts have been made in the literature to draw on this well established body of theory. Morasky observes that systems theory offers a structure for goal definition but does not extend this to address the problem of goal structure (or hierarchy) determination. Kahalas, 1977, notes that systems theory provides an essential perspective for studying organisations but confines his use of it to a rather abstract discussion on identification of environmental components (or levels) and their interaction with the organisation. Perhaps the most comprehensive attempt yet is that made by Mesarovic et al, 1968, in which a multi-level multi-goal system is proposed as a model for an organisation. Justification for this attempt was based on the assertion that a formal conceptual model of an organisation will allow a more extensive use of formal concepts and quantitative techniques in studying its behaviour.

Figure 3.4 illustrates, in general systems terms, the basic form of a goal structure, or system of goals, for a dynamic, open system comprising a process (or processes) for converting inputs into outputs. Any real world organisation can be viewed in these terms,

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4. Thome and Willard (1966) observe ".... use of the systems approach in planning is justified in all types of applications where resources are limited and the systems are sufficiently complex that an intuitive or inductive approach would lack the necessary thoroughness ...."

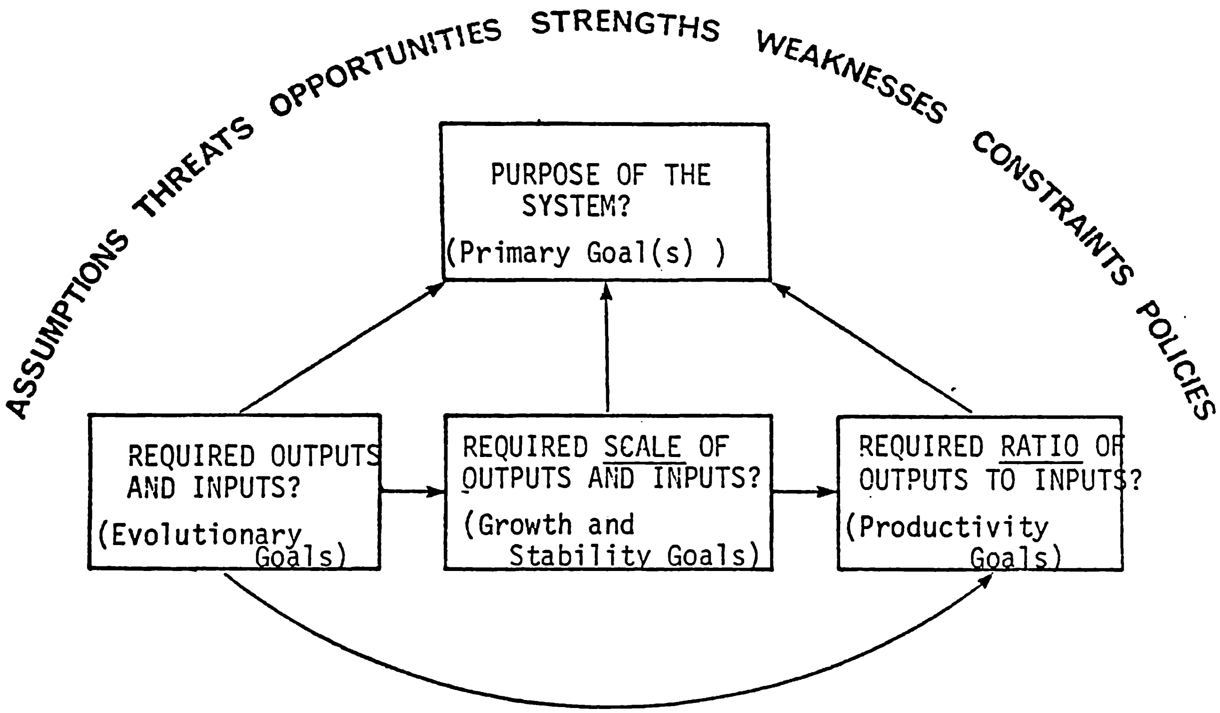

FIGURE 3.4: THE CONCEPT OF GOAL STRUCTURE FOR DYNAMIC OPEN SYSTEMS

with its system of goals and organisational structure constituting its management sub-system and the inputs-processes-outputs structure constituting its logistics sub-system, in the manner suggested by Mesarovic et al.

The goal-seeking, or management sub-system for any given organisation can be regarded as having a system of goals made up of a set of replicated basic structures of the form depicted in Figure 3.4, organised into an ordered, integrated hierarchy. From the corporate planning viewpoint the definition of a comprehensive set of key performance measures and the explicit recognition of their interdependency, is a fundamental requirement which has received little attention in the literature at the practical level. This requirement is accentuated further if the corporate planning process is to evolve into the participative entrepreneurial style outlined in Figure 3.3. Both vertical and horizontal integration of the planning effort can be achieved with maximum effectiveness only if goals are explicitly defined in terms of their meaning as performance measures and their place in the overall scheme of things. It must be possible for a manager at any level in the organisation to perceive a clear path (or paths) from any particular goal, for which he is responsible, to the overall goal of the organisation. Only then is it possible for him to see the goal in its correct perspective, to identify with the overall organisational goals and appreciate the need for 'trade-off' to achieve goal congruence[5].

Table 3.7 provides an illustration of how the concept of goal structure postulated above can be rendered operational at each of the four organisational levels of planning. The 'system' addressed at each of these levels does of course change, but in all instances must be acknowledged as being both open and dynamic.

It should be apparent that general systems theory may also, when coupled with OR/MS, contribute significantly to resolution of the third problem identified in this section, that of achieving an adequate degree of perceptual scope and dynamic responsiveness, while simultaneously achieving both horizontal and vertical integration in the planning process. Mesarovic et al note that the lack of an appropriate description of organisational structure is a prime reason hindering direct application of computational methods and techniques to organisational problems. The problem being addressed here is

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5. As might occur, for example in an organisation where export sales must be accorded priority over domestic sales, due to the effect of tax incentives on profitability.

TABLE 3.7: APPLICATION OF THE CONCEPT OF GOAL STRUCTURE TO THE PLANNING LEVELS OF THE ORGANISATION

PLANNING LEVEL	PRIMARY GOALS	EVOLUTIONARY GOALS	GROWTH & STABILITY GOALS	PRODUCTIVITY GOALS
Corporate	Profitability in terms of Return on Equity after Tax - subject to Constraints & Policies (both financial and non-financial)	New ventures New markets New products New resources New skills New methods New Processes	Market share Sales revenue Investment levels (in fixed and current assets) Staffing levels Financial ratios	% of Sales cost structure Sales per employee Production per employee Stockturn rates Debtor turn rates
Business Unit	Rate of contribution to corporate profit as a Return on Investment - subject to constraints & policies (both financial and non-financial)	As above - for the business unit	As above - for the business unit	As above - for the business unit
Functional	Any one or more of the corporate (or business unit) goals for evolution, growth and stability, or productivity	New resources New skills New methods New processes (at the functional level)	Functional resource levels	Functional outputs per functional resource input
Key Staff	Personal measures for job performance and job satisfaction	New Responsibilities New skills	Personal qualifications Personal experience Level of resources personally administered	Personal work rate

essentially one of inadequacy of current planning techniques (refer Figure 3.2), particularly in the quantitative field. If general systems theory can provide the description of organisational structure, then perhaps the way will be open for systems modelling to provide the kind of support necessary to resolve this problem and make participative entrepreneurial planning, with the optimal balance between the use of entrepreneurial flair and formal techniques, a reality.

As far as OR/MS is concerned, the Ackoff paradigm in which it is seen as being an integral part of the planning process, has already been discussed in the previous Chapter. A closer examination of the role of computer-based models in corporate planning is the subject of the next Chapter, for which the observation of Miller, 1971, serves as an appropriate introduction:

> ".... the ability of models to ask 'what-if' questions and obtain answers that are an approximation of what would happen if the series of events actually happened in the real world, with some measure of the ranges of results that might actually be obtained, is the major contribution of the models ...."

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CHAPTER 4

CORPORATE PLANNING AND THE ROLE OF COMPUTER-BASED MODELLING

From the previous two chapters it can be deduced that:-

(a) OR/MS needs to become more closely oriented towards corporate planning and develop accordingly, both as a process and in terms of its techniques.

(b) Corporate planning needs the support of OR/MS as a model-building discipline if a more effective style of planning is to be attained.

The rapid growth in the use of corporate planning models, in some form or another, has been a distinctive feature of the last decade, being fuelled by both the popularity of the corporate planning concept and advances in computer technology. Naylor & Schauland, 1976, reported that over 2000 corporations in North America and Europe were either using or developing corporate planning models. In a 1976 survey, Higgins and Finn, 1977, randomly sampled the 'Times Top 1000' companies to establish the fact that 60% of those companies used some form of corporate or financial model.

In more recent years the advent of cheaper more versatile and user-oriented computer systems has lowered the threshold of economic feasibility for this kind of modelling to the point where both medium and small-scale organisations can realistically contemplate this specialised activity. It can be strongly argued that for many small companies the use of the computer to support more effective planning constitutes a better deployment of the resource than in the more traditional role of mechanising the routine data processing operations of the business.

4.1 The Historical Development of Corporate Planning Models

The current level of usage and acceptance of computer based planning models is the product of a development process which was characterised by somewhat uncertain beginnings. Failures were both spectacular and frequent, with many model building efforts being undertaken with little or no regard for the needs of users, or of the planning process itself. As a consequence, problems of lack of acceptance, inflexibility and sheer unmanageability produced a high mortality rate amongst these pioneer versions.

Hayes and Nolan, 1974, have identified three phases in the historical development of corporate modelling. During the first phase, spanning the years 1956-63, batch-operated models were built from the 'bottom up' by OR/MS personnel who did not understand the decision-making process well enough to build the general models required for corporate planning. As a consequence, a second phase,lasting for the remainder of that decade, saw the advent of computer time-sharing and modelling languages, which supported aggregated 'top down' models capable of being integrated with the planning process. These models achieved the flexibility lacking in their predecessors, through the gross simplification of modelling the corporate entity in terms of a few highly aggregated accounting relationships.

The third (and current) phase is described by the authors as being that of 'inside out' modelling - supported by teleprocessing, mini-computers, data bases and program-generating software (packages). This phase is characterised by the involvement of managers in the model-building process, with the resultant model (or system of models) being built around decision processes which correspond to those currently in use, or those which the manager considers should be used. Model building is viewed as being a continuous process, commencing with simple models which are then evolved at the decision-maker's pace. The rigid requirement for the model to be a 'correct' representation of reality has given way to the requirement for it to be tailored to the person who will use it. The 'inside out' approach is thus one in which the model building process is sensitive to and responsive to, the inner workings and needs of the decision-making hierarchy, as and when those needs are perceived, or arise.

Taken to its logical conclusion, the basic philosophy of this phase results in a loosely-knit family of models. Hayes and Nolan go as far as to call into question the whole concept of a general model capable of being all things to all managers, but in so doing appear to disregard the possibility, or indeed desirability, of integration to the point where an ordered 'system of models' evolves.

4.2 Modelling Requirements and Principles

On the basis of the experience accumulated during the course of the developmental phases discussed above, together with the support offered by current computing technology and modelling methodologies, the key requirements and principles for successful modelling, in the context of present day corporate planning, can be enunciated. A number of writers[1] have addressed these aspects and the following discussion summarises those points upon which general agreement is evident.

As regards performance requirements, seven basic features emerge as being of fundamental importance.

(1) The need for an adequate measure of 'what if' capability, consistent with the planning style most appropriate to the organisation, its goal structure and the particular role which the model (or models) is expected to play. This capability is determined by the nature and extent

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[1] Boulder, 1973; Hammond, 1974; Hamilton & Moses, 1974; Naylor & Schauland, Higgins & Finn, Meyer 1977; Naylor & Mansfield, 1977.

of scenario and strategy alternatives which can be reflected in the model (or models), the ease and rapidity with which these evaluations can be performed and the extent to which the implications of uncertainty can be reflected. The provision of this capability is now generally acknowledged as being the central role of corporate planning models.

(2) The need for flexibility, in recognition of the fact that the corporate planning process is a process of change, of coping with uncertainty and of dealing with diversity - in terms of both scenarios and strategies. To effectively support the planning process, models must be responsive to changes in the structure and behavioural characteristics of the real world systems which they represent. Models must therefore be flexible in terms of both their data base and their underlying structure.

(3) The need for simplicity, or ease of understanding, to facilitate integration of the model(s) into the planning process and ensure their effective use by managers.

(4) The need for integratibility with other models of the organisation, with the facility for any given model to be linked with other models in the organisation, as well as being operable separately as and when required. This form of integration is being accorded more support in the literature as more advanced computer technology and the concept of data bases becomes established.

In practical terms, this can mean either functional integration (as among finance, marketing and production) or divisional integration to effect consolidation.

(5) The need for on-line access to all models and their associated data bases in a fully interactive mode in order to facilitate flexibility, integration and a fast turnaround in the 'what if' manager-model dialogue. Ideally models should be operated in an environment which provides for <u>both</u> the interactive and batch modes of operation, at the option of the user. Certain models under certain circumstances can impose a computational load on the computer resources which would render the batch mode preferable by reason of the processing time involved.

(6) The need for systems support consistent with all of the above requirements, in the form of computer software, information systems, management education programmes and the appropriate specialist and technical resources.

It must be noted at this point, that the first three requirements collectively pose a serious conflict when it comes to their practical realisation. The need for 'what if' capability can conflict with the need for flexibility which in turn can conflict with the need for integration, while all of these requirements are extremely difficult to meet without a loss of simplicity. Put another way, simple models are too often inflexible and difficult to integrate with other models, even though their simplicity may well facilitate integration with the planning process.

With the above requirements in mind a set of basic modelling principles can be defined as follows:-

(1) Modelling objectives should be clearly defined in terms of the organisation's planning needs (Meyer), both as presently constituted and as they should be constituted in the course of the evolution of the planning process. Areas where operational objectives can be established are:

- the faster, more efficient evaluation of a more comprehensive range of alternative scenarios and strategies (Naylor and Schauland).
- the identification of the effects of uncertainty in alternative scenarios and strategies.
- the heightening of, and improvement in, managerial perception of the business (Naylor and Schauland, Moses 1975).
- the improvement in communications within the organisation, both vertically and horizontally (Seaberg and Seaberg, 1973). This can be achieved through better information handling and the establishment of more uniformity and commonality among the conceptual models of any given situation, which the various managers have as individuals.

(2) The ultimate level of modelling sophistication aimed for in the organisation, in terms of types of models (analytical or simulation, deterministic or stochastic) their scope and level of detail (or disaggregation) and their degree of integration (with other models and data bases) should be at

the lowest level consistent with both the needs of the organisation and the law of diminishing marginal returns. In many organisations, the considerable additional development and maintenance effort associated with linking a model (or models) to the management information system data base, may result in relatively little additional benefit in practical terms (McRae, 1977). The addition of an optimising capability, while appropriate in some large multi-office organisations (Hamilton & Moses), constitutes another dimension of complexity which would for many other organisations negate the limited benefit which that capability would offer (Naylor & Mansfield, Meyer).

(3) Management must be involved in the model building process which in turn must be seen as a continuing process (Hammond).

(4) Models and modelling systems should be designed (in terms of their scope and sophistication) in recognition of the need to support the planning process so that both managers and models are complementary, with each being used in its most effective role (Wheelwright & Makridakis, 1972).

(5) Models and modelling systems should be developed in a modular way as far as possible (Meyer, McRae), in order to facilitate both flexibility and integration with other models. Modularity can also facilitate resolution of the conflict between the need for 'what if' capability and the need for simplicity.

TABLE 4.1: PHASES IN THE NATURE AND USE OF CORPORATE PLANNING MODELS

PHASE	BASIS OF THE MODELLING EFFORT	MODEL BUILDING APPROACH	TYPES OF MODELS PRODUCED	SUPPORTING COMPUTER	SUPPORTING DISCIPLINES
I (1956-63)	The Model Builder's perception of the Planning Process	Bottom-up	Single complex model spanning both physical and Financial aspects of the Firm	Large Mainframe Processors, General Purpose Languages, Batch mode	Mathematics Statistics
II (1964-69)	The Manager's perception of the Planning Process	Top-down	Single simple Financial Model	Large Mainframe Processors, Modelling Languages, Batch Mode	Accounting
III (1970-75)	The Manager's perception of the Firm and the existing Planning Process	Inside-out	Family of loosely integrated Models	Timeshared Dist. Processing, Database Mgt. Systems, Modelling Languages, Interactive & Batch Modes	Accounting Mathematics Statistics
IV (1976-?)	The Manager's perception of the Firm and Planning Process together with a Systems view of all three	Systems Approach	System of hierarchically ordered Models integrated as and when necessary	As above with Program Generators & Modelling Packages	General Systems Theory Accounting Mathematics Statistics

4.3 Future Developments in the Nature and Use of Corporate Planning Models.

The continued evolution of corporate planning and OR/MS methodology, supported by developments in computer technology, will ensure further developments in the nature and use of corporate planning models beyond those summarised in the three phases identified by Hayes and Nolan. More specifically there is already substantial evidence in recent literature of the emergence of a fourth phase, the essential characteristics of which are summarised in Fig. 4.1.

The basis of the modelling effort has progressed from the stage where both the existing planning procedure and the manager's perception of reality were completely ignored, to the present stage where both are accorded recognition. This recognition does not, however, extend to encompass a systems view of the organisation, or how the planning process should be performed. A further broadening of this basis to encompass these latter aspects is suggested here as characterising a fourth developmental phase, which can be described as the systems approach to the building of corporate planning models. This approach is essentially a natural extension of an established trend which has been receiving increasing attention in the literature. The importance of a systems approach to the finance function has been noted by Jenkins, 1973, while Seaberg and Seaberg describe a corporate planning system based on a series of models which can operate either 'stand alone' or as a linked system. A similar system is described by Moses as comprising optimiser, simulator, risk analysis, econometric and information management sub-systems. An interesting benefit noted in respect of this system was the fact that its use changed the manager's view of the organisation to one based on 'systems thinking' .

Naylor and Mansfield perceive a need to be able to integrate the financial, production and marketing models at the business unit or divisional level. They advocate the facility to use such models either 'stand-alone' or as an integrated system, a conceptual framework for which is suggested. In discussing the future of corporate planning models Naylor and Schauland foresee systems of models comprising sub-models linked to an overall corporate planning model and also greater use of optimisation techniques and environmental models. At present the most promising optimising technique appears to be the use of multi-attribute optimisation applied to aggregated financial models (Krouse, 1972). The system described by Moses constitutes an early application of the tandem use of both simulation and optimisation models at the corporate level in a large scale multi-office enterprise where the planning is done primarily in financial terms. Notwithstanding Sutcliffe's observation (Sutcliffe, 1979) that most users of corporate planning models quickly progress from single models to suites of models, the systems phase summarised in Table 4.1 is clearly still very much in embryo form. Integrated systems of models are relatively rare and confined to those large corporations whose planning styles have been at the leading edge of the field over the past decade. Rarer still are those systems which combine simulation and optimisation techniques in a hybrid modelling approach.

Figure 4.1 depicts a more extensive conceptual framework for the 'system of models' concept than that suggested by Naylor and Mansfield, in that it extends beyond the business unit level to encompass environmental models and their associated support systems,

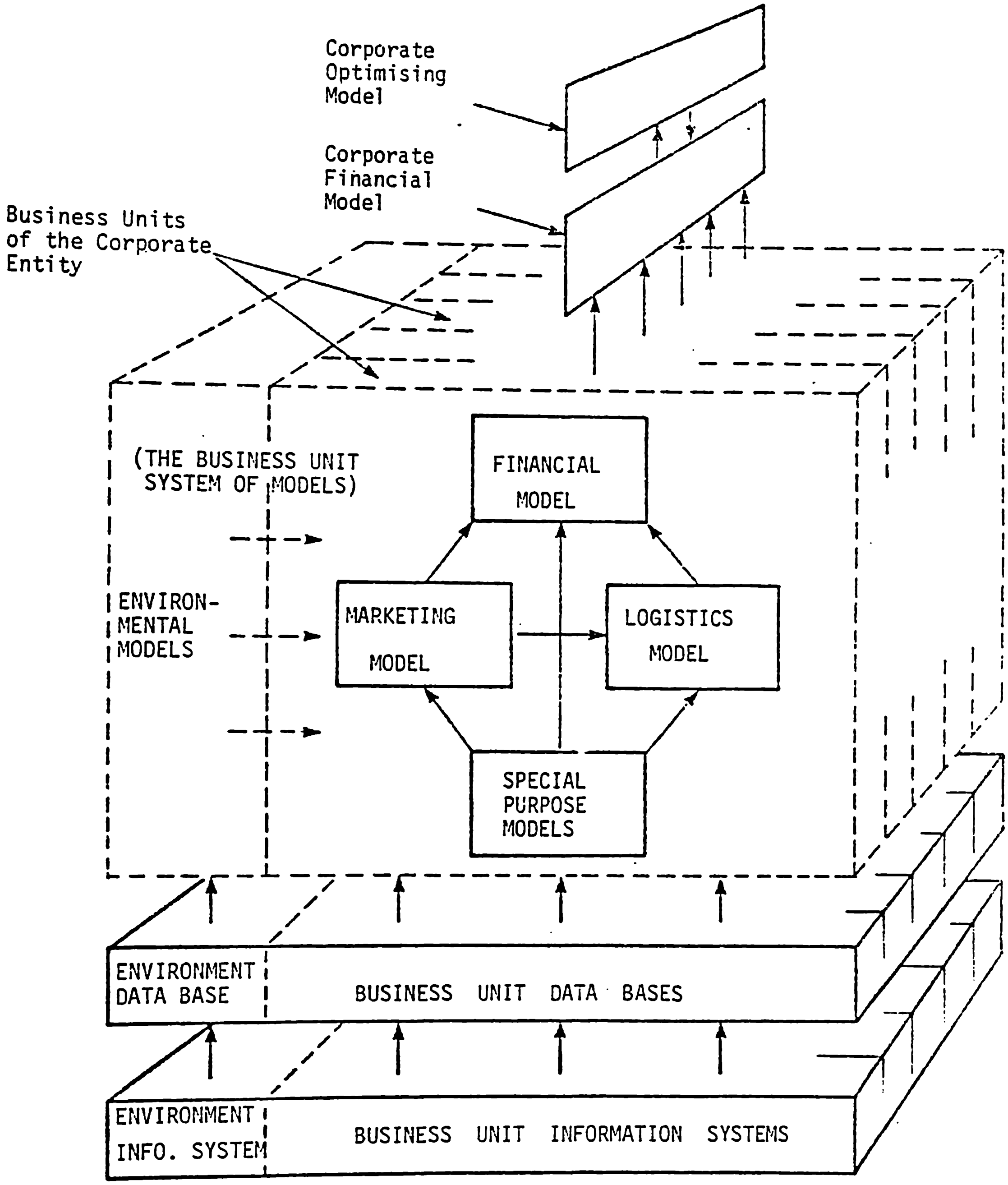

FIGURE 4.1: AN HIERARCHICAL SYSTEM OF CORPORATE PLANNING MODELS

together with the two corporate-level models defined for financial simulation and financial optimisation, in an alternating interactive manner similar to that described by Moses.

The four classes of internal models defined at the business unit level would be integrated in the manner shown and would in general be of the simulation type, with optimisation (or analytical) models being confined to the logistics and/or special purpose classes.

In effect this framework precludes neither of the alternative approaches for the future put forward by Cantley (Cantley, 1973). The practical realisation of a system of models structured according to this framework could conceivably be achieved by either the modular or 'zoom-lens' approaches, or perhaps more realistically by a combination of both. Either way the challenge confronting the existing modelling methodologies is substantial and pressing.

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CHAPTER 5

MODELS AND MODELLING METHODOLOGIES

The paradigm for OR/MS suggested in Chapter 2 establishes it as a model-building process within the wider process of management. This in turn is seen as being a problem-solving process where the 'problem sets' addressed can range from the localised level (operational management) to the corporate level (corporate or strategic planning). OR/MS model-building is defined in a manner which recognises the existence and importance of the manager's conceptual model of the problem-set, as well as the existence of both formal and informal approaches to problem-solving, which need not be mutually exclusive. Within the model building process there exists the set of sub-processes associated with the construction of specific types of models, in the manner shown in Figure 5.1. Thus the methodology of OR/MS can be said to comprise a <u>general methodology</u> associated with the overall OR/MS process within which there exists a set of <u>specific methodologies</u> associated with the sub-processes.

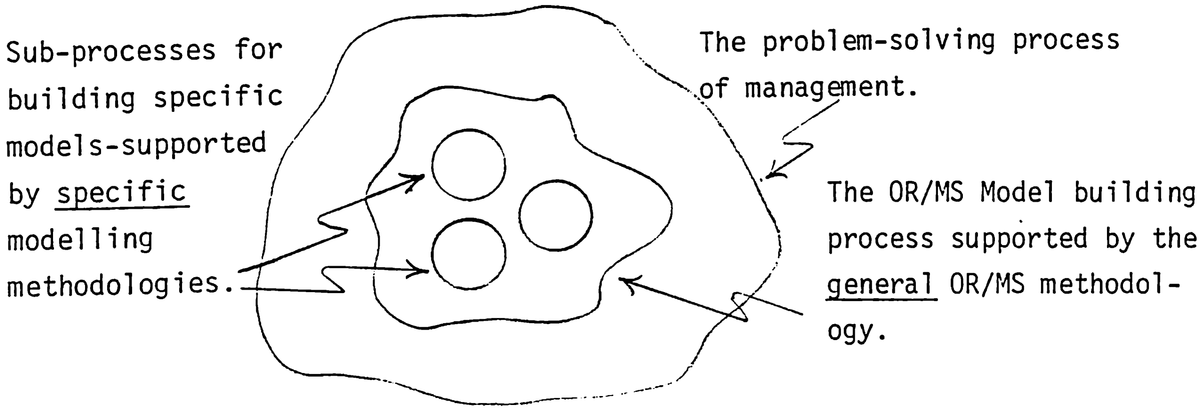


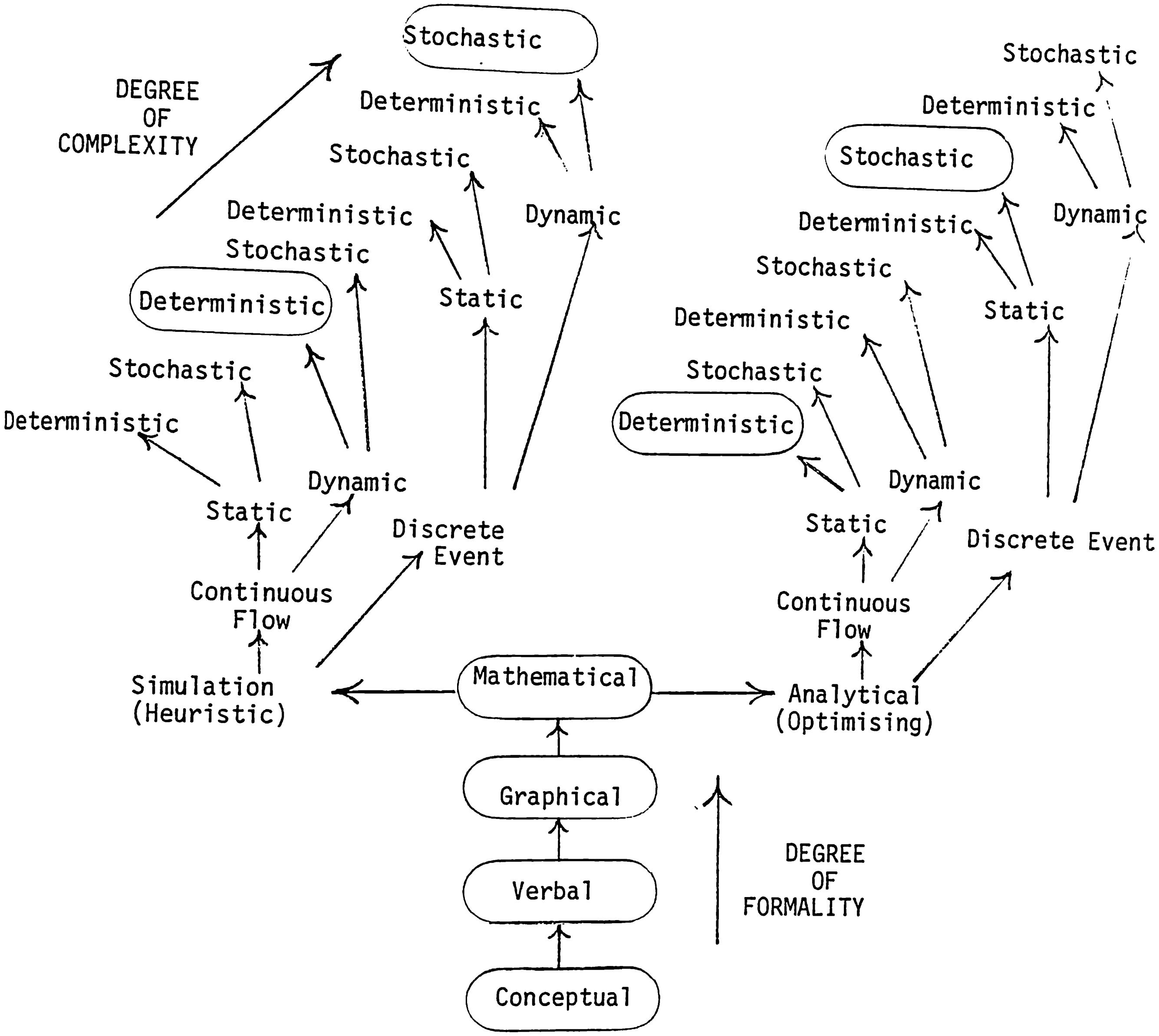
FIGURE 5.1: MANAGEMENT AND THE OR/MS PROCESS

When examining the types of models relevant to OR/MS defined in this manner, a variety of classification bases can be used. Fig. 5.2 is one particular representation based on a five-dimensional framework as follows:-

1) Degree of formality (Conceptual to Mathematical).
2) Rigour of solution techniques (Heuristic to Optimising).
3) Recognition of events (Continuous Flow to Discrete Event).
4) Recognition of time (Static to Dynamic).
5) Recognition of uncertainty (Deterministic to Stochastic).

The terms shown in parentheses describe the polar extremes. In practice intermediate states exist between the extremes defined for each of the five dimensions.

The second, third, fourth and fifth dimensions collectively determine the degree of complexity associated with any formal model. Simulation models are usually dynamic while analytical models,by virtue of the need to be 'solvable' with a rigorous mathematical solution algorithm, are usually restricted to the static variety. When viewed in the context of corporate planning, by far the most common type of model at the present time is the dynamic deterministic simulation model. Indeed, Naylor and Schauland, 1976, report that 94% of corporate planning models in their sample survey of the Times 'Top 1000' Companies were of this type. The simulation approach, whereby models are constructed by building the equation system around the system



Note: The most commonly used models are encircled.

FIGURE 5.2: A TAXONOMY OF OR/MS MODELS

being modelled, is clearly more suited to the needs[1] of the corporate planning process than the more restricted analytical approach, where the real world systems must be accommodated within a pre-defined equation framework. Requirements such as those of 'what if' capability, flexibility and ease of understanding, are generally more readily met with deterministic simulation models in the first instance. Optimising or risk analysis features may then be considered as refinements to be possibly added at some time in the future.

5.1 The General OR/MS Methodology

The general steps in the OR/MS model building process, consistent with the paradigm of Chapter 2, can be identified as follows:-

(1) Selection of the system (or problem-set) to be modelled. As observed earlier this system may be the corporate system as a whole or some sub-system of it. In any given instance this selection would be made in accordance with those development avenues and requirements which have been established in the course of the wider corporate planning process.

(2) Definition of the scope and purpose of the model. This step may well extend to the determination of a staged program of development covering progressive evolution of the model through a series of phases of increasing sophistication.

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[1] As discussed in Chapter 4, p. 61-63.

(3) Construction of a verbal description of the system (i.e. the verbal model). This step constitutes the first part of the model abstraction process per se and should provide the basis for considerable managerial involvement and the establishment of an effective manager-model-builder dialogue.

(4) Selection of an appropriate modelling methodology[2]. At this point the specific type of modelling methodology most appropriate to circumstances, as determined from the preceding steps, should be apparent.

(5) Construction of the model in accordance with the chosen methodology. This step accomplishes the remainder of the model abstraction process to the point where the mathematical form of the model, as a set of equations or relationships, is established.

(6) Development and (or) organisation of the necessary computational resources. Since most mathematical models require computerisation this generally means gaining access to appropriate computer hardware and software. More highly developed modelling methodologies are supported by their own software in the form of either modelling languages or, more recently, modelling packages. In the absence of either, the model must be programmed in a general purpose programming language

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[2] This step may result in a decision to reject all formal methodologies and proceed with a purely intuitive approach. In these circumstances Steps(5), (6) and (7) would be by-passed.

such as FORTRAN or BASIC.

(7) Testing and validation of the model. Testing must be completed to ensure that the model performs as designed, while validation ensures that the model conforms to an acceptable extent with the real world system it represents and in a manner consistent with its stated scope and purpose.

(8) Implementation of the model. In this step the necessary model documentation, user education and training must be completed to the point where effective use of the model, consistent with its purpose, is assured.

(9) Maintenance and development of the model. This involves the continuing requirement to maintain the model's relevance and effectiveness in the face of organisational and environmental change. It also includes the requirement to develop the model in accordance with whatever planned pattern of evolution has been defined for it in the course of Step (2).

The above steps differ from those normally identified in the literature in one important respect, viz., explicit recognition of the fact that the model abstraction process involves a progression from the purely conceptual form through verbal and graphical forms as important intermediate states, to the final mathematical abstraction. This progression is usually compressed into a single step cryptically referred to as 'develop the model' (e.g. Hammond, 1974), in most attempts at describing the general OR/MS methodology.

While inadequate recognition of these intermediate stages in the model abstraction process has serious practical ramifications[3] in any specific model building effort, these ramifications are clearly more serious in respect of the simulation methodologies. These by nature lack the advantage of the rigorously defined equation framework characteristic of analytical modelling techniques. Ideally any specific modelling methodology should offer detailed procedures for accomplishing the model abstraction process in a conceptual-verbal-graphical-mathematical progression. This progression must be supported by a rigorously defined framework of workable concepts constituting its world view, or'weltanschauuing' (Churchman, 1968).

In essence, the benefits to be gained from focusing on the model abstraction process in these terms are two-fold. First, the manager can, in a suitably constructed graphical representation, 'see' the model in a non-mathematical yet rigorously defined form. Second, and more importantly, the model-builder can utilise the resultant communications 'window' to achieve a reconciliation between and among the final mathematical model and the respective conceptual models of the real-world system which are held by the manager and himself.

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3. Particularly as regards manager-model builder communications and involvement, a factor identified earlier (Ch. 2, p.13) as being of significance to OR/MS effectiveness.

Fundamental to this argument of course is the extent to which managers with diverse cognitive styles can relate to graphical representations (i.e. flow diagrams) of complex systems, constructed using generalised concepts[4] and symbols. Support for the affirmative side of this argument can be found in hypotheses ranging in sophistication from the truism that 'a picture is worth a thousand words' (or ten thousand equations!), to the postulates of cognitive science. As far as the latter are concerned, while there is no broad acceptance of theories of cognition (Olsen, 1977), some interesting insights are offered both by theorists in the field and by the findings of those practitioners applying modelling methodologies which are based on the use of flow diagramming as an important stage of the model abstraction process.

From the theoretical standpoint two considerations appear to be particularly relevant, viz., the mechanisms of memory and of information processing in humans. Norman, 1976, argues the need for mental representation which allows for the easy transaction of the mental operations that need to be performed to ensure understanding and retention. While some theorists (e.g. Paivio, 1971) believe that humans have two separate storage systems - one propositional and the other analogical, Norman asserts that an excellent memory for pictures in general is true for most people. While individuals differ in their cognitive styles (e.g. data-driven people versus conceptually-driven people) the basic mechanisms are essentially the same.

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[4] Meaning the concepts constituting the world view of any specific modelling methodology. By definition these concepts must possess sufficient generality to be relevant to the class of problems for which the methodology is applicable.

Support for the analogical form of representation is implied by Manis, 1971, in his observation that assimilation occurs when new objects or concepts are perceived in a manner such as to proximise their similarity to more familiar elements, thus permitting the individual to utilize existing cognitive structures in his response to novel stimuli. Graphical representations based on symbols with a direct physical connotation would therefore seem to facilitate perception and retention - particularly if a coherent structure as well as a strong physical analogy can be drawn from the representation. Bruner, 1963, argues that unless detail is placed into a structured pattern it is rapidly forgotten.

At the practical level, Roberts, 1978, reports favourable results in the teaching of dynamic feedback systems concepts to children as young as ten years old through the use of causal-loop diagrams. Riggs and Inoue, 1975, focus on the value of graphics as the key attribute to the increased usefulness of OR/MS techniques. They promote a more precise formulation of problems and a format for analysis and the display of solutions. The value of this approach is claimed to have been confirmed in university classes, industrial courses and consulting activities.

Poole, and Szymankeiwicz, 1977, also identify the graphical representation of a model as a key step in the model-building process - to permit the separation of model-building from model computation - and to naturally complement the thought processes of the model user. Improved communications between practitioners and modellers is cited by Glover et al, 1979, as the principal advantage of their NETFORM modelling technique, based on the representation of discrete optimisation problems as networks. The resultant pictorial form is described as being an equivalent and effective replacement for the unilluminating algebraic formulation.

5.2 The Systems Approach to Modelling

The future directions for corporate planning and OR/MS, as discussed in the previous Chapters, are both, in effect, predicated on the belief that the traditional approaches to management problem-solving must evolve within the framework of an integrative philosophy of management, or be replaced by approaches which can so evolve. Johnson et al, 1972, acknowledge the need for such a philosophy and suggest that the most promising candidate for fulfilment of this need is the systems approach. This is defined in very general terms by the authors, to embrace systems theory, systems management and systems analysis. The very essence of the systems approach however, is the application of general systems theory to the analysis, design and management of real world systems.

The successful application of general systems theory in any particular context depends almost entirely on the extent to which the systematic theoretical framework of concepts which it provides for explaining the general relationships of the empirical world can be translated into a systematic operational framework of concepts appropriate to that context.

Thus it is more appropriate to think of 'a systems approach' rather than 'the systems approach', as the application of general systems theory in any given situation may take place with varying degrees of rigour and intensity. Churchman acknowledges this by concluding that there is in fact a multiplicity of systems approaches and that the problem of what qualifies as a universally appropriate approach has not yet been solved. In order to sharpen the distinction between what constitutes a systems approach and what does not (i.e. the 'non-systems approaches') the following characteristics can be regarded as being fundamental to the former:-

1) Recognition of the hierarchical nature of systems in terms of the 'input-transformation-output' model of systems theory (Johnson et al). Thus any system, as an organised assemblage of parts, receives inputs from other systems and transforms them into outputs which become inputs for other systems.
2) Some attempt to identify the system under consideration in terms of its boundaries, properties[5] and components, and their interdependencies. This must entail an operational expansion of the conceptual framework implicit in the central input-transformation-output model. When

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[5] In broad terms, these properties include whether or not the system has objectives, its behaviour over time (static or dynamic) and the nature of its components (physical or notional).

considering systems approaches to modelling, this expansion manifests itself as an explicit definition of a 'world view' which is operational to the extent that its constituent concepts effectively span all phases of the model abstraction process (i.e. comprise the building blocks for the verbal, graphical and mathematical forms of the model).

The remainder of this Chapter is devoted to the discussion of a selection of modelling methodologies classified according to their conformity,or otherwise, with the distinctive elements of a systems approach identified above.

5.3 The 'Non Systems' Modelling Methodologies

The traditional approaches to model-building, being those methodologies most often used in practice and described in standard OR/MS texts, are essentially 'non-systems' in nature, if viewed in the light of the systems approach criteria of the previous section. They typically utilise 'world views' which are vaguely identified, or merely implied in the underlying assumptions of the methodology concerned. The progressive stages of model abstraction through intermediate forms is often not explicitly acknowledged by the methodology, which focuses instead on the final mathematical form and (in the case of analytical techniques) the solution algorithm.

Thus linear programming as an analytical modelling methodology is presented as a framework of linear mathematical relationships consisting of an objective function and constraints, for solving, in optimal terms, resource allocation problems associated with a variety of real world systems. Graphical representation, if used, is usually confined to forms incidental to proving or illustrating the solution algorithm.

The non-systems approach to simulation typically pre-supposes a particular class of simulation model (usually the discrete-event probabilistic class of models) as being the embodiment of most (if not all) simulation modelling. The methodological aspects are then discussed in terms of the general sequence of steps in the OR/MS process, the mathematics of random number generation and the mechanics of their use in the Monte Carlo procedure[6]. Occasionally, this non-rigorous treatment is extended to encompass continuous-flow modelling[7] but again without the explicit enunciation of a 'world view'. The distinction between continuous-flow and discrete-event modelling is often blurred and the model building process is presented as a process of direct abstraction of the mathematical form of the model, according to ill-defined procedures for variable definition and equation formulation. Graphical representation, if discussed at all, is confined to the use of vaguely defined symbols for depicting, in highly aggregated form, the physical system being modelled and/or the logical structure of the model itself. Typical side-effects of this non-rigorous style of modelling are the inconsistent use of diagramming symbols and

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6. e.g. Whitehouse & Wechsler, 1977

7. e.g. Wheelwright & Makridakis, 1972.

the failure to distinguish between physical flow charting and logical flow charting in terms of their respective nature and purposes.

Most financial modelling, in practice and in the literature, is conducted in a non-systems manner. The conceptual framework upon which it is based (viz. the accounting framework) is not explicitly defined from the modelling viewpoint, despite the considerable differences between its use in this context, and its use in the historical accounting context. While many of the financial modelling methodologies currently in use display little or no discernible evidence of systems thinking, those which do usually limit it to the use of a two-dimensional matrix structure in which the rows represent the financial report lines and the columns represent the planning periods to be reported on (Meyer, 1977). This representational device is then used as a basis for the direct formulation of the model equations necessary to compute the 'cells' of the matrix. Meyer asserts that financial modelling methodologies utilising this limited conceptual framework are likely to be in use for some time to come despite the challenge offered by methodologies such as Systems Dynamics.

5.4 The 'Systems' Modelling Methodologies

These methodologies are characterised by the presence, to a discernible extent, of the systems approach criteria identified in section 5.2. Thus an explicitly defined conceptual framework or 'world view' based on the input-transformation-output model of systems theory is apparent, and in a form which is operationally developed to the point where the concepts of this framework constitute building blocks applicable at each stage of a conceptual-verbal-graphical-mathematical sequence for model abstraction.

System Dynamics is one of the oldest and most developed of the 'systems' modelling methodologies[8]. It is typically associated with the construction of dynamic, aggregated, continuous-flow models of complex systems in situations where system growth and stability characteristics are of central concern. A fundamental premise of System Dynamics is that social or industrial systems are dynamic systems, which display feedback relationships and behaviour as an integral part of their structure. Thus the principles of servomechanism theory can be applied to the problem of modelling the management (decision-making) sub-system and its effects on the logistics sub-system, in one integrated system model.

On the discrete-event modelling front, GPSS[9] is also a popular and well-established systems methodology for application to that particular class of systems. It too has a clearly defined world view in the form of an operational framework of concepts supporting a conceptual-verbal-graphical-mathematical model abstraction sequence, as does HOCUS[10]. More recently, other

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[8] Pioneered as Industrial Dynamics during the early 1960's by Jay W. Forrester (Forrester, 1961). More recently the technique has been extended to encompass the modelling of social and economic systems (Forrester,1969; Forrester,1971).

[9] For General Purpose Simulation System (Bobillier et al, 1968).

[10] For Hand Or Computer Universal Simulator (Poole & Szymanciewicz, 1977).

systems methodologies such as GERT[11], RPMS[12], NETFORM[13] and GESIFLOG[14] have emerged which extend the systems approach to modelling into the analytical modelling arena. A comparative analysis of four of these methodologies is presented in the next chapter.

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[11] For Graphical Evaluation and Review Technique (Pritzsker & Happ, 1966).

[12] For Resource Planning and Management System (Riggs & Inoue, 1975).

[13] For Network related Formulation Models (Glover et al, 1979).

[14] For Generalised Signal Flow Graphs (Rosenkrantz, 1979).

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CHAPTER 6

THE 'SYSTEMS' MODELLING METHODOLOGIES

The purpose here is to focus on a selection of modelling methodologies, each of which can be regarded as constituting a systems approach in terms of the criteria set forth in the previous chapter. The set of concepts comprising the 'world view' associated with each approach is identified, along with the role which graphical representation plays in the model development process. The comprehensiveness of each approach in terms of the extent to which it spans this process through supporting the four phases of model conceptualisation, graphical representation, mathematical formulation and model computation, is also noted.

6.1 The System Dynamics Modelling Methodology

Despite its early promise and the predictions for its impact on management practice made two decades ago, System Dynamics cannot be said to have established itself as a universally accepted corporate modelling methodology. Meyer, 1977, blames the methodology itself and the unfamiliarity of managers with its concepts, while Sharp, 1977, identifies the lack of interaction between Systems Dynamics and OR/MS as the root cause.

The fundamental elements of the System Dynamics conceptual framework, or 'world view', are captured in Figure 6.1, which depicts the basic structure of an information feedback system consisting of one level (denoted by the rectangle), determined by one flow rate (denoted by the solid arrow), on the basis

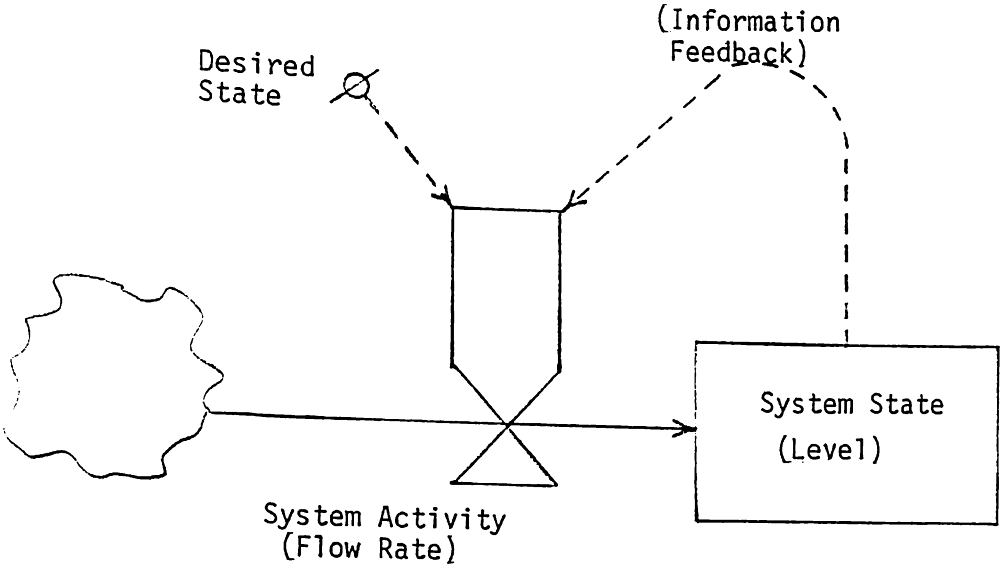


FIGURE 6.1: AN INFORMATION FEEDBACK STRUCTURE IN SYSTEM DYNAMICS

(Adapted from Forrester, 1961, p.67)

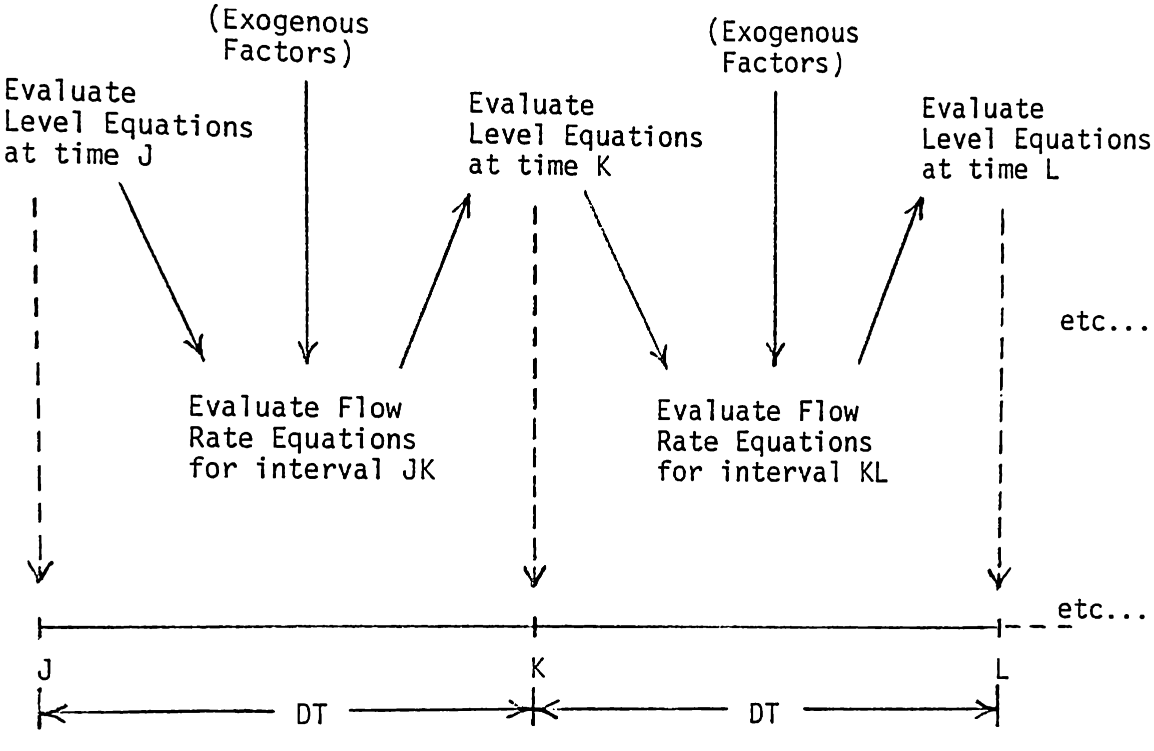
of information 'flows' (denoted by the dotted arrows) about the actual and desired level values. This information is used to regulate the flow rate, a phenomenon denoted by the presence of the regulator symbol attached to the flow rate. The two basic concepts of 'level' and 'flow rate' are used to describe, respectively, the <u>state</u> and <u>activity</u> of any given real world system. They effectively constitute the building blocks of System Dynamics models.

Levels and flow rates can be regarded as representing the accumulations and movements of both physical resources and information within a diversity of systems, some of which are identified in Table 6.1. Networks of levels and flow rates can be constructed to show the dynamic behaviour of materials, money, personnel, equipment and orders in broad aggregate form. An information network embedded within such a structure can, through the defining of feedback loops, reflect the management process as one of influencing levels by regulating flow rates, on the basis of information about those levels, in terms of their actual and desired values.

TABLE 6.1: THE GENERAL SYSTEMS NATURE OF THE LEVEL AND FLOW RATE CONCEPTS OF SYSTEM DYNAMICS

REAL WORLD SYSTEM	THE 'LEVEL' CONCEPT	THE 'FLOW' CONCEPT
Hydrographic	Lakes	Rivers
Demographic	Populations	Births, Deaths, Ageing
Educational	Class Rolls	Enrolments, Passes, Drop-outs
Statistical	Averages	Observations
Financial	Account Balances	Transactions
Production	Stocks, Back-Orders	Resource Inputs, Product Outputs, Order Placements
Marketing	Demand	Sales, Consumption, Promotion

Dynamic representation in System Dynamics models is achieved with a recursive computational procedure involving the stagewise calculation of flow rates and levels in the manner shown in Fig. 6.2. These calculations are performed iteratively over a succession of small time steps and may incorporate delay or time-lag effects whereby changes in any given flow rate or level, in any given time period, can be transmitted to other flow rates in accordance with a delay pattern which spreads the change over a series of successive time periods.



DT = Model Solution Interval

FIGURE 6.2: STAGEWISE SOLUTION SEQUENCE FOR SYSTEM DYNAMICS MODELS

(Adapted from Forrester, p.74)

In the corporate planning context, the principal advantages and disadvantages of System Dynamics can be summarised as follows -

Advantages:

(1) As a 'systems' methodology it has an explicitly defined framework of operational concepts with a high level of general applicability. These concepts support a rigorous, well developed 'conceptual-graphical-mathematical' process for model abstraction.

(2) It presents the model builder with the capability for constructing modular, dynamic, comprehensive models which can take explicit account of time-lag and feedback relationships. Thus it constitutes the most honest approach to corporate modelling (Meyer).

Disadvantages:

(1) Its operational utility is reduced by the complexity which arises from an undue preoccupation with modelling management decision-making in terms of closed feedback loops. The feedback nature of much management decision-making at the strategic or top management level is better reflected through exogenously dependent relationships, or open feedback loops. This permits simpler more palatable models and a greater degree of manager-model complementarity.

(2) Its operational utility is reduced by the high level of aggregation necessary to permit closed feedback loop modelling and the reflection of system growth and stability characteristics. The corporate goal structure (refer Figure 3.4, p.52) also encompasses profitability and productivity measures however, which typically require the definition of model) variables in a much less aggregated form.

(3) Its operational utility is reduced by the dated nature of its supporting software. DYNAMO and its mini-computer based progeny are essentially batch-oriented software systems, with basic characteristics which have remained unaltered over two decades of rapid technological change,

including the advent of interactive time-shared computing.

It is apparent from the above analysis that, in the corporate planning context, the conceptual strengths of System Dynamics are largely offset by its operational weaknesses. These weaknesses stem essentially from the fact that the technique has not developed to meet the evolving needs of formalised corporate planning. These needs cannot be met without some relaxation of the servomechanism analogy which System Dynamics has consistently attempted to force on to the management process. To the extent that the methodology constitutes an attempt to apply the systems concepts of the engineering sciences to industrial and social systems, due heed should be taken of a much earlier attempt at applying these concepts to biological systems. From this attempt, by von Bertalanffy during the 1930's (Riggs & Inoue, 1975) there emerged the clear need to treat biological systems as open system models and to avoid the 'closedness' associated with the systems models of the engineering sciences.

6.2 The GESIFLOG Modelling Methodology

In this approach a graphical representation is derived from the mathematical structure of the model, rather than from the physical structure of the system being modelled. This mathematical structure is depicted as a connected graph which shows the cause-effect inter-relationships of all model variables and constants. The graph is then used to derive solution algorithms to the equation system it portrays. Thus the role of graphical representation in the model abstraction process here differs markedly from its role in System Dynamics. In the latter instance the flow diagram serves as a basis for formulating the mathematical model, which is then 'solved' as a recursive equation system, using pre-determined procedures applicable to all such systems. Rosenkrantz (Rosenkrantz, 1979) notes that System Dynamics networks focus more on this definitional phase of modelling.

In GESIFLOG, the mathematical form of the model must be derived before the network can be constructed. This network can then be used to facilitate simplification and (or) solution of the equation system. Two graphical symbols are used, viz., nodes and arcs, with the former denoting model variables or constants, and the latter denoting the cause-effect relationships between them. All causes and effects in a model are identified precisely, and each model factor (variable or constant) is represented by only one node. The direction of the arc identifies the 'cause' and 'effect' nodes in any given pairing of nodes - with all causes and effects being accounted for in the network.

The conceptual framework of GESIFLOG, in addition to arcs and nodes, encompasses the concepts of arc transmittance and time-shifts. Thus for the arc $[x_i,x_j]$ linking nodes x_i and x_j, representing the variables x_t and y_t respectively, the transmittance m_{ij} induces a transformation of the input (causal) variable x_t. Further, this transformation can be subjected to a specified lag of t_{ij} periods.

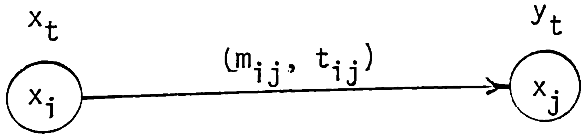


FIGURE 6.3: THE GESIFLOG REPRESENTATION OF A LINEAR EQUATION

(See Rosenkrantz, p.180)

The graphical representation of Figure 6.3 would therefore correspond to the equation $y_t = m_{ij} \cdot x_{(t+t_{ij})}$.

If more than one arc is incident on a node then the variable represented by the incident node is equal to the sum of the cause-effect relationships associated with each incident arc. For stochastic non-conjunctive, or non-linear relationships, new concepts and notations can be introduced into the GESIFLOG methodology. However, as Rosenkrantz observes (Rosenkrantz, p.184) most equations in a corporate model are deterministic and linear.

The GESIFLOG approach, while constituting a powerful tool for facilitating the mathematical formulation and solution of complex models, has the principal disadvantage (in the corporate modelling context) of not providing direct support for the definitional and computational phases of modelling. By contrast, System Dynamics provides a language for system description (Coyle, 1977) together with the appropriate computer software support (the DYSMAP and DYNAMO languages) for model computation.

6.3 The RPMS Modelling Methodology

Development of this methodology was precipitated by the attraction of Riggs and Inoue to the similarity of the techniques employed by business, systems engineering and economics. There was also an awareness of the need for a more precise formulation of problems in a manner which provided a format both for analysis and for the displaying of solutions. RPMS networks constitute a general systems approach to the question of meeting this need for a broad range of problems. It is based on the premise that most OR/MS problems can be represented by a universal network configuration that is independent of the solution procedure to be applied.

In addition to assisting with problem formulation (cause-effect diagrams can be used as a preliminary to network construction) an RPMS network also permits explicit recognition of the duality concept. Thus allocation problems can be seen as having a primal form, involving resource conversion, and a dual form, involving value assignment. Both interpretations can be dealt with in the same network. The two themes of problem formulation and duality are emphasised in the RPMS methodology.

The RPMS 'world view' comprises four fundamental concepts which support the conceptual-graphical model abstraction phases. These concepts are respectively: resource nodes, process (or activity) nodes, minimising and maximising 'objectives' nodes, and the structural linkages, or arrows, relating these nodes.

Figure 6.4 illustrates the use of these concepts in a simple manufacturing situation involving the utilisation of two resources (a machine and materials) to produce two products. The primal objective is that of maximising total profit, with the dual objective of minimising the total 'cost' of the resources used.[1]

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[1] Costed at 'prices' which are imputed to the resources to produce a total resources 'cost' equal to the maximum total profit.

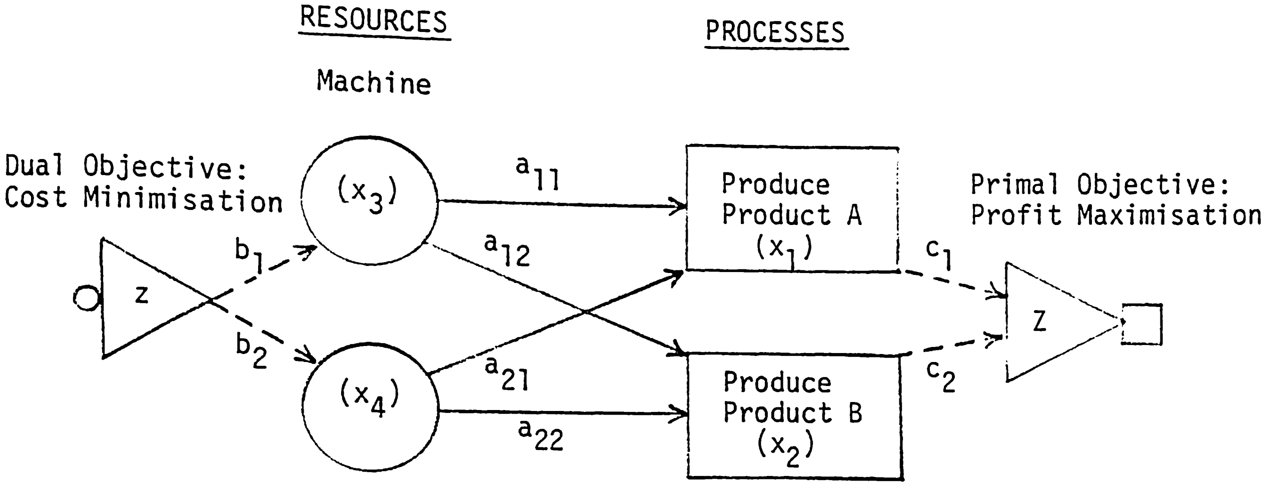

FIGURE 6.4: <u>AN RPMS NETWORK FOR A SIMPLE TWO-PRODUCT MANUFACTURING SYSTEM</u>

(Adapted from Riggs & Inoue, p.81)

This diagram completely specifies the model structure and can be readily augmented with the addition of the necessary model data (in the form of objective function coefficients and resource consumption coefficients) against the arrow to which each relates. The model variables for output quantities and resource residuals can be shown on the relevant process and resource symbols.

Riggs and Inoue have largely concentrated their application of this methodology on the analytical modelling of 'localised' problems, where optimisation is sought in terms of a single-criterion objective function. The operational utility of the RPMS conceptual framework has not been demonstrated at the corporate level, in the specific context of dynamic simulation of the corporate system, using multiple performance criteria in a 'what-if' solution search mode. Also the methodology in its present form is, like GESIFLOG, not oriented towards the definitional or computational phases of modelling. In fact the final mathematical form of models constructed using RPMS is determined by the particular technique with which the RPMS approach is interfaced.

6.4 The NETFORM Modelling Methodology

NETFORM modelling as a technique bears a superficial resemblance to GESIFLOG in terms of the networks which result from its use. The same symbols are used to develop the system of arcs and nodes comprising a network, but with NETFORM the node is used to depict real-world components such as physical sources and destinations (of resources or products). Arcs then identify either the physical flows between sources and destinations, or the conceptual flow associated with the carrying over of resources (such as inventory) from one time period to the next.

As is customary with network representations the dual aspects of flow and cost per unit of flow can be attached to the arc concept. Furthermore, any given arc can be 'tagged' with upper and lower bounds. An arc multiplier can also be applied to modify the amount of flow along the arc, or to transform the flow from one type of good to another (Glover et al, 1978). Stochastic features may also be incorporated with the definition of receiving and distributing functions for each node, together with the probabilities associated with the occurrence of the activities (or flows) entering and leaving the node (Pritsker & Happ, 1966).

As with RPMS, the NETFORM methodology has been applied principally to localised problems involving single-criterion optimisation. It does, however, support the definitional phase

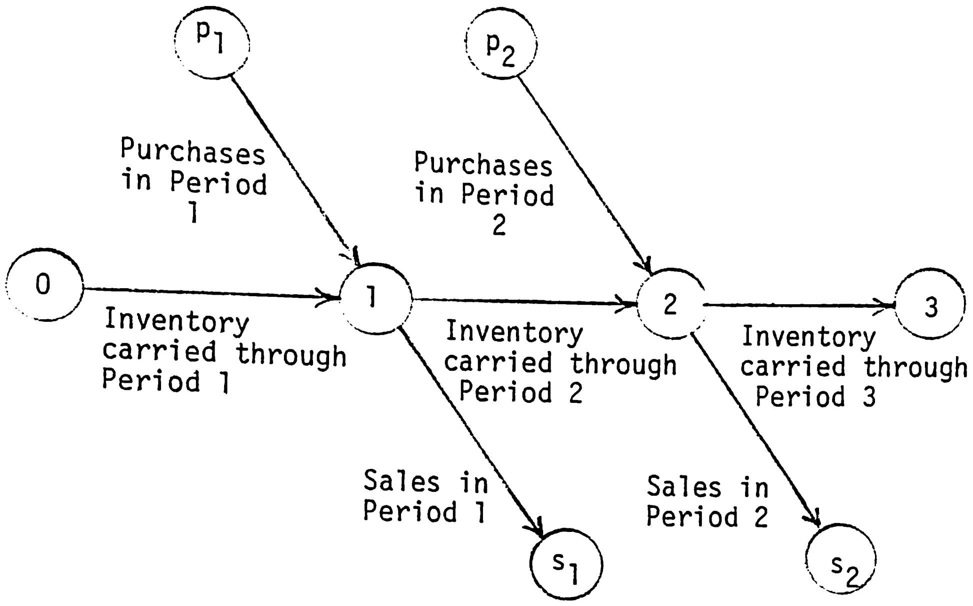

FIGURE 6.5: NETFORM REPRESENTATION OF A DYNAMIC INVENTORY MODEL

(Adapted from Glover & Talmay, 1978)

of model-building to some extent and has, in its application to analytical modelling situations, provided insight into more efficient solution algorithms than those associated with the traditional non-graphical approaches.

6.5 Summary

Both System Dynamics and NETFORM utilise a style of graphical representation which seeks to portray, in the first instance, the physical structure of the system being modelled. The resultant diagram is then used as a basis for formulating the mathematical model. In the case of System Dynamics this is accomplished in terms of a well defined modelling language which permits the construction of a dynamic system of recursive equations which can be 'solved' through computer simulation.

With NETFORM the graphical representation is not supported by a specific modelling language for dynamic simulation. Instead the mathematical model is derived (usually) within the framework of an established analytical modelling technique, such as linear programming. The graphical representation may, however, be used to develop more efficient solution algorithms for any given class of allocation problem (Glover et al, 1978).

The GESIFLOG and RPMS approaches both utilise network representations to depict mathematical structure rather than physical structure. Cause-effect relationships between all model factors are rigorously graphed, with (in the case of RPMS) a convention which permits both the primal and the dual forms of the model to be displayed in the one network. As with NETFORM neither approach is supported by a specific simulation modelling language. Both are usually interfaced with an established analytical modelling framework instead.

A more detailed comparison of the graphical and mathematical conventions adopted by each of these modelling approaches is presented in Chapter 9.

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PART II

SIMPLIFIED SYSTEM DYNAMICS:

METHODOLOGY AND APPLICATIONS

In the chapters of this section the methodology for corporate modelling, developed in accordance with the objectives of this study, is presented and discussed. A series of applications of the methodology is also presented, and used as a basis for assessing its utility in supporting a more effective style of corporate planning.

CHAPTER 7

SIMPLIFIED SYSTEM DYNAMICS - A METHODOLOGY FOR CORPORATE MODELLING

This Chapter describes a methodology for constructing flexible, modular and dynamic simulation models for use in corporate planning. The methodology constitutes a systems approach to the problem of constructing planning models for use in strategic management. It is based upon a 'world view' or framework of concepts drawn from, or utilised by, several established methodologies.

A cornerstone of this hybrid conceptual framework is provided by the level and flow concepts of System Dynamics, which are coupled with the matrix algebra concepts of Input-Output Analysis, to permit the construction of vectorised networks. Further concepts, some of which are analogous to those used in the NETFORM methodology are used to provide the basis for the regulation of the vectorised network flows.

7.1 The Nature and Purpose of the Methodology

Simplified System Dynamics (SSD) is a computer-based modelling methodology designed to provide corporate management with a flexible, low cost and easy-to-use modelling facility, primarily for use in corporate planning. This latter consideration has resulted in a methodology together with a supporting computer software system which has been designed with the needs and principles described in Chapter 4 firmly in mind. More specifically, the methodology is directed at meeting what are identified below as being the minimum attributes necessary for any modelling system to support the style of participative entrepreneurial planning described in Chapter 3. These are:-

(1) To be able to cater, first and foremost, for representation of the highly structured, mechanistic relationships which every organisation possesses, and relegate the less structured 'fuzzy' relationships to the status of being external, user-specified influences. This facilitates model flexibility and model-manager complementarity and avoids the unnecessary counter-productive complexity which inevitably arises when decision process relationships are attempted in the model.

(2) To be able to represent those relationships to be modelled, in a logically organised and systematic framework of concepts and procedures which span the full conceptual-verbal-graphical-mathematical model abstraction sequence. Real world systems are both complex and dynamic, and inevitably it follows that models representing them must, to be useful, also be complex and dynamic. A systematic framework, properly constituted, can permit structured complexity. This is achieved if complex models are constructed using a set of simple graphically presentable concepts which provide a mantle of simplicity, to the extent that the manager can perceive the model as a 'glass box' rather than a 'black box'.

The complex whole can thus be seen as comprising a logically ordered set of essentially simple elements.

This also facilitates model flexibility, through modularity, as well as providing the best compromise between the need to adequately model real world complexity and the need to retain some degree of understandability.

(3) To be able to reflect both continuous flow and discrete-event behaviour, in the sense that transactional activities such as sales, for example, can be treated as continuous flows, while others, such as capital expenditure, can be modelled discretely on a transaction-by-transaction basis. Many real world systems, and the corporate entity is no exception, are hybrid systems in that they display both continuous flow and discrete-event characteristics.

(4) To be able to reflect differing levels of aggregation in the sense of being able to cope with, for example, products grouped into broad categories for the purposes of a financial model, and those same products identified individually, for the purposes of a production planning model. This requirement also arises from the nature of the corporate goal structure, and the fact that performance measures encompassing both profitability and its determinants (in the areas of evolutionary, growth, stability and productivity performance) must be addressed in order to provide an adequate 'what-if?' capability in the resultant model.

(5) To be able to reflect the accounting framework and its established concepts and relationships, within a general

systems framework which also permits the concurrent representation of non-financial aspects of the organisation.

(6) To take the fullest possible advantage of modern computing technology both as it is presently constituted and as it is evolving. In particular this applies to the utilisation of the interactive capability of modern timesharing computers, and the user-oriented program generating capability of their associated software systems.

The remainder of this chapter is devoted to providing an introductory perspective on the SSD methodology in terms of its conceptual framework, model-building steps and supporting software package.

7.2 The Conceptual Framework of the Methodology

The general systems framework upon which the methodology is based consists essentially of the System Dynamics concepts of levels and flows, together with the Input-Output concepts of vectors and matrix transformations. The former provide the general systems capability for dynamic representation of organisations and their sub-systems, while the latter provide the basis for ordered complexity and aggregational flexibility in the resultant models.

The general nature of the System Dynamics methodology as a systems approach to modelling has been discussed in Chapter 4, along with its advantages and disadvantages in the corporate planning context. Real world systems are modelled in terms of levels and flows organised into networks, with flow regulation being dynamically determined by means of information feedback loops. The level and flow concepts can in fact be applied to any system whose physical nature and behaviour can be described in terms of outputs, inputs, and their respective accumulations and movements.

Input-Output Analysis utilises the power of matrix algebra to represent the 'flows' associated with multi-sector organisations as vectors, with complex inter-dependencies being accommodated through the use of matrix transformations. The term 'sector' can be defined to apply to an economic sector, company division, product or resource group, or even individual products and resources. Thus differing levels of aggregation can be adopted, within the limitations imposed by the need for coefficient stability and linearity of relationships. Applied in its traditional form, however, the technique constitutes a static form of analysis, reflecting flows only, over a single time period[1].

The conceptual framework of SSD, as an amalgamation of the conventional System Dynamics and Input-Output Analysis frameworks, permits the representation of real world systems as dynamic, vectorised networks. This hybrid framework of concepts may be described in the following terms:-

(1) The fundamental structural elements, or building blocks

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[1] See Butterworth & Sigloch, 1971, for an excellent rationalisation of a range of examples of Input-Output Analysis applied at the micro-economic level. This rationalisation is accomplished in terms of a generalised Input-Output model. A discussion of this model and its relevance to SSD is presented in Chapter 9.

of the framework are level vectors and flow vectors.

(2) The level and flow vectors are organised into networks through the definition of linkages (linking one level to another), whereby each linkage consists of an inflow vector, outflow vector and a transformation matrix (refer Figure 7.1). The latter transforms the inflow vector into an outflow vector, or vice versa. This in effect is the application of Input-Output Analysis at the 'ultra-micro' level, with the simultaneous equation set, in both its primal and dual form, being uniquely defined for each linkage, and evaluated for each of a series of solution intervals.

(3) Dynamic representation is achieved through the use of a suitably defined model solution interval[2] and the balancing relationship:

(Level vector values at interval end) = (Level vector values at interval start) + (sum of Inflow vector values) - (sum of Outflow vector values)

(4) Flows are determined in the first instance by defined flow determinants which can be, for any given flow vector

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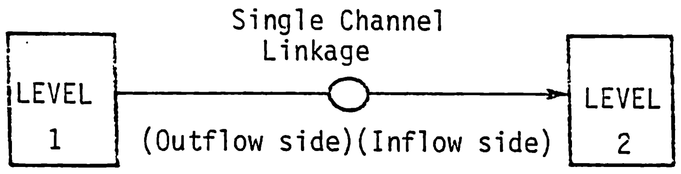
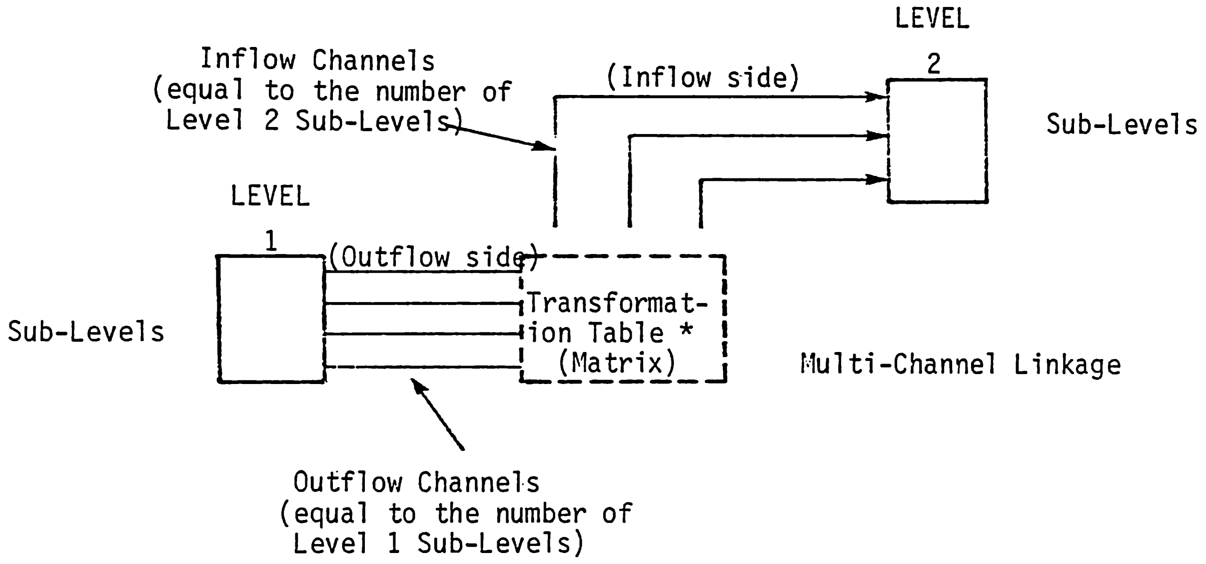
[2] Unlike conventional System Dynamics, the model solution interval DT is always set at 1.0. However the particular time unit for any given model can be chosen to suit the circumstances (e.g. a solution interval of 1 day, 1 week or 1 month may be appropriate for a planning model). This simplification obviously may mask the finer points of a system's dynamic characteristics, but the ability to accommodate more disaggregated models (facilitated by the reduced computational load) more than compensates for this as far as the requirements of corporate planning are concerned. The implications of this simplification on model stability and the use of delays are discussed in Appendix I.

Levels and Flows as single Elements:



Levels and Flows as Vectors:



* For relating the Flow Channels of one side of the Linkage to those of the other

FIGURE 7.1: THE LEVEL AND FLOW CONCEPTS OF SSD

(inflow or outflow);

- another flow vector (inflow or outflow)
- a level vector
- an externally specified base flow (i.e. initialising) vector

These options, in respect of both inflows and outflows, are listed in the equation library inset of Figure 7.2.

(5) Those flow vectors determined by the corresponding inflow (or outflow) vector of their own linkage, are determined by a matrix transformation (i.e. the dependent flow vector of the linkage is equated to the product of the independent flow vector of that linkage, and its transformation matrix[3]. In all other cases, with the exception of the mixed dependency option, the relationship between the flow vector and its determinant is strictly that of a vector equation (i.e. each dependent flow vector element is equated to the corresponding element of the independent, or determinant, flow vector).

(6) For the mixed dependency option, the vector equation requirement, described above, is relaxed to the extent that each element of the dependent flow vector can be equated to any element of the independent flow vector.

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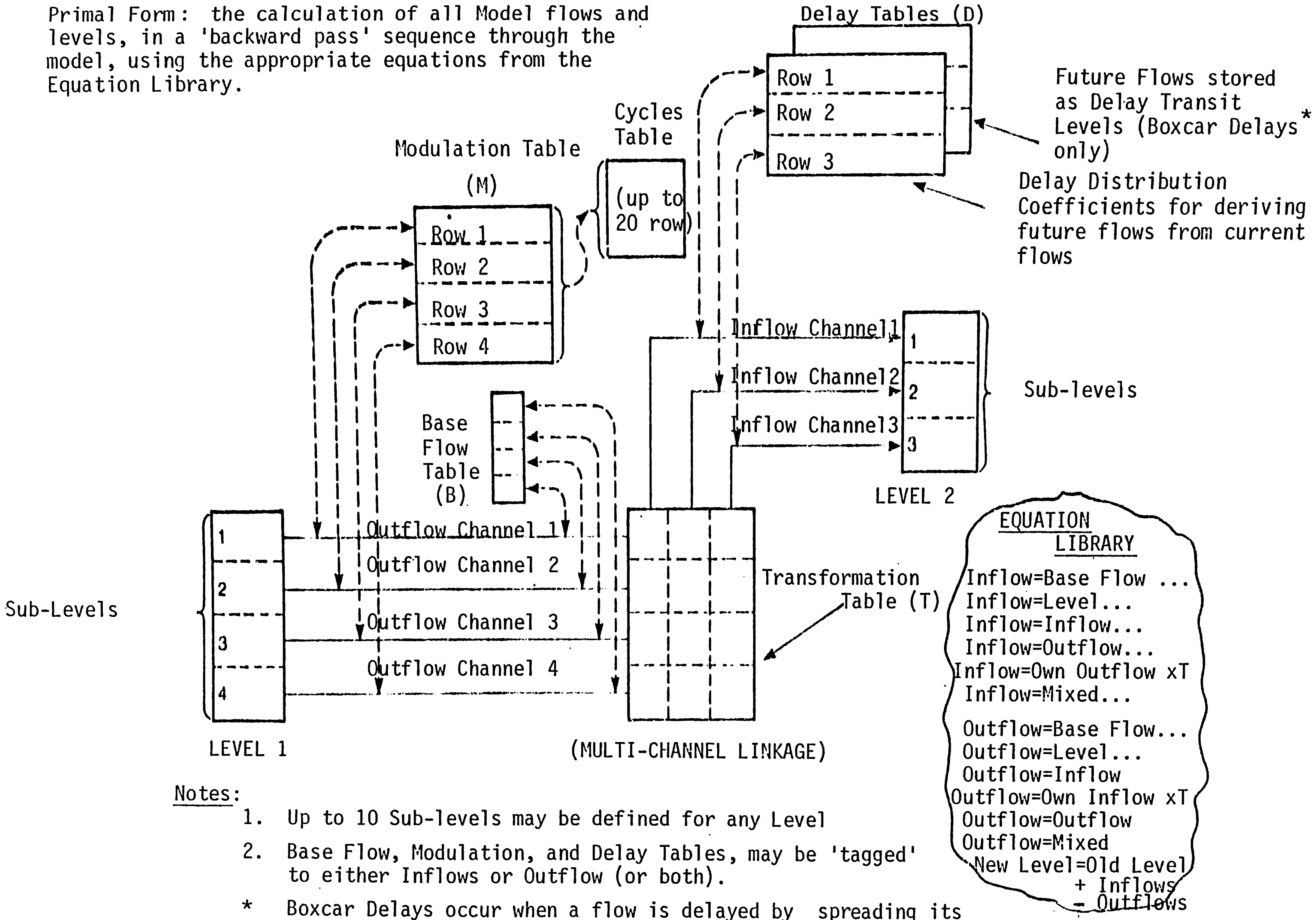
[3] Refer Figure 7.1 and Appendix A for further details of linkage transformations.

Primal Form: the calculation of all Model flows and levels, in a 'backward pass' sequence through the model, using the appropriate equations from the Equation Library.



Notes:

1. Up to 10 Sub-levels may be defined for any Level
2. Base Flow, Modulation, and Delay Tables, may be 'tagged' to either Inflows or Outflow (or both).

* Boxcar Delays occur when a flow is delayed by spreading its 'occurrence' across future time periods according to a discrete distribution.

FIGURE 7.2: THE MODELLING CONCEPTS OF SSD - PRIMAL FORM

(7) Any or all of the above-described dependency options can be used to establish the 'prima facie' dependency relationships within any given model. Once defined however, they can be augmented with the super-imposition of flow influences. This fact is acknowledged symbolically in Figure 7.2 with the presence of dots after the basic equation, e.g. the relationship:-

Inflow = Outflow ....

indicates an inflow vector being determined by an outflow vector, subject to whatever additional flow influences are defined for it.

(8) For any given inflow or outflow vector, two basic types of flow regulating influence can be defined as follows:-

Modulations- which are user-defined time-triggered patterns of positive or negative growth (multiplicative or additive). They can be applied to each, or any, element of a flow vector. Thus each flow channel of a linkage can be 'tagged' with externally specified data which defines a particular type of growth pattern for the flow passing along that channel. Collectively the data associated with the set of flow channels making up the inflow (or outflow) side of the linkage against which a modulation is tagged comprises a Modulation Table (or Matrix), as shown in Figure 7.2 and described in detail in Appendix B.

Delays - which are also user-specified and can regulate the timing of release of any calculated flow amount, according to three basic options. These are the exponential form of delay, the distributed form of boxcar delay, and the 'stack-up' form of boxcar delay[4].

Two forms of data tables carry the necessary data for effecting flow delays on any given inflow or outflow. These are the Delay Distribution Table (or Matrix) and the Delay Transit Table (or Matrix) respectively. As with the Modulation Matrix, each row of each Delay Matrix carries the data pertaining to the corresponding flow channel of the particular linkage against which it is tagged, in the manner shown in Figure 7.2. Further details of the Delay type of flow influence are provided in Appendix C.

(9) Figure 7.2 depicts the basic concepts discussed above, as they apply to any given linkage relating any two levels, when viewed in the 'primal' context. These same concepts, collectively constituting the elements of a vectorised network, also have a dual interpretation in the same manner noted in the previous Chapter in connection with RPMS networks. The conceptual nature of this dual interpretation for SSD networks is depicted in Figure 7.3. In this interpretation the concept of 'flow' is replaced

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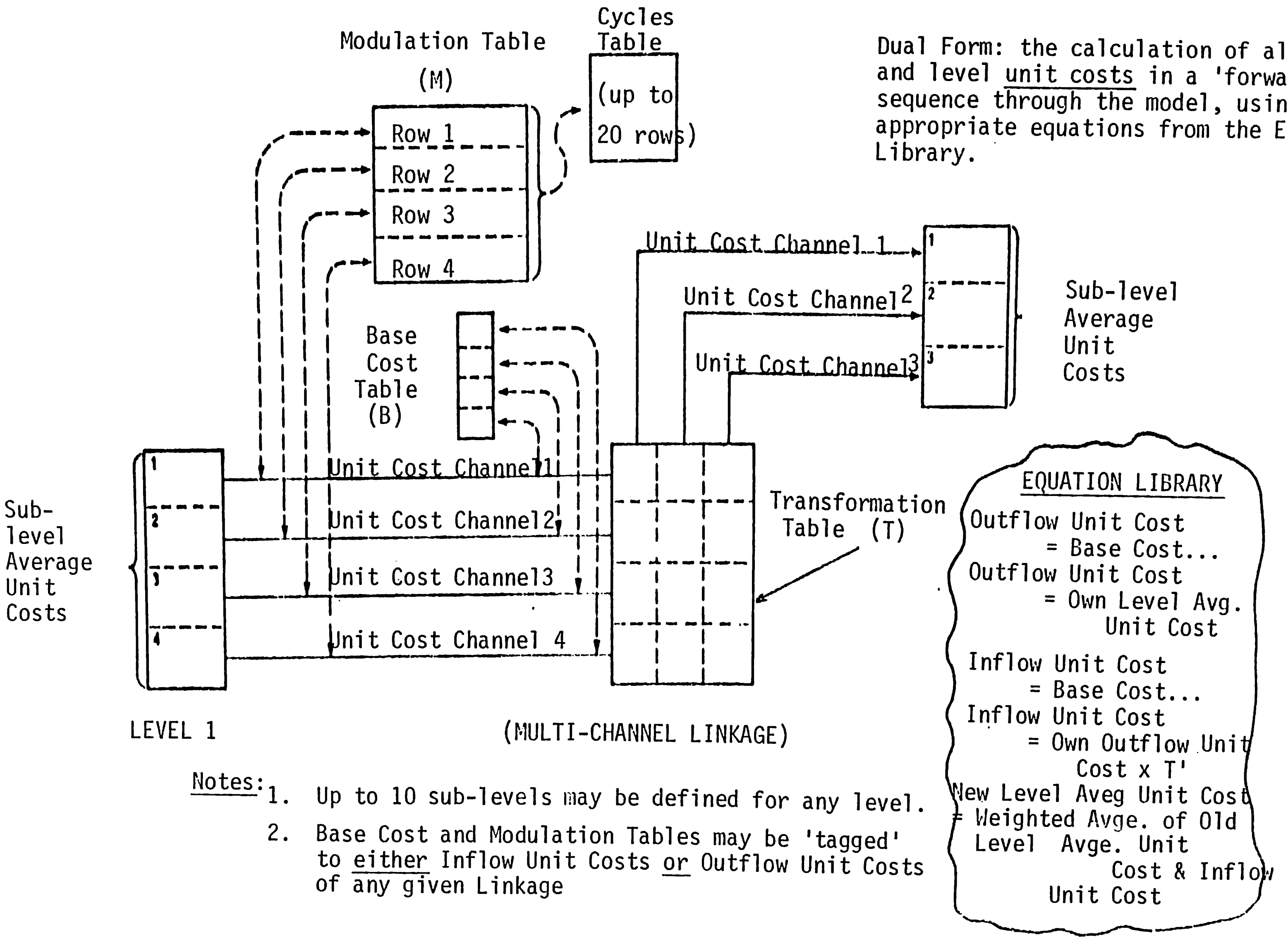
[4] Boxcar delays are defined here, as influences which result in any given flow quantity, in any given solution interval, being spread across a series of future solution intervals, according to a specified discrete distribution, as far as the timing of release is concerned. A stack-up boxcar delay is a variation on this theme whereby flow amounts are <u>accumulated</u> for a specified number of intervals, then spread across a series of successive intervals, in the manner described for the boxcar delay.

Dual Form: the calculation of all flow and level unit costs in a 'forward pass' sequence through the model, using the appropriate equations from the Equation Library.



Notes:
1. Up to 10 sub-levels may be defined for any level.
2. Base Cost and Modulation Tables may be 'tagged' to either Inflow Unit Costs or Outflow Unit Costs of any given Linkage

FIGURE 7.3: THE MODELLING CONCEPTS OF SSD - DUAL FORM

by 'flow unit cost' and the concept of 'level' is replaced with 'level average unit cost'. Thus the flow and level vectors have their dual in the form of flow unit cost and level average unit cost vectors respectively. Further, the primal equation library gives rise to a dual equation library, the options for which are listed in the inset of Figure 7.3. The equation notation used here is as described for the primal form, but in this instance only the modulation type of influence can be superimposed on any given dual relationship. It should also be noted that the Transformation Matrix is replaced by its transpose in the relationship linking flow unit costs on one side of a linkage to those of the other. Also the Base unit cost concept serves the same initialising function as the Base flow concept of the primal form.

To summarise, the conceptual framework of SSD comprises level and flow vectors, which can be organised into vectorised networks, resulting in multi-channel linkages in those networks. The equation system for any given network can, in any given modelling situation, be assembled from two libraries of simple 'prima facie' equations, which can be augmented with the superimposition of externally specified flow regulating influences, in the form of modulations and delays. Further, the two sides of any given linkage can be related by matrix transformation.

This conceptual framework has both a primal and dual interpretation, which, for any given network, gives rise to the primal-dual concepts of flows/levels and flow unit costs/level average unit costs respectively. With reference to Figure 7.1, this primal-dual interpretation can be illustrated in the manner shown in Figure 7.4, for a simple multi-product, multi-resource manufacturing system.

In any given modelling situation, application of this conceptual framework results in the graphical form of the model, as a vectorised network, serving as the basis for the mathematical form, as a recursive equation system[5]. Simultaneity is confined to the intra-linkage transformations operating within each solution interval. The solution procedure for the equation system of any model constructed using the methodology, is described in section 7.4, and in further detail in Appendix I. The broad sequence of events in the procedure is displayed in Figure 7.5.

7.3 The Steps in the Methodology

As stated earlier, the methodology spans all four phases of the model abstraction process, with the graphical form of the

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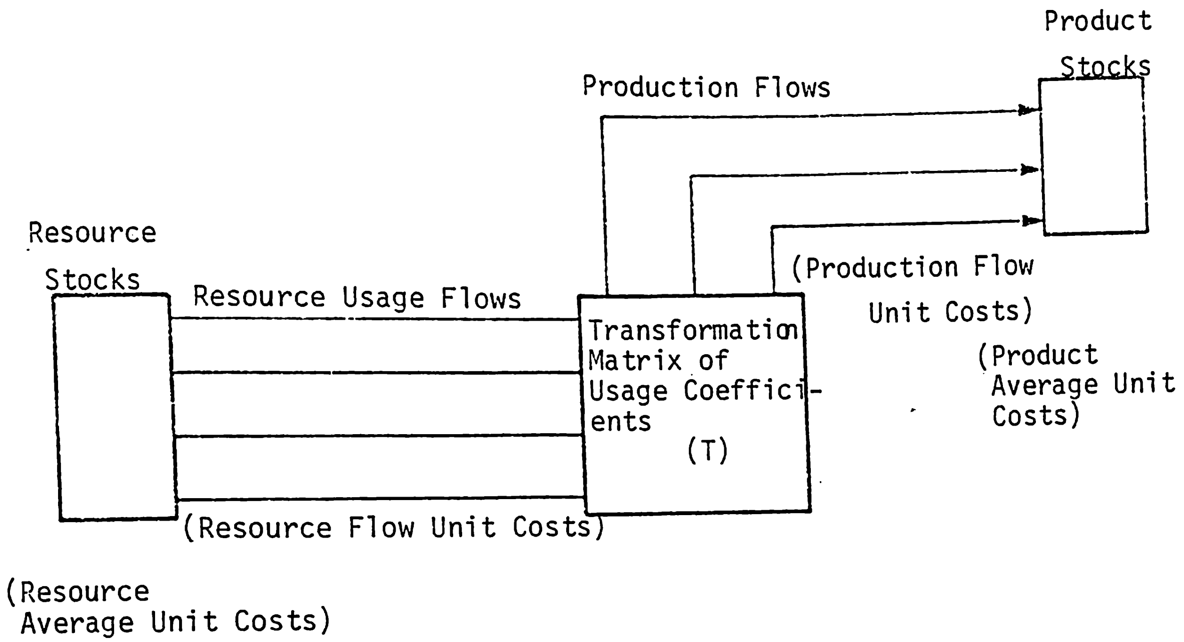
[5] Naylor & Mansfield, 1977, in their suggested criteria for modelling systems, advance an argument for simultaneous equation solution capability based on the supposed inadequacy of dynamic recursive equation systems. The writer does not concur with this argument, in that dynamic recursive equation systems can cope with the kind of 'simultaneity' described in the examples cited by Naylor & Mansfield. The five equation financial model described by them, in support of their argument, is a static (single period) model in which simultaneity arises from the assumptions upon which the model is based, rather than from the real world system being modelled. Specifically, the model assumes that both tax and interest payments occur as cash flows, in the same time interval as the amounts must be charged against profit. Extension of the model to permit dynamic representation not only circumvents this simultaneity, but improves the model's validity as an abstraction of an unquestionably dynamic real world system.



(Note: The Dual Variables are shown in parentheses)

If we define:

I as the Production Vector) = Primal Variables
X as the Resource Usage Vector)

C as the Production Unit Cost Vector) = Dual Variables
K as the Resource Unit Cost Vector)

Then:

$X = I.T$ (The 'backward pass' equation)

and $C = T'.K$ (The 'forward pass' equation)

for any given linkage.

FIGURE 7.4: THE CONCEPT OF DUALITY AS APPLIED TO A SINGLE LINKAGE

model constituting an indispensable communications device, and bridge between the verbal and mathematical forms of any given model. In general terms a set of eight distinct steps can be identified for the overall process of model construction using the SSD methodology. Each of these steps is described below.

Step 1: Construction of the Verbal Model

This must be primarily in terms of those levels and flows which are consistent with the defined purpose of the model. Levels must be defined to represent those real world 'accumulations' to be recognised, while flows must be defined to represent those 'movements' which affect the aforementioned levels. Thus the level definitions are the key to constructing the verbal model, and they must collectively describe the state of the system in a manner consistent with the role defined for the model.

In accounting terms, account balances constitute levels and transactions are flows. Transactions affect or determine account balances just as flows determine levels. The accounting principle of double-entry can thus be restated to the effect that every linkage has both an inflow and outflow side to it, and that inflows must equal outflows for each linkage[6]. The basic convention adopted in the SSD methodology is that inflows constitute debits and outflows are credits. This naturally gives rise

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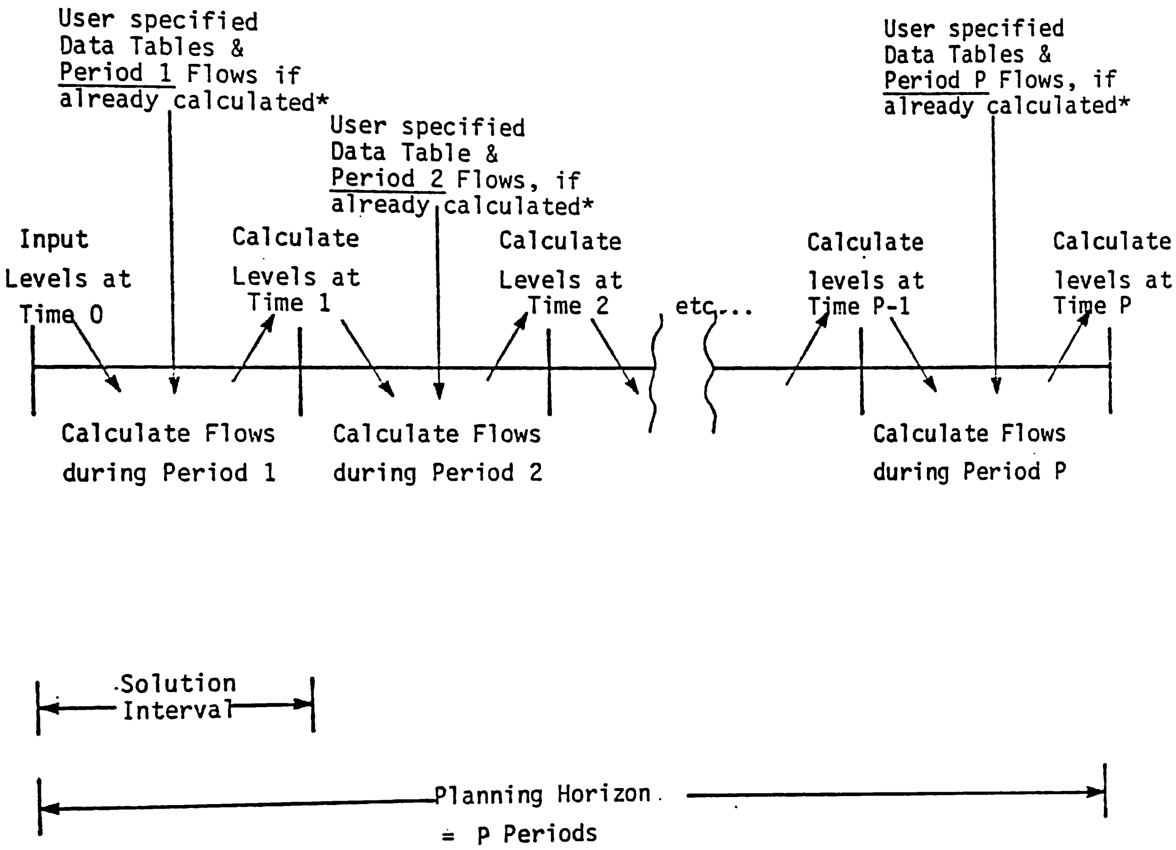
[6] This requirement need not however, be adhered to for all linkages in a financial model, nor indeed for any linkages in a non-financial model. Some non-financial or quasi-financial flows may be defined in such a way as to result in quite valid inequalities as between the inflow and outflow sides of a linkage.



* Linkage flows are evaluated strictly in Linkage number order. Thus any given flow can be assigned another flow as a determinant, within the same solution interval, provided that the determining flow is of a Linkage with a lower Linkage number.

FIGURE 7.5: THE SOLUTION PROCEDURE FOR SSD MODELS

to credit balances being represented as negative-valued levels and debit balances as positive-valued levels.

Table 7. 1 provides some examples of levels and flows commonly found within the corporate system. Vectorisation of levels and flows, such as those shown, permits the definition of sub-levels (or sub-accounts). Thus the Capital Accounts level for example could be vectorised to recognise various Debt and Equity account classifications. The Stock Account might be sub-classified by product group and the Fixed Assets Account by asset type. Any level, if vectorised, should represent a grouping of like sub-levels and in any given modelling situation this should logically develop from the nature of the levels defined for the model. Vectorisation of the flows automatically follows by definition, in accordance with their function of linking the levels.

The description of the system to be modelled, as the verbal form of the model, should be extended beyond merely being a listing of required levels and their associated flows. It must also encompass identification of the determinant of each flow, the influences (modulations and delays) to be defined for each flow (inflow and outflow) and the nature of the transformations required for each linkage[7].

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[7] Transformations may basically manifest themselves in two forms. First, flow switching or directing transformations may be defined as in financial models where debits of an inflow may have to be split into several credits (outflows) for example. Second, flow consumption transformations may be defined as in production models where production (an inflow) gives rise to resource consumption (an outflow) for example.

TABLE 7.1: EXAMPLES OF LEVELS AND FLOWS OF THE CORPORATE SYSTEM

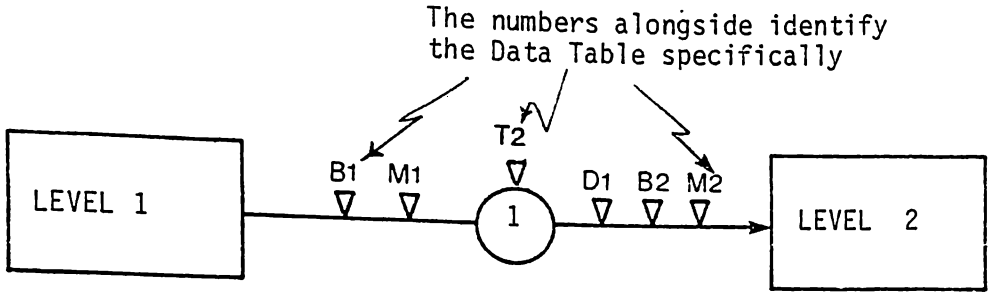
LEVELS	FLOWS WHICH AFFECT THEM
The Financial Sub-system:	
Capital accounts	Borrowing and repayment transactions
Cash accounts	Cash collections & payments transactions
Debtor accounts	Credit sales & cash collections transactions
Creditor accounts	Purchases & creditor payment transactions
Stock accounts	Purchases, production & sales transactions
Nominal accounts (sales, expenses, etc.)	Sales & expenses transactions
Fixed asset accounts	Capital expenditure & depreciation transactions
The Marketing Sub-system:	
Products on-order levels	Order placements and deliveries
Stock levels	Stock replenishments and deliveries
Market demand levels	Promotional activities, market sales and market consumption
The Production Sub-system:	
Finished product stock levels	Finished production and deliveries
Work-in-process stock levels (each stage)	Finished production, intermediate production, resource usage
Materials stock levels	Materials usage and purchases received
Workforce levels	Hirings, retirements, redeployments
The Purchasing Sub-system:	
Materials on-order levels	Purchase order placements & purchases received
Resource market supply levels	Resource consumption, resource production
Materials Stock levels	Materials usage and purchases received

Step 2: Construction of the Graphical Model

This proceeds on the basis of the verbal model and depicts the pattern of levels and inter-connecting flows (i.e. the 'plumbing' of the system). In any given modelling situation it is usually possible to arrive at more than one basic structure for the same model. In these circumstances it is desirable for the choice of structure to be made in favour of that alternative which captures the system plumbing in the most concise and conceptually appealing manner, consistent with the purpose of the model.

The flow diagramming conventions used in the methodology are based on the choice of a simple set of seven symbols, which can be applied to any modelling situation. The meaning and use of these symbols is illustrated in Figure 7.6.

Naturally the flow diagram for a full model would comprise a network of levels and flows utilising the symbols shown in the diagram. In the interests of simplicity, and preservation of the flow diagram as an effective communicating vehicle, vectorisation of the network, if it has taken place, is not shown on the diagram. In some instances however it is useful to show the dimensions of the vectorised levels on the relevant level symbols. Generally the details of vectorisation, in terms of the level vector element definitions (sub-levels) are, along with the various flow determinants, better recorded other than on the diagram.



KEY TO SYMBOLS:

□	denotes a Level
—○→	denotes a Linkage
∇	denotes the 'tagging' of a Data Table to a Linkage (either side)
M	denotes a Modulation Matrix (or Table)
T	denotes a Transformation Matrix (or Table)
D	denotes a Delay Matrix (or Table)
B	denotes a Base Flow Matrix (or Table)

FIGURE 7.6: FLOW DIAGRAMMING SYMBOLS OF THE SSD METHODOLOGY

Step 3: Construction of the Mathematical Model

This is accomplished in two distinct stages and due to the nature of the SSD supporting software[8] as a package, results in the programmed form of the model. The first stage involves capturing the model structure in terms of the defined levels and linkages, flow determinants and influences, directly from the flow diagram, using the Model Specifications program. This is accomplished interactively at the computer terminal, and results in the

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[8] Discussed in the next section.

creation of a permanent set of disk files, unique to the model concerned, which fully specify its structural relationships (i.e. the equation library options to be used, and where they are to be used).

The second stage proceeds directly from, and in accordance with, the first stage. It involves the specification of all of the required model data tables (matrices), which have been 'tagged' against the various linkages. This is also accomplished interactively at the terminal using the Model Data Input program and results in the creation of the model data base as a permanent set of disk files unique to the model concerned (i.e. all of the Modulation, Delay, Transformation and Base Flow/Unit Cost matrices). The initial values (or opening balances) of the defined levels are also part of the model data base.

An important feature of this two-stage approach to development of the programmed mathematical model is the separation of the model structure from its data base. This is generally recognised (Meyer, 1977) as being an important prerequisite for flexibility and ease of use of the developed model.

Step 4: Model Editing, Checking and Testing

This is accomplished with the use of a Model Listing program, to obtain a full listing of the model structure and its data base, together with the use of a Model Editing program to perform a set range of automatic checks on both the model structure and data base. Any necessary amendments to either of these aspects can be accomplished selectively with the specifications and data input programs,

In addition to ensuring that the model structure and data have been entered into the system programs in accordance with the flow diagram and associated data input sheets, the validity of the model, in terms of ensuring that all relevant concepts and functions have been used correctly to produce acceptable results, must be established. This is carried out by performing limited runs of the model using the Model Computation program. This program can, at the option of the user, produce a full 'tracer'[9] of all model calculations, in respect of each linkage and level, for all model solution intervals, if desired. Desk checking of the model can proceed with the use of this supporting data.

Step 5: Model Validation

As with any modelling methodology, the extent to which this can be carried out depends on the nature of the particular model and the availability, or otherwise, of suitable empirical 'benchmark' data. Total assurance of the complete validity of any model can never be anything but an ideal, which in reality must be compromised with the need to be pragmatic. In practice, model validation often needs to be viewed as a continuing process whereby the model is gradually fine-tuned as the history of

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[9] Refer Appendix I for details.

comparative results (actual versus model) is built up.

In the long run, perhaps the best test of model validity can be found in the extent to which the model provides a positive contribution to the management process, over and above that which could be attained with the best available alternative to using the model - which is often reliance on pure intuition.

As with Step 4, any necessary feedback adjustments to the model can be accomplished with the specifications and/or data input programs.

Step 6: Using and Maintaining the Model

The normal use of the model to produce output for management requires the full running of the Model Computation program, over the chosen planning horizon for the model. This produces a permanent disk file of computed data, in the form of calculated level values at the end of each solution interval of the horizon. Formatted reports, in either tabular, or graphical form, may then be produced as and when required, using the Model Report Generating program.

7.4 The Supporting Software System

GENSIM (for Generalised Simulation System) is a package[10],

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[10] As distinct from a high level special purpose modelling language such as DYNAMO or Data*MODEL, where the model equations must be explicitly programmed as lines of code. As a parameter-driven software system, GENSIM automatically generates the model equations on the basis of structural and data base parameters, specified using the specifications and data input programs of the package (refer Figure 7.7 and Appendices E and F for details).

or system of six functionally oriented programs written in the interactive BASIC language for a PDP 11/70 time-sharing computer, operating under the RSTS/E operating system. The programs, their inter-relationship and their use in conjunction with the model building steps identified in the previous section are depicted in Figure 7.7.

All of the programs are fully interactive and can be run independently of one another for any given model, provided that the disk files for that model have been created in accordance with the model building steps outlined above. Details of the nature and use of each of the six programs are provided in Appendices E through to J, while the overall structure of the disk files and programs of the package is depicted in the diagram of Appendix K.

The package in its present form has limitations of both a conceptual and an operational nature. The conceptual limitations arise largely from the fact that as a package it lacks the equation formulation flexibility characteristic of high level languages. For any given model developed with the package, the equation set is derived from a finite library of options, in accordance with data provided by the model builder during the model specification stage. As far as the more highly structured mechanistic relationships of an organisation are concerned, this does not constitute a problem, but in situations where it is essential to reflect in the model the less structured relationships such as those associated with decision processes, problems will arise.

In brief, the package has been designed to cope with the

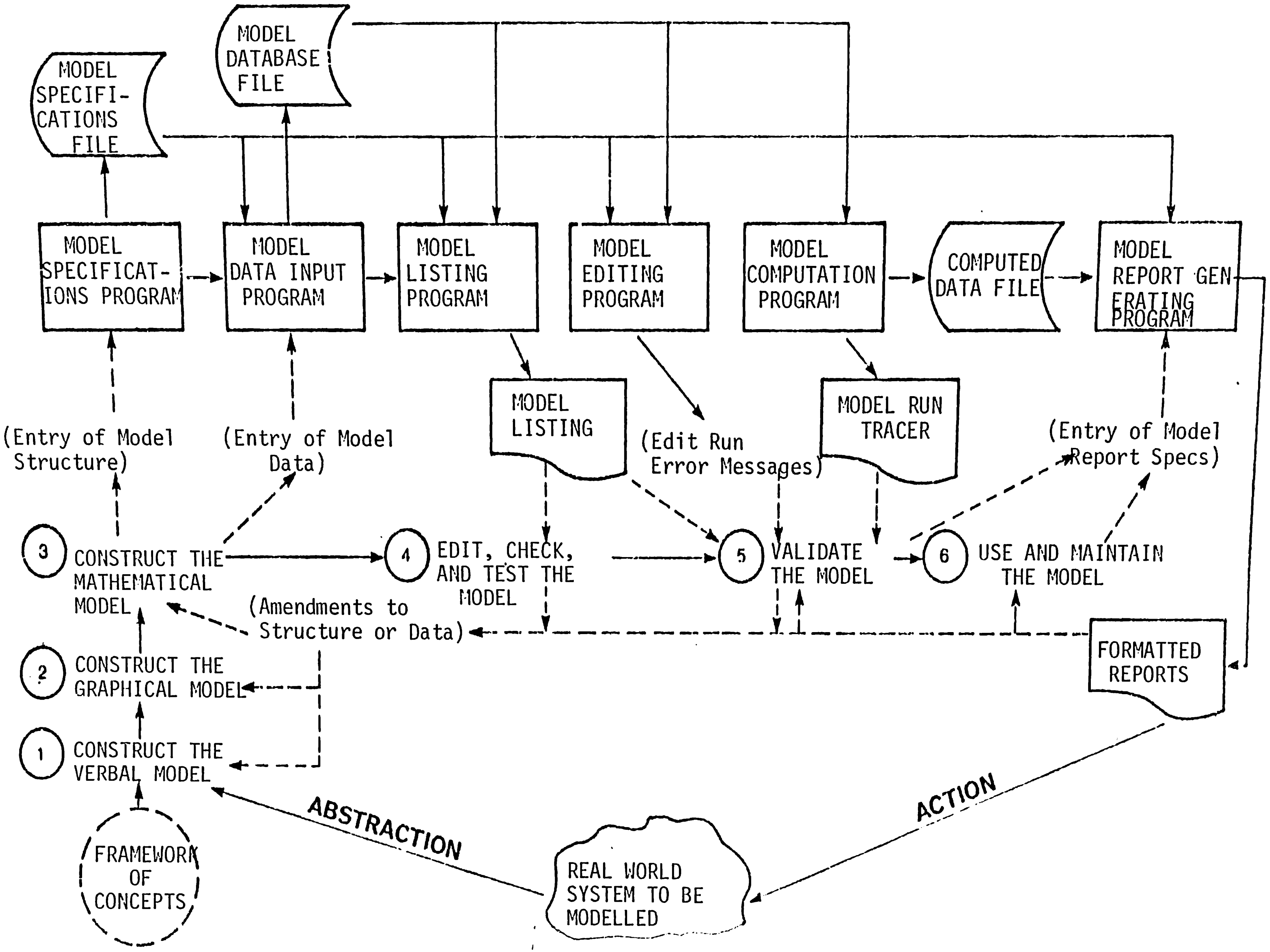

FIGURE 7.7: THE GENSIM PROGRAMS AND THEIR USE

mechanistic type of relationship in the most flexible and efficient manner, at the expense of a diminished capability to cope with the less structured 'fuzzy' relationships of the organisation. The argument in support of this rests on the importance attached to the preservation of understandability in the model, the diminishing marginal returns associated with modelling fuzzy relationships and the importance of model-manager complementarity.

The operational limitations of the package as presently constituted are summarised as follows:-

(1) Planning horizon - not more than 60 periods
(2) Number of levels - not more than 20
(3) Number of linkages - not more than 50
(4) Number of vector elements per level - not more than 10
(5) Number of transformations - not more than 20
(6) Number of modulations - not more than 20
(7) Number of delays - not more than 10

7.5 The Distinctive Features of the Methodology

At this point it is appropriate to summarise the distinctive features of the modelling methodology presented in this chapter. First and foremost, it constitutes a systems approach to the problem of constructing models for use in corporate planning, in which particular emphasis is placed on:-

- providing explicit procedures for each phase of the conceptual-verbal-graphical-mathematical sequence of model abstraction, and
- the efficient, systematic modelling of the highly structured mechanistic relationships of the organisation

with the less structured ones being relegated to the status of user specified influences.

Second, the methodology is based on the use of an explicitly defined hybrid framework of concepts, in which structured complexity and model modularity are achieved through the representation of real world systems as vectorised networks. This also facilitates resolution of the complexity-understandability conflict by ensuring that complex models can be rigorously defined in terms of relatively simple flow diagrams, which can serve as effective communications devices.

The System Dynamics concepts of this framework permit dynamic representation, and the modelling of complex time-lag effects, while the Input-Output Analysis concepts provide the facility for modelling multi-product multi-resource systems in both their primal and dual forms.

Third, the conceptual framework, due to its general systems nature, permits the modelling of both financial and non-financial aspects of the corporate entity with equal ease, either separately or as a single integrated 'corporate' model.

Finally, models are constructed, tested and used with the support of a fully interactive modelling package which takes the maximum advantage of the flexibility and user orientation of modern timesharing computers.

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CHAPTER 8

BUILDING A SIMPLIFIED SYSTEM DYNAMICS MODEL

In this chapter the SSD methodology is applied to a simple financial modelling problem in order to illustrate the use of the level and flow concepts in an accounting context. The system to be modelled comprises the financial aspects of a small retail business, and it is intended to construct a model, embracing these aspects, to produce projected monthly balance sheets over a planning horizon of three years.

Following on from this, the model is then extended by vectorisation, into a more disaggregated form, to enable the explicit definition of a more detailed set of accounts, to the extent that monthly profit and cash statements can also be generated.

8.1 The Verbal Model

In its initial form, the model is defined in purely scalar terms as regards levels and flows and therefore the chart of accounts (or set of levels) reflects only the main asset and liability classification of the business. These are:

(1) Capital (both Debt and Equity)
(2) Cash at Bank
(3) Creditors
(4) Fixed Assets
(5) Debtors
(6) Stocks
(7) Accumulated Profit (i.e. retained earnings)

The flows associated with these levels are transactions of the following types, each of which gives rise to a linkage in the model structure.

(1) Sales
(2) Cost of Sales
(3) Stock Purchases
(4) Expenses
(5) Debtor Collections
(6) Creditor Payments
(7) Depreciation
(8) Capital Borrowings and/or Repayments
(9) Capital Expenditure

Thus the plumbing of the system can be captured in terms of seven levels, and nine linkages (i.e. eighteen flows, given that each linkage has both an inflow and outflow side to it). The principal determinant of each of the eighteen flows is shown in Table 8.1. It should be noted that for this model one side of each linkage, or inflow - outflow pairing, is always dependent upon (or determined by) the other with the dependent side being either the inflow or outflow depending upon the circumstances. The independent side has a determinant which is 'outside' the linkage.

As none of the system levels are vectorised, and the concept of flow consumption is not relevant in this model, no transformations are required for any of the linkages. Both modulations and delays are required, however, and the exact nature and purpose of each is briefly described in Table 8.1. A more detailed description follows, and a full listing of the model data base is provided in Appendix L.

TABLE 8.1: DEFINITION OF LEVELS AND FLOWS FOR THE SIMPLE FINANCIAL MODEL

Level 1 = Capital
Level 2 = Cash at Bank
Level 3 = Creditors
Level 4 = Fixed Asset
Level 5 - Debtors
Level 6 = Stocks
Level 7 = Accumulated Profit

FLOW	FLOW DETERMINANT	FLOW INFLUENCES
Linkage 1 Inflow	Linkage 1 Outflow	
Outflow	User specified via Base Flow B1	Modulated by M1 = Sales Growth Coeff and its Pattern of Change
Linkage 2 Inflow	Linkage 1 Outflow	Modulated by M2 = Cost of Sales Coeff and its Pattern of Change
Outflow	Linkage 2 Inflow	
Linkage 3 Inflow	User specified via Base Flow B3	Modulated by M3 = Purchasing Growth Coeff and its Pattern of Change Delayed by D3 = Purchases Delivery Delay Pattern
Outflow	Linkage 3 Inflow	
Linkage 4 Inflow	User specified via Base Flow B4	Modulated by M4 = Expenses Growth Coeff and its Pattern of Change
Outflow	Linkage 4 Inflow	
Linkage 5 Inflow	Linkage 5 Outflow	
Outflow	Linkage 1 Inflow	Delayed by D5 = Cash Collections from Debtors Delay Pattern
Linkage 6 Inflow	Level 3	Delayed by D6 = Creditor Payments Delay Pattern
Outflow	Linkage 6 Inflow	
Linkage 7 Inflow	Linkage 7 Outflow	
Outflow	Level 4	Modulated by M7 = Depreciation Rate and its Pattern of Change
Linkage 8 Inflow	User specified via Base Flow B8	Modulated by M8 = Borrowing/Repaymetn amounts and timing
Outflow	Linkage 8 Inflow	
Linkage 9 Inflow	User specified via Base Flow B9	Modulated by M9 = Capital Expenditure amounts and timing
Outflow	Linkage 9 Inflow	

M1 carries the data to effect a growth pattern in sales which commences with an increase of 3% on the base rate from months 3 to 6, followed by 7% for months 6 to 9, and finally 11% on the base rate for the remaining 27 months. This growth pattern is coupled with a monthly seasonal index series (cycle 1 in Appendix L).

M2 carries the data to specify the cost of sales rate as a fraction of sales, and its pattern of change. This in fact goes from 69% for the first 4 months to 68% and 67% for each subsequent 4 month period of the first year, followed by 66% and 65% respectively for the second and third years of the planning period.

M3 carries the data to effect a growth pattern in purchases which commences with an increase of 5% on the base rate from months 3 to 6, followed by 10% from months 7 to 9, 15% from months 10 to 12, 28% from months 13 to 24 and finally 40% on the base rate for months 25 to 36.

M4 carries the data to specify the pattern of growth in expenses, which commences at the base rate for the first year with annual increases on this base rate of 10%, 21%, for the second year and third year respectively. This is coupled with a monthly seasonal index series (cycle 2 in Appendix L).

M7 specifies the depreciation rate and its pattern of change, although in this case a rate of 1.1% per month on diminishing value is held constant over the three years.

M8 specifies the program of borrowing and repayments which comprises amounts of $5,500 borrowed in month 7 and $20,000 repaid in month 28.

M9 specifies the Capital expenditure program which comprise amounts of $12,000, $12,000, $6,000, $20,000 and $10,000 in months 5, 11, 18, 24 and 32 respectively.

D5 specifies the pattern of cash collections from debtors, as a box car delay whereby 60% of sales are realised as cash one month from the month of sale, 20% in 2 months, 10% in 3 months and 10% in 4 months.

D6 specifies the pattern of delay in the payment of creditors as an exponential delay with an average delay period of 1.1 months.

D3 specifies the pattern of delay in the delivery of purchases whereby 20% of any month's purchase orders are delivered in two month's time, 50% in three month's time and 30% in four month's time.

8.2 The Graphical Model

This is as depicted in Figure 8.1, with the seven modulations, three delays and five base flows comprising the model data base, each tagged against the linkage relevant to it. Both the level numbers used in the diagram, and the linkage numbers follow the numerical sequence used in the previous section, to identify each respective level, and linkage, Thus linkage 1 relates to sales transactions,

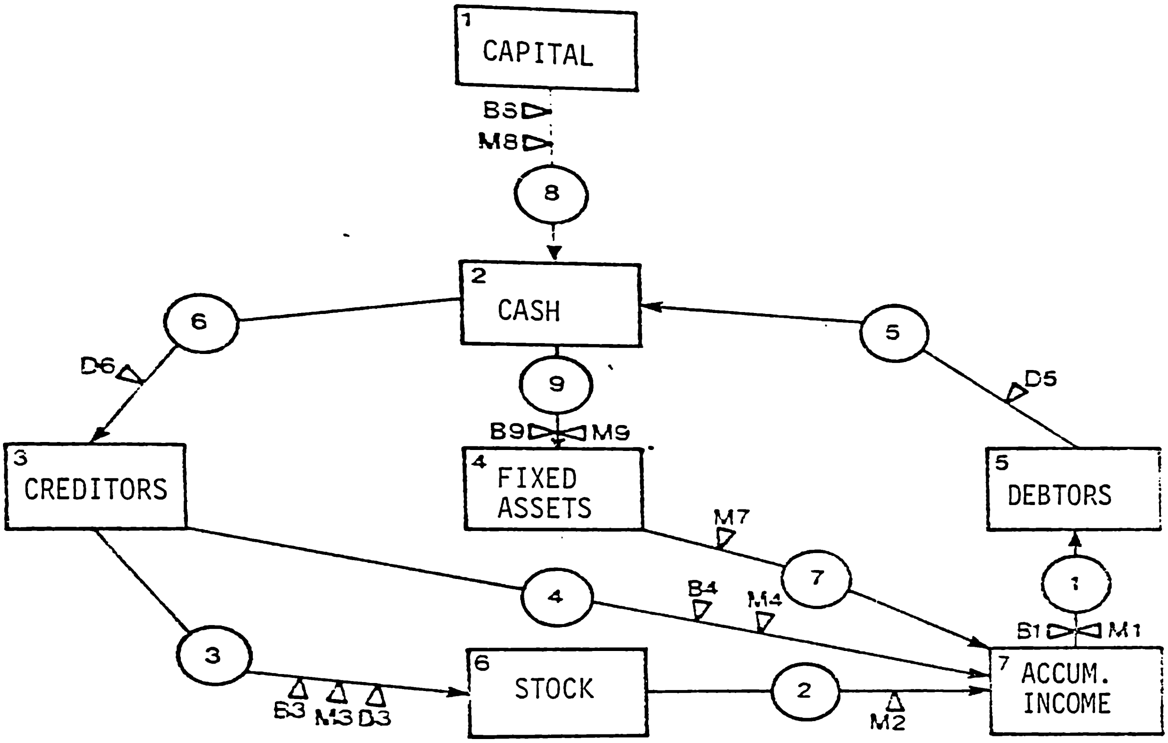


FIGURE 8.1: FLOW DIAGRAM FOR THE SIMPLE FINANCIAL MODEL

linkage 2 to cost of sales transactions etc.

8.3 The Computerised Model

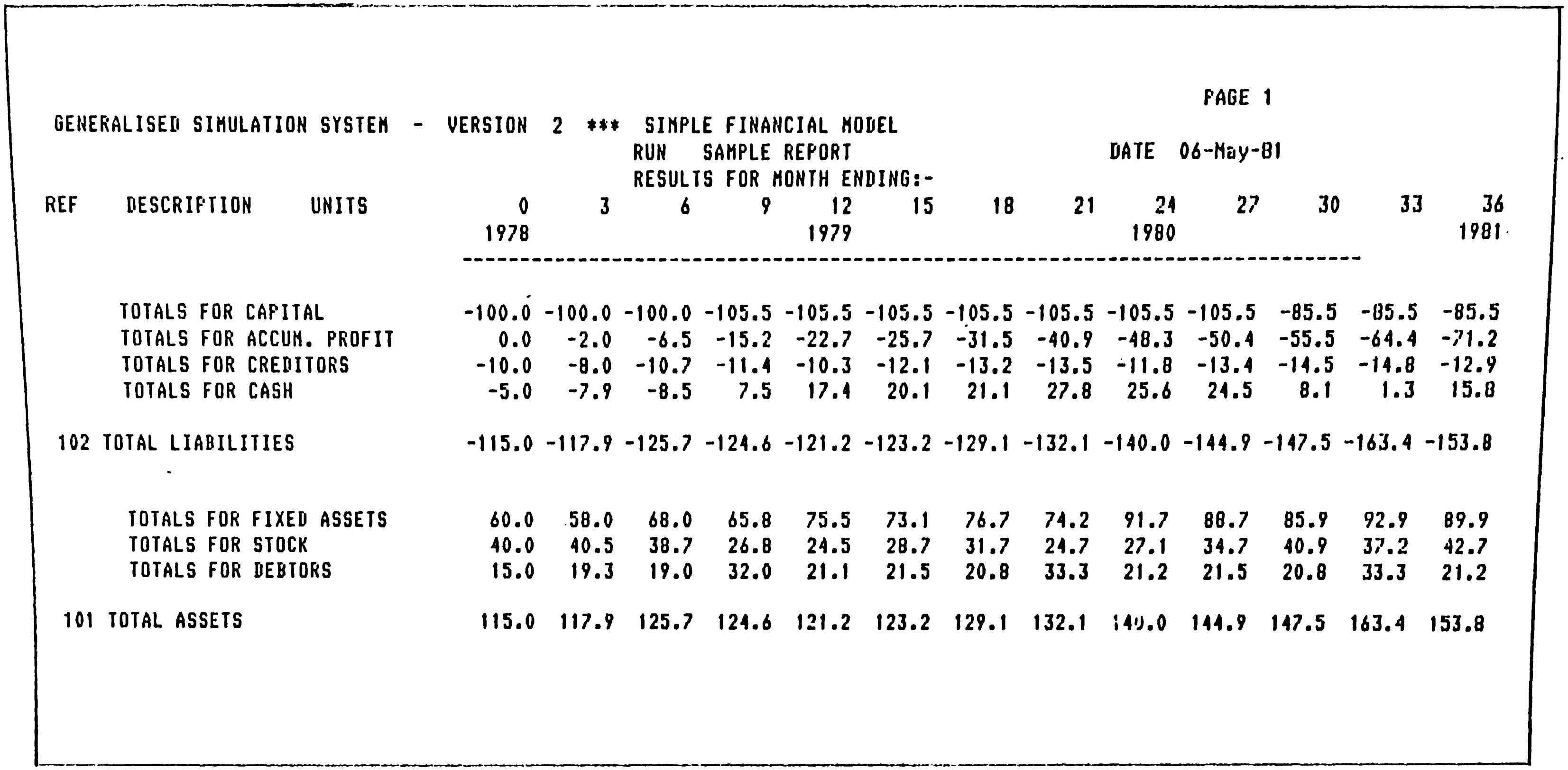
Computerisation of the model is accomplished using the GENSPC and GENINP programs for the specification of the model structure and its data base respectively. The computer prompts the user through the steps associated with each of these phases, in the manner described in Appendices E and F. The listing, editing, checking and running of the model is performed using the GENLIS, GENEDT and GENCOM programs. The structure and use of these programs is described in Appendices G to I.

A full listing of the model specifications and data is provided in Appendix L. Sample output from a full run of the model over a 36 month planning horizon, is depicted in Figures 8.2 and 8.3. The former shows, in tabular format, the balance sheets at quarterly rests, for the three years projected, while the latter shows, in graphical format, the monthly balances for the two selected accounts of Debtors and Stocks respectively.

8.4 Extending the Simple Financial Model

In order to extend the model to cope with a more detailed set of accounts, the structure developed above can be vectorised, and also enlarged to incorporate additional levels and linkages. As far as vectorisation is concerned, the level elements (or sub-levels) resulting from this are set out in Table 8.2. As far as the additional levels and linkages are concerned, the following changes are effected.

(1) Level 7 is replaced with three new levels (7, 8 and 9) for the accumulation of sales, expenses and cost of sales



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                                                                                              PAGE 1
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  SIMPLE FINANCIAL MODEL
                                                   RUN   SAMPLE REPORT                   DATE  06-May-81
                                                   RESULTS FOR MONTH ENDING:-
REF   DESCRIPTION     UNITS              0       3       6       9      12      15      18      21      24      27      30      33      36
                                      1978                            1979                            1980                            1981
                                  ------------------------------------------------------------------------------------------

      TOTALS FOR CAPITAL            -100.0  -100.0  -100.0  -105.5  -105.5  -105.5  -105.5  -105.5  -105.5  -105.5   -85.5   -85.5   -85.5
      TOTALS FOR ACCUM. PROFIT         0.0    -2.0    -6.5   -15.2   -22.7   -25.7   -31.5   -40.9   -48.3   -50.4   -55.5   -64.4   -71.2
      TOTALS FOR CREDITORS           -10.0    -8.0   -10.7   -11.4   -10.3   -12.1   -13.2   -13.5   -11.8   -13.4   -14.5   -14.8   -12.9
      TOTALS FOR CASH                 -5.0    -7.9    -8.5     7.5    17.4    20.1    21.1    27.8    25.6    24.5     8.1     1.3    15.8

102 TOTAL LIABILITIES               -115.0  -117.9  -125.7  -124.6  -121.2  -123.2  -129.1  -132.1  -140.0  -144.9  -147.5  -163.4  -153.8


      TOTALS FOR FIXED ASSETS         60.0    58.0    68.0    65.8    75.5    73.1    76.7    74.2    91.7    88.7    85.9    92.9    89.9
      TOTALS FOR STOCK                40.0    40.5    38.7    26.8    24.5    28.7    31.7    24.7    27.1    34.7    40.9    37.2    42.7
      TOTALS FOR DEBTORS              15.0    19.3    19.0    32.0    21.1    21.5    20.8    33.3    21.2    21.5    20.8    33.3    21.2

101 TOTAL ASSETS                     115.0   117.9   125.7   124.6   121.2   123.2   129.1   132.1   140.0   144.9   147.5   163.4   153.8
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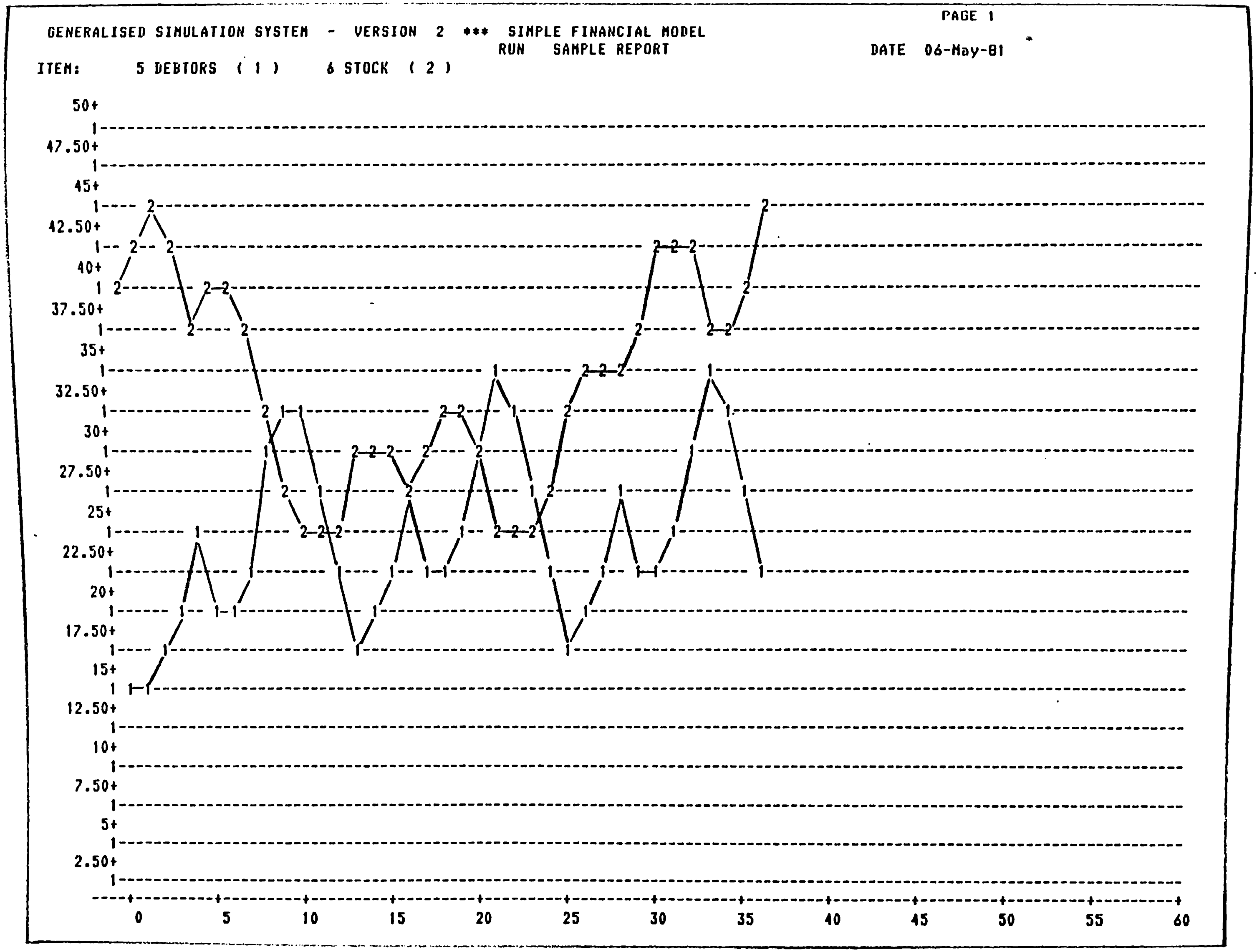
FIGURE 8.2: SAMPLE REPORT- BALANCE SHEET OF THE SIMPLE MODEL



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                                                                                    PAGE 1
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  SIMPLE FINANCIAL MODEL
                                                   RUN   SAMPLE REPORT              DATE  06-May-81
ITEM:      5 DEBTORS  ( 1 )     6 STOCK  ( 2 )
```

FIGURE 8.3: SAMPLE REPORT- DEBTOR AND STOCK ACCOUNT BALANCES OF THE SIMPLE MODEL

respectively - each of which can be expanded to encompass sub-levels (or sub-accounts), through vectorisation, (refer Table 8.2)

(2) Linkage 10 is added to permit the separate computation of interest as an expense.

(3) Levels 10 and 11, together with their associated linkages 11, 12 and 13 are brought in to permit the calculation of profit and tax respectively.

Figure 8.4 constitutes the flow diagram for the extended model. The flows associated with linkages 1 through to 9 are as defined for the simple model as far as their determinants are concerned with the exception of the linkage 4 inflow which has been assigned a mixed dependency. This allows each of the expenses flow channels arising from vectorisation to have its own determinant. The inflows of the three new linkages 11, 12 and 13 have also been assigned mixed dependencies, so that each flow element can be assigned its own specific determinant, or left undetermined, depending on the circumstances. The specific details of all of these mixed dependencies are discussed below[1]. The outflows of these linkages are dependent on their own particular inflows.

(1) There are three flow elements to be determined on the inflow of linkage 4, respectively Bank Interest, Fixed

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[1] The outflow of linkage 10 also has a mixed dependency so that the interest flow channel of this outflow can be assigned the Debt Capital balance (i.e. level 1, element 1) as its determinant.

TABLE 8.2: LEVEL ELEMENT DEFINITIONS FOR THE EXTENDED FINANCIAL MODEL

Level 1. Capital

1. Debt Capital
2. Equity Capital

Level 2. Cash

1. Collections
2. Payments
3. Interest
4. Capital Expenditure
5. Borrowings/Repayments
6. Tax payment

Level 3. Other Liabilities

1. Trade Creditors
2. Sundry Creditors
3. Reserves
4. Tax Provision

Level 4 Fixed Assets

1. Land and Buildings
2. Furniture and Equipment
3. Motor Vehicle

Level 5. Debtors

1. Sundry Debtors

Level 6. Stock

1. Television
2. Refrigerators
3. Other Brown Goods
4. Other White Goods

Level 7. Accumulated Sales

1. Television
2. Refrigerators
3. Other Brown Goods
4. Other White Goods

Level 8. Accumulated Expenses

1. Interest
2. Depreciation
3. Fixed Expenses
4. Variable Expenses

Level 9. Accumulated Cost of Sales

1. Television
2. Refrigerators
3. Other Brown Goods
4. Other White Goods

Level 10. Profit Calculation

1. Sales
2. Television. Cost of Sales
3. Refrigerator.Cost of Sales
4. Brown Goods Cost of Sales
5. White Goods Cost of Sales
6. Interest
7. Depreciation
8. Expenses
9. Gross Margin
10. Net Profit

Level 11. Tax Calculation

1. Before Tax Profit
2. Losses Carried Forward
3. Tax Depreciation
4. Actual Depreciation
5. Other Allowances
6. Taxable Profit

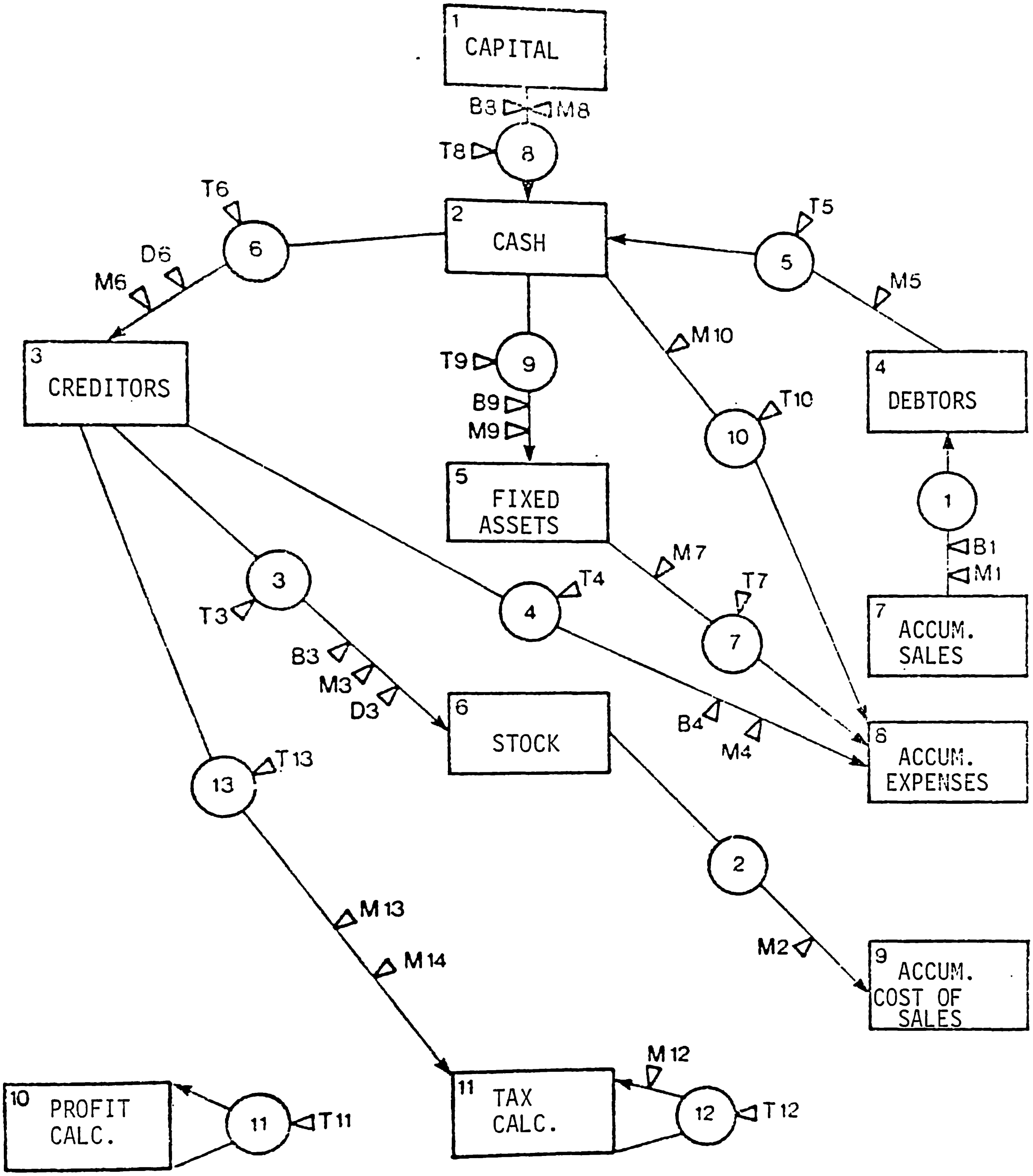


FIGURE 8.4: FLOW DIAGRAM FOR THE EXTENDED FINANCIAL MODEL

Expenses and Variable Expenses. They are assigned the determinants of Cash at Bank (total of level 2), Base Flow B4 element 3, and total sales (linkage 1 inflow element 1).

(2) The linkage 11 inflow elements (8 in total) cover all of the components of net profit (sales, cost of sales, interest, depreciation and expenses), and they are assigned determinants comprising the various flow elements defined for these components elsewhere in the model. Figure 8.5 shows how the transformation matrix T11 is used to derive the gross margins and net profit as outflow elements 9 and 10 respectively.

(3) The linkage 12 inflow elements (6 in total) are defined for net profit, losses carried forward, tax depreciation, actual depreciation, other tax allowances, and taxable profit carried forward, being all of the components in the calculation of the year-end tax liability. Each of these factors is calculated as a flow elsewhere in the model and therefore the determinant assigned to each is the corresponding flow so calculated. Figure 8.6 shows how the transformation matrix T12 is used to derive the taxable profit from these inflow elements, as outflow element 6 of linkage 12.

In order to arrive at the total accumulated taxable profit for a year, when the solution interval is one month, there must be a carry forward of each month's taxable profit. Hence inflow element 6 (of linkage 12) is assigned outflow element 6 as its determinant, in order to effect the carry-forward. Further, if the year-end taxable income

INFLOWS

OUTFLOWS	SALES	TV COST OF SALES	FRIG. COST OF SALES	BROWN COST OF SALES	WHITE COST OF SALES	INTEREST	DEPRECIATION	EXPENSES
SALES	0	0	0	0	0	0	0	0
TV COST OF SALES	0	0	0	0	0	0	0	0
FRIG. COST OF SALES	0	0	0	0	0	0	0	0
BROWN COST OF SALES	0	0	0	0	0	0	0	0
WHITE COST OF SALES	0	0	0	0	0	0	0	0
INTEREST	0	0	0	0	0	0	0	0
DEPRECIATION	0	0	0	0	0	0	0	0
EXPENSES	0	0	0	0	0	0	0	0
GROSS MARGIN*	1	-1	-1	-1	-1	0	0	0
NET PROFIT*	1	-1	-1	-1	-1	-1	-1	-1

* The dependent flows, determined by transformation of the vector of Inflows.

FIGURE 8.5: THE FLOW DIRECTING NATURE OF THE LINKAGE 11 TRANSFORMATION MATRIX (T11)

turns out to be a loss, the amount (equal to outflow element 6 in the twelfth month), must be picked up as the inflow element 2 - representing the losses carried forward from one year to the next. Hence this element too is assigned outflow element 6 as its determinant.

Modulation M12 ensures that only losses are carried forward between years, through the use of the logical 'switching' option available with the modulation function as a pattern. This is coupled with a cycle which 'activates' the flow channel only in month 1 of each year (i.e. cycle 6 in the model data listing of Appendix M).

The inflow elements of linkage 13 (also numbering 6 in total), although assigned the same flow determinants as those for the inflow of linkage 12, in fact are such that only those flows of elements 1 and 6 are relevant - i.e. before tax profit and taxable profit, respectively. This is because the purpose of the linkage is to determine the outflows (i.e. credits) of retained earnings, and provision for tax, to be posted to the reserves and tax provision accounts respectively (defined as sub-levels 3 and 4 of Level 3.)

Figure 8.7 shows how the transformation matrix T13 effects the calculation of these two outflows (flow elements 3 and 4 of linkage 13) as a transformation of the inflows of linkage 13. The modulation matrix M13 carries a logical switch (a defined modulation pattern option), to ensure that only profits at year end are taxed, and a cycle (cycle 5 in Appendix M) to confine the timing of any resultant tax provision as a flow, to the twelfth month of each year. The modulation M14 carries the actual tax rate to be applied to the

OUTFLOWS \ INFLOWS	BEFORE TAX PROFIT	LOSSES C/F	TAX ALLOWED DEPRECN.	ACTUAL DEPRECIATION	OTHER TAX ALLOWANCES	TAXABLE PROFIT
BEFORE TAX PROFIT	0	0	0	0	0	0
LOSSES C/F	0	0	0	0	0	0
TAX ALLOWED DEPRECN.	0	0	0	0	0	0
ACTUAL DEPRECIATION	0	0	0	0	0	0
OTHER TAX ALLOWANCES	0	0	0	0	0	0
TAXABLE PROFIT*	1	1	-1	1	-1	1

* The dependent flow, determined by transformation of the vector of Inflows.

FIGURE 8.6: THE FLOW DIRECTING NATURE OF THE LINKAGE 12 TRANSFORMATION MATRIX (T12)

OUTFLOWS \ INFLOWS	BEFORE TAX PROFIT	LOSSES C/F	TAX ALLOWED DEPRECIATION	ACTUAL DEPRECIATION	OTHER TAX ALLOWANCES	TAXABLE PROFIT
TRADE CREDITORS	0	0	0	0	0	0
SUNDRY CREDITORS	0	0	0	0	0	0
RESERVES*	1	0	0	0	0	-1
TAX PROVISION*	0	0	0	0	0	1

*Credits to these accounts are determined as outflows, by the transformation of the Inflows, after modulation of the latter by M13 and M14 (to apply the tax rate M14) at year end (M13)

FIGURE 8.7: THE FLOW DIRECTING NATURE OF THE LINKAGE 13 TRANSFORMATION MATRIX (T13)

taxable profit. Both of these modulations are tagged to the inflow side of linkage 13, to achieve the desired results for the outflows.

For linkage 10 only the outflow element 3 is in fact assigned a determinant as the others are not used. This element carries the outflows (as credits to the interest account of level 2) associated with the cash payment of interest on debt capital. Therefore, it is assigned the balance of this latter account (sub-level 1 of level 1) as its determinant, while the modulation matrix M10 carries the monthly interest rate to be applied to this balance.

Since this extended version of the model is now in the form of a vectorised network, transformation matrices must be defined for each of the linkages. Those associated with linkages 11, 12 and 13 have already been referred to above. Table 8.3 however, summarises all of the transformation matrices defined for this model and as is customary for a financial model, they all perform a flow directing function, rather than a flow consumption function. Thus the elements of each matrix are either zero or one, as can be seen from the model data listing of Appendix M.

The effect of vectorisation on the modulation matrices is that each flow channel tagged with a modulation can be assigned its own unique modulation pattern. The four sales groups, for example, can thus be assigned their own growth rates and seasonal index cycles. Details of the modulation matrices for the model are contained in Appendix M also.

TABLE 8.3: THE TRANSFORMATION MATRICES OF THE EXTENDED MODEL

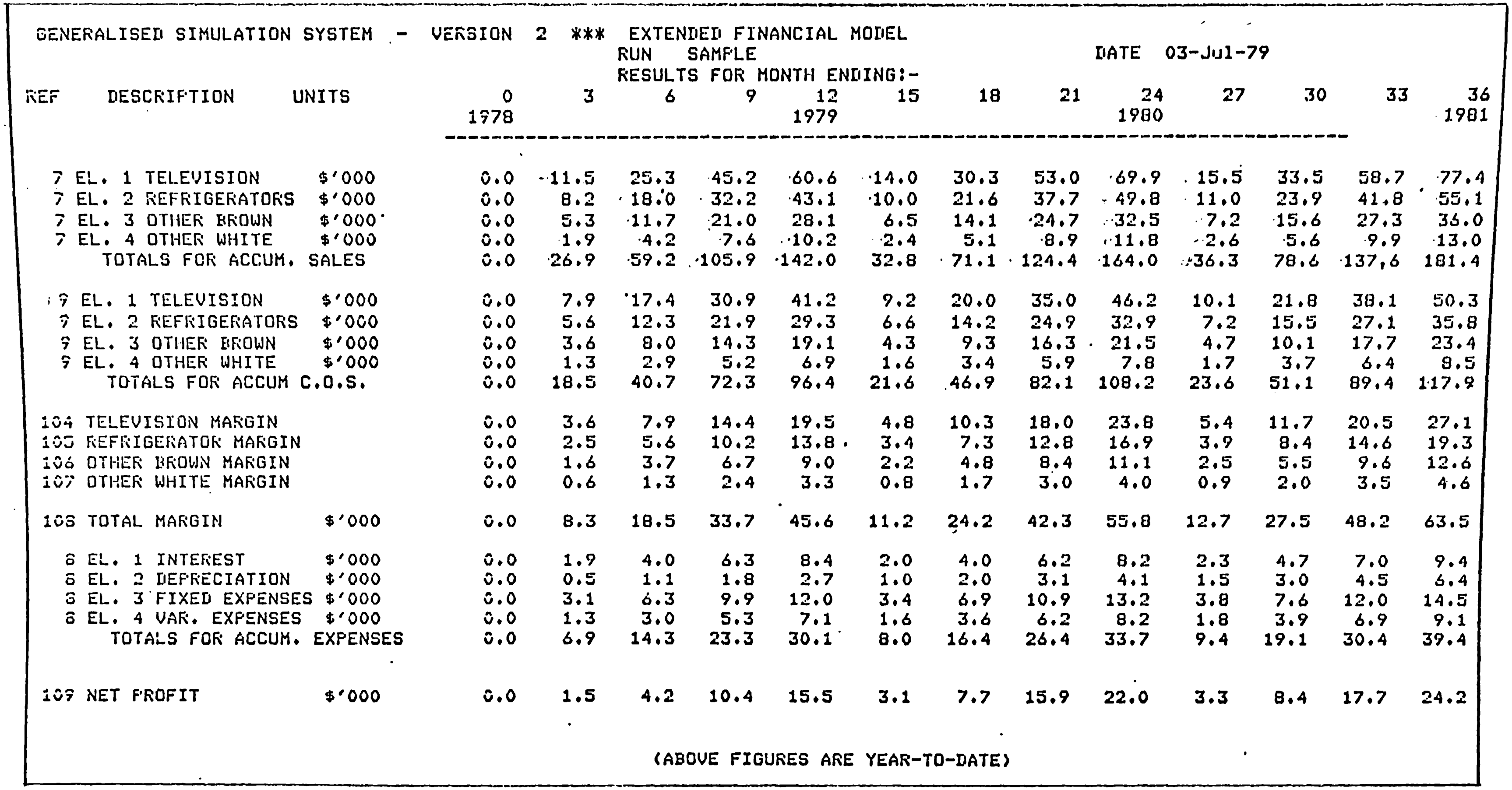
Linkage No.	Transaction Type	Transf. Matrix	Direction of the Transformation	Accounts Debited by the Inflows	Accounts Credited By the Outflow
1	Sales	*	Outflows into Inflows	Sundry Debtors a/c of Level 4 (directed by *)	Sales a/c of Level 7
2	Cost of Sales	*	Inflows into Outflows	Cost of Sales a/cs of Level 9	Stock a/c of Level 6 (as directed by *)
3	Stock Purchases	T3	Inflows into Outflows	Stock a/c of Level 6	Trade Creditors a/c of Level 3 (as directed by T3)
4	Expenses	T4	Inflows into Outflows	Expenses a/cs of Level 8	Sundry Creditors a/c of Level 3 (as directed by T4)
5	Collections	T5	Outflows into Inflows	Collections a/c of Level 2 (as directed by T5)	Sundry Debtors a/c of Level 4
6	Creditor Payments	T6	Inflows into Outflows	All a/cs of Level 3	Payment a/c of Level 2 (as directed by T6)
7	Depreciation	T7	Outflows into Inflows	Depreciation a/c of Level 8 (as directed by T7)	Fixed Asset a/cs of Level 5
8	Borr. & Repayments	T8	Outflows into Inflows	Borr/Repay. a/c of Level 2 (as directed by T8)	Debt Capital a/c of Level 1
9	Capital Expenditure	T9	Inflows into Outflows	Fixed Assets a/cs of Level 5	Capital Expend. a/c of Level 2 (as directed by T9)
10	Interest on Debt	T10	Outflows into Inflows	Interest a/c of Level 8 (as directed by T10)	Interest a/c of Level 2
11	Profit Calculation	T11	Inflows into Outflows	Profit component a/cs of level 10	Profit a/cs of Level 10 (as directed by T11)
12	Tax Calculation	T12	Inflows into Outflows	Taxable Profit component a/cs of Level 11	Taxable Profit a/c of Level 11 (as directed by T12)
13	Transfers of Tax and Profit	T13	Inflows into Outflows	Before Tax Profit & Taxable Profit of Level 11	Reserve & Tax Provn. a/cs of Level 3 (as directed by T13)

*denotes the fact that no transformation is required - sum transformations are performed automatically.

8.5 Output From the Extended Model

Figures 8.8, 8.9 and 8.10 show the output reports from the model, generated according to a quarterly reporting frequency for the purposes of illustration. Clearly more detailed reporting is possible with the more disaggregated set of accounts which results from vectorisation of the network structure of the model.

Figure 8.10 shows the projected balance sheets, while Figures 8.8 and 8.9 show the projected income and cash statements for this particular run of the model on a 'year-to-date' basis.



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GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  EXTENDED FINANCIAL MODEL
                                                   RUN   SAMPLE                          DATE  03-Jul-79
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION       UNITS            0      3      6      9     12     15     18     21     24     27     30     33     36
                                       1978                        1979                        1980                        1981
                                       --------------------------------------------------------------------------------------

  7 EL. 1 TELEVISION       $'000        0.0   11.5   25.3   45.2   60.6   14.0   30.3   53.0   69.9   15.5   33.5   58.7   77.4
  7 EL. 2 REFRIGERATORS    $'000        0.0    8.2   18.0   32.2   43.1   10.0   21.6   37.7   49.8   11.0   23.9   41.8   55.1
  7 EL. 3 OTHER BROWN      $'000        0.0    5.3   11.7   21.0   28.1    6.5   14.1   24.7   32.5    7.2   15.6   27.3   36.0
  7 EL. 4 OTHER WHITE      $'000        0.0    1.9    4.2    7.6   10.2    2.4    5.1    8.9   11.8    2.6    5.6    9.9   13.0
      TOTALS FOR ACCUM. SALES           0.0   26.9   59.2  105.9  142.0   32.8   71.1  124.4  164.0   36.3   78.6  137.6  181.4

  9 EL. 1 TELEVISION       $'000        0.0    7.9   17.4   30.9   41.2    9.2   20.0   35.0   46.2   10.1   21.8   38.1   50.3
  9 EL. 2 REFRIGERATORS    $'000        0.0    5.6   12.3   21.9   29.3    6.6   14.2   24.9   32.9    7.2   15.5   27.1   35.8
  9 EL. 3 OTHER BROWN      $'000        0.0    3.6    8.0   14.3   19.1    4.3    9.3   16.3   21.5    4.7   10.1   17.7   23.4
  9 EL. 4 OTHER WHITE      $'000        0.0    1.3    2.9    5.2    6.9    1.6    3.4    5.9    7.8    1.7    3.7    6.4    8.5
      TOTALS FOR ACCUM C.O.S.           0.0   18.5   40.7   72.3   96.4   21.6   46.9   82.1  108.2   23.6   51.1   89.4  117.9

104 TELEVISION MARGIN                   0.0    3.6    7.9   14.4   19.5    4.8   10.3   18.0   23.8    5.4   11.7   20.5   27.1
105 REFRIGERATOR MARGIN                 0.0    2.5    5.6   10.2   13.8    3.4    7.3   12.8   16.9    3.9    8.4   14.6   19.3
106 OTHER BROWN MARGIN                  0.0    1.6    3.7    6.7    9.0    2.2    4.8    8.4   11.1    2.5    5.5    9.6   12.6
107 OTHER WHITE MARGIN                  0.0    0.6    1.3    2.4    3.3    0.8    1.7    3.0    4.0    0.9    2.0    3.5    4.6

108 TOTAL MARGIN           $'000        0.0    8.3   18.5   33.7   45.6   11.2   24.2   42.3   55.8   12.7   27.5   48.2   63.5

  8 EL. 1 INTEREST         $'000        0.0    1.9    4.0    6.3    8.4    2.0    4.0    6.2    8.2    2.3    4.7    7.0    9.4
  8 EL. 2 DEPRECIATION     $'000        0.0    0.5    1.1    1.8    2.7    1.0    2.0    3.1    4.1    1.5    3.0    4.5    6.4
  8 EL. 3 FIXED EXPENSES   $'000        0.0    3.1    6.3    9.9   12.0    3.4    6.9   10.9   13.2    3.8    7.6   12.0   14.5
  8 EL. 4 VAR. EXPENSES    $'000        0.0    1.3    3.0    5.3    7.1    1.6    3.6    6.2    8.2    1.8    3.9    6.9    9.1
      TOTALS FOR ACCUM. EXPENSES        0.0    6.9   14.3   23.3   30.1    8.0   16.4   26.4   33.7    9.4   19.1   30.4   39.4

109 NET PROFIT             $'000        0.0    1.5    4.2   10.4   15.5    3.1    7.7   15.9   22.0    3.3    8.4   17.7   24.2

                                              (ABOVE FIGURES ARE YEAR-TO-DATE)
```
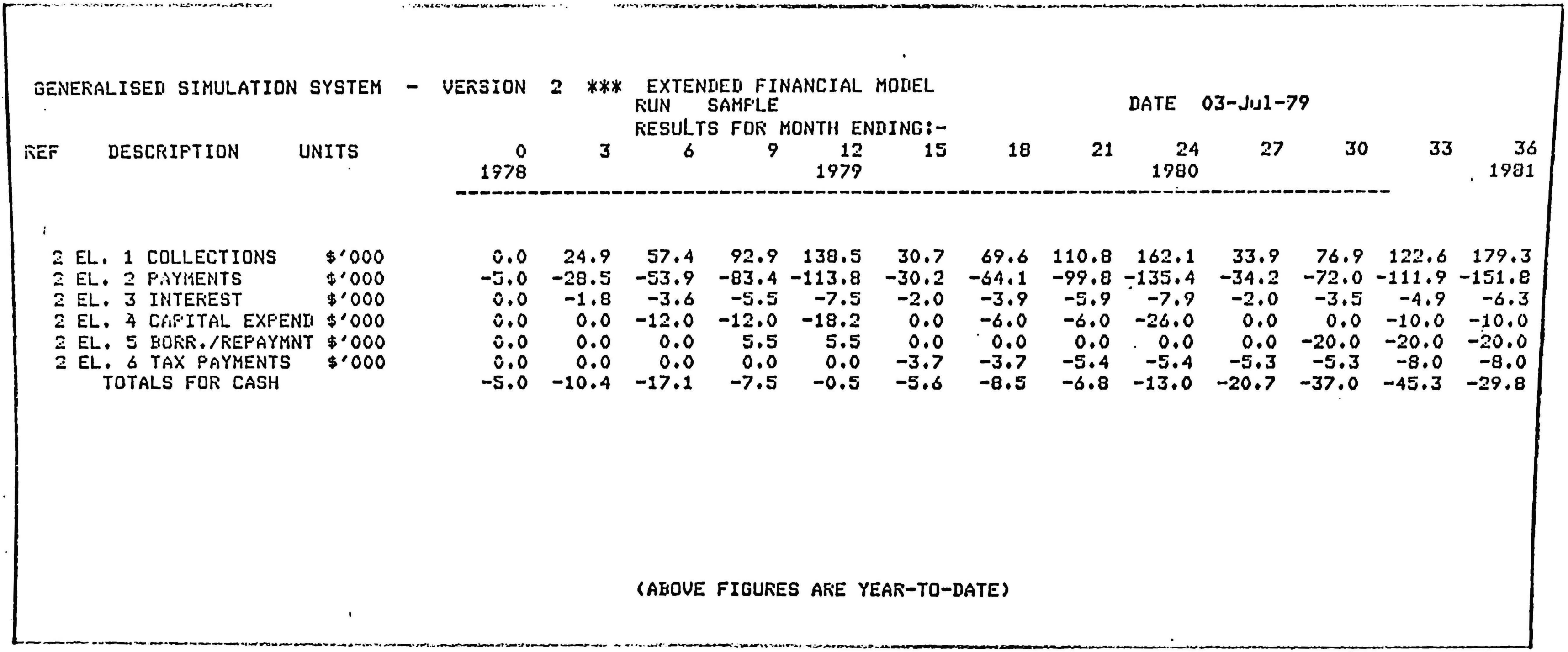
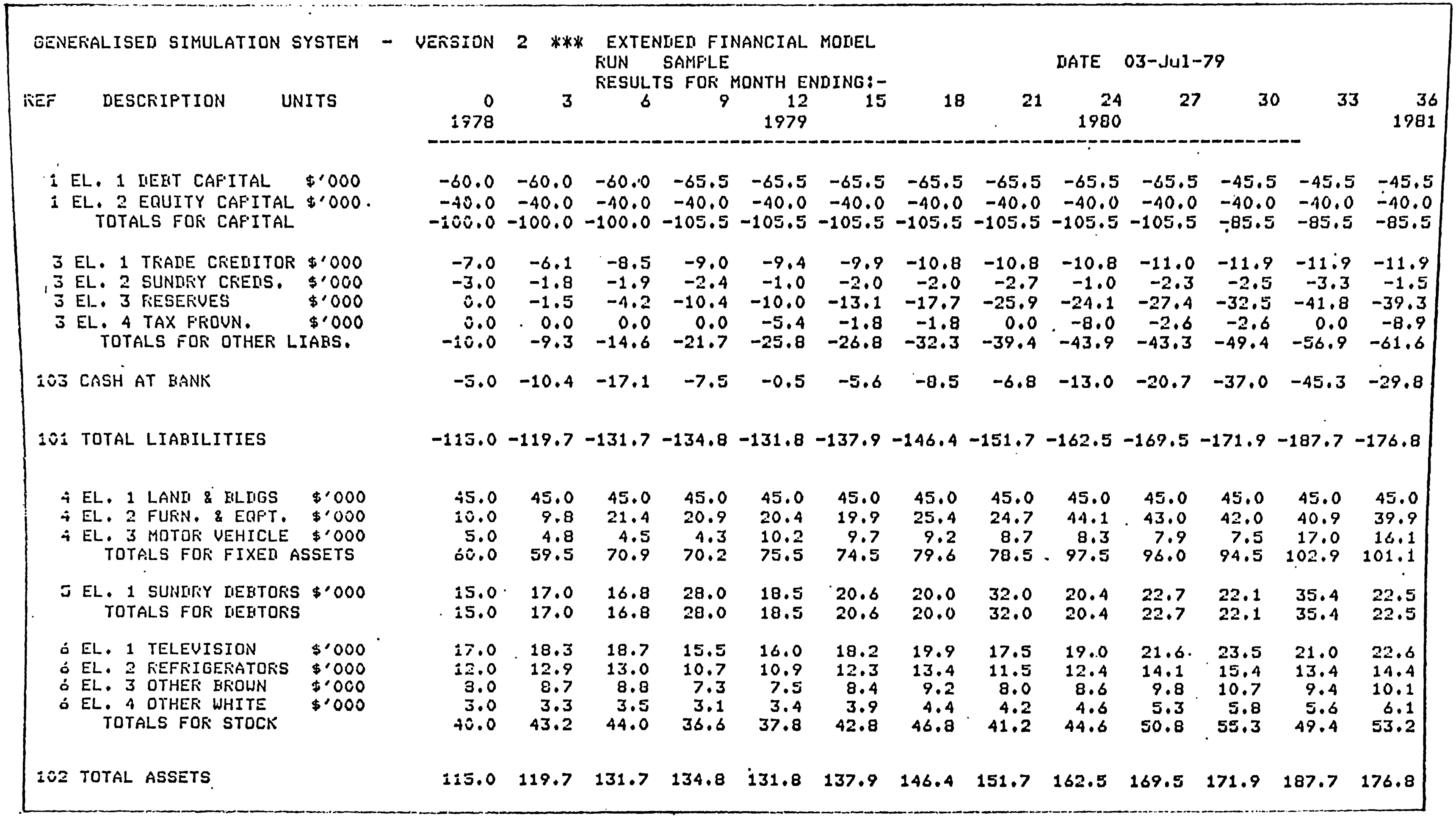

FIGURE 8.8: SAMPLE REPORT- INCOME STATEMENT OF THE EXTENDED MODEL



```
GENERALISED SIMULATION SYSTEM  -  VERSION  2  *** EXTENDED FINANCIAL MODEL
                                                  RUN   SAMPLE                          DATE  03-Jul-79
                                                  RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS       0      3      6      9     12     15     18     21     24     27     30     33     36
                                 1978                        1979                        1980                        1981
                              ------------------------------------------------------------------------------------

  2 EL. 1 COLLECTIONS    $'000    0.0   24.9   57.4   92.9  138.5   30.7   69.6  110.8  162.1   33.9   76.9  122.6  179.3
  2 EL. 2 PAYMENTS       $'000   -5.0  -28.5  -53.9  -83.4 -113.8  -30.2  -64.1  -99.8 -135.4  -34.2  -72.0 -111.9 -151.8
  2 EL. 3 INTEREST       $'000    0.0   -1.8   -3.6   -5.5   -7.5   -2.0   -3.9   -5.9   -7.9   -2.0   -3.5   -4.9   -6.3
  2 EL. 4 CAPITAL EXPEND $'000    0.0    0.0  -12.0  -12.0  -18.2    0.0   -6.0   -6.0  -26.0    0.0    0.0  -10.0  -10.0
  2 EL. 5 BORR./REPAYMNT $'000    0.0    0.0    0.0    5.5    5.5    0.0    0.0    0.0    0.0    0.0  -20.0  -20.0  -20.0
  2 EL. 6 TAX PAYMENTS   $'000    0.0    0.0    0.0    0.0    0.0   -3.7   -3.7   -5.4   -5.4   -5.3   -5.3   -8.0   -8.0
         TOTALS FOR CASH         -5.0  -10.4  -17.1   -7.5   -0.5   -5.6   -8.5   -6.8  -13.0  -20.7  -37.0  -45.3  -29.8




                                                  (ABOVE FIGURES ARE YEAR-TO-DATE)
```

FIGURE 8.9: SAMPLE REPORT- CASH STATEMENT OF THE EXTENDED MODEL



```
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  EXTENDED FINANCIAL MODEL
                                                   RUN   SAMPLE                    DATE  03-Jul-79
                                                   RESULTS FOR MONTH ENDING:-
REF   DESCRIPTION       UNITS        0      3      6      9     12     15     18     21     24     27     30     33     36
                                  1978                       1979                        1980                        1981
                               -----------------------------------------------------------------------------

  1 EL. 1 DEBT CAPITAL    $’000  -60.0  -60.0  -60.0  -65.5  -65.5  -65.5  -65.5  -65.5  -65.5  -65.5  -45.5  -45.5  -45.5
  1 EL. 2 EQUITY CAPITAL  $’000  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0  -40.0
      TOTALS FOR CAPITAL        -100.0 -100.0 -100.0 -105.5 -105.5 -105.5 -105.5 -105.5 -105.5 -105.5  -85.5  -85.5  -85.5

  3 EL. 1 TRADE CREDITOR  $’000   -7.0   -6.1   -8.5   -9.0   -9.4   -9.9  -10.8  -10.8  -10.8  -11.0  -11.9  -11.9  -11.9
  3 EL. 2 SUNDRY CREDS.   $’000   -3.0   -1.8   -1.9   -2.4   -1.0   -2.0   -2.0   -2.7   -1.0   -2.3   -2.5   -3.3   -1.5
  3 EL. 3 RESERVES        $’000    0.0   -1.5   -4.2  -10.4  -10.0  -13.1  -17.7  -25.9  -24.1  -27.4  -32.5  -41.8  -39.3
  3 EL. 4 TAX PROVN.      $’000    0.0    0.0    0.0    0.0   -5.4   -1.8   -1.8    0.0   -8.0   -2.6   -2.6    0.0   -8.9
       TOTALS FOR OTHER LIABS.   -10.0   -9.3  -14.6  -21.7  -25.8  -26.8  -32.3  -39.4  -43.9  -43.3  -49.4  -56.9  -61.6

103 CASH AT BANK                  -5.0  -10.4  -17.1   -7.5   -0.5   -5.6   -8.5   -6.8  -13.0  -20.7  -37.0  -45.3  -29.8


101 TOTAL LIABILITIES           -115.0 -119.7 -131.7 -134.8 -131.8 -137.9 -146.4 -151.7 -162.5 -169.5 -171.9 -187.7 -176.8


  4 EL. 1 LAND & BLDGS    $’000   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0   45.0
  4 EL. 2 FURN. & EQPT.   $’000   10.0    9.8   21.4   20.9   20.4   19.9   25.4   24.7   44.1   43.0   42.0   40.9   39.9
  4 EL. 3 MOTOR VEHICLE   $’000    5.0    4.8    4.5    4.3   10.2    9.7    9.2    8.7    8.3    7.9    7.5   17.0   16.1
       TOTALS FOR FIXED ASSETS    60.0   59.5   70.9   70.2   75.5   74.5   79.6   78.5   97.5   96.0   94.5  102.9  101.1

  5 EL. 1 SUNDRY DEBTORS  $’000   15.0   17.0   16.8   28.0   18.5   20.6   20.0   32.0   20.4   22.7   22.1   35.4   22.5
       TOTALS FOR DEBTORS         15.0   17.0   16.8   28.0   18.5   20.6   20.0   32.0   20.4   22.7   22.1   35.4   22.5

  6 EL. 1 TELEVISION      $’000   17.0   18.3   18.7   15.5   16.0   18.2   19.9   17.5   19.0   21.6   23.5   21.0   22.6
  6 EL. 2 REFRIGERATORS   $’000   12.0   12.9   13.0   10.7   10.9   12.3   13.4   11.5   12.4   14.1   15.4   13.4   14.4
  6 EL. 3 OTHER BROWN     $’000    8.0    8.7    8.8    7.3    7.5    8.4    9.2    8.0    8.6    9.8   10.7    9.4   10.1
  6 EL. 4 OTHER WHITE     $’000    3.0    3.3    3.5    3.1    3.4    3.9    4.4    4.2    4.6    5.3    5.8    5.6    6.1
       TOTALS FOR STOCK           40.0   43.2   44.0   36.6   37.8   42.8   46.8   41.2   44.6   50.8   55.3   49.4   53.2

102 TOTAL ASSETS                 115.0  119.7  131.7  134.8  131.8  137.9  146.4  151.7  162.5  169.5  171.9  187.7  176.8
```

FIGURE 8.10: SAMPLE REPORT- BALANCE SHEET OF THE EXTENDED MODEL

CHAPTER 9

SIMPLIFIED SYSTEM DYNAMICS - SOME COMPARATIVE CONSIDERATIONS

The simple application discussed in the previous chapter demonstrates the essential features of the modelling approach proposed in this thesis. In order to provide further insight into some of the distinctive features of SSD, a comparative discussion of the approach is presented in this chapter. This discussion commences with an examination of the vectorised networks of SSD and the matrix algebra features of Input-Output Analysis. Further study of these aspects then follows, in the course of comparing the array capabilities of SSD with those of DYSMAP and DYNAMO III.

The graphical and mathematical conventions used in SSD are addressed in section 9.3, and compared with those of some other 'systems' modelling approaches (viz., the four methodologies of conventional System Dynamics, GESIFLOG, RPMS and NETFORM which were summarised in Chapter 6). Finally a comparison is drawn between the use of SSD and a traditional 'non-systems' approach to the construction of a financial model.

9.1 Vectorised Networks and the Matrix Algebra Relationships of Input-Output Analysis

Input-Output Analysis was developed during the early 1930's by Wassily Leontief (Leontief, 1951) as a quantitative extension of the work of Leon Walras, on the mathematical theory of general equilibrium. It is based on the use of matrix algebra for analysing flows (either physical or monetary) between and amongst defined sectors of an economic system. It provides a rigorous and systematic means for modelling the behaviour of systems characterised by numerous complex (but essentially linear) inter-relationships.

Traditionally the technique has been applied in the main to macro-economic modelling problems. Since the early 1960's however (as pointed out by Butterworth and Sigloch, 1971) there have been many seemingly varied examples of its use in a micro-economic context (see for example Richards, 1960; Williams and Griffin, 1964; Livingstone, 1969; Farag, 1968; Ijiri, 1968; and Feltham, 1970). Butterworth and Sigloch discuss a broad selection of these applications and demonstrate that they are in fact all special cases of a general multi-stage Input-Output model. Their paper shows that all possible modes of Input-Output analysis for a given problem may be derived from a single general model, under one of two alternative sets of four conditions. The first two conditions in each set are identical, requiring production function linearity and cost function linearity respectively. The remaining two conditions address the relationship between resources and processes, and the relationship between inputs and outputs.

For output-oriented systems (in which unknown inputs are derived from known outputs) there must be a one-to-one correspondence between processes and outputs, and a restriction on self-consumption induced by any given unit of output, to ensure feasibility. For input-oriented systems (in which unknown outputs are derived from known inputs) there must be a one-to-one correspondence between processes and inputs, and a restriction on self-production induced by any given unit of input, to ensure feasibility.

For output-oriented systems[1], the general form of Input-Output model represented by the authors is based on consideration of an (n-1) stage, n state[2] system. Each stage consists of a distinct group of production processes, capable of transforming resource inputs into intermediate, or final outputs, Each state consists of a distinct group of activity variables, measuring input or output, to or from, the production processes.

Inputs purchased from the external market are referred to as initial inputs, and outputs disposed of in the external market are referred to as final outputs. The ordering of the various stages may be arbitrary, as may be the grouping of the processes and activities. In general, however, the model would reflect to the maximum extent possible the sequence of stages and the groupings of processes observed in the system being modelled. Nevertheless the sequential processing of initial inputs into final outputs does not preclude feed-back or feed-forward consumption. The general model is described by the following equation system-

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1. From the corporate planning viewpoint, most business entities are output-oriented systems.

2. The term 'level' is used by the authors, but the term 'state' is used here to avoid confusion with the System Dynamics concept of level.

$$\begin{bmatrix} A_{11} & -A_{12} \cdots\cdots\cdots & -A_{1n} \\ -A_{21} & A_{22} \cdots\cdots\cdots & -A_{2n} \\ \vdots & & \vdots \\ -A_{n1} & -A_{n2} \cdots\cdots\cdots & A_{nn} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \vdots \\ \tilde{x}_n \end{bmatrix} = \begin{bmatrix} \tilde{d}_1 \\ \tilde{d}_2 \\ \vdots \\ \tilde{d}_n \end{bmatrix} \qquad (1)$$

where A_{ij} has dimension $N_i \times N_j$, $\tilde{x}_i$ and $\tilde{d}_i$ are $N_i \times 1$, and $\sum_{i=1}^{n} N_i = N$.

The partitioned vector on the right-hand side of equation (1) represents the net activity level of final demand external to the system being modelled. Further, the simplifying assumption that final demand exists only for the output of the final stage, is made (Butterworth and Sigloch, p. 703). Hence equation (1) is rewritten as-

$$\begin{bmatrix} A_{11} & -A_{12} \cdots\cdots\cdots & -A_{1n} \\ -A_{21} & A_{22} \cdots\cdots\cdots & -A_{2n} \\ \vdots & & \\ -A_{n1} & -A_{n2} \cdots\cdots\cdots & A_{nn} \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \vdots \\ \tilde{x}_n \end{bmatrix} = \begin{bmatrix} \tilde{0} \\ \tilde{0} \\ \vdots \\ \tilde{d} \end{bmatrix} \qquad (2)$$

In every sub-matrix A_{ij}, the coefficient $a_{kl}(i,j)$ represents the amount of activity (output or input) in state i, produced or consumed, by a unit of activity in state j. Production and consumption are distinguished by positive and negative coefficient values respectively.

The sub-matrices A_{ij} are categorised according to whether they are Gross/Net Matrices (the A_{ii} which form the principal diagonal of A), Sequential Matrices (the $A_{i,\ i+1}$ which form the diagonal immediately above the principal diagonal), Jump Matrices (the A_{ij} for $i+1<j$ which includes all sub-matrices above the two diagonals referred to previously) and Feed-back Matrices (the A_{ij} for $i>j$ which includes all sub-matrices below the principal diagonal of A). The equation system of (2) above may be re-written as $A\tilde{x} = \tilde{d}$, and solved by inverting the matrix A and computing $\tilde{x} = A^{-1}\tilde{d}$.

The one-stage version of this general model can be written as-[3]

$$\begin{bmatrix} A_{11} & -A_{12} \\ -A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0 \\ d \end{bmatrix} \qquad (3)$$

and solved by Gaussian reduction methods to yield several different, but equivalent, expressions for $\tilde{x}_1$ and $\tilde{x}_2$.

The Input-Output Analysis features utilised in SSD arise from the interpretation of each linkage of a vectorised network as a one-stage sequential Input-Output model. For this form of model the equation system of (3) above can be re-written as-

---

3. Butterworth and Sigloch, p.705

$$\begin{bmatrix} I & -A_{12} \\ 0 & I \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \end{bmatrix} = \begin{bmatrix} \tilde{0} \\ \tilde{d} \end{bmatrix} \qquad (4)$$

Thus-

$$\tilde{x}_1 - A_{12}\tilde{x}_2 = \tilde{0}$$

and $\tilde{x}_2 = \tilde{d}$

therefore $\tilde{x}_1 = A_{12}\tilde{d}$ (5)

-where for any given linkage $\tilde{x}_1$ is the level outflow vector (of process inputs), A_{12} is the transformation matrix, and $\tilde{d}$ is the level inflow vector (of process outputs).[4]

Butterworth and Sigloch, in the course of discussing the transaction form of their general model, define the row vector of dual prices $\tilde{u}$, and the relationship-

$$\tilde{u} = \tilde{c}A^{-1} \qquad (6)$$

-where $\tilde{c}$ is the row vector of cost coefficients for the initial inputs to the system. Thus the dual form of the general Input-Output model represented by the equation system $A\tilde{x} = \tilde{d}$, is the equation system $\tilde{u}A = \tilde{c}$ (or alternatively $A'\tilde{u} = \tilde{c}$). For a single-stage model this dual form becomes-

$$\begin{bmatrix} A'_{11} & -A'_{21} \\ -A'_{12} & A'_{22} \end{bmatrix} \cdot \begin{bmatrix} \tilde{u}_1 \\ \tilde{u}_2 \end{bmatrix} = \begin{bmatrix} \tilde{c} \\ \tilde{0} \end{bmatrix} \qquad (7)$$

---

[4] Thus equation (5) corresponds to the equation X = I.T presented in Chapter 7, p. 118.

For our single-stage sequential model, the above system reduces to-

$$\begin{bmatrix} I & 0 \\ -A'_{12} & I \end{bmatrix} \begin{bmatrix} \tilde{u}_1 \\ \tilde{u}_2 \end{bmatrix} = \begin{bmatrix} \tilde{c} \\ \tilde{0} \end{bmatrix} \qquad (8)$$

Thus-

$$\tilde{u}_1 = \tilde{c}$$

and $$-A'_{12}\tilde{u}_1 + \tilde{u}_2 = \tilde{0}$$

i.e. $$\tilde{u}_2 = A'_{12}\tilde{u}_1$$

therefore $$\tilde{u}_2 = A'_{12}\tilde{c} \qquad (9)$$

-where for any given linkage $\tilde{u}_2$ is the level inflow unit cost vector (for process outputs), A'_{12} is the transpose of the transformation matrix, and $\tilde{c}$ is the level outflow unit cost vector (for process inputs)[5]. The vectorised networks of SSD can thus be regarded as comprising levels (being accumulations, or stocks, of activity units) connected by linkages, each of which can be regarded as a single-stage sequential input-output system. In effect, Input-Output Analysis is being applied at the ultra micro-economic level, with the input-output relationships associated with any given linkage being analysed in isolation from all other linkages. This isolation is achieved through the 'buffer' effect of the levels to which each linkage is attached.

The whole concept of network vectorisation is a direct outcome of work done by the writer during 1970-71, while under

---

[5] Thus equation (9) corresponds to the equation $C = T'.K$ presented in Chapter 7, p. 118.

contract to Formica (NZ) Limited to develop and commission a multi-stage Input-Output model of that company's manufacturing processes. During the period 1972-73 this work was extended to form the basis of a generalised corporate model, structured as a vectorised network. The results of this research were submitted as a thesis (Craig, 1974) to the University of Auckland for the degree of Master of Commerce. The model described there was supported by a system of batch-oriented FORTRAN programs, developed on a Burroughs B6700 computer by the writer.

9.2 The Array Capabilities of DYSMAP and DYNAMO III

DYSMAP (Cavana and Coyle, 1982) is a simulation language with a structure similar to that of DYNAMO, but with more extensive capabilities for model error diagnostics and model analysis. It compiles into FORTRAN and user-defined functions written in that language can be incorporated in any model. The array handling capabilities of DYSMAP therefore correspond to those available in FORTRAN. There is no evidence in the DYSMAP user documentation (Cavana and Coyle) of any additional structure or functional capability within DYSMAP itself which reflects the network implications of systematically defining levels (and their relevant flow rates) as arrays. Indeed, the use of arrays in System Dynamics does not seem to be perceived by the authors as an avenue for significantly enhancing the power of the methodology.

DYNAMO III (first presented in the fifth edition of the DYNAMO User's Manual (Pugh, 1976)) adds an array capability to the basic DYNAMO language while preserving the characteristics of that language in the areas of variable naming, equation types, time-scripting and functions. This capability is provided in a style similar to that found in FORTRAN (Pugh, p.48), in that any model factor (variable or constant) may be defined as an array through the addition of an array subscript to its name. This subscript is incorporated as an extension to the time-scripting convention of DYNAMO II.

Thus the scalar variable INFLOW.JK, if re-defined as a three-dimensional array, would be written as INFLOW.JK(A,B,C), where A, B and C can be either numerical constants (when addressing a specific array element) or indexing variables (when a range of array elements is to be addressed). Computation of the array and (or) its use in mathematical relationships is therefore effected through use of this subscripting convention.

The use of arrays in DYNAMO III equations must be in accordance with a three-step procedure analogous to that followed in FORTRAN. The number of dimensions must be decided upon (up to three are permitted in DYNAMO III) and the size of each dimension (up to a maximum of 999). Finally these array characteristics must be 'programmed'. In FORTRAN this is done through the use of a DIMENSION statement while in DYNAMO III the array characteristics are inferred from the manner in which the arrays are subscripted and initialised in the equations which incorporate them (Pugh, p.51).

A further important distinction between DYNAMO III and FORTRAN occurs in connection with the formation of computational loops involving arrays. In FORTRAN a DO statement explicitly defines any loop in terms of the relationships involved, the array subscripts involved and the number of iterations to be performed around the loop in respect of that array subscript. In DYNAMO III however a less explicit approach is used which involves the use of a FOR statement placed early in the sequence of model relationships rather than at the precise point where the loop commences. This statement defines an indexing variable and an associated range of values. All relationships following this FOR statement, and containing the indexing variable as an array subscript, will be taken to form a loop which is to be iterated over the specified range of values of the indexing variable.

This approach, while conceptually simpler, can be operationally more difficult in situations where complex array calculations involving nested loops must be programmed.

Computations involving whole arrays can be performed by pre-defined functions in DYNAMO III which are the equivalent of sub-routines in FORTRAN. These functions can be user-defined also, but special functions such as vector summation, array summation and scalar product are available as user options in DYNAMO III.

The array capabilities of GENSIM (the supporting software system for SSD) are derived directly from the concept of network vectorisation. This concept permits a more structured approach to the question of array definitions and array handling, which goes beyond the mere provision of the ability to dimension variables as arrays, and to form computational loops around them. In fact the more structured nature of GENSIM as a parameter-driven package rather than a special purpose language (as is DYNAMO III) derives from the concept of vectorised networks. In brief, for networks up to a pre-determined size (refer p.130) all model factors (variables and constants) are pre-defined and pre-dimensioned. Only the level variables need to be assigned a dimension size. The nature of the vectorised network concept means that all other model factors (inflows, outflows, base flows, transformation coefficients, modulation coefficients and delay coefficients) are automatically assigned the appropriate dimension size. Inflow and outflow variables take on the dimension size of the level to which each is attached. Transformation, Modulation and Delay coefficients take on the dimension sizes associated with the linkage to which each is attached.

Further, the GENSIM software system is specifically structured to handle the matrix multiplication required to reflect the primal and dual forms of single-stage sequential Input-Output models. The primal form of this model applies to any linkage with its outflow (or inflow) dependent upon its own inflow (or outflow). The dual form will be applicable if, for any such linkage, the concept of flow unit cost is relevant. The appropriate equation systems for these models would be invoked automatically from the equation library of the GENCOM program, in the course of solving any model incorporating these relationships (refer Appendix I).

An additional important difference from DYNAMO III and FORTRAN lies in the fact that all computational loops (i.e. those deriving from the input-output relationships discussed above and those deriving from the need to iterate through the network (both backward-pass and forward-pass iterations are required where duality is involved) are automatically formed by GENSIM. This is accomplished through the use of the level and linkage numbering sequences[6] and the level dimension sizes specified by the model builder in the course of constructing the vectorised network of the system being modelled.

Both DYNAMO III and FORTRAN (or any other scientifically oriented high level language such as BASIC for example) can of course be used to model the relationships of a vectorised network. The significant point is, however, the fact that GENSIM is specifically designed to serve as a parameter-driven package, or program generator, for vectorised networks and thus absolve the model-builder from the need to programme the model in the conventional sense. Further, the concept of representing systems as vectorised networks is a cornerstone of the SSD approach. Conventional Systems Dynamics, while providing for the use of array variables in DYNAMO III, does not carry the implications of defining levels and flows as arrays into its network structures. In particular the concept of flow transformation is not recognised. Networks are constructed essentially in accordance with a convention which represents all model factors as scalar elements.

9.3 SSD and Other Network-Based Modelling Methodologies

In this section the network concepts of SSD are compared with those associated with conventional System Dynamics,

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[6] All levels and linkages must be numbered - the latter in accordance with the sequence of primal calculations required for the network.

GESIFLOG, RPMS and NETFORM. Each approach is examined with reference to the concepts of General Systems Theory and the mathematical representation of these concepts in systems modelling. In Chapter 5 the role of General Systems Theory as the basis for a systems approach to the modelling of organisations was discussed. It was suggested that the successful application of General Systems Theory (and hence the systems approach) depends upon the extent to which its framework of general concepts can be translated into an operational form, appropriate to a particular modelling situation. Central among these general concepts is the input-transformation-output view of organisations. Mesarovic et al, 1968, expand upon this viewpoint in proposing that a formal conceptual framework for studying organisations as systems would allow-

(1) A more extensive use of formal concepts and techniques,

(2) An amplification of the logical power of decision makers,

and (3) A greater portability of concepts and methods.

This expanded view results in a multi-level multi-goal definition of the organisation, structured in terms of two major subsystems (the causal and goal-seeking subsystems). The components of both subsystems comprise further subsystems, interconnected in accordance with the structural nature of the overall system. It follows that the input-transformation-output framework can be applied at three levels, viz., the total organisation level, the major subsystem level and the minor subsystem (or individual component) level (see Mesarovic et al, Figure 4, p.299).

Gordon, 1978, and Shannon, 1975, suggest that the mathematical description of dynamic systems can be accomplished through the identification of specific entities, or components of interest in a system, along with their respective attributes or properties. Entities interact in the course of activities, in a manner determined by relationships, to alter the state of the entities, and hence the state of the system as a whole.

Table 9.1 summarises the nature of the graphical representations associated with each of the four selected systems modelling approaches, and SSD. Each is related to the concepts of General Systems Theory and systems modelling discussed above. As can be seen from this table, both RPMS and GESIFLOG utilise graphical conventions which focus on the mathematical structure of the system being modelled, rather than its physical structure. Thus the arc and node symbols are used to depict causes and effects rather than physical movements and states. For the remaining approaches the arc and node symbols relate directly to the movements and states of physical entities in the first instance. Specifically, arcs denote activity of one kind or another and nodes denote inactivity of one kind or another. However, an important distinction in the case of SSD, is the use of a node symbol to depict the transformation activity. This departure permits the separate identification of the flow variables according to whether they are inflows (to levels) or outflows (from levels).

The inflow-transformation-outflow structure of General Systems Theory is therefore explicitly reflected in the network structures of SSD to provide a more 'honest' representation of

TABLE 9.1: COMPARATIVE SUMMARY OF GRAPHICAL REPRESENTATIONS

THE ORGANISATION AS A SYSTEM

Organisations are SYSTEMS consisting of ENTITIES which are hierarchically organised into a CAUSAL SUBSYSTEM and a GOAL-SEEKING SUBSYSTEM.

Entities with ATTRIBUTES interact during ACTIVITIES and in accordance with RELATIONSHIPS. Activities change the STATE of the entities over time.

THE MATHEMATICAL MODEL OF THE ORGANISATION

Entity states are described by STATE VARIABLES which measure the number of entity units in each state and (or) the time spent by each entity in each state.

Entity activity is described by ACTIVITY VARIABLES which measure the flow rate or transformation rate of the entities concerned.

Entity attributes are described by ATTRIBUTE FACTORS which measure key properties associated with each entity, or combination of entities.

The State Variables, Activity Variables and Attribute Factors are linked by RELATIONSHIPS which may be CONSERVATIVE (Causal Subsystem) or NON-CONSERVATIVE (Goal-Seeking Subsystem).

Dynamic behaviour is reflected through the TIME-SCRIPTING of one or more variables.

	RPMS	GESIFLOG	NETFORM	SD	SSD
POSSIBLE ENTITY STATES:					
ACTIVE (Moving, Transforming or being Transformed)	-	-	Arcs	Arcs	Arcs, Nodes
INACTIVE (Waiting or Accumulating)	-	-	Nodes	Nodes	Nodes
ENTITY STATE VARIABLES:					
Level Variables	Nodes	Nodes	Nodes	Nodes	Nodes
Waiting Variables	Nodes	Nodes	Nodes	Nodes	Nodes
ENTITY ACTIVITY VARIABLES:					
Inflow Variables	Nodes	Nodes	Arcs	Arcs	Arc Heads
Transformation Variables	Arc Tags	Arc Tags	Arc Tags	Nodes	Nodes
Outflow Variables	Nodes	Nodes	Arcs	Arcs	Arc Tails
ENTITY ATTRIBUTE FACTORS:					
Constraint Variables/Constants	Arcs	Nodes	Arc/Node Tag	Nodes	Arc Tags
Policy Variables/Constants	-	Nodes	-	Nodes	Arc Tags
RELATIONSHIPS PORTRAYED IN THE NETWORK:					
Causal Subsystem	Primal and Dual Cause-Effect	Primal and Dual Cause-Effect	Primal Flows	Primal Flows	Primal and Dual Flows
Goal-Seeking Subsystem	-	Primal Cause-Effect	-	Primal Cause-Effect	-
DYNAMIC REPRESENTATION:					
Passage of Time	Node-Arc Chains	Node-Arc Chains	Node-Arc Chains	-	-
Lag Effects	-	Arc Tags	Arc Tags	Arc Tags	Arc Tags

the causal subsystems of organisations. Both the primal and dual relationships of this subsystem can be captured within the same set of graphical symbols comprising the network. Unlike conventional System Dynamics, SSD networks do not attempt to portray in any detail the relationships of the goal-seeking subsystem. That is not to say, however, that these relationships, to the extent that they are endogenous to the model, cannot be depicted separately using simple cause-effect diagrams.

The essential point is, that an SSD network, in the interests of clarity and of meeting the broad-based needs of the corporate planning process[7], seeks to provide a rigorous representation of the causal subsystem in the first instance, and to reflect only the more mechanistic and structured relationships of the goal-seeking subsystem, explicitly in the model. The less structured relationships of that subsystem are, in the interests of a more balanced and pragmatic approach to supporting the corporate planning process, better reflected as exogenous influences on the model - effected through close manager-model interaction. This interaction is becoming much more of a practical reality as the power and accessibility of computers increases. It can be argued, in fact, that the full potential of computers in management will not be realised until managers use and perceive computers as a natural extension of their own faculties.

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7. These needs, identified in Chapter 4, call for a 'what-if?' modelling capability which goes beyond identification of organisational growth and stability characteristics.

Dynamic representation in SSD is accomplished, as in conventional System Dynamics, through the time-scripting of the relevant model variables, and not through the use of node-arc chains as is the case with GESIFLOG, RPMS, and NETFORM. Clearly the diagrammatic representation of time dependent variables using node-arc chains can only be practicable with relatively small models.

Table 9.2 summarises the respective mathematical representations associated with each modelling approach. Aside from the fact that only RPMS and SSD utilise a mathematical form which incorporates the concept of duality, important differences exist in the subscripting conventions utilised by each approach, and in the manner in which time is accommodated in the mathematical formulations associated with each approach.

Neither RPMS nor NETFORM utilises any form of time subscripting. The node-arc chains associated with a succession of time periods are handled using the i-j notation for node and arc identification respectively, regardless of whether or not time is the basis for that identification. In the case of GESIFLOG the i-j notation can be extended with the addition of t as a time subscript.

In both System Dynamics and SSD the graphical representation always constitutes a 'snapshot' of the system's structure applicable at any point in time. The representation of inter-period relationships is confined to the mathematical form of the model, and node-arc chains are not used to depict them. In the case of System Dynamics all model variables are subscripted according to the J-K-L convention. The double

TABLE 9.2: COMPARATIVE SUMMARY OF MATHEMATICAL REPRESENTATIONS

	RPMS	GESIFLOG	NETFORM	SYSTEM DYNAMICS	SSD
STATE VARIABLES					
Level Variables - Primal	x_i	y_i (or y_{it})	s_i and d_j	Name.J,Name.K	L(N,V)
Dual	y_i	-	-	-	A(N,V)
ACTIVITY VARIABLES					
Inflow Variables - Primal	x_j	y_i (or y_{it})	x_{ij}	Name.JK,Name.KL	I(N,V)
Dual	y_j	-	-	-	C(N,V)
Transformation Variables	a_{ij}	m_{ij} (or m_{ijt})	a_{ij}	-	TO(T,I,J)
Outflow Variables - Primal	x_j	y_i (or y_{it})	x_{ij}	Name.JK,Name.KL	X(N,V)
Dual	y_j	-	-	-	K(N,V)
ATTRIBUTE FACTORS					
Constraint Variables/ Constants	b_i or c_j	y_i or x_i	U_{ij},L_{ij},b_i	Name.J,Name.K or Name	BO(T,V) and MO(T,V,Z)
Policy Variables/Constants	b_i or c_j	y_i or x_i	b_i, c_{ij}	Name,J,Name.K or Name	
Time Subscripts	None formally assigned - ij notation is used	ij notation or subscript t	None formally assigned - ij notation is used	J,K,L notation	Z subscript (applied to Modulation and Delay Coeffs. only)
Time-Lag Variables	-	t_{ij}	-	Incorporated in Delay functions	Incorporated in Delay functions

subscripts JK or KL are used for the activity variables (flow rates) and the single subscripts J, K or L are used for the state variables (levels). The only other subscripting in System Dynamics is that associated with the definition of model variables (or constants) as arrays (refer section 9.2).

With SSD on the other hand, the state and activity variables are not time-scripted and any values assigned to them are always current period values which are over-written as the model computations advance over time. A further important distinction between the mathematical representations utilised by System Dynamics and SSD derives from the latter's more highly structured form, which allows its supporting software to operate as a parameter-driven package rather than as a programming language. This distinction is the explicit naming of all model factors (variables and constants) as a 'built-in' feature of the GENSIM package. The unique identification of each model factor, within the software system, permits a modular or 'building block' approach to model construction and use. Alpha characters are defined to identify every factor type (e.g. the letter I denotes an inflow, X denotes an outflow, L denotes a level, etc.), and the subscript N permits the unique identification of any given level (node) and linkage (arc). In fact all model levels, inflows and outflows are addressed by their assigned number when constructing an SSD model.

The subscript T is used to enumerate model factors other than the 'core' variables of levels and flows. Thus specific data arrays such as those defined for transformation (labelled TO), for flow initialisation (labelled BO), for modulation (labelled MO) and time lagging (labelled DO and D1) can all be identified and addressed using this subscript. A further subscript (Z) is used to add a time dimension to the modulation and delay arrays, while the subscript V is reserved for network vectorisation (i.e. the specification of the model levels and flows as arrays). The subscripts I and J are also associated with network vectorisation in that they identify specific elements of the transformation array, linking the two sides of any given linkage.

In the SSD modelling approach therefore, every model factor is pre-defined, and is addressable by the model-builder in the course of model construction, by referencing the appropriate label and subscript value. Vectorisation of an SSD network begins and ends (as far as the model builder is concerned) with the assignment of dimension sizes for the levels. The array sizes of all other model factors then automatically follow, in accordance with their role in the network.

9.4 SSD and Traditional Financial Modelling

In order to highlight the principal points of difference between SSD and traditional financial modelling, a comparative analysis of the two is presented in this section. This analysis is based on consideration of each approach in its application to the demonstration financial modelling problem presented in Chapter 8. The traditional 'non-systems' approach is, for the purpose of this analysis, well exemplified by the 'DATA*MODEL' financial modelling system.[8]

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8. Mini Computer Modelling Inc., 1978. This system, is an example of a financial modelling software system written for use on interactive time-sharing computers, but based on the use of accounting concepts with no underlying systems framework. Thus no support is provided for the conceptual-graphical-mathematical sequence of the model building process.

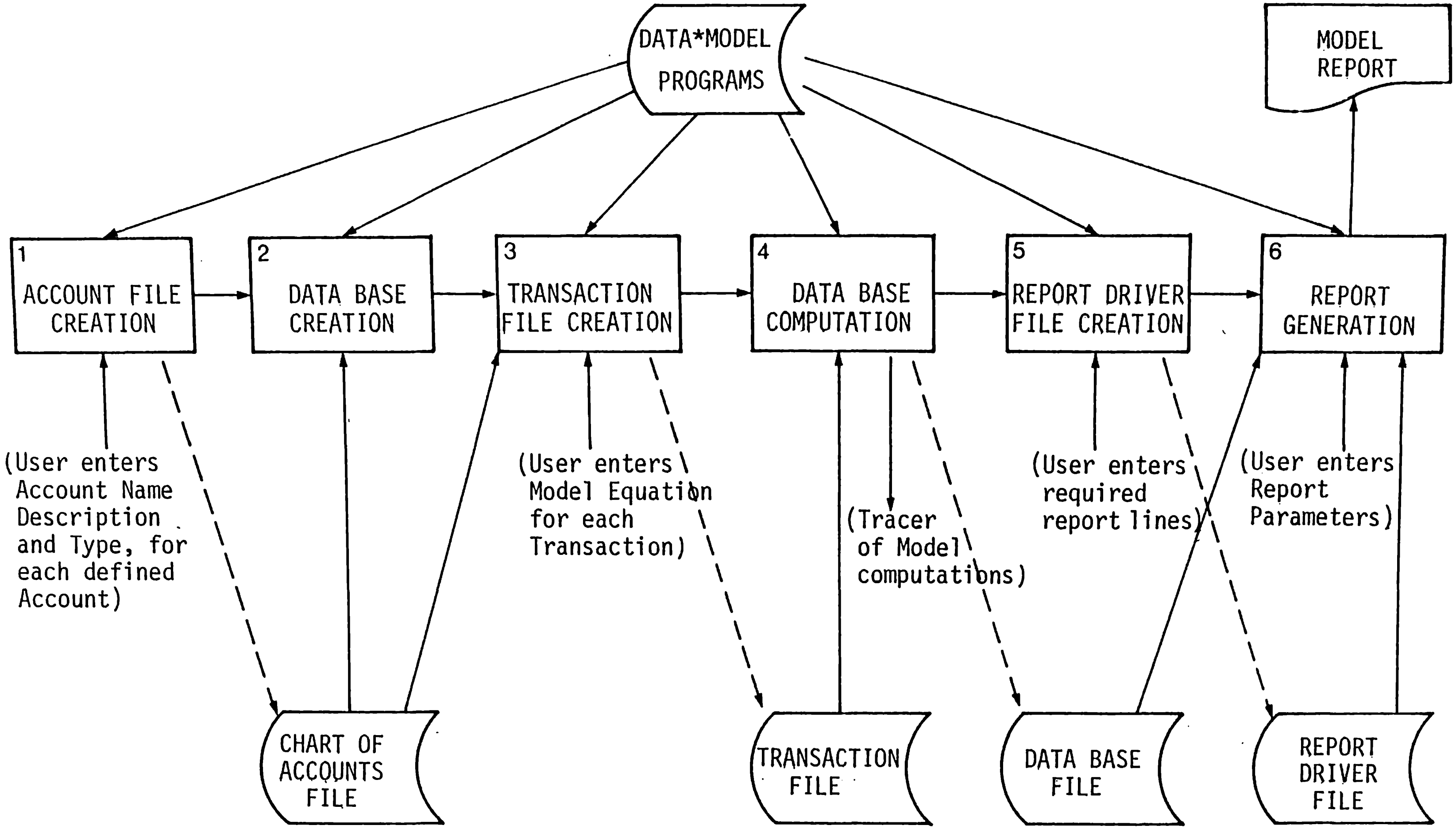

FIGURE 9.1: THE STEPS IN THE DATA*MODEL FINANCIAL MODELLING METHODOLOGY

The computer programs of this system are written in the BASIC language, with versions available for use on Digital Equipment Corporation and Datapoint computers. A total of 21 programs are present in the system which can be used for both comprehensive financial modelling, and specialised discounted cash flow modelling. Models are constructed in accordance with a sequence of six steps, which are summarised in Figure 9.1.

Construction of the financial model of Chapter 8 commences with the creation of the Chart of Accounts file. The term 'account' is accorded a much broader meaning here than its conventional accounting connotation, in that it embraces all factors in the model which must be recognised as algebraic variables. A total of 35 'accounts' must therefore be defined for this simple model, in order to preserve a degree of flexibility equivalent to that obtained under GENSIM[9]. These accounts are listed in Table 9.3.

Creation of the Transactions file is the next major step, with the whole model abstraction process in effect being compressed into this and the preceding step. For the model under consideration here the following equations must be formulated for the Transaction file, using the accounts defined in Table 9.3.

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9. DATA*MODEL does not permit the separation of the raw model data from the model equation system. Both must be defined in the transaction file, and separation within this file can only be achieved by defining data elements as variables (i.e. accounts). The equation system can then comprise the transactional relationships and a separate set of relationships for assigning numerical values to the data elements. Failure to effect this separation results in the model data being embedded in the transaction equations with a consequent loss of model flexibility.

TABLE 9.3: THE DATA*MODEL CHART OF ACCOUNTS FOR THE SIMPLE FINANCIAL MODEL

Account Name	Account Type	Account Description
CAP	Number	Capital
CASH	"	Cash at Bank
CREDS	"	Creditors
FAS	"	Fixed Assets
DEBS	"	Debtors
STOCKS	"	Stocks
PROFIT	"	Retained Profit
SALES	"	Sales
COS	"	Cost of Sales
PURCHS	"	Purchases
EXPS	"	Expenses
COLLECT	"	Debtor Collections
PAY	"	Creditor Payments
DEPN	"	Depreciation
BORR	"	Borrowings
REPAY	"	Repayments
CAPEX	"	Capital Expenditure
SRATE	"	Sales Growth Rate
CRATE	"	Cost of Sales Rate
PRATE	"	Purchases Growth Rate
ERATE	"	Expenses Growth Rate
SEAS1	"	Seasonal Index for Sales
SEAS2	"	Seasonal Index for Expenses
DDC1	"	Debtors Delay Coeff. - Month 1
DDC2	"	Debtors Delay Coeff. - Month 2
DDC3	"	Debtors Delay Coeff. - Month 3
DDC4	"	Debtors Delay Coeff. - Month 4
CDC	"	Creditors Delay Coeff.
PDC1	"	Purchases Delay Coeff. - Month 1
PDC2	"	Purchases Delay Coeff. - Month 2
PDC3	"	Purchases Delay Coeff. - Month 3
PDC4	"	Purchases Delay Coeff. - Month 4
TOTASS	Number	Total Assets
TOTLIA	Number	Total Liabilities
MONTH	Statistic	Month
TMONTH	Statistic	Test Month for Delays

(a) Initialising Equations - a total of 31 of these must be written to set opening balances for the real accounts, to set the values of the various transaction rate coefficients (including growth coefficients, seasonal indices, and cash flow lag coefficients) and to set various time counters needed to control the processing logic of the equation system.

(b) Transaction Equations - a total of 13 of these are needed to compute the transaction flows which affect the real accounts defined for the model. These transaction-flow values (stored as nominal accounts in the model) comprise monthly values for sales, expenses, cash collections, cash payments, purchases and cost of sales.

(c) Account Balance Equations - a total of 9 of these are required to compute the month-end balances for all of the real accounts, together with the associated totals for assets and liabilities. As with the transaction equations, these equations must be evaluated within a processing loop controlled by the time counters referred to in (a) above.

The principal points of comparison between the two modelling approaches, presented in the context of their application to the development of the simple financial model, are summarised in Table 9.4. The difference apparent with regard to those aspects associated with the model abstraction

TABLE 9.4: DATA*MODEL vs SSD - A COMPARATIVE SUMMARY

FACTOR	DATA*MODEL	SSD
Conceptual Form of the Model	35 Accounts	7 Accounts (Levels) 9 Transaction Paths (Linkages) 7 Transaction Modulations 3 Transaction Delays
Graphical Form of the Model	None	Network of Accounts and Transaction Paths (see Fig. 8.1)
Mathematical Form of the Model	53 Equations coded and logically related by the user	25 Transactions coded and logically related by GENSIM on the basis of Account and Transaction parameters specified by the user
Model Data Base Structure	Accounts File, Transactions File (comprising raw data and equations) and a Computed Data File	Separate files for the Model Structure (i.e. Account and Transaction Parameters), Raw Data and Computed Data
Model Report Generation	Tabular, generated from the Computed Data File using a Report Driver File	Tabular or Graphical, generated from the Computed Data File using Report Specifications Files
Model Changes	All changes must be effected by changing the model equation system	Can selectively change model data independently of model structure. The concept of vectorisation permits extension of the structure without adding to the equation system
Model Computing Requirements (for 36 month planning period)	Processor Time:33.7 secs Disk Space:109 Blocks	Processor Time:47.8 secs Disk Space:759 Blocks

process (the conceptual, graphical and mathematical forms of the model, together with its data base structure) stem directly from the fact that DATA*MODEL lacks a base of systematically organised concepts.

As a 'non-systems' methodology, DATA*MODEL is typical of many financial modelling systems in that the model abstraction process is largely compressed into a single stage of equation formulation. Little or no support is provided for the crucial intermediate stages of formulating the conceptual and graphical forms of the model. As a consequence the model builder is left with the task of manually effecting the equation coding and processing logic requirements for the model.

SSD utilises a structured conceptual base which allows for the explicit and separate identification of accounts, transaction paths and transaction influences. The 'account' concept can retain its conventional accounting connotation with this more structured conceptual base. The practical ramifications of this are clearly apparent even at the low level of model complexity present in the application used in this study. The 53 equations comprising the DATA*MODEL version of the model must be augmented with processing logic statements in order to accommodate the time-lag relationships required in the model, and which are common to most business systems. Logic statements are also required to effect looping around those statements which must be evaluated iteratively over the planning horizon defined for the model. This inevitably adds to the risk of logical errors in the model and erodes much of the advantage of using a special purpose language instead of a general purpose language (such as BASIC). This is particularly apparent when the latter can be used in conjunction with the kind of supporting utilities and program generating software which have been developed in recent years. An example is provided by the programs of USER-11 (North County Computer Services, 1980).

The database structure of models developed using DATA*MODEL, in not permitting the ready separation of raw data from the model equation system and computed data, gives rise to an operational weakness quite apart from those emanating from the non-systems nature of the approach itself. Selective access to individual elements of model data for review and amendment purposes is an important requirement for the effective and efficient 'what-if' use of any model. This should not entail the re-specification of model equations.

All of the above points of difference become more significant in their negative impact on model development time and model flexibility, as the scale and complexity of the modelling application increases. Extension of the simple financial model of Chapter 8 is effected through the relatively simple process of network vectorisation, using SSD whereas with DATA*MODEL the number of equations to be coded and logically ordered increases approximately three-fold.

As a special purpose modelling language DATA*MODEL does however provide some of the operational advantages typical of modelling languages as compared to modelling packages. These advantages are greater choice in the range of equation types which can be formulated, and (usually) more efficient computational characteristics. In the case of DATA*MODEL the former attribute does not compare favourably with BASIC as many common requirements (e.g. loop formation and mixed arithmetic expressions) are quite cumbersome to programme.

The computational characteristics of the system in terms of processing efficiency and disk storage are significantly better than those associated with GENSIM as can be seen from Table 9.4. For the majority of financial modelling applications however, these aspects are of relatively low importance when viewed in the total economic context of computer-based modelling.

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CHAPTER 10

APPLICATION I: THE HALLMARK FINANCIAL PLANNING MODEL

Hallmark International is a medium-sized manufacturing company specialising in the manufacture of a compact range of back packs, tents, sleeping bags and camping accessories. By 1978 the company had undergone a seven year period of rapid growth, during which both sales and total assets increased six-fold. Profitability in terms of return on equity, although high, had declined somewhat due to a sixteen-fold increase in the company's equity base, arising from the retention of earnings over this period. This high rate of growth, coupled with a marked seasonality in sales, and inadequate production planning and stock control, resulted in recurring liquidity problems, and undue reliance on costly short-term finance. This chapter focuses on the development of a financial planning model aimed at providing a central 'what-if?' modelling facility to support a more formal, comprehensive and quantitative style of planning - in both the short and long term.

10.1 Preliminary Considerations

Development of the financial planning model for this organisation proceeded in accordance with a two-stage programme in recognition of the novelty of the technique to the organisation, and the need to quickly establish its worth in a high pay-off area of application. Typically this situation, in many organisations, is best dealt with by following a staged programme in which the initial model focuses on cash planning[1], and then is extended into a cash and profit model, and finally a full financial model embracing cash, profit, and balance sheet projections in a single integrated structure. In the case of Hallmark International, a cash planning model was developed for short term cash management purposes, on a rolling 12-month basis. Extension of this model into a full financial model then proceeded as a second-stage development, once the role of the first model in the management process (and its credibility) had been clearly established.

10.2 The Cash Planning Model

Development of this model using the SSD methodology, followed the six-step sequence discussed in the previous two chapters. The model encompasses both cash flows and those flows which have a direct bearing on them, such as sales and the placement of orders for materials.

One of the key factors behind the stock control-related liquidity problems faced by the company was clearly associated with order placement decisions being made without adequate consideration being given to sales projections and the timing of the resultant cash flows[2]. The model was structured to address this problem and provide

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[1] For most organisations the relationships associated with cash flows are the most highly structured, and the most readily ascertainable. Relevant historical data are also usually available to support validation, and the benefits of cash planning models are more immediate and visible to management.

[2] Approximately 45% of the company's materials are imported, with delivery lead times extending up to 8 months in duration, followed by payment terms based on 120 day bills. Thus substantial time lags involving significant amounts of cash added considerably to the problems of the organisation.

cash projections, using a solution interval of one month, for up to sixty consecutive months. However, in using the model the emphasis was to be on the immediate 12 months ahead, and the interactive testing of alternatives covering a variety of different sets of assumptions in the areas of overhead and sales projections, capital expenditure programs and purchase order placement programs. The flow diagram of the model is shown in Figure 10.1 with vectorisation permitting the explicit definition of the sub-levels (or accounts) listed in Table 10.1. Thus the model consists of a total of 16 'accounts' organised into a 4-level, 3-linkage vectorised network. The model database (aside from the account opening balances) consists of the data tables (or matrices) associated with 3 base flows, 3 modulations, 3 transformations and 2 delays - tagged to the linkages as depicted in Figure 10.1. The specific nature of each linkage, in terms of its flow determinants and data tables, is summarised in Table 10.2.

In broad terms the model relationships are as follows. The inflows of linkage 1 (purchase order placements) are initialised with the base flow B1 and modulated according to the desired order placements program specified in M1 - for both local and imported orders separately. Transformation T1 then transforms these two inflows into two outflows along channels 3 and 4 of linkage 1, which are delayed by D1 to reflect the combined effect of delivery lead times and payment terms, before being released as cash payments for crediting to the appropriate accounts in level 1.

The inflows of linkage 2 (other cash payments) are initialised with the base flow B2 and modulated by M2. This modulation matrix

TABLE 10.1: THE LEVEL DEFINITIONS FOR THE HALLMARK CASH PLANNING MODEL

LEVEL NO.	LEVEL DESCRIPTION (ACCOUNT GROUP)	SUB-LEVEL DESCRIPTION (ACCOUNT)
1	Accumulated Cash	1. Local Collections 2. Export Collections 3. Local Purchase Payments 4. Import Purchases Payments 5. Other Payments
2	Accumulated Purchase Order Placements	1. Local Order Placements 2. Import Order Placements
3	Accumulated Other Payments	1. Manufacturing Wages 2. Overheads 3. Salaries 4. Capital Expenditure 5. Repayments & Borrowings 6. Tax Payments 7. Distributions (to shareholders)
4.	Accumulated Sales	1. Local Sales 2. Export Sales

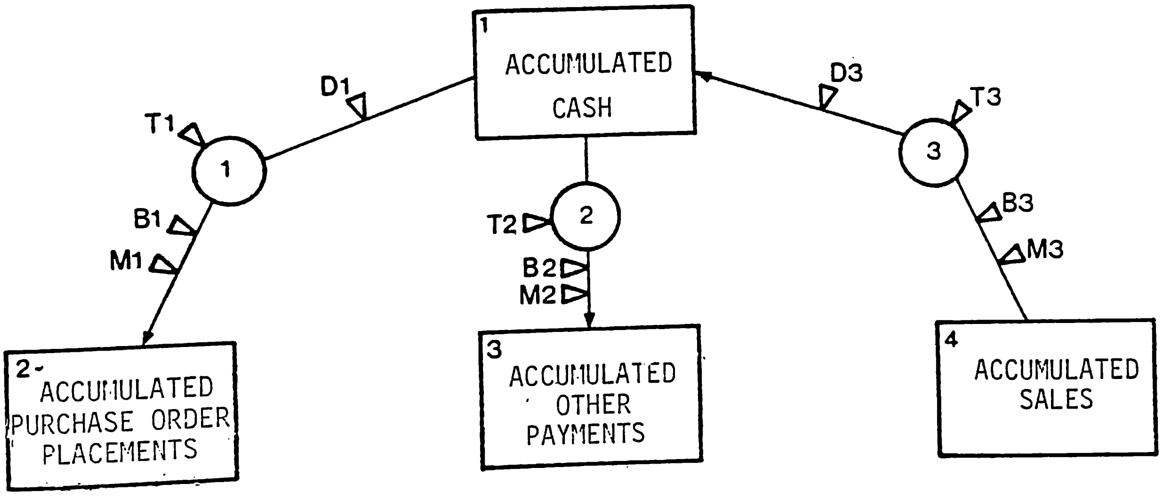


FIGURE 10.1: FLOW DIAGRAM FOR THE HALLMARK CASH PLANNING MODEL

carries the growth pattern for wages, overheads and salaries, as well as the payment programs for capital expenditure, borrowings and repayments, tax and distributions to shareholders. Transformation T2 switches or directs each of these inflows to give rise to the corresponding outflows (or credits) in the appropriate flow channels of the outflow side of linkage 2.

The outflows of linkage 3 (sales) are initialised with B3 and modulated by M3, which carries the specified growth rates for each class of sales, together with their respective monthly seasonal index series. Transformation T3 directs the sales outflows of linkage 3 into the appropriate linkage 3 inflows representing cash collections. These inflows are tagged with the delay D3 which superimposes an appropriate time-lag pattern for the cash collections associated with each class of sales.

Input to the model consists of all the data matrices tagged to the linkages and the appropriate account opening balances - set at zero for all levels except the total of level 1. This is equated to the latest bank overdraft, being the net cash balance at the start of the planning period associated with any given model run. An important part of the input which is of considerable significance to the projections resulting from any given run of the model, are the boxcar delay transit levels. These are the future cash flows 'in the pipeline' relating to transactions (sales and order placements) which have already taken place. In the case of the order placements delay, this data was obtainable directly from the purchasing records, while for the cash collections delay it was established from the latest aged debtors balances listing.

TABLE 10.2: FLOW EQUATIONS OF THE CASH PLANNING MODEL

Linkage No.	Flow Description (Transaction Type)		Is Equal to ...	Transformed by	Modulated by	Delayed by ....
1.	Purchases	- Inflow	Base Flow B1	-	M1*	-
		- Outflow	Own Inflow	T1	-	D1
2.	Other Payments	- Inflow	Base Flow B2	-	M2*	-
		- Outflow	Own Inflow	T2	-	-
3.	Sales	- Inflow	Onw Outflow	T3	-	D3
		- Outflow	Base Flow B3	-	M3*	-

* These modulations also incorporate unique cyclical influences in the form of seasonal index series for order placements, selected payment types and sales.

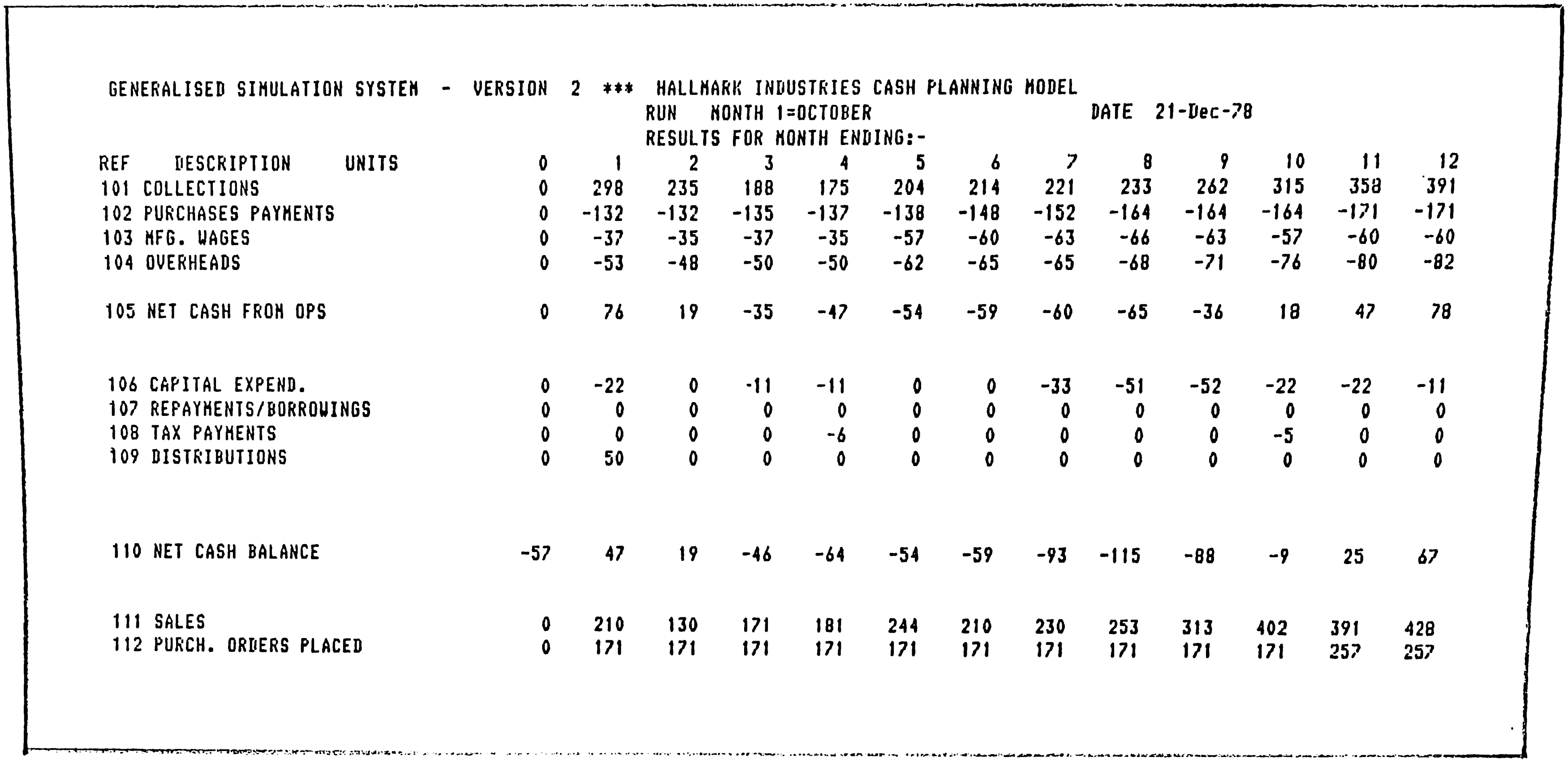
The model is run monthly for management, to provide rolling 12 monthly cash projections (see Figure 10.2 for a sample report) which usually take the form of optimistic, pessimistic and 'most likely' projections - based on a given program of order placements, and three sets of sales forecasts (optimistic, pessimistic and most likely). The model is also run, as and when required, to test the likely cash implications of specific and selective changes to the model data base reflecting significant environmental occurrences (e.g. a general wage order), or strategic changes (e.g. a revised capital expenditure programme).

An interesting structural adaptation to this model involved redefining the solution interval to that of one day and re-running the model (using the pessimistic set of assumption) to establish peak bank overdraft requirements in terms of both timing and amount. This exercise had not previously been attempted by the company, an omission which frequently produced 'management by crisis' consequences.

The above adaptation involved merely the use of the GENSPC program to effect the solution interval change, followed by the use of the GENINP program to amend the data base (base flows, modulations and delays) accordingly. Graphical output from a sample run of this amended model projecting the daily bank overdraft requirements is shown in Figure 10.3.

10.3 The Financial Planning Model

Development and acceptance of the cash planning model described in the previous section paved the way for a full financial planning model capable of generating projections in terms of monthly cash statements, profit statements and balance sheets. The purpose of this model was to play a central role in support of the corporate



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GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INDUSTRIES CASH PLANNING MODEL
                                                   RUN   MONTH 1=OCTOBER                     DATE  21-Dec-78
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS               0      1      2      3      4      5      6      7      8      9     10     11     12
101 COLLECTIONS                             0    298    235    188    175    204    214    221    233    262    315    358    391
102 PURCHASES PAYMENTS                      0   -132   -132   -135   -137   -138   -148   -152   -164   -164   -164   -171   -171
103 MFG. WAGES                              0    -37    -35    -37    -35    -57    -60    -63    -66    -63    -57    -60    -60
104 OVERHEADS                               0    -53    -48    -50    -50    -62    -65    -65    -68    -71    -76    -80    -82

105 NET CASH FROM OPS                       0     76     19    -35    -47    -54    -59    -60    -65    -36     18     47     78


106 CAPITAL EXPEND.                         0    -22      0    -11    -11      0      0    -33    -51    -52    -22    -22    -11
107 REPAYMENTS/BORROWINGS                   0      0      0      0      0      0      0      0      0      0      0      0      0
108 TAX PAYMENTS                            0      0      0      0     -6      0      0      0      0      0     -5      0      0
109 DISTRIBUTIONS                           0     50      0      0      0      0      0      0      0      0      0      0      0



110 NET CASH BALANCE                      -57     47     19    -46    -64    -54    -59    -93   -115    -88     -9     25     67


111 SALES                                   0    210    130    171    181    244    210    230    253    313    402    391    428
112 PURCH. ORDERS PLACED                    0    171    171    171    171    171    171    171    171    171    171    257    257
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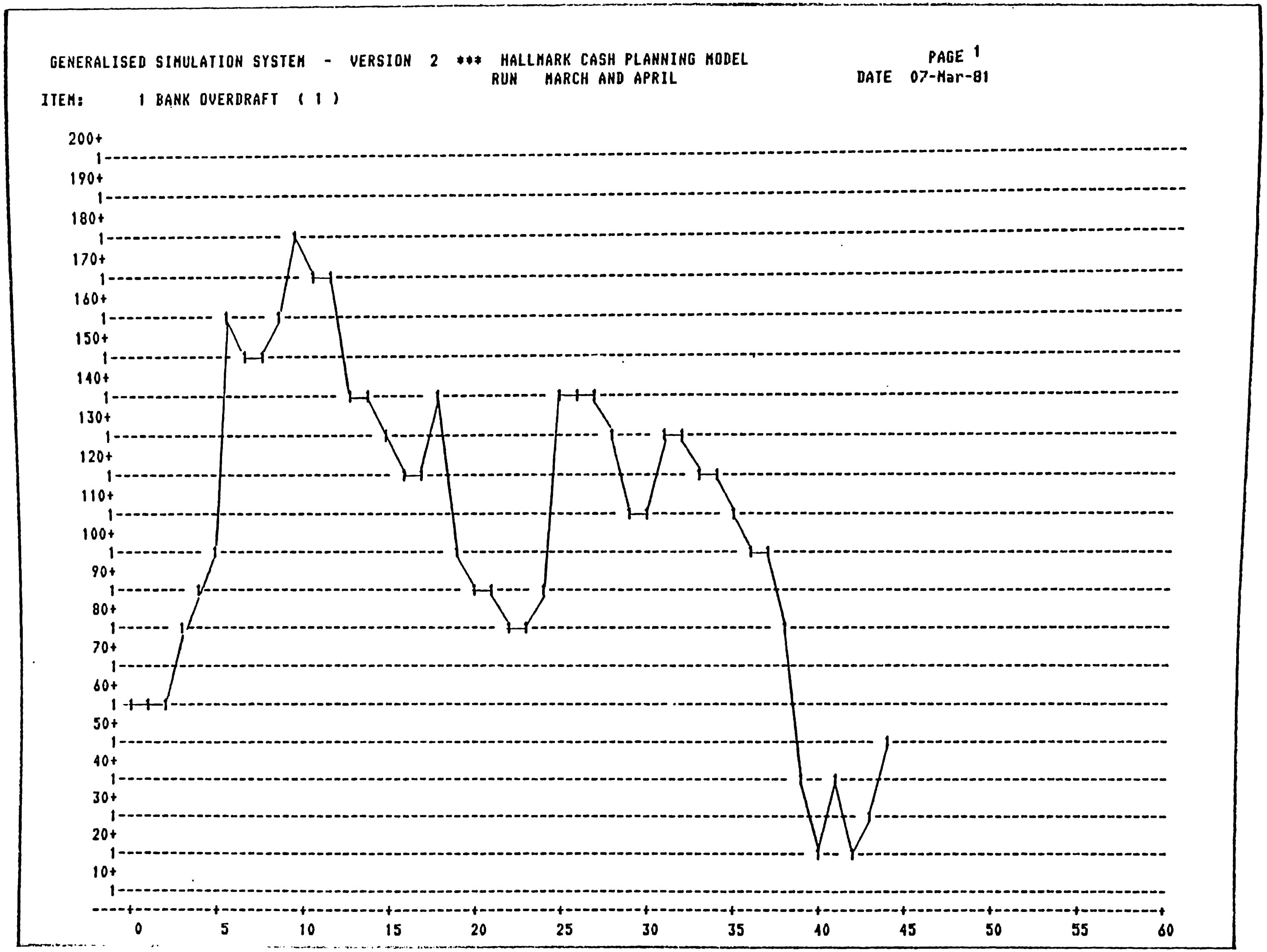
FIGURE 10.2: SAMPLE REPORT- CASH FLOW STATEMENT OF THE HALLMARK CASH PLANNING MODEL



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GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK CASH PLANNING MODEL                PAGE 1
                                                   RUN   MARCH AND APRIL                DATE  07-Mar-81
ITEM:      1 BANK OVERDRAFT  ( 1 )
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FIGURE 10.3: SAMPLE REPORT- BANK OVERDRAFT BALANCE OF THE HALLMARK CASH PLANNING MODEL

planning process by facilitating the quick testing and evaluation of a range of scenarios and strategies. Measurement of the financial effects associated with each set of model parameters needed to be in terms of the three types of financial statements referred to above, and also in terms of a defined corporate goal structure (refer Figure 10.6).

(a) Model Structure

Again, a monthly solution interval was deemed to be most appropriate, together with a planning horizon of 5 years (or 60 months). In order to provide the scope for adequately specifying scenarios and strategies and for their evaluation in terms of the corporate goal structure defined for the company, the levels (and sub-levels) defined in Table 10.3 had to be recognised. The graphical form of the model is displayed in Figure 10.4, as a 17-level 17-linkage vectorised network, drawn with linkages as defined in Table 10.4.

The details of the flow determinants and influences associated with each linkage are provided in this Table. Table 10.5 expands this detail further by setting out the individual flow channel determinants for each of the linkage inflows (or outflows) which have a mixed dependency.

In brief, linkage 1 is defined for sales transactions, initialised by B1 and subject to the growth rates and sales seasonality cycles of M1. Linkage 2 carries the cost of sales flows calculated as a specified fraction (M2) of sales, while linkage 3 carries the cost of production

TABLE 10.3: LEVEL DEFINITIONS OF THE HALLMARK FINANCIAL MODEL

Level No.	Level Description (Account Group)	Sub-Level Description (Accounts)
1.	Capital and Reserves	1. BNZ Term Loan 2. BNZ Export A/c 3. DFC Term Loan 4. Other Loans 5. Shareholder Capital 6. Shareholder Current A/c's 7. Asset Revaluation Reserve
2.	Cash at Bank	1. Collections 2. Purchases 3. Mfg. Wages 4. Overhead 5. Divs & Other Payments 6. Capital Expenditure 7. Tax Payments 8. Repay/Borrowing 9. Korucraft Payments
3.	Current Liabilities	1. Bills Payable 2. Loc. Creds . - Mat. 3. Loc. Creds. - Exp. 4. Other Creds. 5. Div. Provision 6. Tax Provision 7. Tax Deferred 8. Retained Profit
4.	Fixed Assets	1. Land & Buildings 2. Plant & Equipment 3. Vehicles 4. Other 5. Korucraft Advance
5.	Debtors	1. Local Debtors 2. Export Debtors 3. Koru Current A/c
6.	Fixed Overheads	1. Administration 2. Local Marketing 3. Export Marketing 4. Production 5. Research & Development 6. Warehouse 7. Management 8. Depreciation 9. Rent & Rates 10. Contingency
7.	Variable Overheads	1. Administration 2. Local Marketing 3. Export Marketing 4. Production 5. Research and Development 6. Warehouse 7. Interest

TABLE 10.3: Continued ....

Level No.	Level Description (Account Group)	Sub-Level Description (Accounts)
8.	Other Overheads	1. Miscellaneous
		2. Koru Recovery
9.	Accumulated Sales	1. Local Mfg. Sales
		2. Local W/s Sales
		3. Export Sales
		4. Army Pack Sales
		5. Koru Income
10.	Material Stocks	1. Local Materials
		2. Imported Materials
11.	Finished Stocks	1. Manufactured Stocks
		2. Wholesale Stocks
12.	Accum. Cost of Sales	1. Local Mfg Cost of Sales
		2. Local W/s Cost of Sales
		3. Export Cost of Sales
		4. Army Pack Cost of Sales
		5. Other Cost of Sales
13.	Profit Factors	1. Local Sales
		2. Export Sales
		3. Other Sales
		4. Mfg Cost of Sales
		5. W/s Cost of Sales
		6. Fixed Overhead
		7. Variable Overhead
		8. Other Overhead
		9. Depreciation
14.	Tax Factors	1. Operating Profit
		2. Losses Carried Forward
		3. Export Sales
		4. Export Sales Base
		5. Market Dev. Expend
		6. Actual Depreciation
		7. Tax Depreciation
		8. Other Adjustments
15.	Interest	1. BNZ Loan Interest
		2. BNZ Export Interest
		3. DFC Loan Interest
		4. Other Loan Interest
		5. Bank O/D Interest
		6. Current A/c Interest
		7. Total Interest
16.	Operating & Taxable Profits	1. Monthly Operating Profit
		2. Monthly Taxable Profit
		3. YTD Operating Profit
		4. YTD Taxable Profit
17.	Divident & Tax Provisions	1. Operating Profit
		2. Divident Provision
		3. Tax Provision

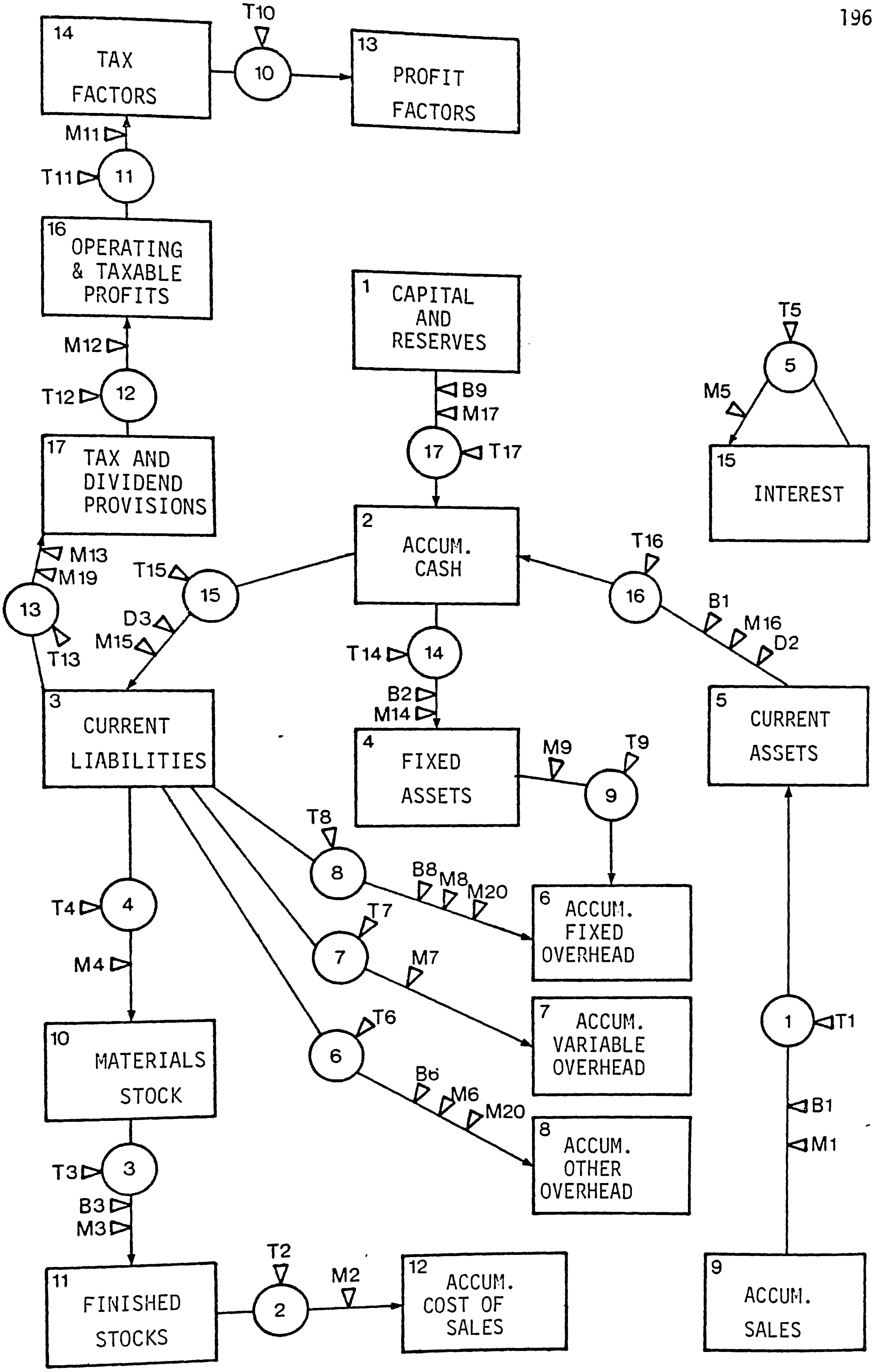

FIGURE 10.4: FLOW DIAGRAM FOR THE HALLMARK FINANCIAL PLANNING MODEL

flows[3]. These are intialised by B3 and subject to the growth rates and production seasonality cycles of M3.

Linkage 4, as the materials purchases linkage, is equated to the outflow of linkage 3 (materials requirements of production), subject also to the superimposed growth rates of M4. Linkage 5 inflows constitute the interest charges on each loan category, at the interest rates of M5.

Linkages 6,7 and 8 are defined for the various classes of overhead recognised in the model, with linkage 7 relating to the volume dependent overheads calculated using rates applied to each determinant volume measure by M7. Linkages 6 and 8 are for the 'fixed' overhead charges, which are initialised by B6 and B8 respectively, and subjected to growth rates applied by M6 and M8 respectively. Inflation rates are also applied to these charges, with M20.

Linkage 9 is reserved exclusively for depreciation flows calculated from the fixed asset balances of level 4, using depreciation rates specified in M9. Linkages 10, 11, 12 and 13, together with their associated levels, are defined for the sole purposes of transferring earnings to the retained profit account (of level 3) and determining the end of year provisions for dividend and taxation. The detailed structure of this sector of the model is described

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3. Transformed into labour and materials costs (outflows) by T3.

TABLE 10.4: FLOW EQUATIONS OF THE HALLMARK FINANCIAL PLANNING MODEL

Linkage No.	Flow Description (Transaction Type)		Is Equal to	Transformed by	Modulated by	Delayed by ....
1.	Sales	- Inflow	Own Outflow	T1	-	-
		- Outflow	Base Flow B1	-	M1	-
2.	Cost of Sales	- Inflow	Link 1 Outflow	-	M2	-
		- Outflow	Own Inflow	T2	-	-
3.	Cost of Production	- Inflow	Mixed Factors*	-	M3	-
		- Outflow	Own Inflow	T3	-	-
4.	Materials Purchases	- Inflow	Link 3 Outflow	-	M4	-
		- Outflow	Own Inflow	T4	-	-
5.	Interest Charges	- Inflow	Mixed Factors*	-	M5	-
		- Outflow	Own Inflow	T5	-	-
6.	Other Overhead Charges	- Inflow	Base Flow B6	-	M6 & M20	-
		- Outflow	Own Inflow	T6	-	-
7.	Variable Overhead Charges	- Inflow	Mixed Factors*	-	M7	-
		- Outflow	Own Inflow	T7	-	-
8.	Fixed Overhead Charges	- Inflow	Base Flow B8	-	M8 & M20	-
		- Outflow	Own Inflow	T8	-	-
9.	Depreciation Charges	- Inflow	Own Outflow	T9	-	-
		- Outflow	Level 4	-	M9	-
10.	Profit Calculation	- Inflow	Mixed Factors*	-	-	-
		- Outflow	Own Inflow	T10	-	-
11.	Taxable Profit Calc.	- Inflow	Mixed Factors*	-	M11	-
		- Outflow	Own Inflow	T11	-	-

* See Table 10.5

TABLE 10.4: Continued ....

Linkage No.	Flow Description (Transaction Type)		Is Equal to	Transformed by	Modulated by	Delayed by ....
12	Year Total Profit Calc.	- Inflow	Mixed Factors*	-	M12	-
		- Outflow	Own Inflow	T12	-	-
13.	Dividend and Tax Calc.	- Inflow	Mixed Factors*	-	M13 & M19	-
		- Outflow	Own Inflow	T13	-	-
14.	Capital Expenditure	- Inflow	Base Flow B2	-	M14	-
		- Outflow	Own Inflow	T14	-	-
15.	Creditor Payments	- Inflow	Mixed Factors*	-	M15	D5
		- Outflow	Own Inflow	T15	-	-
16.	Debtor Collections	- Inflow	Own Outflow	T16	-	-
		- Outflow	Link 1 Inflow	-	M16	D2
17.	Capital Transactions	- Inflow	Own Outflow	T17	-	-
		- Outflow	Base Flow B9	-	M17	-

* See Table 10.5

TABLE 10.5: THE MIXED DEPENDENCY RELATIONSHIPS OF THE HALLMARK FINANCIAL PLANNING MODEL

Dependent Flow	Dependent Flow Description	Dependent Flow Channel Number									
		1	2	3	4	5	6	7	8	9	10
Linkage 3 Inflow	Cost of Production	B(3,1)	X(2,2)	-	-	-	-	-	-	-	-
Linkage 5 Inflow	Interest Chares	L(1,1)	L(1,2)	L(1,3)	L(1,4)	L(2,Tot)	L(1,6)	-	-	-	-
Linkage 7 Inflow	Variable Overhead	X(1,1)	X(1,1)	X(1,3)	I(3,1)	X(1,1)	X(5,1)	-	-	-	-
Linkage 10 Inflow	Profit Calculation	I(1,1)	I(1,2)	I(1,3)	X(2,1)	X(2,2)	X(8,3)	X(7,3)	X(6,3)	I(9,8)	-
Linkage 11 Inflow	Taxable Profit Calc.	X(10,1)	X(12,3)	X(1,3)	B(10,4)	I(8,3)	I(9,8)	B(10,7)	B(10,8)	-	-
Linkage 12 Inflow	Year Total Profits	X(11,1)	X(11,2)	L(16,3)	L(16,4)	-	-	-	-	-	-
Linkage 15 Inflow	Creditor Payments	X(4,1)	X(4,2)	L(3,3)	X(4,4)	L(3,5)	L(3,6)	L(3,7)	L(3,8)	-	-

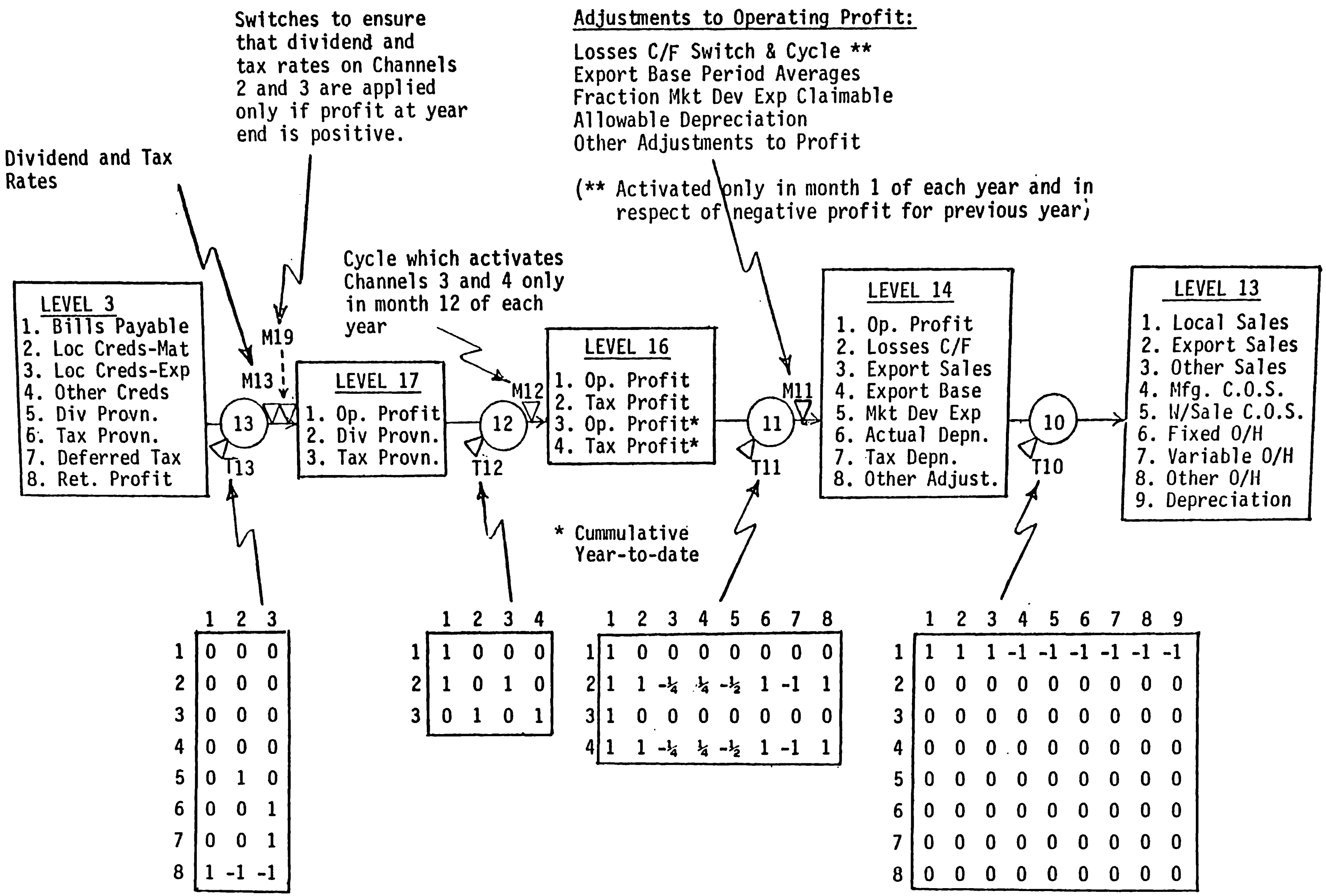
NOTE: L(N,V) denotes Level N, Sub-level V
I(N,V) denotes Linkage N, Inflow Channel V
X(N,V) denotes Linkage N, Outflow Channel V
B(N,V) denotes Base Flow N, Flow Element V

in Figure 10.5.

The calculation sequence for this sector commences with Linkage 10, which serves to determine the monthly profit before tax (as its outflow channel 1) by transforming its inflows, defined as the nine components of profit listed under level 13. Linkage 11 determines the taxable profit on the basis of the profit before tax, together with all necessary adjustments, which are effected using M11 applied to the various factors identified under level 14. These factors collectively constitute the components of taxable profit. The outflows of linkage 11, comprising monthly profit before tax and monthly taxable profit, are accumulated on a year-to-date basis as sublevels 3 and 4 of level 16.

Linkage 12 is defined to permit the direct transfer of monthly profit before tax through to the retained profit account of level 3 (via linkage 13), as well as to pick up the year-to-date profits (before tax and taxable), up to (but not including) the last month of each year, and add to them that month's profit figures. This results in the year totals occurring as the outflows of channels 2 and 3 in the twelfth month of each year. A cycle comprising 12 indices, all of which are zero except the twelfth, ensures this year-end calculation. This cycle is applied to the inflow channels 3 and 4, by M12.

Linkage 13 completes the calculation sequence by applying



	1	2	3
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	1	0
6	0	0	1
7	0	0	1
8	1	-1	-1

	1	2	3	4
1	1	0	0	0
2	1	0	1	0
3	0	1	0	1

	1	2	3	4	5	6	7	8
1	1	0	0	0	0	0	0	0
2	1	1	-¼	¼	-½	1	-1	1
3	1	0	0	0	0	0	0	0
4	1	1	-¼	¼	-½	1	-1	1

	1	2	3	4	5	6	7	8	9
1	1	1	1	-1	-1	-1	-1	-1	-1
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0

FIGURE 10.5: DIVIDEND AND TAXATION CALCULATION SECTOR OF THE HALLMARK FINANCIAL PLANNING MODEL

the respective rates for dividend and taxation (using M13) to the year totals for profit before tax and taxable profit, both of which are assigned to its inflow channels 2 and 3 respectively. Inflow channel 1 merely performs the transfer of monthly profit before tax to retained profits. A logical switch[4] is also necessary on inflow channels 2 and 3 to ensure that dividends and tax are only calculated on positive year-end profits (i.e. losses are ignored). This logical switch is the exact opposite of the one applied using M11 in respect of the carry-forward of losses from one year to the next.

Linkage 14 serves the purpose of reflecting the cash flows associated with capital expenditure, as specified by M14, while linkages 15 and 16 are defined for creditor payments (including dividend and tax payments) and debtor collections respectively. Boxcar delays are applied to each of these linkages in order to reflect the relevant time-lags associated with these cash flows. Finally, linkage 17 accommodates capital transactions associated with loan borrowing and repayments according to the program specified in M17.

(b) Model Inputs and Outputs

The model data base, consisting of all level opening balances,

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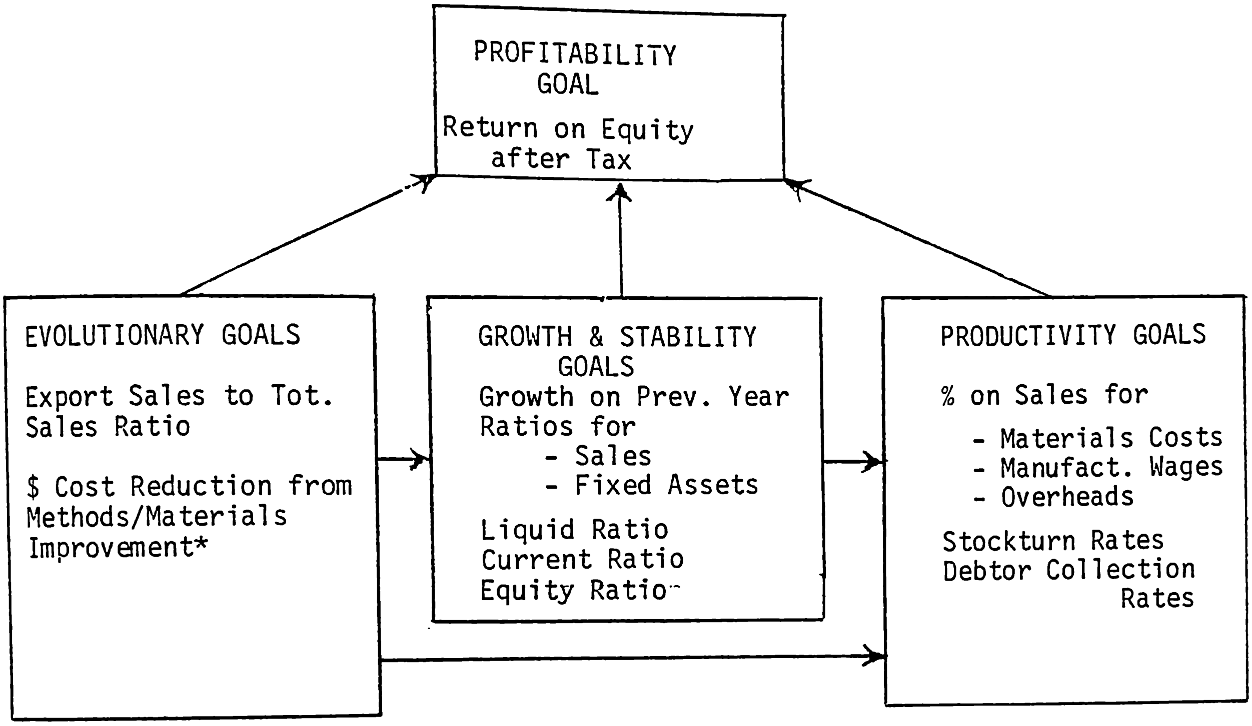
[4] This is a specific modulation pattern option (specified with M19 in this case) whereby the flow value is tested against a specified lower limit (zero in this instance) and assigned the value zero if it is less than that limit. Refer to Appendix B for details.

base flows, modulations, transformations and cycles was set up in the customary manner, with the GENINP program, after the structure of the model had been captured with the GENSPC program. As with most financial models, the transformation matrices perform a flow directing rather than a flow consumption role and thus comprise tables of 'zero-one' coefficients. The exceptions to this occur with T3 and T11 where fractional coefficients are used to split the cost of production according to its materials and labour content (T3), and to reduce the export sales and export market development expenditures to tax-allowable amounts (T11).

The various base flows and modulations were set up according to the roles defined for them, while the data tables associated with the two delays were derived in the manner described for the cash planning model.

As far as output from the model is concerned, as it is much larger than the cash planning model, and used for both short and long term planning in terms of the comprehensive set of performance measures defined within the goal structure of Figure 10.6, a wide range of tabular reports is necessary. These reports span the balance sheet, profit statement and cash statement formats using a monthly reporting frequency for the immediate 12 months ahead and an annual reporting frequency for the remaining years of a 5-year planning horizon. Sample reports (both monthly and annual) are set out in Figures 10.7 to 10.12 inclusive.

It should be noted that the section of these reports



* not calculated as a performance measure by the model but specified externally, and reflected in the data input to the model.

FIGURE 10.6: HALLMARK CORPORATE GOAL STRUCTURE AND ASSOCIATED PERFORMANCE MEASURES

showing the key performance measures obtained from the company's goal structure, is derived through the use of the performance factor routines of the report generating program GENREP. Details of the nature and use of these routines are provided in Appendix J. A further point of relevance to reporting concerns the 'accumulator' levels (levels 2, 6, 7, 8, 9 and 12 in this model) and the frequency at which they are reset to zero. If, for reports showing monthly results, it is desired to show year-to-date amounts in respect of these levels, their zero-setting frequency must be assigned the value of 12.

(c) Using the Model

Clearly this model is considerably more comprehensive than the cash planning model, as it inevitably must be in order to fulfil its role as a central tool in the corporate planning process. This role can be described more specifically as being to:

(i) Provide a powerful facility for testing alternative scenarios and strategies and establishing their full financial implictions for the firm, in both the short and the long-term.

(ii) Provide detailed 12 month budgets for managerial use, in respect of any chosen scenario-strategy alternative and any subsequent amendments and revisions thereto.

The parameter set, or range of data base factors, which exist in the model for the purposes of quantitatively describing alternative scenarios and strategies encompasses the following:

- Sales growth rates and seasonality cycles
- Cost of sales coefficients
- Production growth rates and seasonality cycles
- Materials purchasing growth rates
- Expense growth rates and seasonality cycles
- Interest rates and depreciation rates
- Inflation rates
- Creditor payments and debtors collections delay patterns
- Export Incentives
- Tax Rates
- Dividend rates and payment programmes
- Capital borrowing and repayment programmes
- Capital expenditure programmes

Selective access to any of the above factors is of course available through the use of the GENINP program. Fundamental structural changes to the model (e.g. the specification of new accounts, or account groups) require the use of the GENSPC program, followed by the use of GENINP to effect any extensions or amendments to the model data base which may arise as a result of a structural change to the model.

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                                                                                           PAGE 1
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                   RUN   1981 TARGETS VERSION 4          DATE  30-Apr-81
                                                   RESULTS FOR MONTH ENDING:-
REF   DESCRIPTION      UNITS          0      1      2      3      4      5      6      7      8      9     10     11     12
                                   1980    JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                -----------------------------------------------------------------------------


131 LOCAL MFG. SALES             1802.5   68.0  153.0  246.5  365.5  598.9  832.4 1048.8 1290.7 1477.7 1681.7 1902.7 2089.7
132 WHOLESALE SALES                60.0    2.8    6.3   10.2   15.1   20.7   26.3   31.2   37.1   44.8   53.2   62.3   70.0
133 EXPORT SALES                  890.0   25.0   87.5  150.0  237.5  350.0  462.5  600.0  737.5  862.5  987.5 1125.0 1250.0

134 TOTAL SALES                  2752.5   95.8  246.8  406.7  618.1  969.6 1321.1 1679.9 2065.3 2385.0 2722.4 3090.0 3409.7

135 LOCAL MARGIN                  674.4   26.2   59.0   95.1  140.9  228.7  316.6  397.8  488.9  561.0  639.7  724.9  797.0
136 WHOLESALE MARGIN               15.0    0.7    1.6    2.5    3.8    5.2    6.6    7.8    9.3   11.2   13.3   15.6   17.5
137 EXPORT MARGIN                 213.6    6.0   21.0   36.0   57.0   84.0  111.0  144.0  177.0  207.0  237.0  270.0  300.0

138 TOTAL MARGIN                  903.0   32.9   81.6  133.6  201.7  317.9  434.1  549.6  675.2  779.2  890.0 1010.4 1114.5

103 ADMINISTRATION                136.6   12.5   25.7   39.4   52.7   66.1   79.4   92.5  105.0  116.8  127.9  138.6  148.9
107 LOCAL MKTG.                    76.4    7.1   14.3   21.4   28.6   35.7   42.8   50.0   57.1   64.2   71.4   78.5   85.7
108 EXPORT MKTG.                  140.6    8.3   19.1   30.0   42.6   56.9   71.3   87.4  103.4  118.7  133.9  150.0  165.2
105 WAREHOUSE                      61.9    4.0    8.3   12.8   17.6   22.8   27.9   32.7   38.0   43.9   50.2   56.6   62.6
109 PRODUCTION                     91.8    8.8   17.7   26.5   35.4   44.2   53.1   61.9   70.8   79.6   88.5   97.3  106.2
110 R & D                          83.7    8.1   16.2   24.2   32.3   40.4   48.5   56.6   64.6   72.7   80.8   88.9   97.0
104 FIXED O/H                      91.7    9.0   18.0   26.9   35.8   44.6   53.5   62.5   71.5   80.5   89.5   98.4  107.3
106 MANAGEMENT                     45.5    5.1   10.2   15.2   20.3   25.4   30.5   35.6   40.7   45.7   50.8   55.9   61.0
140 CONTINGENCY                     0.0    3.5    7.0   10.5   14.0   17.5   21.0   24.5   28.0   31.5   35.0   38.5   42.0
129 TOTAL OVERHEAD                728.2   66.5  136.4  207.0  279.3  353.6  428.0  503.6  579.1  653.7  727.9  802.8  875.7

139 OTHER INCOME                   50.0    1.8    3.7    5.5    7.4    9.2   11.0   12.9   14.7   16.6   18.4   20.3   74.9

128 NET PROFIT                    224.8  -31.7  -51.2  -67.9  -70.2  -26.5   17.2   58.9  110.8  142.0  180.5  227.9  313.6
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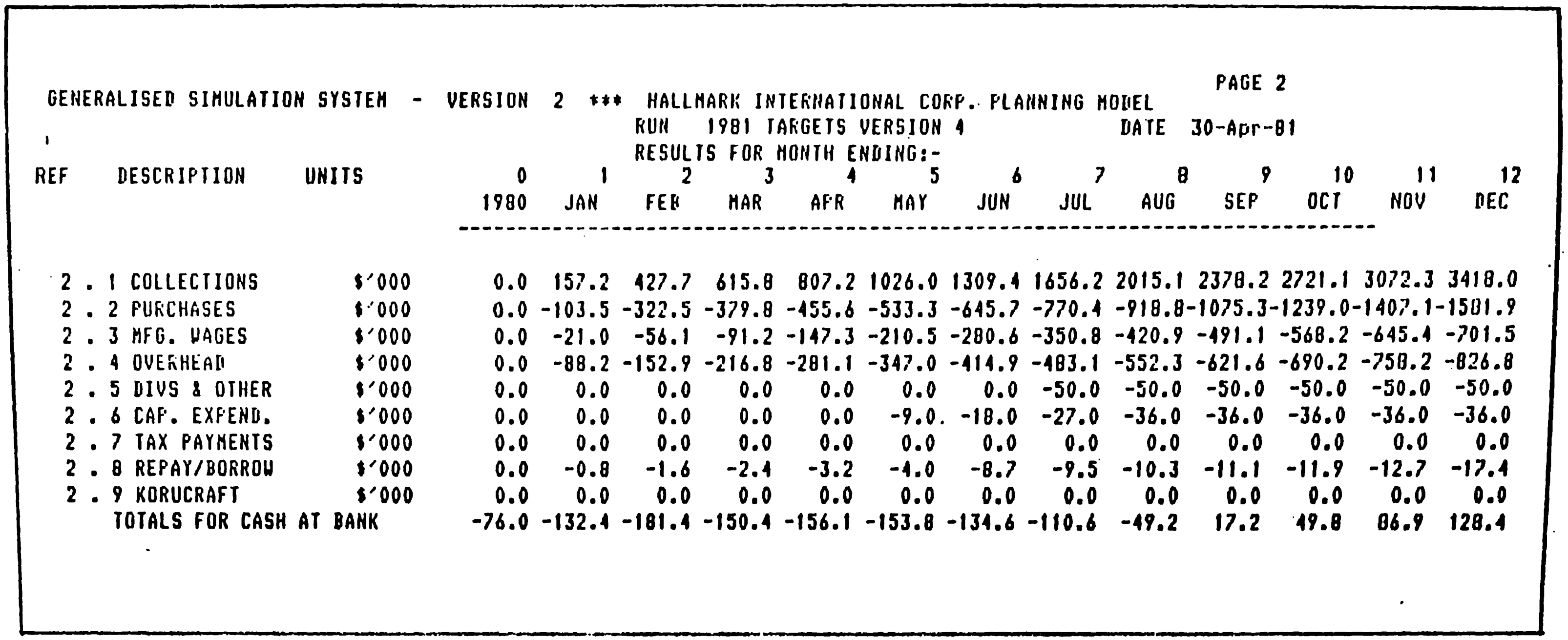
FIGURE 10.7: SAMPLE REPORT- INCOME STATEMENT OF THE HALLMARK FINANCIAL MODEL (MONTHLY)



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                                                                                    PAGE 2
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                   RUN    1981 TARGETS VERSION 4             DATE  30-Apr-81
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS             0      1      2      3      4      5      6      7      8      9     10     11     12
                                       1980    JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                       ----------------------------------------------------------------------------------


 2 . 1 COLLECTIONS        $'000         0.0  157.2  427.7  615.8  807.2 1026.0 1309.4 1656.2 2015.1 2378.2 2721.1 3072.3 3418.0
 2 . 2 PURCHASES          $'000         0.0 -103.5 -322.5 -379.8 -455.6 -533.3 -645.7 -770.4 -918.8-1075.3-1239.0-1407.1-1581.9
 2 . 3 MFG. WAGES         $'000         0.0  -21.0  -56.1  -91.2 -147.3 -210.5 -280.6 -350.8 -420.9 -491.1 -568.2 -645.4 -701.5
 2 . 4 OVERHEAD           $'000         0.0  -88.2 -152.9 -216.8 -281.1 -347.0 -414.9 -483.1 -552.3 -621.6 -690.2 -758.2 -826.8
 2 . 5 DIVS & OTHER       $'000         0.0    0.0    0.0    0.0    0.0    0.0    0.0  -50.0  -50.0  -50.0  -50.0  -50.0  -50.0
 2 . 6 CAP. EXPEND.       $'000         0.0    0.0    0.0    0.0    0.0   -9.0. -18.0  -27.0  -36.0  -36.0  -36.0  -36.0  -36.0
 2 . 7 TAX PAYMENTS       $'000         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 2 . 8 REPAY/BORROW       $'000         0.0   -0.8   -1.6   -2.4   -3.2   -4.0   -8.7   -9.5  -10.3  -11.1  -11.9  -12.7  -17.4
 2 . 9 KORUCRAFT          $'000         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
       TOTALS FOR CASH AT BANK        -76.0 -132.4 -181.4 -150.4 -156.1 -153.8 -134.6 -110.6  -49.2   17.2   49.8   86.9  128.4
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FIGURE 10.8: SAMPLE REPORT- CASH STATEMENT OF THE HALLMARK FINANCIAL MODEL (MONTHLY)

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                                                                                          PAGE 3
 GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                   RUN   1981 TARGETS VERSION 4           DATE  30-Apr-81
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION     UNITS              0      1      2      3      4      5      6      7      8      9     10     11     12
                                       1980    JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                     ---------------------------------------------------------------------------------


  1 . 1 BNZ TERM LOAN      $'000        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  1 . 2 BNX EXPORT A/C     $'000     -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0 -100.0
  1 . 3 DFC TERM LOAN      $'000      -66.0  -66.0  -66.0  -66.0  -66.0  -66.0  -62.1  -62.1  -62.1  -62.1  -62.1  -62.1  -58.2
  1 . 4 OTHER LOANS        $'000      -27.0  -26.2  -25.4  -24.6  -23.8  -23.0  -22.2  -21.4  -20.6  -19.8  -19.0  -18.2  -17.4
  1 . 5 S/HOLD CAPITAL     $'000      -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0  -60.0
  1 . 6 INT. PARTNERS.     $'000     -404.0 -404.0 -404.0 -404.0 -404.0 -404.0 -404.0 -354.0 -354.0 -354.0 -354.0 -354.0 -354.0
  1 . 7 ASSET REVAL RES.   $'000     -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0 -146.0
        TOTALS FOR CAPITAL & LOANS   -803.0 -802.2 -801.4 -800.6 -799.8 -799.0 -794.3 -743.5 -742.7 -741.9 -741.1 -740.3 -735.6

  3 . 1 BILLS PAYABLE      $'000     -207.0 -187.7  -53.0  -67.5  -95.5 -140.0 -177.3 -211.5 -228.4 -238.6 -248.6 -258.5 -246.9
  3 . 2 LOC CREDS-MAT      $'000     -100.0  -66.2  -65.0  -76.5 -105.1 -131.9 -147.2 -152.9 -152.9 -152.9 -162.5 -168.2 -139.5
  3 . 3 LOC CREDS-EXP      $'000     -105.0  -77.0  -76.1  -76.6  -78.5  -80.8  -81.2  -82.4  -82.5  -81.6  -81.0  -81.6  -79.9
  3 . 4 OTHER CREDS        $'000        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  3 . 5 DIV PROVISION      $'000        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0  -47.0
  3 . 6 TAX PROVISION      $'000        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  3 . 7 TAX DEFERRED       $'000      -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0  -22.0
  3 . 8 REVENUE RESERVE    $'000     -368.0 -336.3 -316.8 -300.1 -297.8 -341.5 -385.2 -426.9 -478.8 -510.0 -548.5 -595.9 -634.6
        TOTALS FOR CURRENT LIABS.    -802.0 -689.2 -532.9 -542.7 -598.8 -716.2 -812.9 -895.7 -964.6-1005.1-1062.5-1126.3-1170.0

 130 CASH AT BANK                     -76.0 -132.4 -181.4 -150.4 -156.1 -153.8 -134.6 -110.6  -49.2   17.2   49.8   86.9  128.4


 101 TOTAL LIABILITIES              -1681.0-1623.8-1515.7-1493.7-1554.7-1669.0-1741.7-1749.8-1756.5-1729.9-1753.8-1779.7-1777.2
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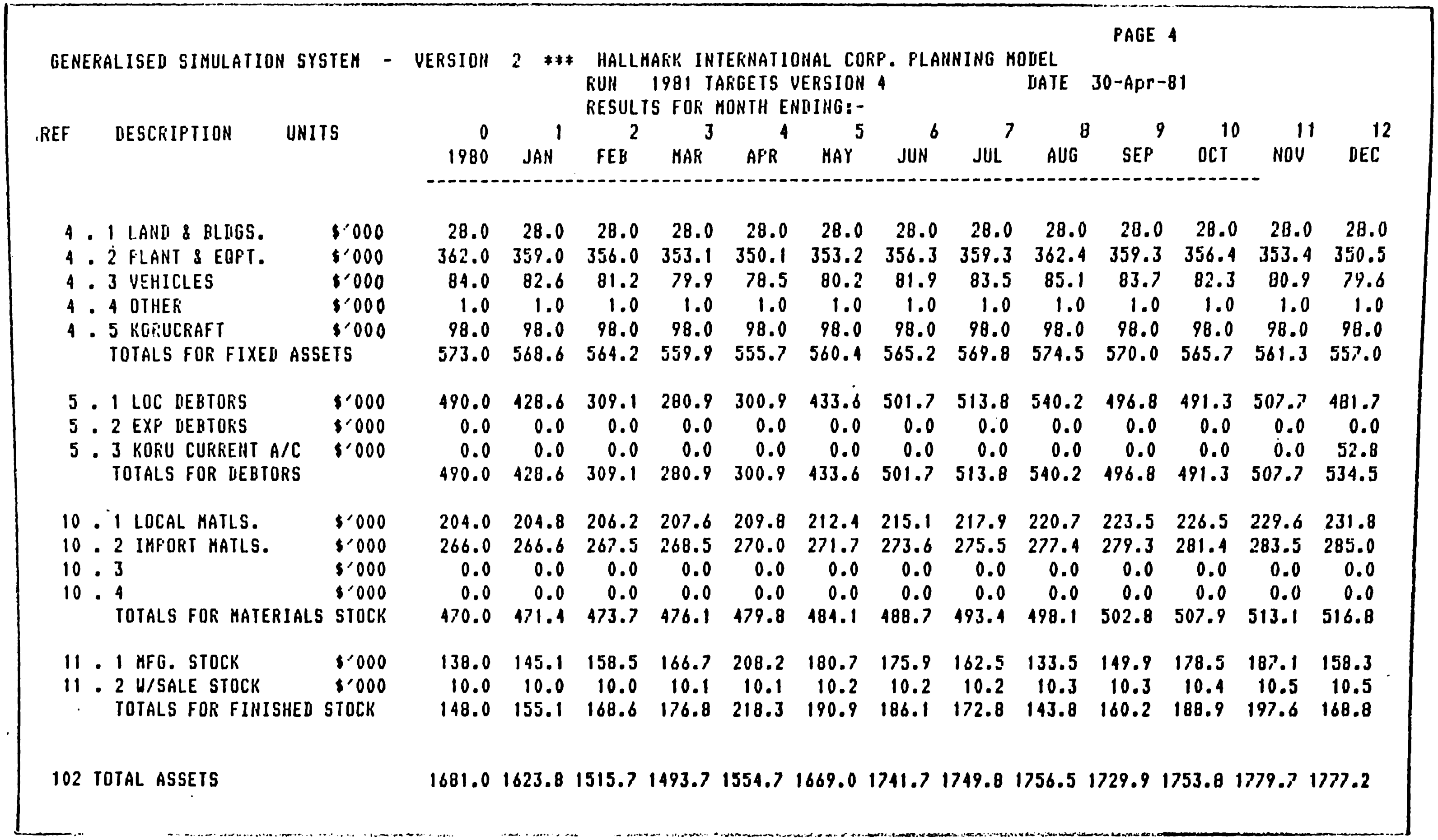
FIGURE 10.9: SAMPLE REPORT- BALANCE SHEET OF THE HALLMARK FINANCIAL MODEL (MONTHLY)



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                                                                                                           PAGE 4
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                   RUN   1981 TARGETS VERSION 4           DATE  30-Apr-81
                                                   RESULTS FOR MONTH ENDING:-
.REF    DESCRIPTION     UNITS           0       1       2       3       4       5       6       7       8       9      10      11      12
                                     1980     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
                                   -------------------------------------------------------------------------------------------------


   4 . 1 LAND & BLDGS.      $'000    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0    28.0
   4 . 2 PLANT & EQPT.      $'000   362.0   359.0   356.0   353.1   350.1   353.2   356.3   359.3   362.4   359.3   356.4   353.4   350.5
   4 . 3 VEHICLES           $'000    84.0    82.6    81.2    79.9    78.5    80.2    81.9    83.5    85.1    83.7    82.3    80.9    79.6
   4 . 4 OTHER              $'000     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
   4 . 5 KORUCRAFT          $'000    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0    98.0
         TOTALS FOR FIXED ASSETS    573.0   568.6   564.2   559.9   555.7   560.4   565.2   569.8   574.5   570.0   565.7   561.3   557.0

   5 . 1 LOC DEBTORS        $'000   490.0   428.6   309.1   280.9   300.9   433.6   501.7   513.8   540.2   496.8   491.3   507.7   481.7
   5 . 2 EXP DEBTORS        $'000     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   5 . 3 KORU CURRENT A/C   $'000     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    52.8
         TOTALS FOR DEBTORS         490.0   428.6   309.1   280.9   300.9   433.6   501.7   513.8   540.2   496.8   491.3   507.7   534.5

  10 . 1 LOCAL MATLS.       $'000   204.0   204.8   206.2   207.6   209.8   212.4   215.1   217.9   220.7   223.5   226.5   229.6   231.8
  10 . 2 IMPORT MATLS.      $'000   266.0   266.6   267.5   268.5   270.0   271.7   273.6   275.5   277.4   279.3   281.4   283.5   285.0
  10 . 3                    $'000     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  10 . 4                    $'000     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         TOTALS FOR MATERIALS STOCK 470.0   471.4   473.7   476.1   479.8   484.1   488.7   493.4   498.1   502.8   507.9   513.1   516.8

  11 . 1 MFG. STOCK         $'000   138.0   145.1   158.5   166.7   208.2   180.7   175.9   162.5   133.5   149.9   178.5   187.1   158.3
  11 . 2 W/SALE STOCK       $'000    10.0    10.0    10.0    10.1    10.1    10.2    10.2    10.2    10.3    10.3    10.4    10.5    10.5
         TOTALS FOR FINISHED STOCK  148.0   155.1   168.6   176.8   218.3   190.9   186.1   172.8   143.8   160.2   188.9   197.6   168.8


 102 TOTAL ASSETS                  1681.0  1623.8  1515.7  1493.7  1554.7  1669.0  1741.7  1749.8  1756.5  1729.9  1753.8  1779.7  1777.2
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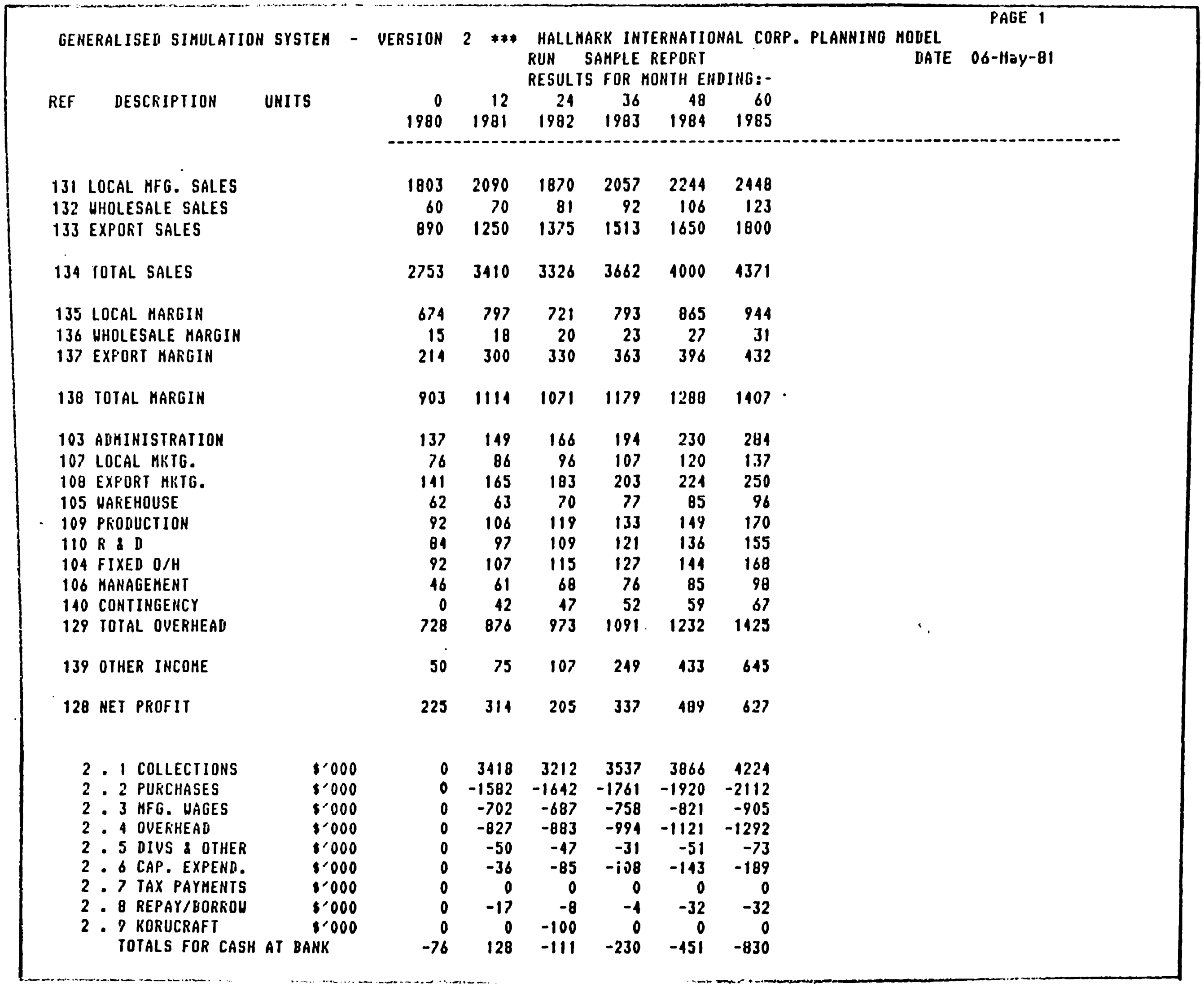
FIGURE 10.9: Continued......



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                                                                                          PAGE 1
   GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                      RUN   SAMPLE REPORT                    DATE  06-May-81
                                                      RESULTS FOR MONTH ENDING:-
  REF    DESCRIPTION     UNITS          0      12      24      36      48      60
                                     1980    1981    1982    1983    1984    1985
                                 -----------------------------------------------------------------------------


  131 LOCAL MFG. SALES               1803    2090    1870    2057    2244    2448
  132 WHOLESALE SALES                  60      70      81      92     106     123
  133 EXPORT SALES                    890    1250    1375    1513    1650    1800

  134 TOTAL SALES                    2753    3410    3326    3662    4000    4371

  135 LOCAL MARGIN                    674     797     721     793     865     944
  136 WHOLESALE MARGIN                 15      18      20      23      27      31
  137 EXPORT MARGIN                   214     300     330     363     396     432

  138 TOTAL MARGIN                    903    1114    1071    1179    1288    1407

  103 ADMINISTRATION                  137     149     166     194     230     284
  107 LOCAL MKTG.                      76      86      96     107     120     137
  108 EXPORT MKTG.                    141     165     183     203     224     250
  105 WAREHOUSE                        62      63      70      77      85      96
  109 PRODUCTION                       92     106     119     133     149     170
  110 R & D                            84      97     109     121     136     155
  104 FIXED O/H                        92     107     115     127     144     168
  106 MANAGEMENT                       46      61      68      76      85      98
  140 CONTINGENCY                       0      42      47      52      59      67
  129 TOTAL OVERHEAD                  728     876     973    1091    1232    1425

  139 OTHER INCOME                     50      75     107     249     433     645

  128 NET PROFIT                      225     314     205     337     489     627


    2 . 1 COLLECTIONS       $'000       0    3418    3212    3537    3866    4224
    2 . 2 PURCHASES         $'000       0   -1582   -1642   -1761   -1920   -2112
    2 . 3 MFG. WAGES        $'000       0    -702    -687    -758    -821    -905
    2 . 4 OVERHEAD          $'000       0    -827    -883    -994   -1121   -1292
    2 . 5 DIVS & OTHER      $'000       0     -50     -47     -31     -51     -73
    2 . 6 CAP. EXPEND.      $'000       0     -36     -85    -108    -143    -189
    2 . 7 TAX PAYMENTS      $'000       0       0       0       0       0       0
    2 . 8 REPAY/BORROW      $'000       0     -17      -8      -4     -32     -32
    2 . 9 KORUCRAFT         $'000       0       0    -100       0       0       0
          TOTALS FOR CASH AT BANK     -76     128    -111    -230    -451    -830
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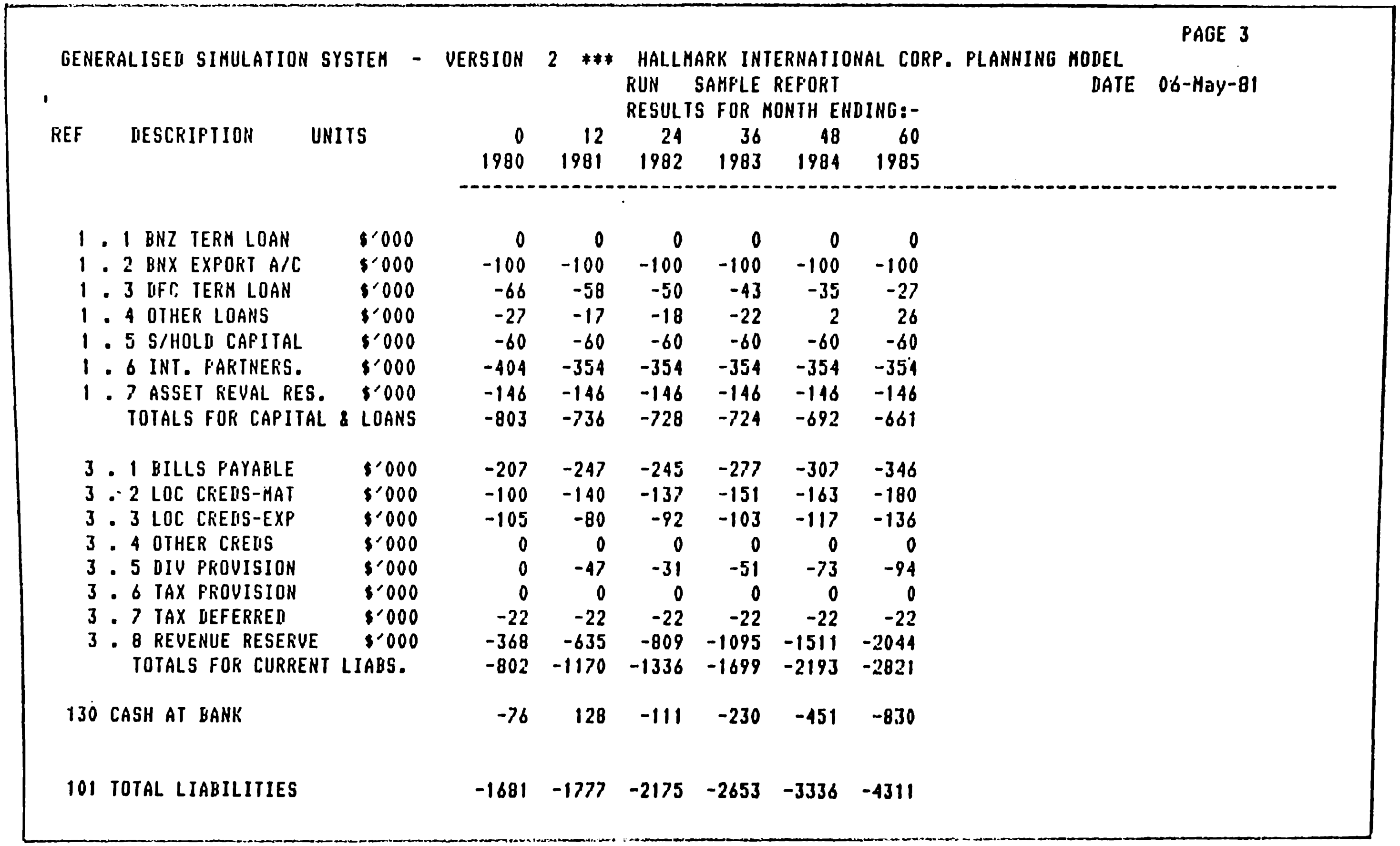
FIGURE 10.10: SAMPLE REPORT- INCOME STATEMENT AND CASH STATEMENT OF THE HALLMARK FINANCIAL MODEL (YEARLY)



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                                                                                          PAGE 3
   GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                     RUN   SAMPLE REPORT                   DATE  06-May-81
                                                     RESULTS FOR MONTH ENDING:-
  REF    DESCRIPTION     UNITS             0     12     24     36     48     60
                                        1980   1981   1982   1983   1984   1985
                                      ------------------------------------------------------------------------------

    1 . 1 BNZ TERM LOAN      $'000         0      0      0      0      0      0
    1 . 2 BNX EXPORT A/C     $'000      -100   -100   -100   -100   -100   -100
    1 . 3 DFC TERM LOAN      $'000       -66    -58    -50    -43    -35    -27
    1 . 4 OTHER LOANS        $'000       -27    -17    -18    -22      2     26
    1 . 5 S/HOLD CAPITAL     $'000       -60    -60    -60    -60    -60    -60
    1 . 6 INT. PARTNERS.     $'000      -404   -354   -354   -354   -354   -354
    1 . 7 ASSET REVAL RES.   $'000      -146   -146   -146   -146   -146   -146
          TOTALS FOR CAPITAL & LOANS    -803   -736   -728   -724   -692   -661

    3 . 1 BILLS PAYABLE      $'000      -207   -247   -245   -277   -307   -346
    3 . 2 LOC CREDS-MAT      $'000      -100   -140   -137   -151   -163   -180
    3 . 3 LOC CREDS-EXP      $'000      -105    -80    -92   -103   -117   -136
    3 . 4 OTHER CREDS        $'000         0      0      0      0      0      0
    3 . 5 DIV PROVISION      $'000         0    -47    -31    -51    -73    -94
    3 . 6 TAX PROVISION      $'000         0      0      0      0      0      0
    3 . 7 TAX DEFERRED       $'000       -22    -22    -22    -22    -22    -22
    3 . 8 REVENUE RESERVE    $'000      -368   -635   -809  -1095  -1511  -2044
          TOTALS FOR CURRENT LIABS.     -802  -1170  -1336  -1699  -2193  -2821

  130 CASH AT BANK                       -76    128   -111   -230   -451   -830


  101 TOTAL LIABILITIES                -1681  -1777  -2175  -2653  -3336  -4311
```

FIGURE 10.11: SAMPLE REPORT- BALANCE SHEET OF THE HALLMARK FINANCIAL MODEL (YEARLY)

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                                                                                          PAGE 4
   GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                     RUN   SAMPLE REPORT                     DATE  06-May-81
                                                     RESULTS FOR MONTH ENDING:-
  REF    DESCRIPTION      UNITS              0     12     24     36     48     60
                                          1980   1981   1982   1983   1984   1985
                                          ---------------------------------------------------------------------------

    4 . 1 LAND & BLDGS.      $'00           28     28     28     28     28     28
    4 . 2 PLANT & EQPT.      $'00          362    350    373    405    455    530
    4 . 3 VEHICLES           $'00           84     80     89    107    133    168
    4 . 4 OTHER              $'00            1      1      1      1      1      1
    4 . 5 KORUCRAFT          $'00           98     98    198    198    198    198
          TOTALS FOR FIXED ASSETS          573    557    689    739    815    925

    5 . 1 LOC DEBTORS        $'000         490    482    595    720    855   1001
    5 . 2 EXP DEBTORS        $'000           0      0      0      0      0      0
    5 . 3 KORU CURRENT A/C   $'000           0     53    135    356    758   1368
          TOTALS FOR DEBTORS               490    534    730   1076   1612   2369

   10 . 1 LOCAL MATLS.       $'000         204    232    259    289    322    358
   10 . 2 IMPORT MATLS.      $'000         266    285    304    324    346    371
   10 . 3                    $'000           0      0      0      0      0      0
   10 . 4                    $'000           0      0      0      0      0      0
          TOTALS FOR MATERIALS STOCK       470    517    563    613    668    729

   11 . 1 MFG. STOCK         $'000         138    158    182    213    228    275
   11 . 2 W/SALE STOCK       $'000          10     11     11     12     13     14
          TOTALS FOR FINISHED STOCK        148    169    193    225    240    289


  102 TOTAL ASSETS                        1681   1777   2175   2653   3336   4311
```
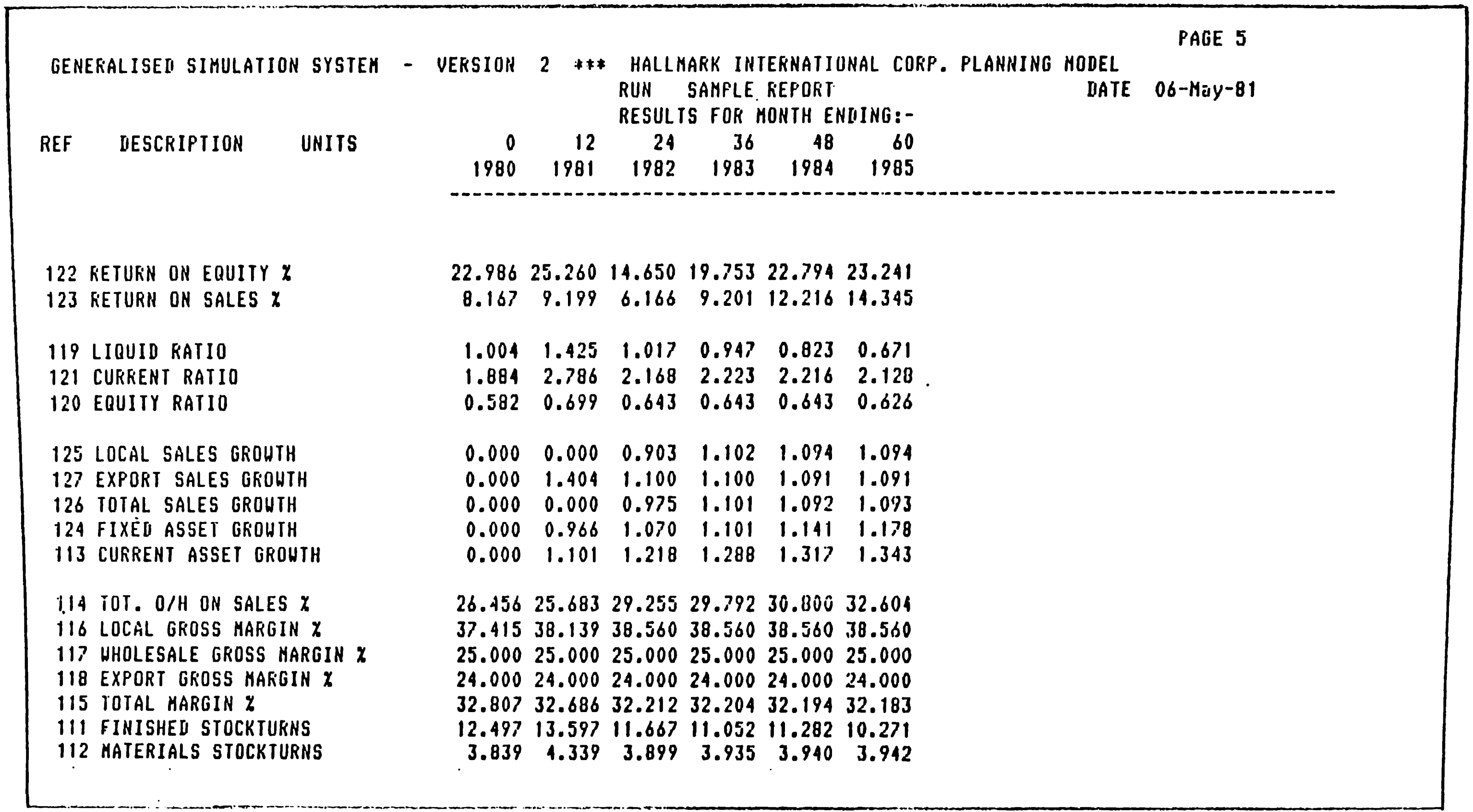

FIGURE 10.11: Continued......



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                                                                                      PAGE 5
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK INTERNATIONAL CORP. PLANNING MODEL
                                                   RUN   SAMPLE REPORT                DATE  06-May-81
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS             0       12      24      36      48      60
                                       1980     1981    1982    1983    1984    1985
                                       ------------------------------------------------------------------------


122 RETURN ON EQUITY %                22.986 25.260 14.650 19.753 22.794 23.241
123 RETURN ON SALES %                  8.167  9.199  6.166  9.201 12.216 14.345

119 LIQUID RATIO                       1.004  1.425  1.017  0.947  0.823  0.671
121 CURRENT RATIO                      1.884  2.786  2.168  2.223  2.216  2.128
120 EQUITY RATIO                       0.582  0.699  0.643  0.643  0.643  0.626

125 LOCAL SALES GROWTH                 0.000  0.000  0.903  1.102  1.094  1.094
127 EXPORT SALES GROWTH                0.000  1.404  1.100  1.100  1.091  1.091
126 TOTAL SALES GROWTH                 0.000  0.000  0.975  1.101  1.092  1.093
124 FIXED ASSET GROWTH                 0.000  0.966  1.070  1.101  1.141  1.178
113 CURRENT ASSET GROWTH               0.000  1.101  1.218  1.288  1.317  1.343

114 TOT. O/H ON SALES %               26.456 25.683 29.255 29.792 30.800 32.604
116 LOCAL GROSS MARGIN %              37.415 38.139 38.560 38.560 38.560 38.560
117 WHOLESALE GROSS MARGIN %          25.000 25.000 25.000 25.000 25.000 25.000
118 EXPORT GROSS MARGIN %             24.000 24.000 24.000 24.000 24.000 24.000
115 TOTAL MARGIN %                    32.807 32.686 32.212 32.204 32.194 32.183
111 FINISHED STOCKTURNS               12.497 13.597 11.667 11.052 11.282 10.271
112 MATERIALS STOCKTURNS               3.839  4.339  3.899  3.935  3.940  3.942
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FIGURE 10.12: SAMPLE REPORT- SELECTED PERFORMANCE MEASURES OF THE HALLMARK FINANCIAL MODEL

CHAPTER 11

APPLICATION II - THE HALLMARK PRODUCTION PLANNING MODEL

This chapter focuses on a third model developed for Hallmark International using the SSD methodology - a production planning model for use in the short term planning of monthly resource requirements (materials and labour) and the concurrent projection of the direct unit costs of the company's products. The nature of this model is such that the capability of the methodology to cope with highly disaggregated variables and their interdependencies, in both the primal and dual forms, is utilised.

The purpose of the model is to support the production planning process by deriving the monthly production volumes for each product, together with their associated monthly resource requirements (in materials, labour and machine hours) for a given set of annual product volumes, resource usage coefficients and monthly production indices. This 'backward-pass' explosion is performed by the primal form of the model, while for the same set of data, the 'forward-pass' implosion constituting the dual form results in the calculation of final product unit costs - associated with any given set of resource unit costs. Thus the direct costs per unit ofproduct and their likely pattern of change can be established for any given pattern of change in the resource unit costs.

11.1 Model Structure

The flow diagram of the model as a vectorised 8-level 15- linkage network is shown in Figure 11.1. The sub-levels arising from vectorisation are as defined in Table 11.1

TABLE 11.1: LEVEL DEFINITIONS OF THE PRODUCTION PLANNING MODEL

Level No.	Level Description (Account Group)	Sub-level Description (Accounts)
1.	Packs Group A	1. P5
		2. P6
		3. P7
		4. P8
		5. P9
		6. P10
		7. P11
		8. P19
		9. P20
		10. P21
2.	Packs Group B	1. P22
		2. P23
		3. P24
		4. P24
		5. P26
		6. P28
		7. P30
		8. P31
		9. P32
		10. P33
3.	Packs Group C	1. P34
		2. P35
		3. P36
		4. P37
		5. P38
		6. P39
		7. SC1
		8. SC2
		9. SC3
4.	Tents	1. T1
		2. T2
		3. T3
		4. T4
		5. T5
		6. T6
		7. T7
		8. TF1
		9. TF2

TABLE 11.1: continued ....

Level No.	Level Description (Account Group)	Sub-level Description (Accounts)
5.	Sleeping Bags	1. SB2
		2. SB3
		3. SB4
		4. SB5
		5. SB6
		6. CB1
		7. CB2
		8. BC1
		9. PA1
		10. PA2
6.	Materials Group A	1. Cordura heavy
		2. F306 nylon
		3. F300 nylon
		4. Ripstop 210T
		5. Polyester WB
		6. Mesh back bank
		7. Ripstop Mat. Ch.
		8. Canvas
		9. Japara
7.	Materials Group B	1. Cuff matl.
		2. Parka mesh
		3. Cire ripstop
		4. Cire pre-dyed
		5. Hollofill 10 oz
		6. Hollofill 6 oz
		7. Pl dyed PR 210
		8. Pl dyed UNPR 190
		9. Polyester 12 x 12
		10. Mesh F50
8.	Machine & Labour hours	1. Pack M/c hrs
		2. Tents M/c hrs
		3. S/bag M/c hrs
		4. Parka M/c hrs
		5. Other M/c hrs
		6. Pack Lab. hrs
		7. Tent Lab. hrs
		8. S/bag Lab. hrs
		9. Parka Lab. hrs
		10. Other Lab. hrs

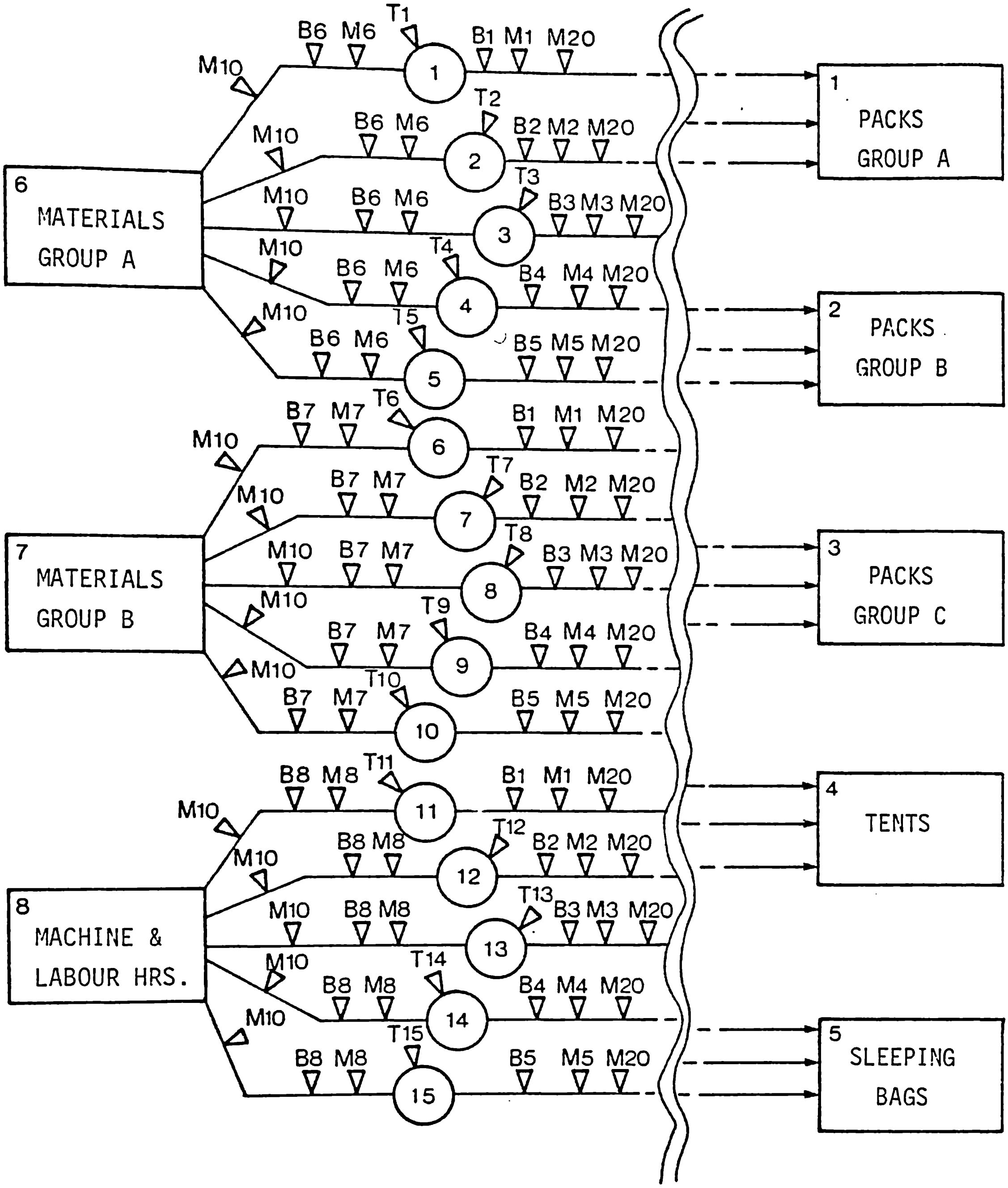


FIGURE 11.1: FLOW DIAGRAM FOR THE HALLMARK PRODUCTION PLANNING MODEL

In order to preserve clarity in the flow diagram of Figure 11.1, the complete linkage pattern whereby every one of the three resource levels is linked to every one of the 5 product levels, has been only partially drawn in. In actual fact linkages 1 to 5 link _level 6_ to levels 1, 2, 3, 4 and 5 respectively; linkages 6 to 10 link _level 7_ to levels 1, 2, 3, 4 and 5 respectively, and linkages 11 to 15 link _level 8_ to levels 1, 2, 3, 4 and 5 respectively. Thus base flows B1 to B5 initialise the production flows of Packs Group A, Packs Group B, Packs Group C, Tents and Sleeping Bags respectively, while modulations M1 to M5 provide the corresponding growth patterns for those flows. Each of these modulations utilises a cyclical index series to reflect the monthly pattern of production to be followed in respect of each product group.

Transformations T1 to T15 carry the resource consumption coefficients for each of the five product groups, in respect of each of the three resource groups. Thus each coefficient, in any given transformation table, equates to the number of resource units of a particular resource consumed, per unit of a particular product produced.

The outflow unit costs are initialised with base values assigned by B6, B7 and B8, being the initial resource unit costs of the resources of levels 6, 7 and 8 respectively. These are then subject to modulation by M6, M7 and M8 respectively, which permit unique growth patterns to be assigned to each resource unit cost.

Modulations M10 and M20 are defined solely to adjust for the fact that for levels with multiple inflows, the inflows are summed and their unit costs are averaged, when deriving the levels and their average unit costs. For this model the reverse convention is required - the inflows should be averaged and their unit costs summed[1]. M20 and M10 correct for this by scaling the inflows by a factor of 1/3 (M20) and the outflows by a compensating factor of 3 (M10).

The flow equations for both the primal and dual forms of the model, are summarised in Tables 11.2 and 11.3 respectively.

11.2 Model Inputs and Outputs

The model data base comprises 15 transformation matrices, 10 modulation matrices, and 8 base flows/flow unit cost tables, together with the initial values for the eight model levels (and their associated average unit costs). The data for the transformations are derived from the standard product specifications for each product, while those for the production modulations (M1 to M5) are set in accordance with the pattern of monthly production desired for each product[2]. The base flows correspond to the annual total production (in units) to be achieved in respect of each product item, while the level initial values are set at zero for this model.

---

1. This arises from the basic definition of the linkages of this model. Each 'product' level has three linkages only because there are three resource levels required and not because there are three equivalent sources ofproduction for the products of that level. Only one production flow vector exists but it must be applied to each of the three linkages.

2. In this case these are specified using a series of five production 'seasonality' cycles which can be coupled with longer term growth coefficients within each modulation, if desired.

TABLE 11.2: FLOW EQUATIONS OF THE HALLMARK PRODUCTION MODEL (PRIMAL FORM)

Linkage No.	Flow Description (Transaction Type)			Is Equal to	Transformed by	Modulated by	Delayed by ....
1.	Packs Group A	Production	- Inflows	Base Flow B1	-	M1 and M20	-
		Resources	- Outflows	Own Inflow	T1	-	
2.	Packs Group B	Production	- Inflows	Base Flow B2	-	M2 and M20	-
		Resources	- Outflows	Own Inflow	T2	-	-
3.	Packs Group C	Production	- Inflows	Base Flow B3	-	M3 and M20	-
		Resources	- Outflows	Own Inflow	T3	-	-
4.	Tents	Production	- Inflows	Base Flow B4	-	M4 and M20	-
		Resources	- Outflows	Own Inflow	T4	-	-
5.	Sleeping Bags	Production	- Inflows	Base Flow B5	-	M5 and M20	-
		Resources	- Outflows	Own Inflow	T5	-	-

The above equations are repeated for Linkages 6 to 10 (with transformations T1 to T5 being replaced by transformations T6 to T10) and for Linkages 11 to 15 (with transformations T1 to T5 being replaced by transformations T11 to T15)

TABLE 11.3: FLOW EQUATIONS OF THE HALLMARK PRODUCTION MODEL (DUAL FORM)

Linkage No.	Flow Description (Transaction Type)		Is Equal to	Transformed by	Modulated by	Delayed by ....
1.	Packs Group A	Resource Costs - Outflows	Base Cost B6	-	M6	-
		Product Costs - Inflows	Own Outflow	T1	-	-
2.	Packs Group B	Resource Costs - Outflows	Base Cost B6	-	M6	-
		Product Costs - Inflows	Own Outflow	T2	-	-
3.	Packs Group C	Resource Costs - Outflows	Base Cost B6	-	M6	-
		Product Costs - Inflows	Own Outflow	T3	-	-
4.	Tents	Resource Costs - Outflows	Base Cost B6	-	M6	-
		Product Costs - Inflows	Own Outflow	T4	-	-
5.	Sleeping Bags	Resource Costs - Outflows	Base Cost B6	-	M6	-
		Product Costs - Inflows	Own Outflow	T5	-	-

The above equations are repeated for Linkages 6 to 10 (with transformations T1 to T5 being replaced by transformations T6 to T10, base cost B6 being replaced by B7 and modulation M6 being replaced by M7) - and Linkages 11 to 15 (with transformations T1 to T5 being replaced by T11 to T15, base cost B6 being replaced by B8, and modulation M6 being replaced by M8)

The level average unit costs for each product item are similarly set to zero since they will be computed in the course of the dual calculations of the model. The resource average unit costs will automatically be assigned the values given to the base unit costs of their corresponding outflows (B6, B7 and B8 respectively). These in turn are determined as the current unit costs of the resources to the company with their respective modulations M6, M7 and M8 reflecting the anticipated patterns of change in them, over the 12 months of the planning horizon. The modulations M20 and M10 are used to apply constant scaling factors to the inflows and outflows of each linkage, as explained earlier.

Output from one 12 month run of the model is shown in Figures 11.2, 11.3 and 11.4. Figure 11.2 shows the full monthly production programme for each of the final products. Figure 11.3 lists the corresponding resource requirements, by month and resource type, while Figure 11.4 provides a schedule of the final product unit cost build-ups for each month of the planning period - derived from the dual form of the model.

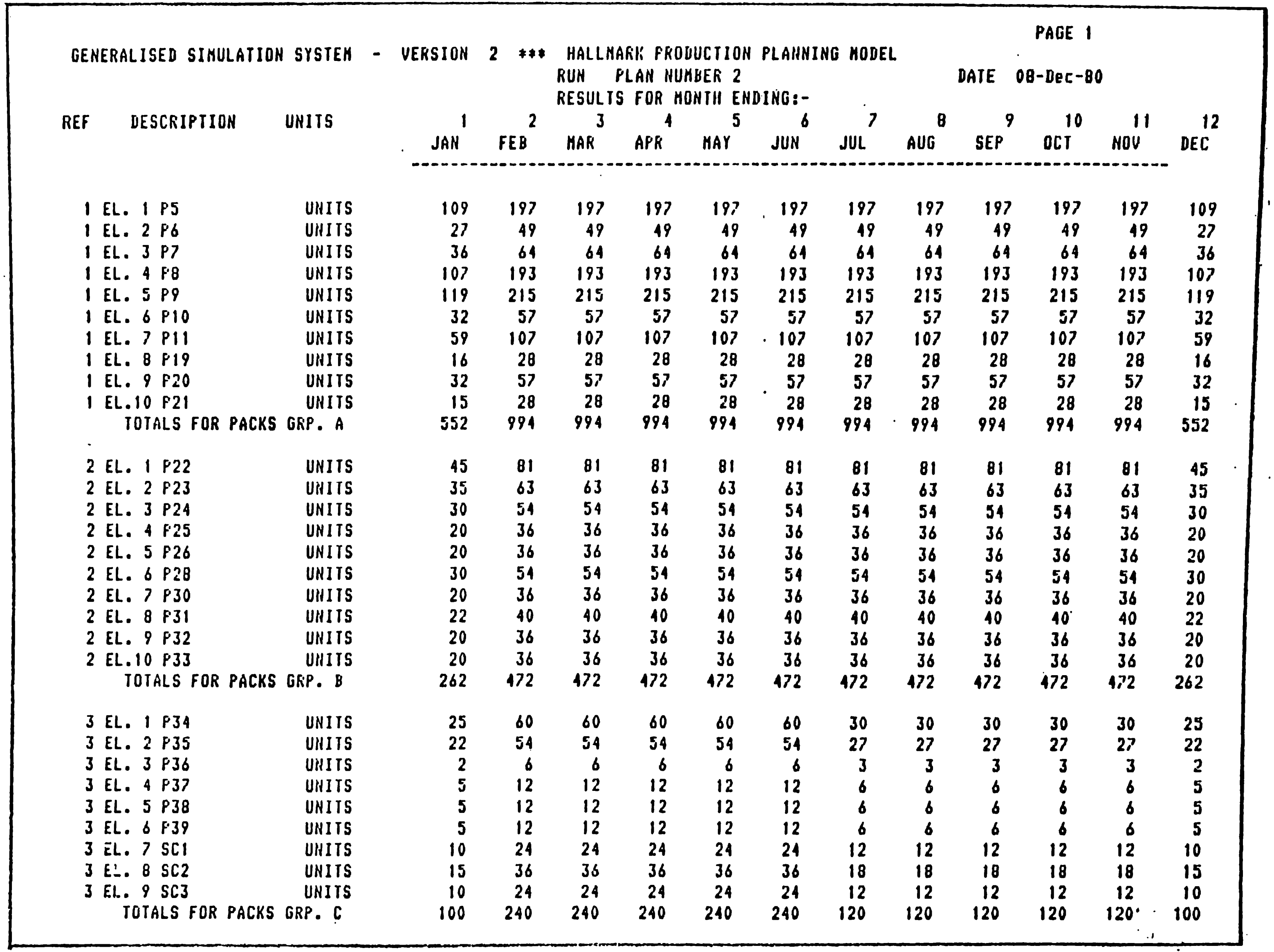
11.3 Using the Model

As a short run planning tool the model is capable of quickly establishing the implications on monthly resource requirements of changes in the annual level of final production and/or the pattern of monthly production for any given product item or group of products. The product costing facility provided also enables monthly cost schedules to be produced which can reflect any given pattern of change in resource unit costs. Finally both the monthly resource requirements and product unit cost schedules can be run to reflect any changes in the technical coefficients of resource consumption.

Thus the parameter set available to management encompasses:

- monthly production 'seasonality' patterns
- monthly production growth rates
- coefficients of resource consumption
- resource unit costs
- resource unit cost growth rates

Although the reports presented here all relate to monthly figures, the model can provide year-to-date projections, in respect of production units and resource requirements, merely by altering the 'zero-set' frequency associated with each level, from 1 to 12, using the GENSPC program (refer Appendix E). Extension of the planning horizon beyond 12 months naturally enables longer term projection of annual production volumes, resource requirements and product unit costs.



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                                                                                                  PAGE 1
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN    PLAN NUMBER 2                        DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS          1      2      3      4      5      6      7      8      9     10     11     12
                                     JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                    -------------------------------------------------------------------------------

  1 EL. 1 P5            UNITS        109    197    197    197    197    197    197    197    197    197    197    109
  1 EL. 2 P6            UNITS         27     49     49     49     49     49     49     49     49     49     49     27
  1 EL. 3 P7            UNITS         36     64     64     64     64     64     64     64     64     64     64     36
  1 EL. 4 P8            UNITS        107    193    193    193    193    193    193    193    193    193    193    107
  1 EL. 5 P9            UNITS        119    215    215    215    215    215    215    215    215    215    215    119
  1 EL. 6 P10           UNITS         32     57     57     57     57     57     57     57     57     57     57     32
  1 EL. 7 P11           UNITS         59    107    107    107    107    107    107    107    107    107    107     59
  1 EL. 8 P19           UNITS         16     28     28     28     28     28     28     28     28     28     28     16
  1 EL. 9 P20           UNITS         32     57     57     57     57     57     57     57     57     57     57     32
  1 EL.10 P21           UNITS         15     28     28     28     28     28     28     28     28     28     28     15
    TOTALS FOR PACKS GRP. A          552    994    994    994    994    994    994    994    994    994    994    552

  2 EL. 1 P22           UNITS         45     81     81     81     81     81     81     81     81     81     81     45
  2 EL. 2 P23           UNITS         35     63     63     63     63     63     63     63     63     63     63     35
  2 EL. 3 P24           UNITS         30     54     54     54     54     54     54     54     54     54     54     30
  2 EL. 4 P25           UNITS         20     36     36     36     36     36     36     36     36     36     36     20
  2 EL. 5 P26           UNITS         20     36     36     36     36     36     36     36     36     36     36     20
  2 EL. 6 P28           UNITS         30     54     54     54     54     54     54     54     54     54     54     30
  2 EL. 7 P30           UNITS         20     36     36     36     36     36     36     36     36     36     36     20
  2 EL. 8 P31           UNITS         22     40     40     40     40     40     40     40     40     40     40     22
  2 EL. 9 P32           UNITS         20     36     36     36     36     36     36     36     36     36     36     20
  2 EL.10 P33           UNITS         20     36     36     36     36     36     36     36     36     36     36     20
    TOTALS FOR PACKS GRP. B          262    472    472    472    472    472    472    472    472    472    472    262

  3 EL. 1 P34           UNITS         25     60     60     60     60     60     30     30     30     30     30     25
  3 EL. 2 P35           UNITS         22     54     54     54     54     54     27     27     27     27     27     22
  3 EL. 3 P36           UNITS          2      6      6      6      6      6      3      3      3      3      3      2
  3 EL. 4 P37           UNITS          5     12     12     12     12     12      6      6      6      6      6      5
  3 EL. 5 P38           UNITS          5     12     12     12     12     12      6      6      6      6      6      5
  3 EL. 6 P39           UNITS          5     12     12     12     12     12      6      6      6      6      6      5
  3 EL. 7 SC1           UNITS         10     24     24     24     24     24     12     12     12     12     12     10
  3 EL. 8 SC2           UNITS         15     36     36     36     36     36     18     18     18     18     18     15
  3 EL. 9 SC3           UNITS         10     24     24     24     24     24     12     12     12     12     12     10
    TOTALS FOR PACKS GRP. C          100    240    240    240    240    240    120    120    120    120    120    100
```

FIGURE 11.2: SAMPLE REPORT- PRODUCTION SCHEDULE OF THE HALLMARK PRODUCTION MODEL

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                                                                                                PAGE 2
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN   PLAN NUMBER 2                      DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF     DESCRIPTION     UNITS           1      2      3      4      5      6      7      8      9     10     11     12
                                      JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                     ------------------------------------------------------------------------------------


  4 EL. 1 T1            UNITS          13     27     27     27     27     27      0      0      0      0      0      0
  4 EL. 2 T2            UNITS          45     91     91     91     91     91      0      0      0      0      0      0
  4 EL. 3 T3            UNITS          13     27     27     27     27     27      0      0      0      0      0      0
  4 EL. 4 T4            UNITS          18     36     36     36     36     36      0      0      0      0      0      0
  4 EL. 5 T5            UNITS          13     27     27     27     27     27      0      0      0      0      0      0
  4 EL. 6 T6            UNITS          18     36     36     36     36     36      0      0      0      0      0      0
  4 EL. 7 T7            UNITS           9     18     18     18     18     18      0      0      0      0      0      0
  4 EL. 8 TF1           UNITS          18     36     36     36     36     36      0      0      0      0      0      0
  4 EL. 9 TF2           UNITS          18     36     36     36     36     36      0      0      0      0      0      0
      TOTALS FOR TENTS                166    337    337    337    337    337      0      0      0      0      0      0

  5 EL. 1 SB2           UNITS           0      0      0      0      0      0    255    255    255    255    255    126
  5 EL. 2 SB3           UNITS           0      0      0      0      0      0     91     91     91     91     91     45
  5 EL. 3 SB4           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL. 4 SB5           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL. 5 SB6           UNITS           0      0      0      0      0      0     27     27     27     27     27     13
  5 EL. 6 CB1           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL. 7 CB2           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL. 8 BC1           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL. 9 PA1           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
  5 EL.10 ST1           UNITS           0      0      0      0      0      0      0      0      0      0      0      0
      TOTALS FOR SLEEPING BAGS          0      0      0      0      0      0    373    373    373    373    373    184
```
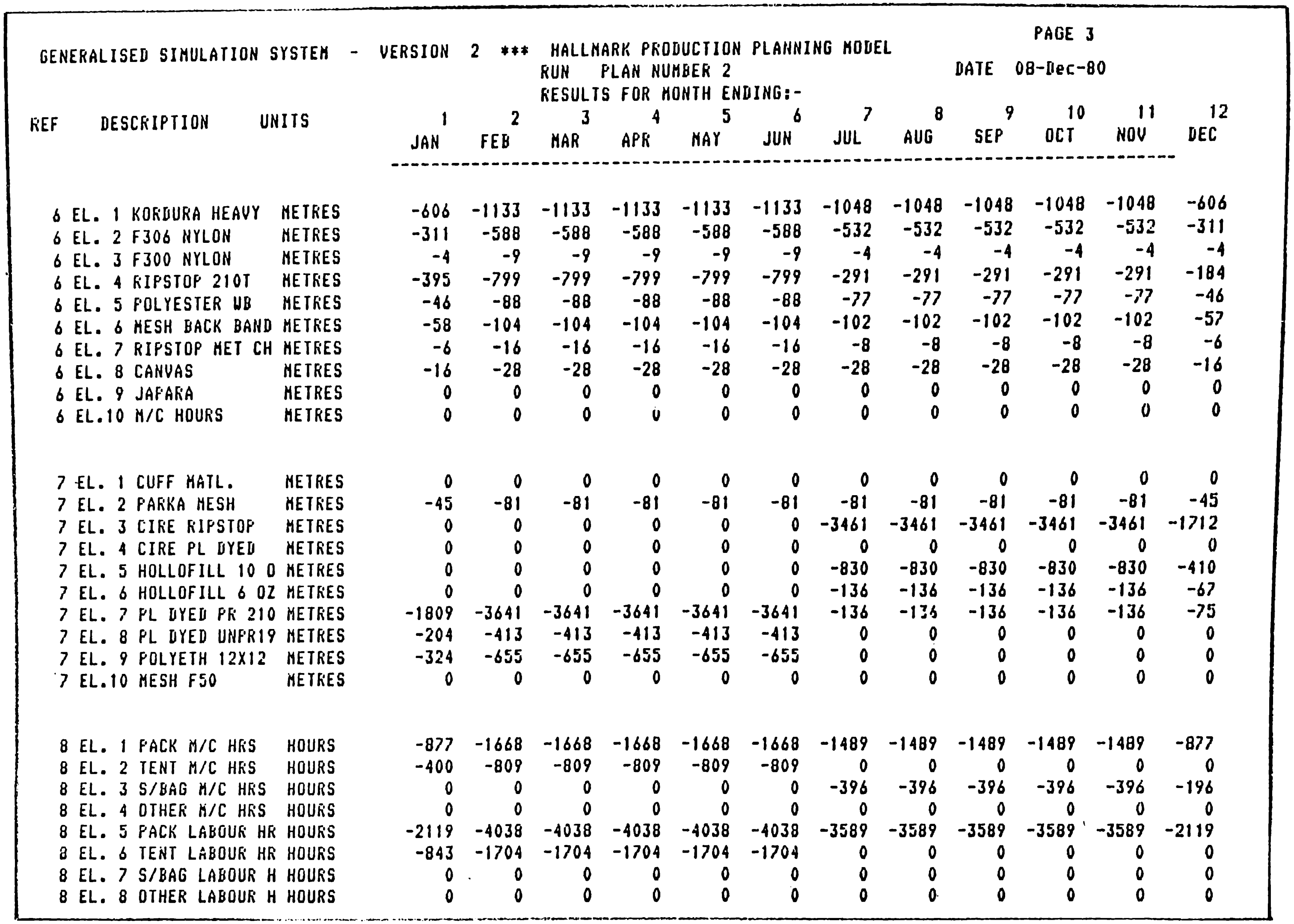

FIGURE 11.2: Continued......



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                                                                                             PAGE 3
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN   PLAN NUMBER 2                  DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF   DESCRIPTION     UNITS           1      2      3      4      5      6      7      8      9     10     11     12
                                    JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                               ---------------------------------------------------------------------------------


  6 EL. 1 KORDURA HEAVY  METRES    -606  -1133  -1133  -1133  -1133  -1133  -1048  -1048  -1048  -1048  -1048   -606
  6 EL. 2 F306 NYLON     METRES    -311   -588   -588   -588   -588   -588   -532   -532   -532   -532   -532   -311
  6 EL. 3 F300 NYLON     METRES      -4     -9     -9     -9     -9     -9     -4     -4     -4     -4     -4     -4
  6 EL. 4 RIPSTOP 210T   METRES    -395   -799   -799   -799   -799   -799   -291   -291   -291   -291   -291   -184
  6 EL. 5 POLYESTER WB   METRES     -46    -88    -88    -88    -88    -88    -77    -77    -77    -77    -77    -46
  6 EL. 6 MESH BACK BAND METRES     -58   -104   -104   -104   -104   -104   -102   -102   -102   -102   -102    -57
  6 EL. 7 RIPSTOP MET CH METRES      -6    -16    -16    -16    -16    -16     -8     -8     -8     -8     -8     -6
  6 EL. 8 CANVAS         METRES     -16    -28    -28    -28    -28    -28    -28    -28    -28    -28    -28    -16
  6 EL. 9 JAPARA         METRES       0      0      0      0      0      0      0      0      0      0      0      0
  6 EL.10 M/C HOURS      METRES       0      0      0      0      0      0      0      0      0      0      0      0


  7 EL. 1 CUFF MATL.     METRES       0      0      0      0      0      0      0      0      0      0      0      0
  7 EL. 2 PARKA MESH     METRES     -45    -81    -81    -81    -81    -81    -81    -81    -81    -81    -81    -45
  7 EL. 3 CIRE RIPSTOP   METRES       0      0      0      0      0      0  -3461  -3461  -3461  -3461  -3461  -1712
  7 EL. 4 CIRE PL DYED   METRES       0      0      0      0      0      0      0      0      0      0      0      0
  7 EL. 5 HOLLOFILL 10 O METRES       0      0      0      0      0      0   -830   -830   -830   -830   -830   -410
  7 EL. 6 HOLLOFILL 6 OZ METRES       0      0      0      0      0      0   -136   -136   -136   -136   -136    -67
  7 EL. 7 PL DYED PR 210 METRES   -1809  -3641  -3641  -3641  -3641  -3641   -136   -136   -136   -136   -136    -75
  7 EL. 8 PL DYED UNPR19 METRES    -204   -413   -413   -413   -413   -413      0      0      0      0      0      0
  7 EL. 9 POLYETH 12X12  METRES    -324   -655   -655   -655   -655   -655      0      0      0      0      0      0
  7 EL.10 MESH F50       METRES       0      0      0      0      0      0      0      0      0      0      0      0


  8 EL. 1 PACK M/C HRS   HOURS     -877  -1668  -1668  -1668  -1668  -1668  -1489  -1489  -1489  -1489  -1489   -877
  8 EL. 2 TENT M/C HRS   HOURS     -400   -809   -809   -809   -809   -809      0      0      0      0      0      0
  8 EL. 3 S/BAG M/C HRS  HOURS        0      0      0      0      0      0   -396   -396   -396   -396   -396   -196
  8 EL. 4 OTHER M/C HRS  HOURS        0      0      0      0      0      0      0      0      0      0      0      0
  8 EL. 5 PACK LABOUR HR HOURS    -2119  -4038  -4038  -4038  -4038  -4038  -3589  -3589  -3589  -3589  -3589  -2119
  8 EL. 6 TENT LABOUR HR HOURS     -843  -1704  -1704  -1704  -1704  -1704      0      0      0      0      0      0
  8 EL. 7 S/BAG LABOUR H HOURS        0      0      0      0      0      0      0      0      0      0      0      0
  8 EL. 8 OTHER LABOUR H HOURS        0      0      0      0      0      0      0      0      0      0      0      0
```

FIGURE 11.3: SAMPLE REPORT- RESOURCE REQUIREMENTS SCHEDULE OF THE HALLMARK PRODUCTION MODEL

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                                                                                              PAGE 4
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN   PLAN NUMBER 2                     DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION       UNITS           1      2      3      4      5      6      7      8      9     10     11     12
                                       JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC
                                    ------------------------------------------------------------------------------------

201 EL. 1 P5             COST P/U    6.514  6.514  6.514  6.806  6.806  6.806  7.687  7.687  7.687  7.687  7.687  7.687
201 EL. 2 P6             COST P/U    9.635  9.635  9.635 10.186 10.186 10.186 11.287 11.287 11.287 11.287 11.287 11.287
201 EL. 3 P7             COST P/U   10.002 10.002 10.002 10.608 10.608 10.608 11.709 11.709 11.709 11.709 11.709 11.709
201 EL. 4 P8             COST P/U   10.599 10.599 10.599 10.925 10.925 10.925 12.576 12.576 12.576 12.576 12.576 12.576
201 EL. 5 P9             COST P/U    5.294  5.294  5.294  5.513  5.513  5.513  6.247  6.247  6.247  6.247  6.247  6.247
201 EL. 6 P10            COST P/U   15.903 15.903 15.903 16.324 16.324 16.324 18.893 18.893 18.893 18.893 18.893 18.893
201 EL. 7 P11            COST P/U   13.592 13.592 13.592 14.198 14.198 14.198 16.033 16.033 16.033 16.033 16.033 16.033
201 EL. 8 P19            COST P/U   16.983 16.983 16.983 17.910 17.910 17.910 19.928 19.928 19.928 19.928 19.928 19.928
201 EL. 9 P20            COST P/U   17.791 17.791 17.791 18.564 18.564 18.564 20.950 20.950 20.950 20.950 20.950 20.950
201 EL.10 P21            COST P/U   16.543 16.543 16.543 17.836 17.836 17.836 19.120 19.120 19.120 19.120 19.120 19.120


202 EL. 1 P22            COST P/U   15.872 15.872 15.872 16.764 16.764 16.764 18.599 18.599 18.599 18.599 18.599 18.599
202 EL. 2 P23            COST P/U   15.156 15.156 15.156 15.997 15.997 15.997 17.832 17.832 17.832 17.832 17.832 17.832
202 EL. 3 P24            COST P/U   19.680 19.680 19.680 20.455 20.455 20.455 23.208 23.208 23.208 23.208 23.208 23.208
202 EL. 4 P25            COST P/U   19.917 19.917 19.917 20.489 20.489 20.489 23.609 23.609 23.609 23.609 23.609 23.609
202 EL. 5 P26            COST P/U    8.868  8.868  8.868  9.297  9.297  9.297 10.398 10.398 10.398 10.398 10.398 10.398
202 EL. 6 P28            COST P/U   12.622 12.622 12.622 13.214 13.214 13.214 14.866 14.866 14.866 14.866 14.866 14.866
202 EL. 7 P30            COST P/U   16.133 16.133 16.133 17.402 17.402 17.402 18.686 18.686 18.686 18.686 18.686 18.686
202 EL. 8 P31            COST P/U   24.805 24.805 24.805 25.885 25.885 25.885 29.188 29.188 29.188 29.188 29.188 29.188
202 EL. 9 P32            COST P/U   18.638 18.638 18.638 19.757 19.757 19.757 21.776 21.776 21.776 21.776 21.776 21.776
202 EL.10 P33            COST P/U   14.994 14.994 14.994 15.992 15.992 15.992 17.460 17.460 17.460 17.460 17.460 17.460


203 EL. 1 P34            COST P/U   21.673 21.673 21.673 22.709 22.709 22.709 25.462 25.462 25.462 25.462 25.462 25.462
203 EL. 2 P35            COST P/U   20.591 20.591 20.591 21.428 21.428 21.428 24.180 24.180 24.180 24.180 24.180 24.180
203 EL. 3 P36            COST P/U   27.859 27.859 27.859 29.261 29.261 29.261 32.564 32.564 32.564 32.564 32.564 32.564
203 EL. 4 P37            COST P/U   21.533 21.533 21.533 22.311 22.311 22.311 25.430 25.430 25.430 25.430 25.430 25.430
203 EL. 5 P38            COST P/U   26.304 26.304 26.304 27.109 27.109 27.109 31.146 31.146 31.146 31.146 31.146 31.146
203 EL. 6 P39            COST P/U   15.990 15.990 15.990 16.449 16.449 16.449 18.834 18.834 18.834 18.834 18.834 18.834
203 EL. 7 SC1            COST P/U    9.708  9.708  9.708  9.772  9.772  9.772 11.607 11.607 11.607 11.607 11.607 11.607
203 EL. 8 SC2            COST P/U   13.558 13.558 13.558 13.649 13.649 13.649 16.218 16.218 16.218 16.218 16.218 16.218
203 EL. 9 SC3            COST P/U   16.355 16.355 16.355 16.453 16.453 16.453 19.572 19.572 19.572 19.572 19.572 19.572
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FIGURE 11.4: SAMPLE REPORT- PRODUCT AND RESOURCE UNIT COST SCHEDULE OF THE HALLMARK PRODUCTION MODEL .

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                                                                                                     PAGE 5
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN   PLAN NUMBER 2                     DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS              1       2       3       4       5       6       7       8       9      10      11      12
                                         JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
                                        ------------------------------------------------------------------------------------------


204 EL. 1 T1               COST P/U     65.845 65.845 65.845 73.110 73.110 73.110  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 2 T2               COST P/U     74.399 74.399 74.399 82.935 82.935 82.935  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 3 T3               COST P/U     79.016 79.016 79.016 87.672 87.672 87.672  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 4 T4               COST P/U     93.127 93.127 93.127103.866103.866103.866  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 5 T5               COST P/U     97.377 97.377 97.377108.020108.020108.020  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 6 T6               COST P/U    123.569123.569123.569138.141138.141138.141  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 7 T7               COST P/U     48.923 48.923 48.923 53.171 53.171 53.171  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 8 TF1              COST P/U     46.307 46.307 46.307 50.449 50.449 50.449  0.000   0.000   0.000   0.000   0.000   0.000
204 EL. 9 TF2              COST P/U     46.886 46.886 46.886 52.079 52.079 52.079  0.000   0.000   0.000   0.000   0.000   0.000


205 EL. 1 SB2              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000 27.590 27.590 27.590 27.590 27.590 27.590
205 EL. 2 SB3              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000 27.590 27.590 27.590 27.590 27.590 27.590
205 EL. 3 SB4              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL. 4 SB5              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL. 5 SB6              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000 36.018 36.018 36.018 36.018 36.018 36.018
205 EL. 6 CB1              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL. 7 CB2              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL. 8 BC1              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL. 9 FA1              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000
205 EL.10 ST1              COST P/U      0.000   0.000   0.000   0.000   0.000   0.000  0.000   0.000   0.000   0.000   0.000   0.000


206 EL. 1 KORDURA HEAVY    COST P/U      7.680   7.680   7.680   8.832   8.832   8.832   8.832   8.832   8.832   8.832   8.832   8.832
206 EL. 2 F306 NYLON       COST P/U     11.010  11.010  11.010  12.662  12.662  12.662  12.662  12.662  12.662  12.662  12.662  12.662
206 EL. 3 F300 NYLON       COST P/U     12.630  12.630  12.630  14.525  14.525  14.525  14.525  14.525  14.525  14.525  14.525  14.525
206 EL. 4 RIPSTOP 210T     COST P/U      1.350   1.350   1.350   1.553   1.553   1.553   1.553   1.553   1.553   1.553   1.553   1.553
206 EL. 5 POLYESTER WB     COST P/U      2.400   2.400   2.400   2.760   2.760   2.760   2.760   2.760   2.760   2.760   2.760   2.760
206 EL. 6 MESH BACK BAND   COST P/U      3.600   3.600   3.600   4.140   4.140   4.140   4.140   4.140   4.140   4.140   4.140   4.140
206 EL. 7 RIPSTOP MET CH   COST P/U      0.990   0.990   0.990   1.139   1.139   1.139   1.139   1.139   1.139   1.139   1.139   1.139
206 EL. 8 CANVAS           COST P/U     17.640  17.640  17.640  20.286  20.286  20.286  20.286  20.286  20.286  20.286  20.286  20.286
206 EL. 9 JAPARA           COST P/U     18.330  18.330  18.330  21.080  21.080  21.080  21.080  21.080  21.080  21.080  21.080  21.080
206 EL.10 M/C HOURS        COST P/U      0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
```
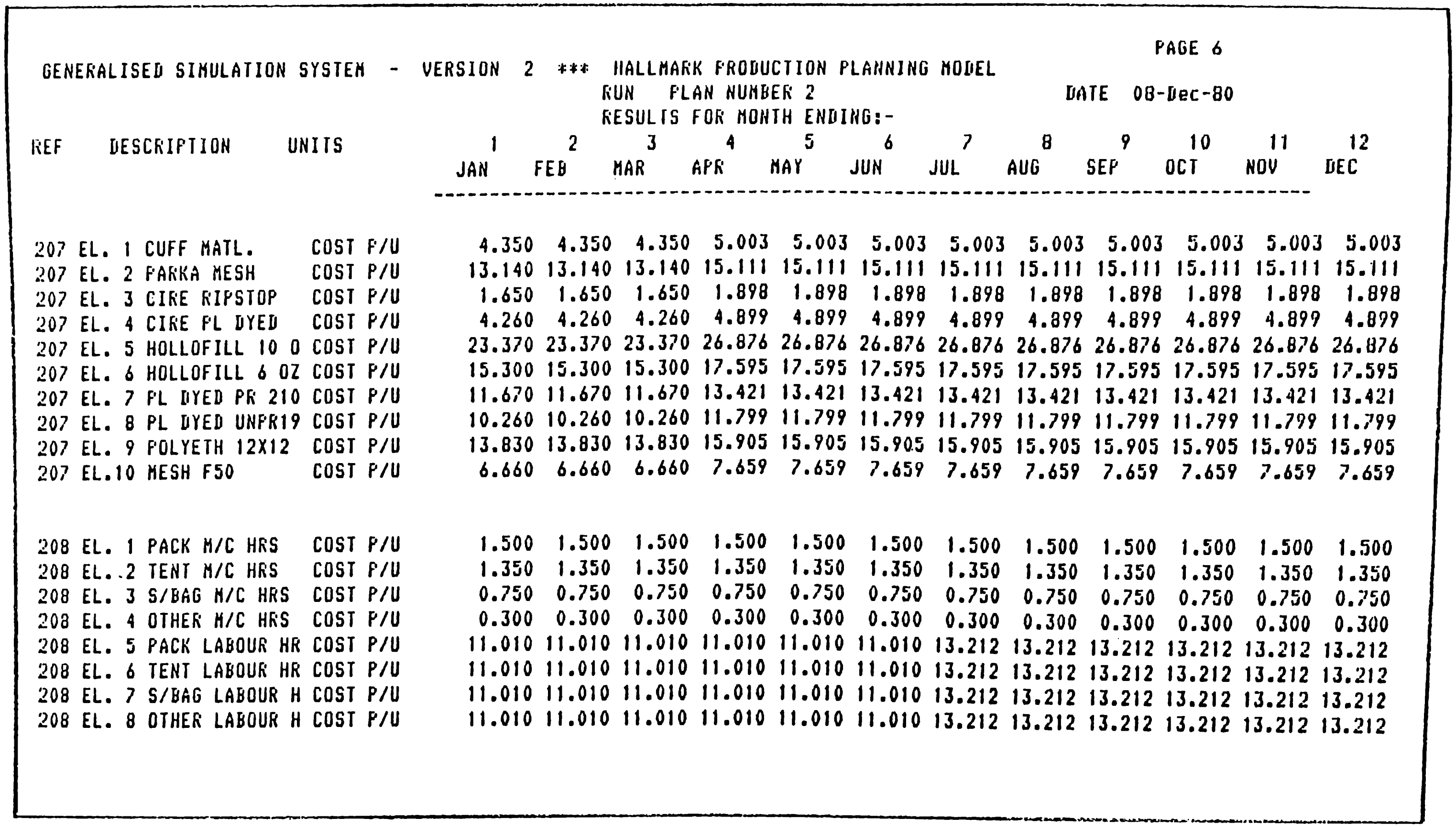

FIGURE 11.4: Continued........



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                                                                                                    PAGE 6
GENERALISED SIMULATION SYSTEM  -  VERSION  2  ***  HALLMARK PRODUCTION PLANNING MODEL
                                                   RUN   PLAN NUMBER 2                       DATE  08-Dec-80
                                                   RESULTS FOR MONTH ENDING:-
REF    DESCRIPTION      UNITS            1       2       3       4       5       6       7       8       9      10      11      12
                                        JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
                                       ---------------------------------------------------------------------------------------

207 EL. 1 CUFF MATL.      COST P/U     4.350   4.350   4.350   5.003   5.003   5.003   5.003   5.003   5.003   5.003   5.003   5.003
207 EL. 2 PARKA MESH      COST P/U    13.140  13.140  13.140  15.111  15.111  15.111  15.111  15.111  15.111  15.111  15.111  15.111
207 EL. 3 CIRE RIPSTOP    COST P/U     1.650   1.650   1.650   1.898   1.898   1.898   1.898   1.898   1.898   1.898   1.898   1.898
207 EL. 4 CIRE PL DYED    COST P/U     4.260   4.260   4.260   4.899   4.899   4.899   4.899   4.899   4.899   4.899   4.899   4.899
207 EL. 5 HOLLOFILL 10 O  COST P/U    23.370  23.370  23.370  26.876  26.876  26.876  26.876  26.876  26.876  26.876  26.876  26.876
207 EL. 6 HOLLOFILL 6 OZ  COST P/U    15.300  15.300  15.300  17.595  17.595  17.595  17.595  17.595  17.595  17.595  17.595  17.595
207 EL. 7 PL DYED PR 210  COST P/U    11.670  11.670  11.670  13.421  13.421  13.421  13.421  13.421  13.421  13.421  13.421  13.421
207 EL. 8 PL DYED UNPR19  COST P/U    10.260  10.260  10.260  11.799  11.799  11.799  11.799  11.799  11.799  11.799  11.799  11.799
207 EL. 9 POLYETH 12X12   COST P/U    13.830  13.830  13.830  15.905  15.905  15.905  15.905  15.905  15.905  15.905  15.905  15.905
207 EL.10 MESH F50        COST P/U     6.660   6.660   6.660   7.659   7.659   7.659   7.659   7.659   7.659   7.659   7.659   7.659


208 EL. 1 PACK M/C HRS    COST P/U     1.500   1.500   1.500   1.500   1.500   1.500   1.500   1.500   1.500   1.500   1.500   1.500
208 EL. 2 TENT M/C HRS    COST P/U     1.350   1.350   1.350   1.350   1.350   1.350   1.350   1.350   1.350   1.350   1.350   1.350
208 EL. 3 S/BAG M/C HRS   COST P/U     0.750   0.750   0.750   0.750   0.750   0.750   0.750   0.750   0.750   0.750   0.750   0.750
208 EL. 4 OTHER M/C HRS   COST P/U     0.300   0.300   0.300   0.300   0.300   0.300   0.300   0.300   0.300   0.300   0.300   0.300
208 EL. 5 PACK LABOUR HR  COST P/U    11.010  11.010  11.010  11.010  11.010  11.010  13.212  13.212  13.212  13.212  13.212  13.212
208 EL. 6 TENT LABOUR HR  COST P/U    11.010  11.010  11.010  11.010  11.010  11.010  13.212  13.212  13.212  13.212  13.212  13.212
208 EL. 7 S/BAG LABOUR H  COST P/U    11.010  11.010  11.010  11.010  11.010  11.010  13.212  13.212  13.212  13.212  13.212  13.212
208 EL. 8 OTHER LABOUR H  COST P/U    11.010  11.010  11.010  11.010  11.010  11.010  13.212  13.212  13.212  13.212  13.212  13.212
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FIGURE 11,4: Continued........

CHAPTER 12

MANAGERIAL CONSIDERATIONS IN THE DEVELOPMENT AND USE OF THE HALLMARK MODELS

In the previous chapter the detailed structure and purpose of each of the three Hallmark models was discussed. Here the intention is to address some of the more important practical aspects of management's involvement in constructing and using the models. Specifically, attention is drawn to the questions of model validation and to the role of the models in heightening managerial perception of the business. The extent to which the models achieve their principal goal of improving the effectiveness and efficiency of the planning process is examined in terms of the elements suggested in Chapter 4, for measuring modelling benefits (refer p.64).

12.1 Validating the Hallmark Models

A significant feature of the SSD modelling approach is the construction of models which capture the more mechanistic and more structured relationships in the organisation. The less structured models are usually accorded the status of exogenously specified influences, superimposed on the network through the use of data tables and the concept of 'tagging' the network arcs (or linkages) with them at the appropriate points. The question of model validation in these circumstances then becomes a case of ensuring that -

(a) The level variables (accounts) defined in the model network are appropriate for, and consistent with, the purpose of the model.

(b) The linkages (transaction paths) defined in the model network faithfully reflect each and every mechanistic relationship involved in the determination of the level values (account balances).

(c) The various data tables defined for the network provide the necessary data base of constants and parameters to complete the mechanistic relationships and to effect the flow (transaction) influences appropriate to those decision processes which are relevant but external to the model.

(d) The data tables themselves are correctly specified.

As far as the Cash Planning model is concerned, its purpose was to aid cash management, through the provision of a structure which integrated the cash effects of sales, purchases and overhead expenditure. This structure was to be capable of giving predictive insight into the dynamics of the monthly cash balance, over a planning horizon of at least 12 months. In particular management wished to pinpoint the likely extent and timing of acute cash shortages, having regard to the marked seasonality of the company's sales. It was also desired to experiment with flexing the discretionary components of expenditure to produce an acceptable cash budget.

The validation question for this model, and indeed for most SSD models, constitutes a potential problem only in respect of points (c) and (d) - given that the purpose of the model has been clearly stated. For validation in terms of point (c), the location and type of delays defined for the model were of prime importance. Significant delays were obviously being experienced with purchase payments and cash collections. The duration of these delays together with their other observable characteristics[1] indicated the need for the boxcar type of delay in each instance. Decision points in the model were clearly associated with those flows defined for purchase order placements, overhead incurrences, and sales. Hence modulation tables had to be tagged against each of them. For validation in terms of point (d), the delay tables (for both the delay distribution coefficients and the delay transit initial values) had to be soundly based on historical data. For the purchases delay coefficients, averages were struck from several months of historical data pertaining to both local purchases and overseas purchases.

If necessary a finer distinction could have been made here to permit the derivation of separate delay tables (and modulation tables regulating order placement) for different classes of local and imported purchases. This would be accomplished by increasing the dimensions of levels 1 and 2, or by the creation of new levels. The delay transit initial values were obtained directly from the schedules of outstanding materials orders, maintained by the Purchasing Dept.

Historical records in the form of the aged debtors balances were applied in deriving the cash collections delay tables. First the delay distribution coefficients (associated with the latest aged

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[1] Attributable, as far as purchase payments were concerned, to the delivery and payment terms imposed on the Purchasing Dept. by materials suppliers and the company's trade financing arrangements.

debtors balances) were determined from those balances, using the monthly sales figures which had given rise to them and the set of simultaneous equations:

$$\begin{array}{rcl} S_1(p_1+p_2+\ldots\ldots+p_n) & = & B_1 \\ S_2(p_2+\ldots\ldots+p_n) & = & B_2 \\ \vdots & & \vdots \\ S_n\,(p_n) & = & B_n \end{array}$$

(where, for the jth ageing period, B_j denotes the balance, S_j denotes the sales and p_j denotes the delay coefficient)

- which can be solved for $p_1, p_2, \ldots\ldots p_n$, given the values of S_j and B_j for each $j = 1,2,\ldots\ldots n$.

This calculation was repeated several times at random points over the previous two years, to check coefficient stability. The final set of values for these coefficients was obtained by averaging.

Next the delay transit level initial values were calculated using the relationships -

$$\begin{array}{lcl} D_1 & = & S_1p_1 + S_2p_2 + \ldots\ldots + S_np_n \\ D_2 & = & \phantom{S_1p_1 + {}} S_1p_2 + \ldots\ldots + S_{n-1}p_n \\ \vdots & & \vdots \\ D_n & = & \cdot + S_1p_n \end{array}$$

Where D_i denotes the delay transit level initial values associated with the ith delay period.

Separate sets of delay tables were calculated for the collections arising from local sales and export sales, reflecting the different payment terms applicable to each.

The most important decision process relevant to this model was unquestionably that related to the placement of purchase orders for materials. Here the decision process itself was not structured into the model[2] but rather the output from it, in the form of a projected programme of order placements, was transmitted to the model through the modulation table M1. Having ensured that all data tables of the model were soundly based on the relevant historical records and (or) managerial expectations, the final test of the model's validity centred on the comparison of an 'ex post' forecast of cash flows for the previous year, with the actual flows for that year. The comparison of actual against forecast for cash collections was of particular interest as a test of the delay table D1 (refer Figure 12.1). Here it was found that the forecasted pattern of collections was much smoother than the actual pattern, due to the use of averages (for both the delay coefficients and the seasonal indices for sales). The actual collections were of course affected by random shocks impinging on both the collections and on the monthly sales giving rise to them.

Clearly the effect of this randomness needed to be established and translated into confidence intervals for the cash balance forecasts produced by the model. This was done by establishing confidence limits for the delay coefficients from analysis of the sample set of values calculated from the aged debtors balances at selected points in time, as discussed earlier. The model was run three times for any

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[2] As distinct from the full financial model where purchase order placements are 'tied' to sales (at least in part), in a feedback relationship. Ideally the long-term order placement programme generated by this model would be used to derive the data for modulation table M1.

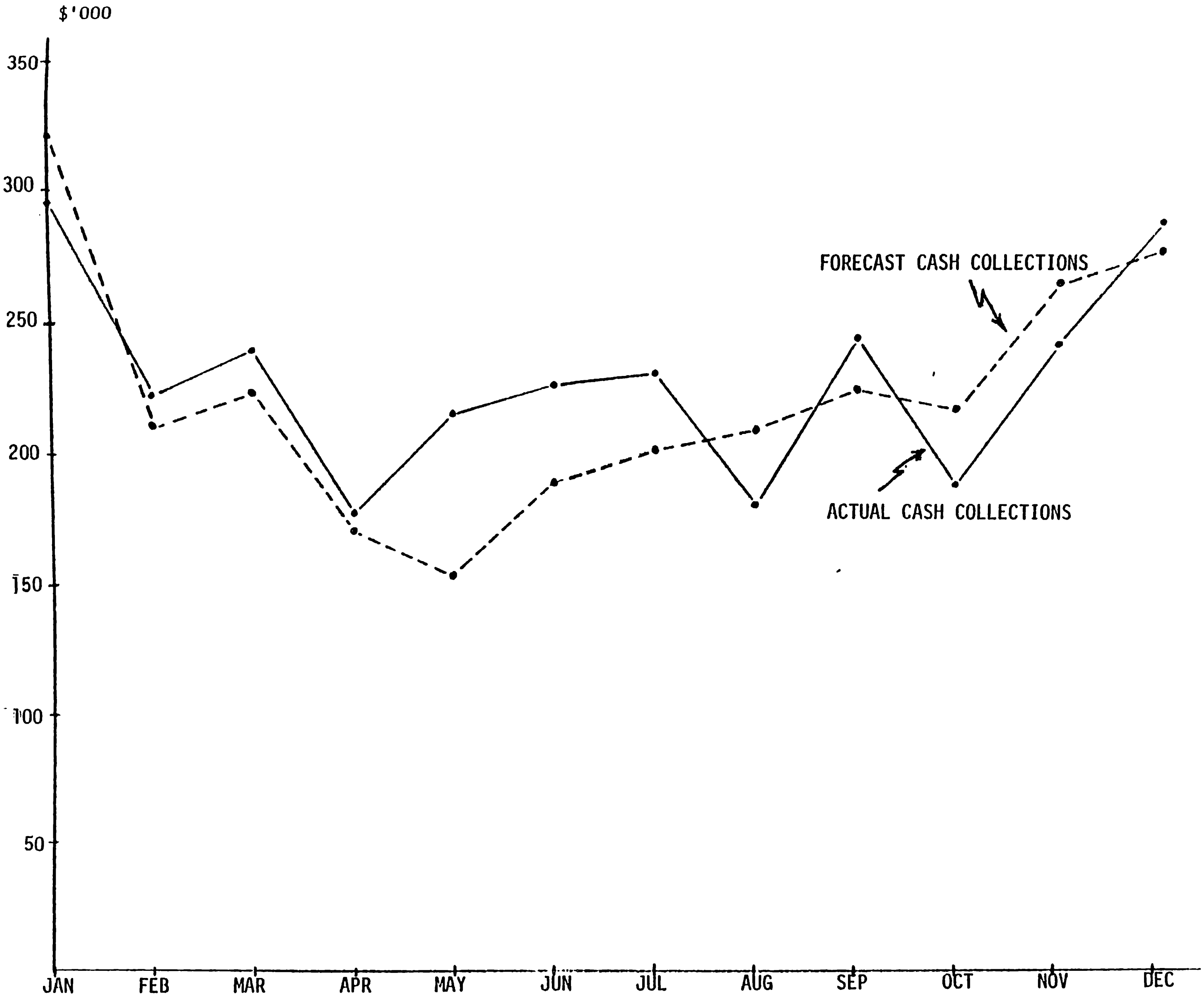

FIGURE 12.1: ACTUAL vs FORECAST CASH COLLECTIONS FOR THE HALLMARK CASH PLANNING MODEL

given set of parameter values, using respectively, the average, highest and lowest set of delay coefficients.

The information gained in the course of validating the Cash Planning model was directly relevant to the Financial Planning model. Further testing to ensure the validity of this latter model centred on the linking of purchase order placements to production, and the linking of production to sales. In each instance suitable multipliers had to be found which gave rise to an acceptable pattern of materials and finished stocks, over the planning period concerned. Several runs of the model with different data values for modulations M4 and M3 respectively enabled an appropriate choice of multiplier to be made for each of these tables.

The Production Planning model required the least effort as far as validation was concerned, owing to the exclusively mechanistic nature of the relationships involved. The product-explosion resource-implosion function performed by this model rested, in terms of validity, on the accuracy of the matrices of technical coefficients comprising the transformation tables. Careful checking of these tables to ensure that the coefficients (based directly on product specifications) had been correctly entered was therefore a necessary (and sufficient) condition for model validity - given that the flow diagram correctly reflected the underlying physical structure of the production system.

12.2 Managerial Understanding of the Hallmark Models and Their Role in Heightening Perception of the Business

An important pre-requisite to managerial acceptance of models, and to their effective deployment by managers, is unquestionably the development of a sound understanding, by all concerned, of the purpose and structure of each model (see p. 12-15). At Hallmark the fact that each of the three models was designed to fill a very specific and recognised gap in the organisation's planning systems, led to universal and unconditional acceptance of the need for the models to be built. In the early stages the principal concern in fact was not whether the models were justified, but rather how quickly they would become available for use.

Acceptance of the need does not however lead necessarily to acceptance of the final 'product' designed to fill that need. There must be a clear understanding of the key characteristics of the product, and how it should be used. In modelling terms this means an understanding of the model structure (at least in broad terms), of the output which will be generated by the model, and of the input required by the model. This understanding was secured at every stage of the model-building process[3] and in particular at the level definition stage, where the specific output capability of any given model is determined. The central tool in communicating model structure to management was, in every instance, the flow diagram. The larger the model the more important the flow diagram became, as a focal point for discussing the model, the system being modelled, and the role of individual managers in providing input to the model.

While the flow diagram of an SSD model typically depicts the basic system structure in terms of levels, the flows which affect them, and the user-specified flow influences, it does not show

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[3] Refer p.119-127 for discussion of the specific steps in the SSD modelling approach.

explicitly the determinants of flows where those determinants are levels or other flows. This additional information on model structure can, however, be either added to the flow diagram (using broken line arrows to show the direction of influence) or presented separately. The separate presentation of cause-effect relationships in a model can be in tabular form (e.g. Tables 10.3 and 10.4) or in a diagrammatic form (i.e. influence diagrams).

While the tabular form has been used throughout this thesis, influence diagramming is an important tool for developing conventional System Dynamics models (Coyle, 1977) and can easily be used in SSD modelling, either as a developmental aid or as an aid to communications. However, the more open nature of SSD models and their emphasis on the mechanistic 'intra-linkage' types of relationship often results in the influence diagram conveying only marginally more information than the flow diagram. Nevertheless, in situations where it is desired to use influence diagrams the more structured nature of SSD does permit a more structured diagramming style. This style is illustrated in Figure 12.2, and involves a standard columnar format based on Coyle's List Extension Method (Coyle, p.72-77). Here the far right-hand column is used for the key level variables defined for the model (determined according to the purpose of the model), the centre column is used for the flow variables (descriptions and alphanumeric references) and the left-hand column is used to show any relevant base flows or modulations.

Cause-effect relationships linking the model variables are shown as solid arrows, with any relevant transformations or delays being shown alongside the arrow linking the pair of variables concerned. The alphanumeric labelling of all model variables permits

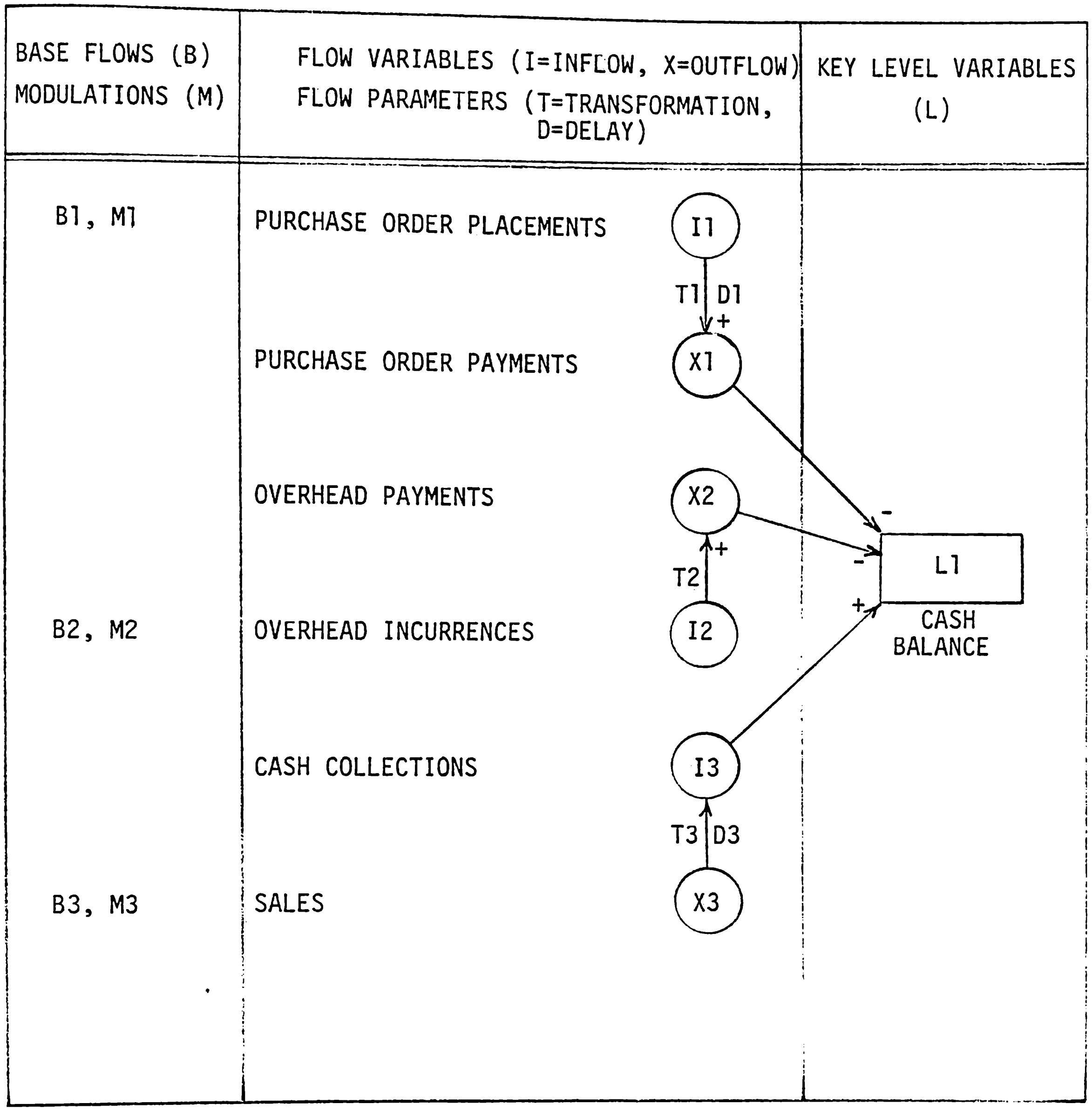


FIGURE 12.2: INFLUENCE DIAGRAM FOR THE HALLMARK CASH PLANNING MODEL

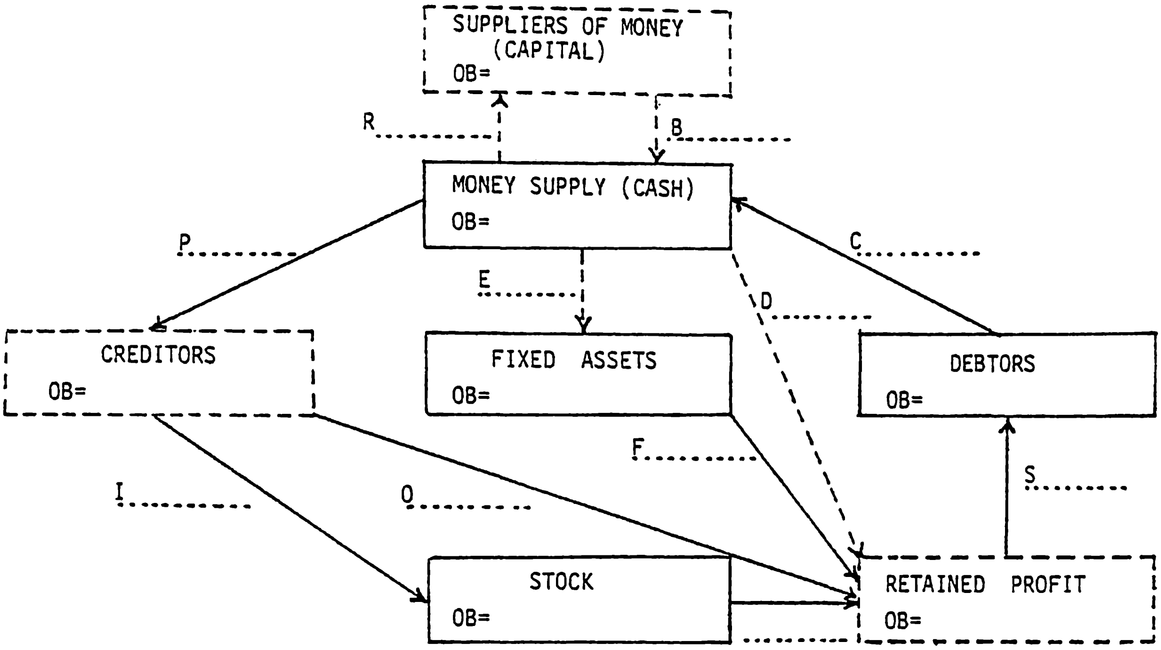
cross-referencing to the flow diagram. Thus L1 denotes level number 1, while I1 and X1 denote (respectively) the inflows and outflows of linkage number 1. The data tables are all labelled according to the convention used in the flow diagrams.

By far the most significant factor in securing management's understanding of the SSD modelling approach, and in improving their perception of the business, was the use of a worksheet structured around a simplified version of the Financial Planning model. This worksheet (refer Figure 12.3) was used by each manager to manually perform, in effect, one complete iteration of the model, and to produce from this (in conventional format) a balance sheet, cash statement and income statement.

In each instance the manager was provided with a copy of the worksheet on which had been entered (on the diagram portion) a set of opening balances for each level (denoted by 'OB') and a set of transaction values (or flows) pertaining to one month. The latter values were entered on the dotted lines alongside the transaction path (or linkage) to which they related. The manager was then required to prepare the month-end balance sheet, income statement and cash statement from the information provided, using the formulae shown in parentheses on the lower half of the worksheet.

On completion of this exercise the worksheet was used to fully explain the SSD flow diagramming conventions, introducing the concepts of flow initialisation, flow modulation, flow delay and flow transformation. In addition to providing insight into the SSD modelling approach itself, the exercise enabled managers to obtain

FINANCIAL MODELLING WORKSHEET



BALANCE SHEET AS AT:____________

LIABILITIES (-ve)	$	ASSETS (+ve)	$
Capital (= OB-B+R)		Fixed Assets (= OB+E-F)	
Creditors (= OB+P-I-O)		Debtors (= OB+S-C)	
		Stock (= OB+I-X)	
Retained Profit(=OB+D+F+O+X-S)		Cash (= OB+C+B-R-P-E-D)	
TOTAL LIABILITIES		TOTAL ASSETS	

INCOME STATEMENT FOR:	$	CASH STATEMENT FOR:	$
Sales (=S)		Debtors Collections (=C)	
Cost of Sales (=X)		Creditor Payments (=P)	
GROSS PROFIT (=S-X)		Capital Expenditure (=E)	
Depreciation (=F)		Repayments (=R)	
Overhead (=O)		Borrowings (=B)	
		Dividends/Drawings (=D)	
NET PROFIT (= S-X-F-O)		NET CASH FLOW (= C-P-E-R+B-D)	

⬚ LIABILITIES = CREDIT BALANCES (or NEGATIVE amounts))
) OB = Opening Balances
▭ ASSETS = DEBIT BALANCES (or POSITIVE amounts))

- - - →
——→ TRANSACTIONS OR FLOWS (ARROWHEAD=DEBIT, ARROWTAIL=CREDIT)

FIGURE 12.3: THE FINANCIAL MODELLING WORKSHEET

a much clearer perspective on the 'funds loop'[4] which is a central part of all business organisations. The importance of a systems approach to management was highlighted and translated into terms which each manager could relate back to his own sphere of decision-making. In particular the managers could perceive the need for balance and co-ordination between cash-related decisions and profit-related decisions.

12.3 Using the Hallmark Models to Improve Planning

Prior to the development of the models described in Chapters 10 and 11, planning at Hallmark was undertaken on a rather fragmented basis with little regard for key factors in the business, other than sales and profit. The principal determinants of profit and net cash flow were not clearly identified as the focal points of planning and control in the organisation. However, the rate of growth of the company coupled with the periodic occurrences of 'cash crises' had produced the realisation that a more sophisticated approach to planning in both the short and long term was essential.

In the area of long term planning considerable effort had been expended in developing a participative, cyclical pattern of environmental appraisal, company appraisal, strategy formulation and tactical planning. This planning approach was based on the framework depicted in Figure 3.3, p.49. Steps 1 to 4 are accomplished by the individual key staff (functional area managers) acting alone. This is followed by a planning seminar held at a site remote from the work place and attended by all key staff. Steps 5 to 16 are accomplished at this seminar. Finally steps 17 to 20, resulting in

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[4] i.e. the 'cash-resources-products-cash' cycle. It is the dynamics of this loop, of course, which the Financial Planning model seeks to project.

the full specification of goals for each strategic option, are accomplished by the Accounting and Finance Manager, with the aid of the Financial Planning model. The whole cycle is repeated at approximately six monthly intervals.

The effectiveness of this planning process was being inhibited, however, by the lack of computational support for the evaluation of strategies (in terms of the goal structure depicted in Figure 10.6) and for their translation into detailed operating budgets. The manual preparation of proforma balance sheets and income statements placed practical limitations on the range of strategic options which could be evaluated, the comprehensiveness of any given evaluation and the ability for any given strategy to be flexed in response to external change.

Difficulty was experienced also in defining and co-ordinating the responsibilities of the individual managers for the provision of information to be used in the planning process and to be reported on for control purposes. Comprehensive budgeting and regular forecasting of key short-run performance measures was not being undertaken. In short management lacked the basic ability to plan according to an integrated framework of key decision variables and to close the planning and control loop by reporting actual performance against these variables.

The Cash Planning model performed an important 'ice-breaking' role in providing quick, readily identifiable benefits to management with no previous experience in computer-based modelling. These benefits consisted of -

(a) The provision of regular short-term cash forecasts portraying the dynamic behaviour of the monthly cash balance, based on seasonal and lag patterns in both cash receipts and cash payments.

(b) The ability to quickly test the effects of different patterns of discretionary expenditure, purchase order placements and sales, on the projected monthly cash balances.

(c) The realisation by management of the importance of purchase order placements as a decision variable, of the need to identify the short term effects of the longer term decisions made in respect of this variable, and of regular monitoring of this factor through management reports.

The Production Planning model also supported short term planning in providing detailed schedules of resource requirements for any given production schedule. These production schedules were derived from the Financial Planning model in the first instance. The materials requirements generated by the production model from these schedules formed the basis of the purchase order placement programmes entered as input to the Cash Planning model. Finally the product costing capability of the production model supported both product pricing and production cost control decisions.

From the foregoing discussions it is clear that the Financial Planning model, in addition to providing the computational support for strategy evaluation and tactical planning (or budgeting), also facilitated the link between long term and short term planning. More specifically it enabled management to -

(a) Quickly evaluate a broader range of strategic options. Within twelve months of its use new commercial ventures were being put forward for evaluation. A special 'new ventures' model was commissioned to fully explore the economic potential of these proposals (in terms of their individual patterns of return on investment). This model was similar in structure to the extended financial model discussed in Chapter 8, which has the advantage of portability (from one business context to another) due to the general applicability of its structure.

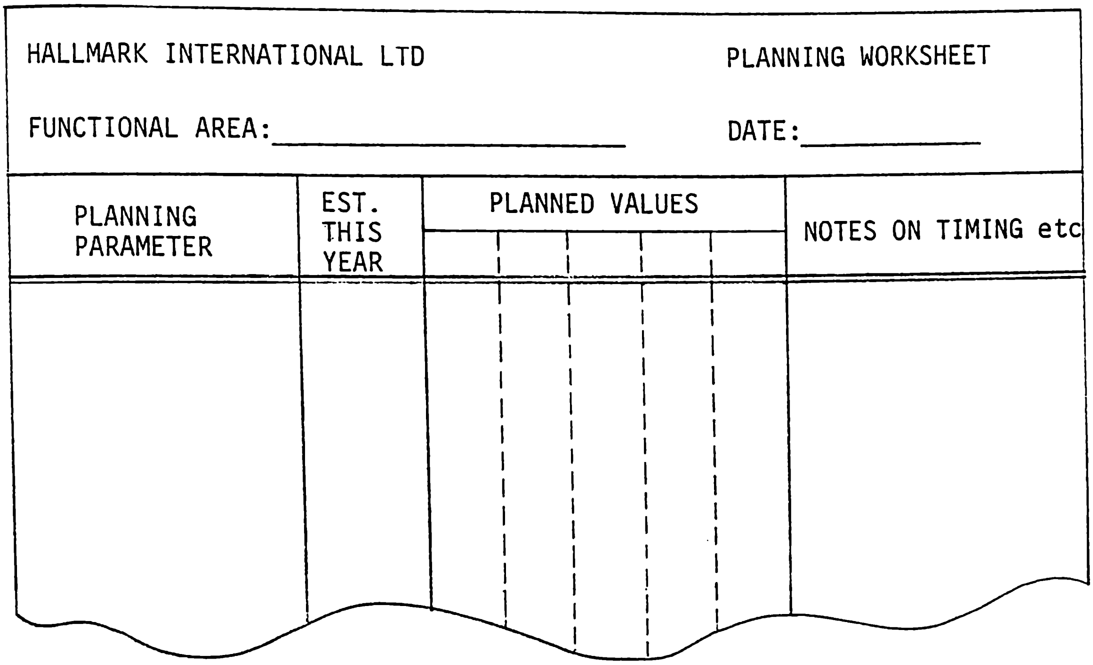
(b) Consider all strategic options together with any externally imposed economic shocks, in terms of their effect on the primary goal of the company for after tax return on equity.

(c) Direct managerial attention to key measures within the corporate goal structure to which corporate return on equity was most sensitive. The evolutionary goal set for the development of new export markets was an outstanding example of this. The model specifically identified the incremental effects on after tax return on equity (largely brought about by the export incentives) which could be expected from speeding up the rate of growth in export sales. This information served not only to provide management with a clear direction for the company, but also to promote unity and commitment to this direction.

(d) Close the planning-control loop by facilitating the translation of a chosen long term strategy into detailed operating budgets for the immediate year ahead. This, coupled with monthly reporting, upgraded to focus on key performance measures which corresponded to those being projected by the model, resulted in the effective integration of planning and control. Earlier attempts by the company to introduce long range planning had foundered because of the separation of planning from control - a separation which extended beyond mere procedures to manifest itself in the minds of the managers themselves.

(e) Conduct contingency planning whereby the full financial implications of a significant downturn in sales could be established, along with the effectiveness of various expenditure and cost reduction programmes to counter such a development.

(f) Clearly identify the responsibilities and requirements on the part of each manager, for the provision of quantitative planning data. A simple planning worksheet (see Figure 12.4) was used by each functional area manager to set out this data prior to any major re-run of the model.



HALLMARK INTERNATIONAL LTD PLANNING WORKSHEET

FUNCTIONAL AREA:________________ DATE:__________

PLANNING PARAMETER	EST. THIS YEAR	PLANNED VALUES					NOTES ON TIMING etc

FIGURE 12.4 : THE PLANNING WORKSHEET FOR THE HALLMARK FINANCIAL PLANNING MODEL

After eighteen months of use the Financial Planning model was re-structured to reflect the aquisition of a new venture (which had been evaluated using the 'new ventures' model discussed earlier). This re-structuring was effected quickly through the re-dimensioning of the model levels for fixed assets, debtors, sales, cost of sales and overheads. New accounts to represent the assets aquired and their expected contribution to overall corporate profitability could then be introduced.

REFERENCE

Coyle, R.G., 1977. Management System Dynamics. John Wiley & Sons, London, 463p.

CHAPTER 13

FURTHER APPLICATIONS OF SIMPLIFIED SYSTEM DYNAMICS

The purpose of this chapter is to illustrate the general applicability of the SSD methodology to the construction of planning models in a diversity of organisations. A key factor in achieving this objective is the provision of as many practical illustrations as possible which incorporate novel uses of the available conceptual framework. It is hoped that the contents of this chapter contribute significantly in this regard, while avoiding the volume of detail[1] which a full account of each application would inevitably entail.

In section 13.1 a selection of financial applications is presented which encompasses both profit and non-profit organisations. This is followed by a discussion of some non-financial applications, where the framework of levels and flows is used to model relationships involving populations, and the processes of birth, ageing and death. Finally, in section 13.3 the problem of integrating SSD models into hierarchical systems of models is examined with reference to the Hallmark applications, and in a general context.

13.1 Financial Applications of SSD

13.1.1 The Caldwell Financial Planning Model

Caldwell Holdings Ltd is the parent company of an organisation consisting of three subsidiaries involved in the activities of caravan

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[1] The technical details of fourteen separate applications of SSD, including those applications discussed here, are contained in Departmental working papers held at the Department of Management Studies, University of Waikato, Hamilton, New Zealand.

sales, caravan hire and caravan financing respectively. Each subsidiary operates as a profit centre in its own right and the financial model described here captures the overall financial structure of the three subsidiaries in a single integrated model. The basic purpose of this model was to provide both short and long term financial projections for the organisation, in the form of subsidiary company profit statements, and consolidated profit statements, cash statements and balance sheets. The model was initially required to determine the effects on profit, cash flow and financial stability, of a planned expansion of the finance subsidiary's operations, over a four year planning horizon.

In order to meet these objectives, the 18-level 21-linkage structure depicted in Figure 13.1 was defined. A model solution interval of three months (i.e. a quarterly solution interval) was chosen in order to facilitate representation of the lagged effects, on cash and profit, of the finance subsidiary's activities in the areas of three year and four year hire purchase contracts. The network of Figure 13.1 was vectorised to permit the definition of a total of 113 accounts, as sub-levels.

In general the model linkages depicted in Figure 13.1 cover the usual transaction types of sales, cost of sales, overheads, depreciation, cash payments, cash collections, borrowings and capital expenditure, in a fairly conventional way. The profit and tax calculation sector of the model (encompassing levels 14 to 18 and their associated linkages) is structured in the same manner as described for the Hallmark model of Chapter 10 - except that profit calculation is performed in two stages, and the calculation of dividends is not required in this instance.

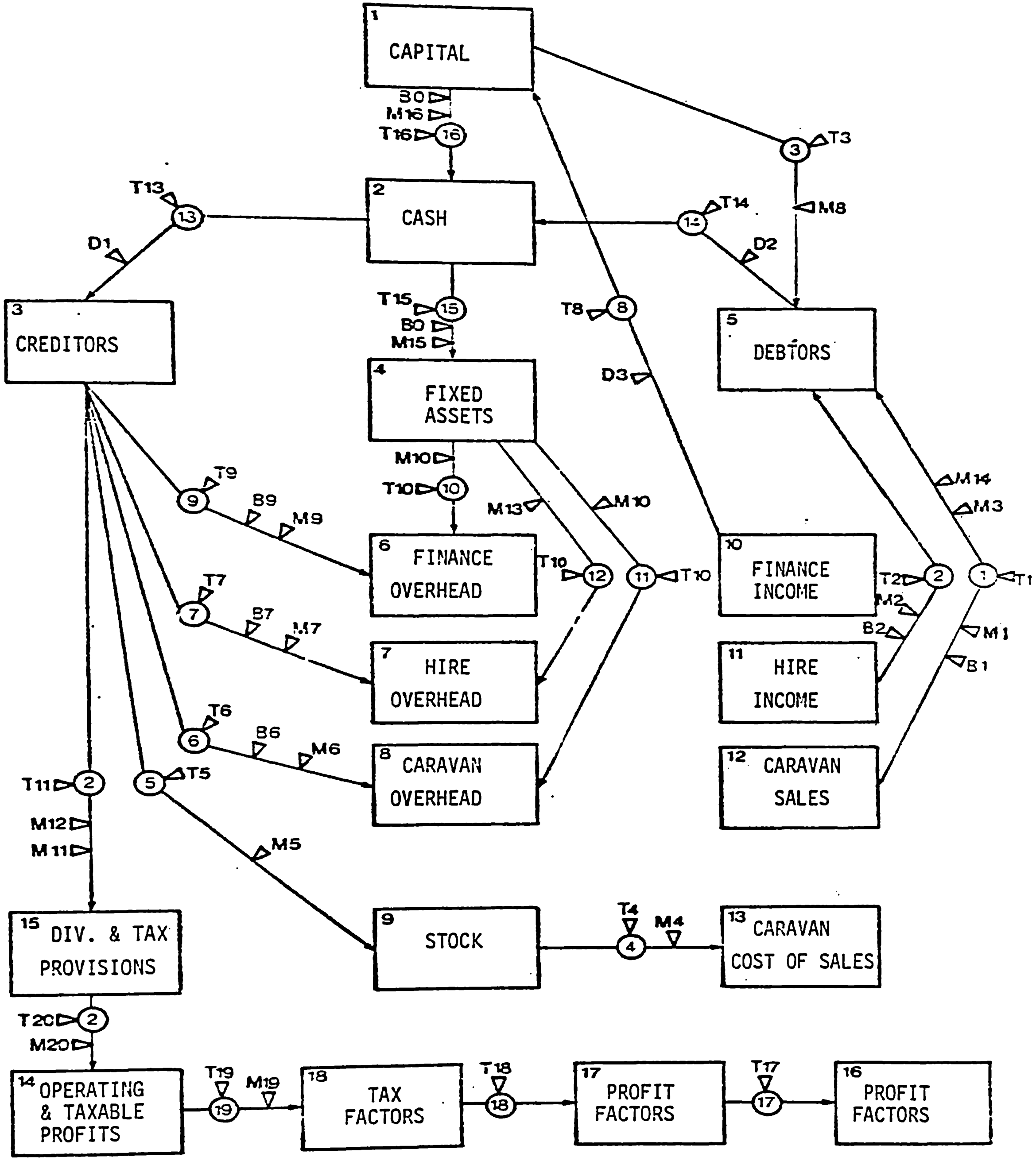


FIGURE 13.1: FLOW DIAGRAM FOR THE CALDWELL FINANCIAL PLANNING MODEL

A further point of departure from the norm is the definition of linkages 3 and 8 for reflecting the interest component (of the HP sales transactions of the finance subsidiary) as unearned income (linkage 3), and for releasing the appropriate portions of this interest as earned income - as and when appropriate (linkage 8). This latter function is effected by passing the HP charges carried by linkage 3 through the box-car delay (D3) which spreads them across future periods according to the 'rule of 78'. The output from D3 is then earned income to the finance subsidiary. Both 3 year and 4 year HP interest charges are dealt with in this manner, but separately within the delay D3, to accommodate the different delay distribution coefficients which derive from applying the 'rule of 78' to the 3 year and 4 year HP terms. In accounting terms this income realisation is effected through linkage 8, as a debit (inflow) to the unearned interest account of level 1 and a credit (outflow) from the finance income accounts of level 10.

In effect, the model parameters which are of central importance to management, are all found in the modulation tables. Of particular importance among these are the growth rate patterns for sales, overhead, the HP interest rates charged, capital expenditure and capital borrowing. The transformation matrices in this model serve in a purely flow directing capacity, and hence comprise 'zero-one' tables, forming part of the model structure rather than its data base.

The first run of the model constituted a 'status quo' projection of corporate performance based on a continuation of current trends. Further runs were then made to test the effects on corporate performance of both higher and lower rates of growth for the finance and hire subsidiaries. A final 'planned projection' was then made incorporating growth rates believed to be attainable from a major new product to be launched by the caravan sales subsidiary - with 'flow on' effects anticipated for the finance and hire subsidiaries.

13.1.2 The James Cash and Profit Planning Model

James Aviation Limited is a divisionalised enterprise specialising in the activities of aerial topdressing, aerial spraying, helicopter operations, fertiliser storage, aircraft engineering and aircraft sales. Four main operating divisions exist within the organisation, respectively those of James Aviation, James Aviation (Overseas), Avonex Industries and James Air. The principal division, James Aviation, is, for the purposes of planning and control, organised into ten operating departments, seven of which relate (respectively) to the seven aircraft types flown by the company. The remaining three departments are concerned with aircraft sales, engineering operations and chemical operations.

Formalised planning within the overall organisation had in the past been confined to the manual preparation of fairly detailed twelve-month budgets for income and expenditure within each division and for each department of the James Aviation division. These budgets provided the basis for cash forecasting in the form of manually prepared monthly cash projections for the immediate year ahead, reducing to quarterly projections for an eighteen month period beyond that.

The purpose of the model described in this section was to computerise the above process and provide a facility for reflecting the components of cash flow and profit, in a fairly disaggregated framework.

The model had to be capable of generating detailed divisional profit statements together with consolidated cash statements, on a monthly basis.

In order to reflect the detail being accommodated within the existing manual procedures, a total of 183 accounts organised into 20 levels had to be defined. These accounts then provided the basis for the 20 level, 37 linkage structure depicted in the flow diagram of Figure 13.2. The 'core' of the model consists of two levels for the accounts associated with cash receipts and cash payments and a further eleven levels to accommodate all of the sales and overhead accounts which give rise to cash flows. Non-cash department overheads are dealt with separately (level 20 and its associated linkage) and a further level (level 18) was defined to encompass the aircraft departmental accounts for the departmental allocations of net administration overhead - allocated via linkage 16. The remaining levels (1, 15, 16 and 19) were defined for the purposes of providing supplementary accounts for departmental production hours, gross margins, net profits and overhead totals, respectively, for the James Aviation division.

As with the Caldwell model, all of the linkage transformations perform a flow directing function, with the management parameters for the model being confined to the flow modulations. These specify sales growth rate and price change patterns, overhead rates, overhead apportionment coefficients, and programmes for capital expenditure, repayments and borrowings.

Important new features introduced to the budgeting process by the model, in addition to providing a powerful facility for strategy

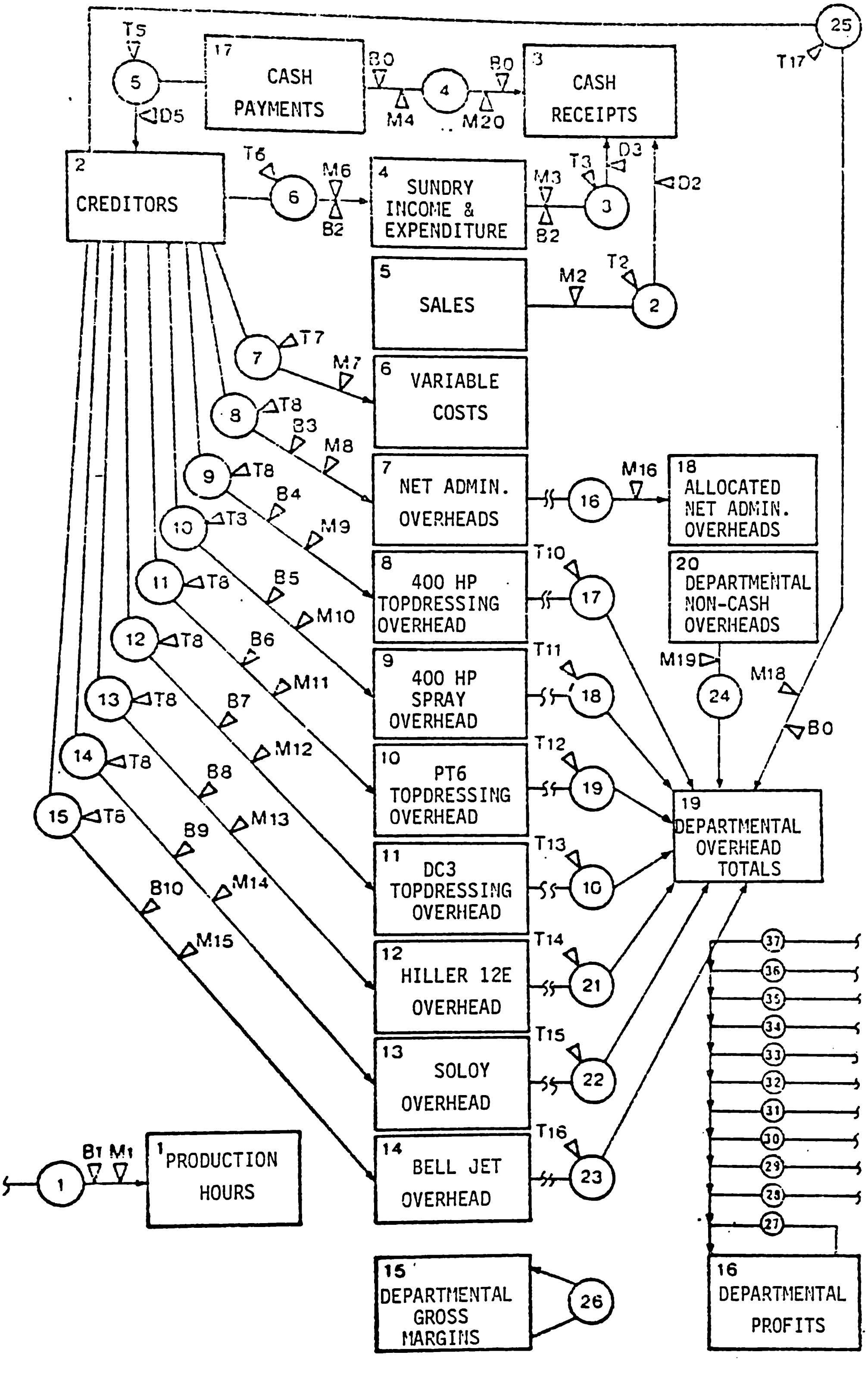


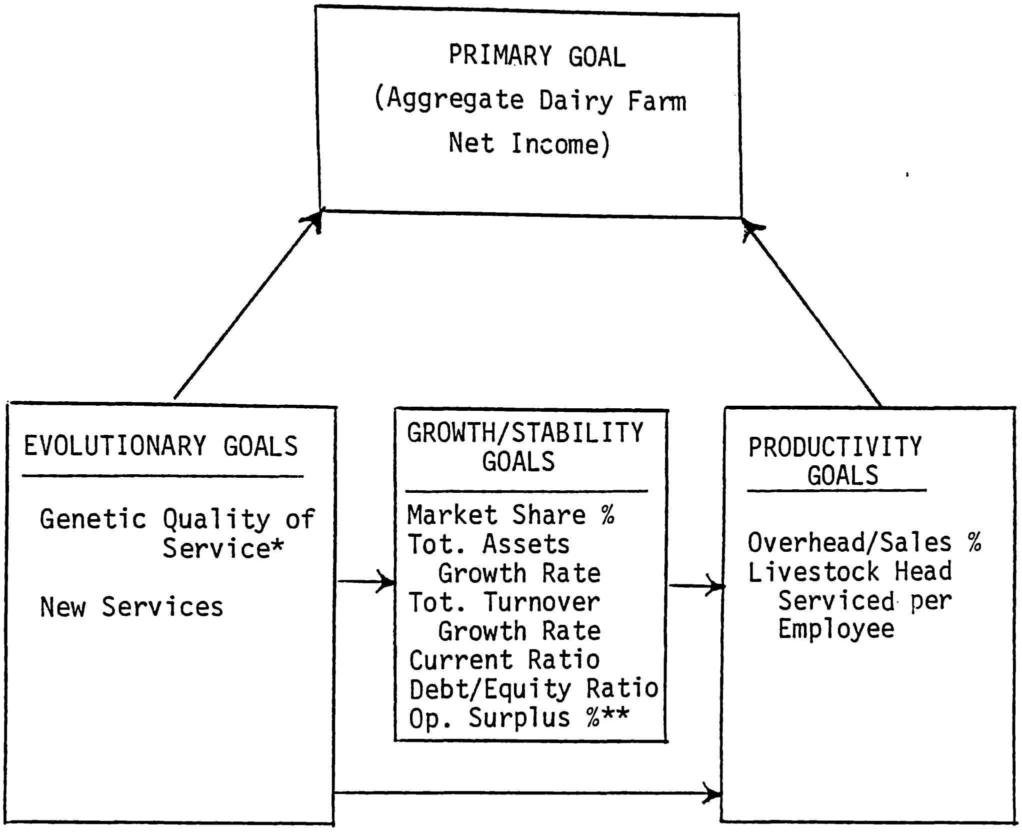
FIGURE 13.2: FLOW DIAGRAM FOR THE JAMES CASH AND PROFIT MODEL

evaluation, include the explicit definition of multi-period delay patterns for cash receipts and payments, together with a range of seasonality coefficients for both sales and overheads.

13.1.3 The Livestock Improvement Association Financial Planning Model

The New Zealand Federation of Livestock Improvement Associations is an organisation comprising six regional Livestock Improvement Associations (LIA's) serving the areas of Northland, Auckland, Bay of Plenty-East Coast, Wellington - Hawkes Bay, and the South Island. Each of the regional associations is an autonomous farmer co-operative with the artificial insemination of livestock and the testing and recording of dairy herd production being their main activities. Two specific artificial breeding services are currently offered - a service for dairy farmers, and to a lesser extent a service for beef growers (beef plan). Semen for both of these services is purchased on a group basis, at cost, from the artificial breeding centres of the New Zealand Dairy Board.

The broad long-run objective of the Federation is to maximise the aggregate net income of New Zealand dairy farms. Consideration of this objective had prompted management to question the nature and extent of its existing services, and those of the Federation's competitors. This in turn, led to identification of the organisational goal structure depicted in Figure 13. 3, in which the avenues for improving aggregate dairy farm net income are identified as being those of evolutionary change (improving the quality of existing services or developing new services), growth in the scale of operations, and (or) better productivity resulting in a lowering of service costs to the farmer.



* see Wickham et al, 1978 for empirical evidence of the effects of genetic improvement on New Zealand dairy cattle.

** The concept of 'Operating Surplus' arises from the non-profit nature of the LIA's which results in the performance measure of profitability being replaced by Operating Surplus %. This measure is accorded the status of a sub-goal, or constraint, which needs to be recognised in the interests of financial stability and growth potential.

FIGURE 13.3: GOAL STRUCTURE FOR THE FEDERATION OF LIVESTOCK IMPROVEMENT ASSOCIATIONS

One particularly evolutionary development which has received considerable managerial attention over the past three years, has been the introduction of a 'do it yourself' (DIY) artificial breeding service for dairy farmers. Due to the double-edged effect of this service (cheaper to the farmer, but genetically a lower quality service), and uncertainty as to the magnitude of these effects, management has been unable to make the decision as to whether or not DIY should be introduced.

The model described in this section was developed as part of a comprehensive program of research aimed at establishing a sound quantitative basis for making the DIY decision - and other strategic decisions which would inevitably arise in the course of establishing and pursuing the goals identified in the structure of Figure 13.3. The financial structure of any given regional LIA is reflected in the model, in a way which is entirely consistent with this goal structure, and with the strategic decision-making needs of management as far as financial information is concerned.

The purpose of the model was to project balance sheets and operating statements for any given regional LIA, over a variable planning horizon of 5 to 15 years. Essentially the model was designed to serve as a prototype for use at the regional level and (at a later stage) to support a consolidated model of the entire federation capable of being interfaced with a national dairy herd genetics model (refer Section 13.2).

The 32 accounts defined for the model are organised into the 7-level 8-linkage network depicted in Figure 13.4.

In its present form the model provides a standardised framework for the representation of the financial structures of the regional LIA's - which can also be used for the consolidated structure of the federation. The linking of a consolidated model to the genetics model (discussed in Section 13.2.1) and to the market model (discussed in Section 13.2.2) would be effected through the market model providing the previous two models with the projected cow populations constituting the Federation's market share of the national dairy herd totals. These projections are currently supplied exogenously to both models as user-specified base flows. To complete the family of models required to support the goal structure identified in Figure 13.3 a fourth model capable of projecting federation-induced changes in the national aggregate dairy farm net income, on the basis of outputs from the other three models, would need to be added.

The resultant system of models, operating over a fifteen year planning horizon, would be capable of establishing the full long-run implications on aggregate dairy farm net income, of a considerable variety of strategic changes in the nature and extent of the services offered by the federation. Also the direct financial implications of any given change, at both the federation and regional LIA levels could be established. The financial model, operated on a stand-alone basis could of course provide full support for long term financial planning at both of these levels, and with the adoption of a solution interval of one month, this support would naturally extend to also cover financial planning and budgeting in the short term.

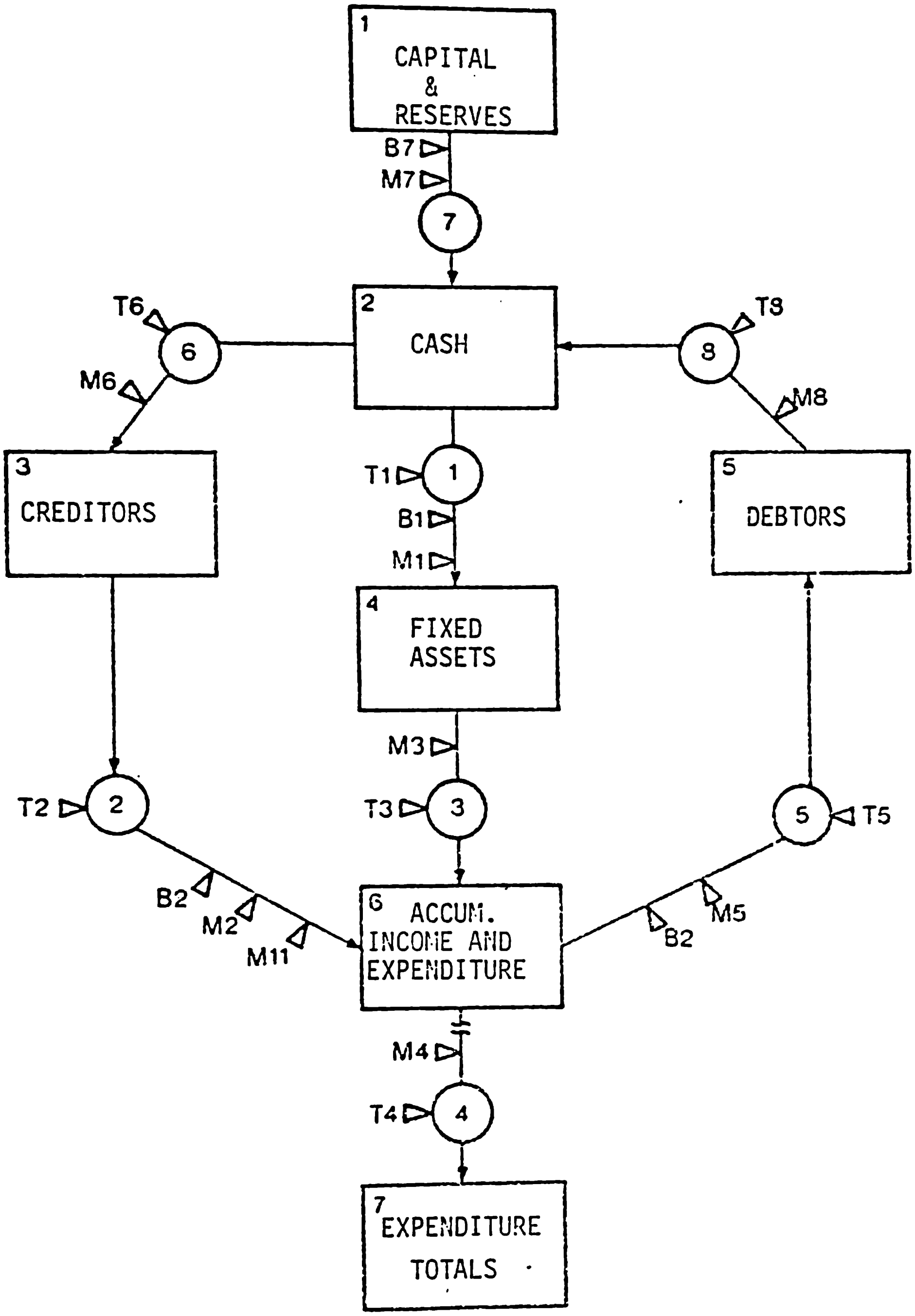


FIGURE 13.4: FLOW DIAGRAM FOR THE LIA FINANCIAL MODEL

13.1.4 The Inflation Accounting Model

The model described in this section is structured to constitute a generalised model for the dynamic simulation of a hypothetical trading enterprise, using any of the three main methods of accounting for inflation[2]. In recent years considerable research has been undertaken on various methods of accounting for inflation and the manner in which they describe the financial status and performance of different enterprises[3]. A large proportion of this research has been based on the 'ex-post' application of the various methods to the historical accounting records of specific organisations, with comparatively little evidence in the literature of 'ex ante' applications and the use of planning models to support them.

In the few instances where planning models have been used for the purposes of producing comparative projections, the models so used have been highly simplistic and structured on the traditional accounting period of one year (e.g. Minahan et al, 1977). Exceptions to this have been the very theoretical model described by Greenball (Greenball, 1968) and a model structured on a daily solution interval, for the limited purposes of assessing the effects on net income of using current costs (Benjamin, 1973).

The structure of the generalised inflation accounting model presented here, is set out in Figure 13.5. The 'core' of the model constitutes the customary structure for a financial model of a trading

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[2] Taken here to be those of Current Purchasing Power Accounting, (Emmanual, 1976), Current Cost Accounting (Hume, 1976) and Continuously Contemporary Accounting (Craswell, 1976).

[3] Wanless and Forrester, 1979.

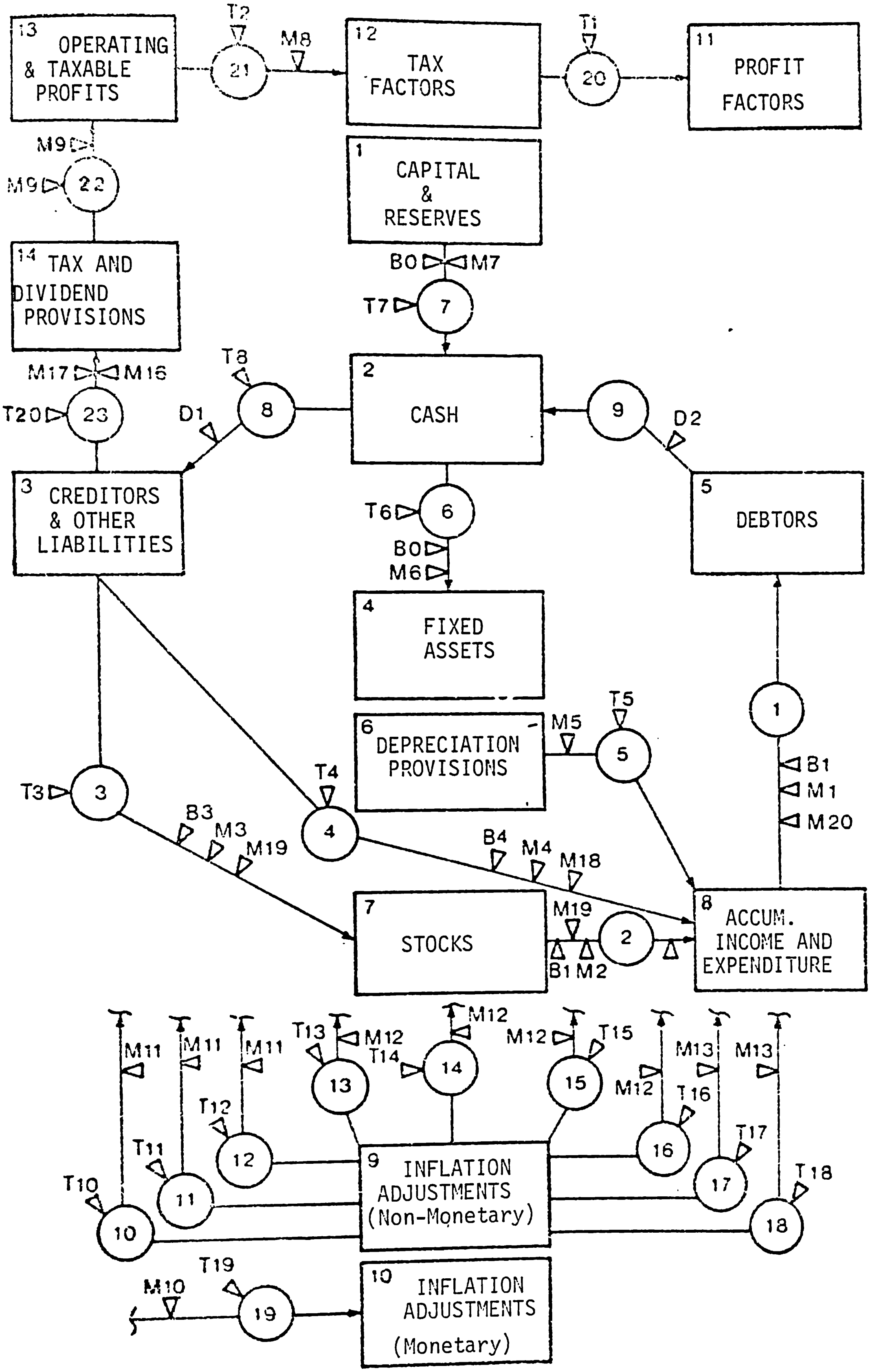

FIGURE 13.5: FLOW DIAGRAM FOR THE GENERALISED INFLATION ACCOUNTING MODEL

enterprise. Specific recognition is given to all of those financial parameters which are usually of significance to management, and which have been identified in the financial applications discussed earlier. The only distinctive additional feature of this central structure is the introduction of the cost and price inflation modulations, M18, M19 and M20. The last modulation permits the specification of various pricing policies which can be independent of the expected patterns of cost inflation.

An important feature of this model, necessary to reflect significant dynamic effects (including time lags of both a conventional and inflation-related nature) is the use of a monthly solution interval. Thus the full effects of short-term surges of inflation, which are becoming increasingly prevalent, can be assessed.

A further feature is the complete separation of all inflation-related adjustments from the traditional historical accounting computations which are preserved intact in the core of the model. This facilitates comprehensive comparative analysis and flexibility in the manner in which the effects of inflation can be reported for any given run of the model. This separation is achieved through the linkages which effect the inflation adjustments not being physically attached to any of the levels comprising the core of the model.

The two levels 9 and 10, together with their associated linkages, permit the computation of all of the inflation adjustments associated with the three methods of accounting for inflation referred to above. The nature of these adjustments and the manner in which they are modelled is discussed in the working papers referenced earlier (p.250). The basic premise upon which this sector of the model is structured, however, is the assumed validity of the following two general relationships:

(1) Adjusted Level (account balance) at the end of a solution interval = (Unadjusted Level) X (Inflation Factor for the solution interval)

(2) Adjusted Flow (transaction) during a solution interval = (Unadjusted Flow) X (Average Inflation Factor during the solution interval)

The inflation factor referred to can be based on the movements of either a general price index (as would be appropriate for the CPP method) or a specific price index (as would be required in the case of CCA and COCOA). If, for example, a general price index such as the Consumer Price Index were being used and showed values of 1000 and 1100 respectively for the start and end-points of a solution interval, the inflation factor for this interval would be 1.10 and the amount of the adjustment is therefore .10 times the unadjusted level concerned. A further assumption is that, for a solution interval of one month, the average inflation factor during the interval can be taken as the 'mid-point' value (i.e. 1.05 in the above example) without any significant distortion.

Although the model described in this section is put forward as pertaining to a hypothetical entity, its core structure can clearly be modified to reflect the relationships of a specific entity -

subject to the operational constraints of the GENSIM software system. Thus the inflation accounting sector of the model, if appended to a core structure representing a specific firm, can provide a model in which the ability to project the effects of inflation can add another useful dimension to the corporate planning process.

13.2 Non-Financial Applications of SSD

13.2.1 The Livestock Improvement Federation Genetics Model

This section focuses on the second of three models developed for the Federation of Livestock Improvement Associations, using the SSD modelling methodology. The purpose of this particular model is to simulate the livestock populations and breeding characteristics of the Sire Proving Scheme (SPS) and Premier Sire Service (PSS) dairy cattle herds over planning horizons of up to fifteen years. These herds form the main artificial breeding activities presently being undertaken by the Federation.

For each herd, it is desired to compute the population and breeding indices, for each of four specified age groups, with separate calculations being made for bulls and cows, within each age group. The procedure for performing these calculations was detailed in a working paper (Jackson, 1979) provided by the Farm Production Division of the New Zealand Dairy Board, and is summarised below.

Assuming a population of N cows, this can be subdivided into two populations comprising N_1 and N_2 cows defined for the purposes of the PSS and SPS programmes respectively. Similarly, two subpopulations of M_1 PSS bulls and M_2 SPS bulls are required to complete the system as a closed, self-perpetuating structure operating as follows:

(1) Each year, the M_1 PSS bulls are mated to the N_1 PSS cows to produce offspring in the following year classified at that time as being of age 0 years.

(2) The female offspring (50% of the total) are not brought into milk production and into the breeding scheme until age 2.

(3) The top 75 male offspring are brought into the SPS bull population for mating at age 1 year, with the SPS cows, at ages 2 and 3 years.

(4) PSS cows can be re-graded to the SPS herd and vice versa (i.e. diffusion between the two sub-populations can occur). The probabilities associated with each direction of diffusion can be assumed to be equal.

(5) Both PSS and SPS cows are culled after their second year, at a specified culling rate.

(6) For the purposes of this model all livestock can be assumed to be retired from their respective populations at age 4 years.

(7) The model must be capable of projecting all four livestock populations, by age, as well as two breeding indices - the genotype (an index of <u>potential</u> butter fat production) and phenotype (an index of <u>expected</u> butter fat production). Only the former index applies to bulls.

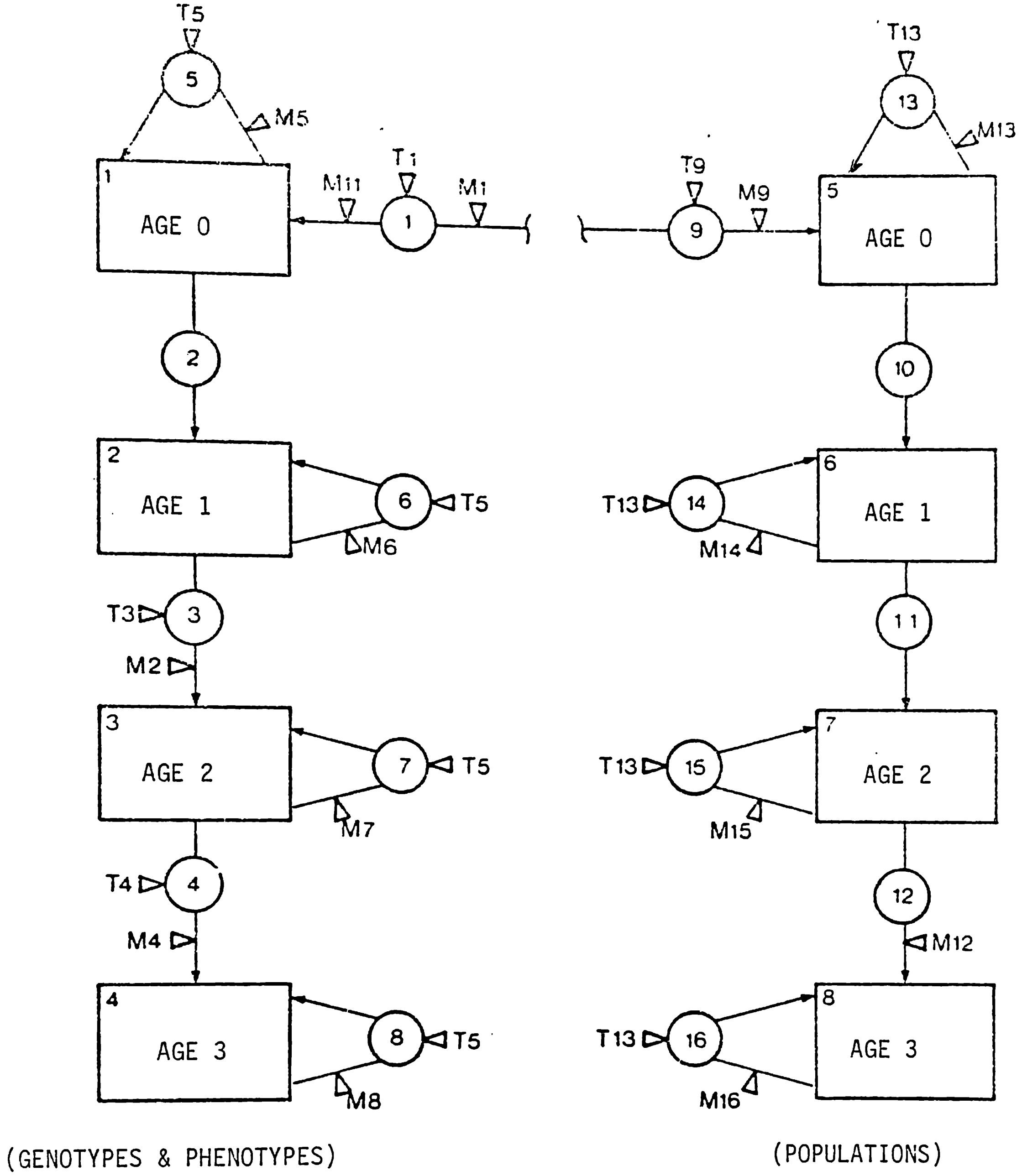

FIGURE 13.6: FLOW DIAGRAM FOR THE LIF GENETICS MODEL

The requirements enunciated above resulted in the 8-level 16-linkage structure depicted in Figure 13.6.

The model is designed around a solution interval of one year and can produce the required projections for livestock populations and genetic indices, for each year of the chosen planning horizon.

It constitutes a scaled down prototype of the model which will eventually be used to support Federation planning in terms of the goal structure discussed earlier (refer Figure 13.3). However, the differences are essentially only those of scale - with the design of the eventual model differing from its prototype in the number of ages catered for. It is intended to extend the prototype to cover up to 20 sub-populations of cows and up to 15 age classes. (c.f. the present model characteristics of 2 sub-populations and 4 age classes).

The principal uses of the model are envisaged as including the testing of different culling policies, selection differentials, production differentials and mating policies - in terms of their dynamic effects on genotype averages, phenotype averages and populations, over planning horizons of up to 15 or 20 years. The latter two measures, in respect of any given set of policies and assumptions would be of particular relevance to the Federation by reason of their importance as determinants of aggregate dairy farm net income.

13.2.2 The Livestock Improvement Federation Market Model

This model constitutes the central model in the four-part system of models referred to earlier (p.260). Its purpose was to provide market segment projections, for a defined set of market segments, on the basis of projected patterns of growth in the total market, in average herd sizes, and in market segment shares. In particular, these projections must include the number of cows expected to be serviced by the Federation, in each year of a planning horizon of 15 - 20 years.

The structure of the model is depicted in Figure 13.7. In this structure, four market segments are recognised and reflected in each of the three levels of the model. The level 2 sub-levels are extended, however, to distinguish between artificial breeding (AB) cows and natural mating (NM) cows, for each market segment. This must be done in order to arrive at the projected Federation cow numbers referred to above.

Linkage 1 determines the pattern of growth in the total market in terms of both the number of farms and the average herd sizes per farm, within each market segment. This is accomplished by initialising the inflow with the base number of farms in each segment (B1) and applying the appropriate growth rates to this with M1. The dual variables to these inflows are the average herd sizes - initialised at base values (B10) and subjected to the growth rates of M10.

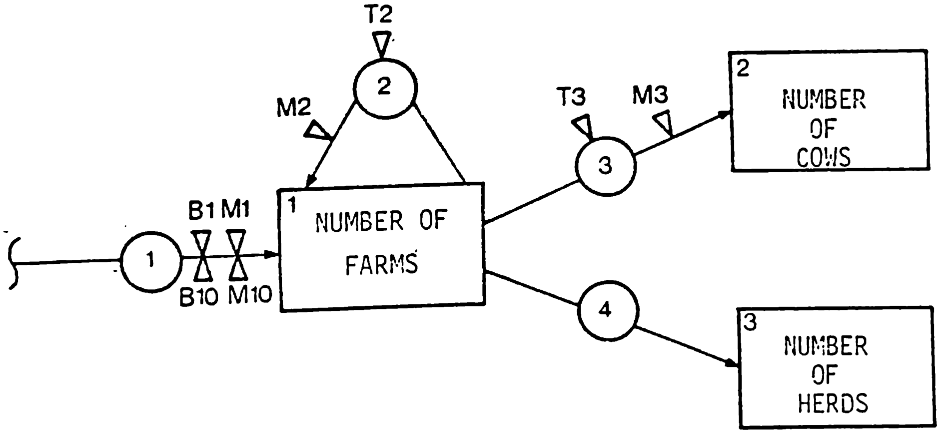

FIGURE 13.7: FLOW DIAGRAM FOR THE LIF MARKET MODEL

Linkage 2 transmits the effect of any market segment share change across each of the remaining segments. This is done by equating the inflows of linkage 2 to the total number of farms in the market (i.e. the total of level 1). The modulation M2 is then used to impose a pattern of expected percentage increments in the market share, on the inflow channel pertaining to each market segment. Transformation T2 can then be defined to reflect the specific market segments which are expected to 'give-up' the increments specified in M2.

Linkages 3 and 4 are defined to convert the resultant market segment shares (measured in terms of the number of farms in each segment) into the numbers of cows and herds (respectively) associated with each market segment. In order to do this, the outflows of each must be equated to level 1, with the additional requirement (in the case of linkage 3) that its outflow must be converted to cow numbers. This is done using the level 1 dual variables of average herd sizes per farm, and the result is then split into the AB and NM cow populations, in respect of each market segment. This split is accomplished by transforming the four outflow channels of this linkage into eight inflow channels (using transformation T3) then applying the appropriate split percentages with modulation M3.

Projections of the required cow populations and the number of herds, relating to each market segment, can be made for each year of the specified planning horizon using this model. It too has been developed to operational status for the Federation along with the financial and genetics models described earlier. Output from the model, in the form of the annual projected populations of AB cows serviced by the Federation, constitutes essential input to both the genetics and financial models. These projections would also be required for the proposed aggregate farm income model.

13.2.3 The University Enrolments Model

The model described here has been used, albeit in a rather more aggregated form[4], to assist in planning at the Department of Management Studies, Waikato University. Here a four year undergraduate programme is offered, for the degree of Bachelor of Management Studies. The structure of the model is shown in Figure 13.8. Using a solution interval of one year, the model produces enrolment, graduation and staffing projections over a planning period of seven years. These projections can be based on user-specified rates for student intake, passes, withdrawals and 'repeats' - together with their associated patterns of change.

The level definitions for the model are such that one level is assigned to each year of the 4-year study programme, with the principal courses taken in each year, being defined as sub-levels. Less influential courses, in terms of enrolments and resource requirements, are grouped for each of these levels, according to whether they are 'management' or 'non-management'.

The 13 linkages of the model cover all of the activity (or transfer) possibilities inherent in the system - from initial enrolment (linkage 1) to withdrawal (linkages 9 to 12), or graduation (linkage 13). Repeat enrolments at each year of study are accommodated using linkages 5 to 8.

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4. Using non-vectorised levels resulting in projected enrolments, in total, by year of study.

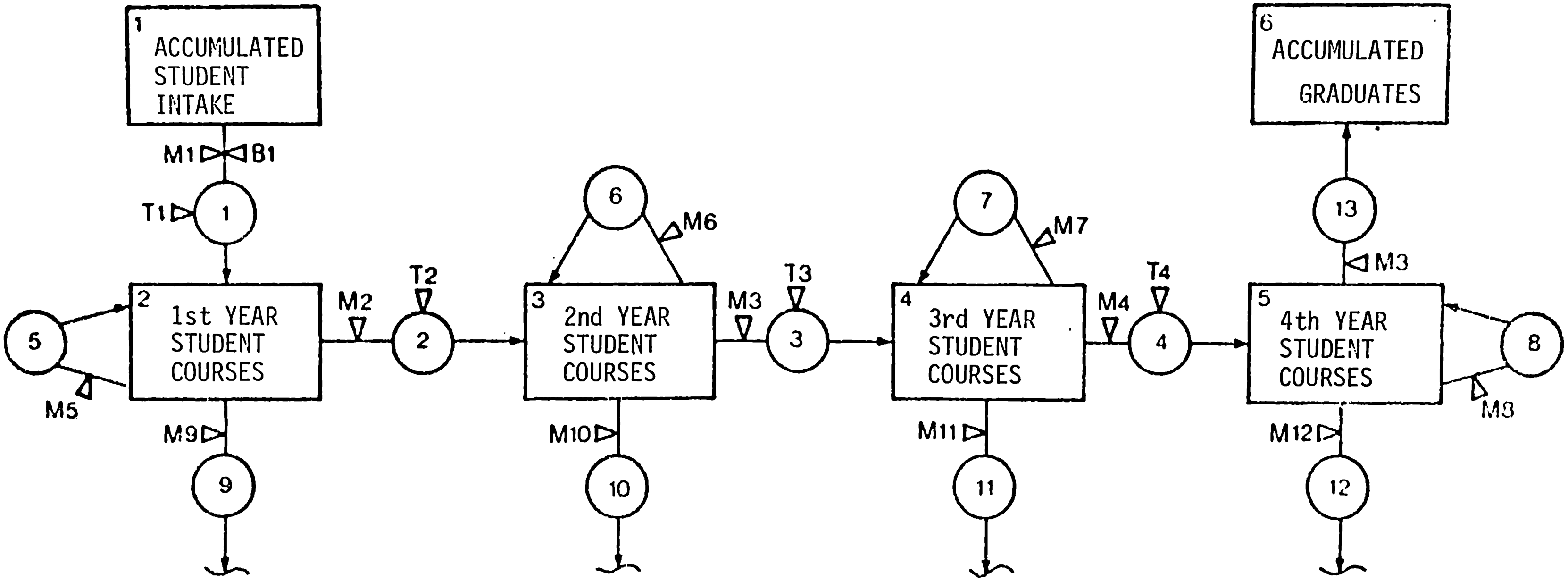

FIGURE 13.8: FLOW DIAGRAM FOR THE UNIVERSITY ENROLMENTS MODEL

13.3 Integrating SSD Models into Hierarchical Systems of Models

This section addresses the question of integrating a set of related SSD models into an hierarchical system. The desirability of this was apparent in connection with both the Hallmark models (discussed in Chapters 10 and 11) and with the Livestock Improvement Federation models discussed earlier in this chapter. More importantly the phenomenon of integrated systems of models has already been identified (refer Chapter 4 p. 66-70) as a central feature of the emerging fourth phase in the evolution of computer-based models for use in corporate planning.

Beer, 1972, envisages as the physical embodiment of his 'system 4'[5] a managerial war room, the walls of which would be used for the visual display of management information. Two of the walls would each provide a large, fully automated electronic diagram of the firm. One diagram would display the dynamics of the firm's actual performance while the other would display the dynamics of the firm's projected performance.

The author's principal argument (Beer, p. 247) in support of this style of presentation is founded on the psychology of perception together with the same conclusions regarding the power of graphical representation as those presented in Chapter 5 (p. 79-81). Beer does not suggest any specific methodology for effecting these displays, but acknowledges the relevance of System Dynamics in this context (Beer, p. 250-251).

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[5] The fourth in a set of five systems proposed by the author as constituting a general model of the overall organisation and its management. Systems 1, 2 and 3 are concerned with the regulation of internal stability. System 4 is concerned with maintaining dynamic equilibrium with the external world, while System 5 is concerned with the determination of organisational direction.

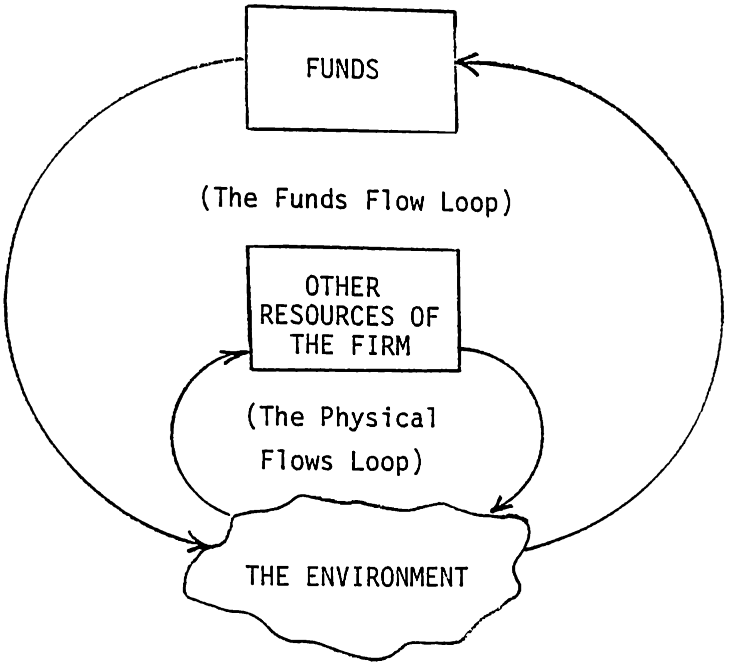

FIGURE 13.9: THE KEY ELEMENTS OF A VISUAL DISPLAY: THE FUNDS FLOW LOOP (Financial Model) AND THE PHYSICAL FLOWS LOOP (Logistics Model)

The SSD approach is ideally suited to precisely this kind of animated visual display. Both the 'actual' and the 'projected' displays would need to conform to the same structure, as any reporting in terms of actual performance against planned performance must share a common format. To be effective as a communications device the displays must capture the essential character and dynamics of both the funds loop and the underlying physical flows loop (see Figure 13.9), using the minimum of symbols, organised in the most systematic manner possible. Specifically, there would be no room in this type of display for superimposing the information network typical of traditional System Dynamics representations without a considerable loss of clarity, or alternatively an unacceptably high level of data aggregation.

The simpler conceptual base (four graphical symbols versus the six symbols used in conventional System Dynamics networks) and the more open nature of SSD models permits a less complex graphical portrayal. The tagging of flow channels to reflect exogenous influences corresponding to the five critical control parameters suggested by Beer (Beer, p.250) could be effected by using the standard 'labelled tag' symbol of SSD (in the case of a digital computer-based screen display[6]) or the more basic 'knobs and indicators' proposed by the author (in the case of an analogue display).

Further, the aggregational flexibility afforded by SSD and in particular the capability it provides for efficiently constructing and diagramming disaggregated models (through the use of matrix algebra and the concept of vectorised networks) adds to the suitability of SSD in this context. The kind of representation of complex systems being advocated by Beer can only be accomplished with the simplest possible set of symbols, and the maximum use of techniques for the orderly presentation of a large number of relationships.

In considering how SSD might be applied to this problem reference should be made to Figure 4.1 of Chapter 4. Here an idealised structure of models appropriate to a divisionalised enterprise is put forward. As evidenced by the applications discussed earlier, in this chapter and in the preceding two chapters, SSD may be readily applied to the construction of the logistics model, the market model(s) and the financial model, in respect of any given business unit. It may also be applied in the construction of the overall corporate financial model as a consolidation of the various business unit financial models. A new module recently added to the GENSIM system of programs (GENSUM) automatically performs this consolidation by merging the files of

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6. A software enhancement to GENSIM in the form of a graphics module is proposed in Chapter 14, p. 297).

computed data pertaining to a nominated set of business unit financial models.

The question of whether or not the various models within a business unit should be formally integrated, either wholly or in part, should be dealt with on the basis of the relevant costs and benefits of formal integration, together with any relevant computational constraints which might apply. Informal integration (i.e. the sequential computation of the models with manual intervention to effect the transfer of relevant data from one model to the next) may be a more attractive alternative.

Formal integration results in the merging of the networks of each component model into a single network. Clearly this would give rise, in most instances, to networks of a scale which would be difficult to accommodate in a single display of the kind envisaged for the managerial war room. Some form of 'zoom-lens' capability within the computer-based graphics module to allow access to selected sectors of any given network would seem desirable, or alternatively the ability to perform four-directional screen scrolling.

Both of the above forms of integration, applied within the business unit, constitute vertical integration. Integration across the various business units (which would be confined to their respective financial models) constitutes horizontal integration. The practical ramifications of effecting each, as far as SSD modelling is concerned, are discussed below.

(a) Vertical Integration

In general the procedure for vertically integrating

SSD models can be summarised as follows.

(i) Define the set of models to be integrated.

(ii) Define the precise nature of their interdependency. This can be facilitated by the use of 'macro' influence diagrams such as those used for depicting organisational goal structures (refer Figures 10.6 and 13.3).

(iii) Establish the precise implications of the 'macro' influence diagrams for each component model. These will take the form of either network (i.e. structural) changes or flow dependency changes to one or more of the models.

(iv) Identify the specific structural changes to be made to each component model. These changes may involve

- linkage additions or deletions
- level additions or deletions
- level dimension changes
- solution interval changes

(v) Identify the specific flow dependency changes to be made to each component model. These changes may involve any given inflow (or outflow) dependency being re-defined to be

- directly dependent on an inflow
- directly dependent on an outflow

-directly dependent on a level

-directly dependent on a combination of the above

-indirectly dependent (via modulation) on an inflow, outflow, level or some combination of these three factors[7].

(vi) Identify the level and (or) linkage re-numbering necessary as a result of steps (iv) and (v) above.

(vii) Use the GENSPC and GENINP programs to effect the above changes.

Table 13.1 summarises the implementation of these steps with respect to the Hallmark Production Planning and Financial Planning models. These two models are related to the extent that the former is an expansion of the production linkage (linkage 3) of the latter. Thus formal integration would be achieved by replacing linkage 3 on Figure 10.4 and its attached levels with the 15-linkage 8-level network of the production model (Figure 11.1).

To do this the cost of sales linkage of the financial model (linkage 2 on Figure 10.4) must be replaced with

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7. This type of dependency is not possible with the current version of the GENSIM software. All modulation tables are user-specified as data input and cannot be linked to any other model variable. A software enhancement to permit this will add considerably to the capability of the system to handle a variety of feedback relationships, and in particular relationships involving a multiplicative association of two or more model variables (either levels or flows).

TABLE 13.1: SUMMARY OF CHANGES TO EFFECT INTEGRATION OF THE HALLMARK MODELS

TYPE OF CHANGE	THE PRODUCTION PLANNING MODEL (Logistics Model)	THE FINANCIAL PLANNING MODEL
Linkage Additions	-	6
Linkage Deletions	-	1
Level Additions	-	-
Level Deletions	-	2
Solution Interval Changes	-	-
Level Re-Numbering	Add 17 to each of the 8 Levels	-
Linkage Re-Numbering	-	Add 21 to each Linkage except Linkages 2,3 & 4
New Flow Dependencies		
For the 5 Cost of Sales Linkages:		
Outflows Dependent on-	Base Flows for each Product Modulated by Product Sales Growth Coefficients	
Outflow Unit Costs Dependent on-	Average Unit Costs of the Product Stock Levels	
Inflows Dependent on -	Own Linkage Outflows converted to $ units using Outflow Unit Costs	
For the 3 Purchases Linkages:		
Inflows Dependent on -	Base Flows for each Materials Type Modulated by Purchases Growth Coefficients	
Inflow Unit Costs Dependent on -	Base Unit Costs Modulated by Materials (and Labour) Cost change Coefficients	
Outflows Dependent on-	Own Linkage Inflows converted to $ units using Inflow Unit Costs	

five linkages in recognition of the fact that there will now be five levels for finished stocks. Similarly the purchases linkage of the financial model (linkage 4 on Figure 10.4) must be replaced with three linkages to recognise the three levels required for materials stocks.

The resultant model, being an integrated logistics and financial planning model (in the terminology of Figure 4.1 of Chapter 4) consists of 23 levels and 37 linkages.

(b) Horizontal Integration

For a multi-divisional enterprise this will usually constitute the consolidation of the various business unit models to form an overall corporate financial model. The key requirement for this consolidation is the use of a common chart of accounts structure when defining the levels and level elements of the business unit financial models. The availability of a module within the GENSIM system of programs for performing consolidation has already been noted.

To summarise, the SSD modelling methodology can provide a concise and systematic means for graphically representing complex systems at various levels of aggregation. The resultant networks could, with the use of suitable computer software and hardware resources, be animated to provide dynamic visual displays of the funds and physical flow loops of the organisation. These displays may relate to departments within the business unit, to the business unit itself, or to the overall financial structure of a multi-divisional enterprise.

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CHAPTER 14

CONCLUSION

In this final chapter, an assessment is made of the simplified System Dynamics modelling methodology as presented in the preceding chapters. This assessment is made in terms of its strengths and weaknesses, to the extent that these are apparent from the applications which have been completed to date. The potential and directions for further development of the methodology are also discussed - on the basis of its perceived strengths and weaknesses viewed against the needs of the evolving process of corporate planning. Consideration is also given to the implications of some recent developments in computing technology.

In Chapter 3 the historical evolution of the corporate planning process was traced through three phases to its present state. This state was identified as being one of transition from the third phase of bureaucratic planning to a fourth phase described as participative entrepreneurial planning. The increased effectiveness of this style of planning can be measured in terms of the four dimensions of conceptual scope, organisational depth, perceptual scope and dynamic responsiveness.

An explicit statement of the modelling implications of participative entrepreneurial planning was presented in Chapter 4, after reviewing the historical development of corporate planning models - from the unsuccessful 'bottom-up' modelling attempts of the 1950's to the 'inside-out' modelling approach currently being advocated in the literature. These implications, or requirements are summarised as follows:

(1) The need for a comprehensive interactive capability for evaluating scenario and strategy alternatives in terms of a multi-level corporate goal structure. This goal structure will in general encompass profitability, evolutionary, growth, stability and productivity performance measures, organised into an 'ends-means' hierarchy. Fulfilment of this need is fundamental to broadening the perceptual scope of the planning process.

(2) The need for model flexibility in terms of its data base, structure and level of aggregation. This is directly related to the need for greater dynamic responsiveness and organisational depth in the planning process.

(3) The need for integratability with regard to the various planning models of the organisation.

(4) The need for planning models to be understandable to managers, in terms of their structure, function, and limitations. They must also be accessible to managers, either directly or indirectly, in order to facilitate fulfilment of all of the above requirements.

(5) The need for support in the form of appropriate computing resources, information systems and management education programmes.

In order to meet these needs, it is argued that the 'bottom-up' 'top-down' and 'inside-out' approaches to modelling must be replaced by a systems approach. The lack of acceptance by planners, however, of any of the existing systems approaches to modelling is noted in Chapter 5 and leads to the critical examination of these methodologies which is presented in Chapter 6.

System Dynamics emerges from this study as conceptually the most promising modelling approach for corporate planning in the 1980's. Its utility in this regard is diminished however, by some significant operational weaknesses. Principal among these are the over-emphasis on 'closed-loop' representation of decision processes in System Dynamics models, the high level of aggregation required in the models as a result of this, and the dated nature of the supporting software.

Simplified System Dynamics is presented as a methodology for corporate modelling which retains, in essence, the conceptual base of conventional System Dynamics. However, it permits the construction of more open models which focus on explicit representation of the well structured, mechanistic relationships of the organisation. The less structured 'fuzzy' relationships associated with decision processes are generally reflected as exogenously specified influences. In addition, the conventional System Dynamics concepts of levels and flows are augmented by the matrix algebra concepts of Input-Output Analysis, to permit representation of real-world systems as vectorised networks.

Finally, the methodology is supported by a fully interactive system of computer programs (GENSIM), which operates as a model generating package rather than as a modelling language.

14.1 The Strengths and Weaknesses of Simplified System Dynamics

The modelling applications described in Chapters 10 to 13 provide a comprehensive basis for an assessment of the methodology in terms of the modelling system requirements summarised above.

As far as the 'what-if?' capability of models constructed using SSD is concerned, all of the applications discussed have provided a much greater range of planning parameters for management to address than they had previously been accustomed to. In each case the range of performance measures defined for strategy evaluation was similarly extended. This was particularly apparent with those applications which involved the construction of full financial models. Separation of the model data from the model structure, within a systematic framework, greatly facilitated parametric changes both in the data base and structure of any given model.

In all applications, the planning style being used by management dictated the extent to which any particular model was utilised. To varying degrees, all were under-utilised with respect to their capacity to test strategies. It seemed apparent, however, that this under-utilisation would diminish as management's planning style evolved to take advantage of the new resource available to them.

The modular structure of the SSD models as vectorised networks also permitted flexibility to the extent that major structural changes, brought about by consideration of strategies such as the aquisition or divestment of business activities, were readily accommodated with little more effort than that required for data changes. This aspect was well tested with the Hallmark and Caldwell financial models, both of which had to be re-specified to reflect the aquisition of new business ventures.

The ramifications of integrating SSD models to form hierarchical systems of models (refer Chapter 4, p. 68-70 and Chapter 13, p. 274-281). must be considered in the context of both the methodology itself, and its supporting software. Any structured and systematic approach to model-building, such as SSD, will naturally facilitate integration, particularly where graphical representation is an integral part of the modelling process. Barriers, if there are any, will usually be encountered in the supporting software system owing to the increased scale and complexity inevitably associated with integrated systems of models.

SSD is no exception in this regard in that GENSIM and the PDP 11/70 computer which the package was written for both impose computational limitations (flow dependency relationships in the former instance and model size limitations in the latter instance) which do not in any way stem from the methodology itself. They are purely computational barriers which can reasonably be expected to be swept aside with advances in computing technology. The virtual memory capabilities of Digital Equipment Corporation's VAX machine is an example of the kind of technological advance relevant to the problem of processing limitations associated with highly structured and parameter-driven packages such as GENSIM.

Perhaps the most important point to emerge from the applications work concerns the role of the flow diagram as a communications device, or 'window' on the model, for both management and the model-builder alike. This form of the model was invariably a focal point for discussions conducted in the course of both the development and the use of any given model. The simpler conceptual base of SSD compared to that of conventional System Dynamics, whereby flow diagramming is accomplished in terms of capturing only the system's 'plumbing', data table types and their points of influence, allows a largely unencumbered view of the broad 'funds loop' structure of business organisations. This loop is of course of central importance in the corporate planning process.

Differences were encountered, nevertheless, in the ability of managers to respond to this kind of representation. These seem to reflect the different cognitive styles of the various managers. While further research would clearly be needed to establish the nature and implications of different cognitive styles, a common thread associated with poor response to the flow diagrams seemed to be merely the novelty of 'systems thinking' and the use of flow diagrams to support it. This being the case, it follows that the key to achieving maximum benefit from the flow diagram, and hence understandability of the model, would lie with the appropriate management education programmes and the use of devices to aid presentation of the diagrams (e.g. video equipment and (or) computer graphics). To conclude this discussion the strengths and weaknesses of the SSD methodology are summarised below.

(a) Strengths:

(1) As a systems approach to modelling the methodology goes further towards meeting the needs of corporate planning as envisaged during the 1980's than any of the existing systems methodologies. The general systems nature of the conceptual framework of SSD is used to model complex systems in terms of a logically ordered set of essentially simple elements, which can be organised into vectorised networks. This form of representation facilitates flexibility, integratability and understandability[1],

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[1] The vectorised network representations serve both as a crucial intermediate step in the model abstraction process, and as a vehicle for communicating a 'glass-box' understanding of the model to managers.

in the resultant models. These characteristics in turn facilitate the achievement of more effective planning in terms of the scope, depth and responsiveness measures identified in Chapter 3.

(2) More realistic models of the corporate entity as a total system are possible through the general systems nature of the concepts used in the methodology. Both financial and non-financial relationships of the organisation can be modelled with equal ease, separately or as an integrated whole.

(3) The model development and maintenance effort associated with the methodology is considerably less than that associated with the 'non-systems' approaches to the construction of corporate planning models, which are traditionally used. This advantage increases dramatically with the size of the model[2], owing to the fact that the SSD methodology supports each phase of the model abstraction sequence. Also the supporting software is a parameter-driven package rather than a high level modelling language, with real-world complexity being modelled in a systematic and highly structured manner.

(4) The highly interactive nature of the GENSIM software system allows selective access to both the data base and structural files of any given model constructed using

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[2] There are of course operational limitations on model size which are imposed by the GENSIM software system in its present form. (refer p.130). However, theoretically there is no limitation on the size of models which can be constructed using the methodology.

the system. This selective access is available for both enquiry and amendment purposes.

(b) Weaknesses:

(1) The GENSIM package in its present form imposes size restrictions on the models which can be constructed with the package. In addition to the limits on data tables, in terms of their number and size and the limit on the total number of levels and linkages, the restriction on vectorisation to an upper limit of 10 elements (or sub-levels) for any given level, is of particular concern when modelling manufacturing systems. In these circumstances, the matrix transformation feature provides the facility for modelling the primal and dual relationships of resource consumption and product costing, respectively.

Vectorisation restrictions can, however, give rise to model design problems especially where large-scale manufacturing systems are involved. As the advantages of the methodology are more pronounced with larger models, any factor which inhibits its use in this context must naturally be of prime concern.

(2) The GENSIM package in its present form does not adequately provide for the programming of special relationships which fall outside the scope of those options provided for by the equation library of the package. Although by their nature such relationships are not frequently encountered, occasions do nevertheless arise when the ability to add them to the equation library would be desirable. (e.g. the need for indirect flow dependency relationships

identified in Chapter 13, p. 279).

(3) The GENSIM package is not as efficient computationally as most of the modelling languages, for basically the same reason that the latter lack the efficiency of the general purpose programming languages. The greater degree of structure inherent in the package is attained at the cost of reduced computational efficiency. This manifests itself in the form of slow processing and greater disk storage requirements, as illustrated by the comparative analysis of Chapter 9 (refer Table 9.4, p.179).

(4) The use of general systems terminology in the place of more specific and familiar jargon of the organisation and its functional areas, can clearly pose problems with regard to managerial acceptance[3]. This particular weakness can however be minimised through the use of more familiar terms for the level and flow concepts, in keeping with the circumstances of the particular application (e.g. use of the terms 'account' and 'transaction' for financial models).

The above weaknesses are quite clearly associated with the supporting software system for the most part rather than the methodology itself. For this reason the future developments discussed in the next section focus on the software system.

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3. Meyer, 1977, identifies this problem in his discussion on the utility of System Dynamics as a financial modelling methodology.

14.2 Future Development of the Methodology

Development of the methodology in the immediate future should be directed at enhancements to the supporting software system. These enhancements are as follows:

(1) Removal of Model Size Limitations

Restructuring of the system of programs could be accomplished to redefine the factors currently fixing the size of the models which can be supported by the system. These factors, encompassing the upper limits for the number of levels and sub-levels, the number of linkages and the numbers of modulations, transformations, delays and base flows respectively, could all be defined as structural parameters, to be set by the user in accordance with available disk space and the requirements of the applications being considered.

(2) Enlargement of the System's Equation Library

While some degree of additional flexibility in equation formulation can be achieved by merely adding more modulation pattern options to the system (e.g. patterns for random variable generation), complete flexibility requires the facility for the specification, storage, and accessing of special equations, as required by the user in any given circumstance. This could be accomplished with the addition of a further flow dependency type to the five types currently available in the system. This special dependency option would require the specification by the user of an equation identifier or key, enabling access to be gained to the required equation as specified in the equation library. This equation would have been added to the equation library earlier by the user.

The above enhancement would add little in the way of complexity to the methodology, owing to the relative infrequency of the need for special relationships in any given modelling situation. The benefits arising from the ability to tailor the equation system in this way, however, would be significant.

(3) Provision for Superimposition of User Terminology

The managerial acceptance difficulties, which could arise from the unfamiliar terminology associated with the general systems concepts of the methodology, could be avoided by the addition of the facility for a user-specified dictionary of descriptive labels. These labels would be applied to any or all of the concepts of levels, linkages, flows, transformations, modulations, delays and base flows. The setting up of this dictionary would be part of the process of setting the structural parameters for the modelling system (including the model size parameters referred to in (1) above).

(4) Development of a Run Management Module

This enhancement, although not related to any of the weaknesses identified in Section 14.1, would greatly facilitate the orderly conduct of multiple runs in any given 'what-if?' modelling situation. A specific program, dedicated to the creation, maintenance and reporting of a file storing the history of all model runs, could be added to the system. This file would provide a continuous historical record of the values assigned to a selection of nominated data base parameters, and the values generated by the model for a selection of system performance measures.

The passive record-keeping role of this module could conceivably be extended to encompass the active management of a succession of model runs. This could involve the use of a defined 'algorithm' for the iterative progression of the model runs, towards predefined 'goal' values for a selection of performance measures.

(5) Integration with Data Base Management Systems

Recent developments in the area of powerful user-oriented systems for data base management[4] offer the prospect of linking the software support for the methodology to these systems. The complete integration of planning models, with one another and with the historical information data bases of the organisation, could then be effected.

The realisation of a fully integrated hierarchical system of models, along the lines of the structure depicted in Figure 4.1 of Chapter 4, will require the support of sophisticated data base management software systems of this kind.

Use of the simplified System Dynamics methodology, with the support of software developed with USER-11 would in fact permit all of the enhancements enumerated above as well as facilitating integration to whatever extent the circumstances warranted. The rewriting of the GENSIM programs with USER-11 would result in all of the file creation and maintenance functions being taken over by the appropriate USER-11 utilities with only the 'core' programs for model computation

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[4] e.g. the USER-11 Data Management System (North County Computer Services, 1980) currently available for use on Digital PDP 11/70 computer systems.

and report generation[5] retaining their existing structure and identity.

(6) The Development of a Graphics Module

Recent developments in the area of computer graphics hardware and software provide a major new dimension to simulation modelling, particularly in respect of those methodologies which incorporate graphical representation as an integral part of the modelling process.

Simplified System Dynamics stands to be strengthened considerably as a management and educational tool, through the use of computer graphics resources to 'animate' the flow diagrams which constitute a central part of the methodology. The communicative power of visual, interactive simulation for heightening managerial perception of complex models, and the systems which they depict, has already received attention in the literature[6].

On the educational side, the use of colour graphics for dynamically displaying the computations of, for example, the simple financial model of Chapter 8 (using an animated representation of its flow diagram) could provide an excellent device for the teaching of basic accounting principles and relationships.

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5. The report generating utilities of USER-11 could be used to advantage in a supplementary capacity here, however.

6. Hurrion and Secker, 1978, describe the implementation of a micro-computer based system for visual, interactive, discrete-event simulation.

(7) Conversion of the GENSIM Programs to Permit a Visicalc Style of Screen Display

Visicalc (Fylstra and Loop, 1979) is an extremely popular micro-computer based system of programs for the construction of 'top-down' planning models. It is based on the concept of an 'electronic spread sheet' where the components of the model are displayed to the user on a screen terminal, in a two-dimensional array. This tabular layout can be scrolled vertically and horizontally thus providing the user with a 'window' on the spread-sheet which is moveable to any area of the sheet.

The spread-sheet comprises 63 columns and 255 rows for most versions of Visicalc. The screen 'window' is usually of the order of 8 columns and 21 rows.

All cell positions on the sheet are individually accessable to the user, for the entry of labels (i.e. row and column titles), numeric values, or formulae which may incorporate the values of cells above and to the left of the cell being addressed.

Cells are referenced by their co-ordinates on the spread sheet.

Visicalc is a modelling package rather than a modelling language, with structural parameters in the form of the spread-sheet co-ordinates. The user is thus absolved from the need to program his model in the conventional sense (i.e. the specification of lines of code together with the logic relating them). The computational sequence for any given model is built into Visicalc through its spread-sheet structure just as it is built into GENSIM through the level and linkage numbering convention of that system.

Access to any given cell position is gained by pointing the screen cursor at that position. A screen display field is linked to the cursor. This field (located at the top left-hand corner of the screen) always shows the co-ordinates of the cell which the cursor is pointing at, and the contents of that cell.

Where a formula has been entered, this field displays the formula, while the cell on the spread-sheet displays the computed value of that formula.

The array defined in GENSIM for the computed data associated with any given model is almost equivalent to a Visicalc spread-sheet with the columns dedicated to representing time periods and the rows dedicated to representing the model levels. The computational sequence for this 'spread-sheet' is in fact down the columns, on a column by column basis. Full equivalence to a Visicalc spread-sheet would require augmentation of this array with the arrays defined for modulations transformations and delays.

The SSD modelling approach would clearly benefit from a Visicalc style of screen display, to effect the functions of model specification, listing, editing and report generation. For the small-scale 'top-down' models these functions can easily be merged as they are in Visicalc with its single spread-sheet concept. However, for large-scale dynamic models these functions would inevitably require separation owing to the number of factors and the computational time involved. In these circumstances the single spread-sheet concept would need to be extended to encompass a system of spread-sheets. This system would, for SSD, consist of the following-

(i) A Model Specifications Spread-Sheet

This sheet would be defined with columns representing model linkages and rows representing model levels. Any given cell could then be 'entered' with a shorthand notation defining an inflow/level (or outflow/level) pairing, together with any relevant data tables. For example, the notation 'I/M9/B2/D4' entered for a cell occupying the 11th row and 7th column would indicate that the inflow of the 7th linkage flows into the 11th level, and is tagged with modulation table M9, base flow B2, and delay table D4.

Ideally this particular spread-sheet would be replaced by the Graphics module discussed in the previous section, if this module was capable of providing the user with the facility for the interactive drawing of the flow diagram for any given model.

(ii) A Model Data Input Spread-Sheet

This sheet would allow the user to input and edit all of the model data tables which had been defined in the course of structuring the model specifications spread-sheet. The rows would be dedicated to the various flows (and flow channels if vectorisation has occurred) while the columns would be dedicated to the various data tables (partitioned into sectors for base flows, modulations, delays and transformations respectively). Pointing the cursor at any given cell position would result in the display field showing the full data relevant to a particular flow (or flow channel) and data table pairing. The sheet itself would show only the relevant data table tag number notation (e.g. M8 for modulation table No. 8).

(iii) A Model Output Spread-Sheet

This sheet would display the array of computed data for any given model, with columns representing the time periods of the planning horizon and rows representing the model levels. User interaction with this sheet would cover row and column manipulations such as relocations and arithmetical operations (in addition to those structured into the model). Typically these would be the simple Visicalc style of calculation capable of being performed in the immediate mode.

All of the developments discussed above relate to either the lifting of software-imposed constraints on the methodology, or the utilisation of recent advances in computer technology to render it more effective as a management tool. Thus these developments are in effect confined to the operational level with the underlying conceptual base of the methodology being retained. The extensive range of applications documented in the latter chapters of this study provide support for both the retention of this conceptual design and for its practical utility. The methodology needs to be applied to the construction of large-scale models, however, to gain the full measure of its advantages over the traditional corporate modelling methodologies.

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APPENDICES

Technical details of the GENSIM system of computer programs, in terms of their purpose and structure, are contained in these Appendices. The full listings of the demonstration models viz., the Simple Financial Model and the Extended Financial Model are also provided.

APPENDIX A

THE TRANSFORMATION TABLE (MATRIX)

(For switching, or directing flows within a linkage. Inflows can be transformed into outflows or vice versa. The transformation can involve the merging or splitting of the independent flow to derive the dependent flow. Only inflows and outflows of the same linkage can be related in this way, however.)

Inflow Channel Number

(matching those channels on the inflow side of the linkage to which the Table is attached)

Outflow Channel Number

(matching those channels on the outflow side of the linkage to which the Table is attached)

	1	2	3	4	5	6	7	8	9	10
1										
2						.3				
3										
4										
5						.7				
6										
7				1						
8										
9										
10										

FIGURE A.1: FORMAT OF THE TRANSFORMATION MATRICES

Data is entered in the Table in such a way as to relate the inflow channels (columns) to the outflow channels (rows) in the desired manner. Examples are:

(1) A "1" in the column 4 - row 7 square "ties" inflow channel 4 to outflow channel 7, and vice versa. Thus whatever flows along the former will also flow along the latter.

(2) A ".3" in the column 6 - row 2 square and a ".7" in the column 6 - row 5 square will "split" the inflow channel 6 between outflow channels 2 and 5 respectively. Thus if 100 units flow along the former, then 30 units and 70 units

will flow along the latter two channels.

Care must be exercised to ensure that the Table is filled out correctly, bearing in mind which side of the linkage is the independent one. If the inflows are giving rise to the outflows, the Table will be the transpose of that needed if the outflows were giving rise to the inflows.

APPENDIX B

THE MODULATION AND CYCLES TABLES (MATRICES)

(For exerting user-specified influences on linkage flows, conforming to any one of a library of patterns involving addition, subtraction or multiplication, of or by, specified amounts or coefficients)

FLOW CHANNEL NUMBER (matching up with those channels of the flow to which the Table is attached)

	FLOW CHANGE/TIMING PAIRS												
	1st Pair		2nd Pair		3rd Pair		4th Pair		5th Pair		6th Pair		MODULATION PATTERN CODE
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

FIGURE B.1: FORMAT OF THE MODULATION MATRICES

For any CHANGE/TIMING Pair (up to 6 pairs may be specified) the convention is as follows:

(1) 1st Amount is the Change factor (to be added, subtracted or used for multiplying with, depending upon the chosen Pattern Code)

(2) 2nd Amount is the Timing factor (the time interval or period for which the above Change factor is to be operative)

The Modulation Pattern Codes:

The code consists of up to 4 digits defined as follows:

(1) 1st two digits (from left) - the cycle series number if cyclical effects are required to be superimposed. If not these two digits can be ignored, and the code reduces effectively to only the 2 digits below.

(2) 2nd two digits - The actual pattern code. If the desired code No. is less than 10 then only the one digit is entered.

Available patterns and their codes are listed in Table B.1

TABLE B.1: THE MODULATION PATTERN OPTIONS

Code	Pattern Description
0	Multiplication by the Change Factor, for each period less than or equal to the Timing Factor.
1	Multiplication by the Change Factor, only in the period specified as the Timing Factor.
2	Addition of the Change Factor, in each period less than or equal to the Timing Factor.
3	Addition of the Change Factor only in the period specified as the Timing Factor.
4	Sets the flow equal to the amount specified as the Change Factor it its value exceeds the latter (i.e. clips back to an upper limit). Applies every period up to and including the period specified as the Timing Factor.
5	Sets the flow equal to the amount specified as the Change Factor if its value is less than the latter (i.e. clips up to a lower limit). Applies every period up to and including the period specified as the Timing Factor.
6	Sets the flow equal to 0 if its value exceeds the amount specified as the Change Factor, otherwise sets the flow equal to 1. Applies every period up to and including the period specified as the Timing Factor.
7	Sets the flow equal to 1 if its value is less than the amount specified as the Change Factor, otherwise sets the flow equal to 0. Applies every period up to and including the period specified as the Timing Factor.
8	Compound Multiplication of the flow, at the rate specified as the Change Factor, every period up to and including the Timing Factor.
9	Compound Division (i.e. Discounting) of the flow at the rate specified as the Change Factor, every period up to and including the Timing Factor.

NOTE: For Pattern Codes 8 and 9 the rate (e.g. 10%) must be entered in coefficient form, i.e. as 1.10 if the rate is 10%. Also a maximum of only Five change/timing pairs is allowable. (c.f. six for all other pattern codes).

Example pattern codes are:-

A pattern code of 8 denotes modulation with pattern option No. 8 and no cycling.

A pattern code of 708 denotes modulation with pattern option No. 8 and cycle No. 7.

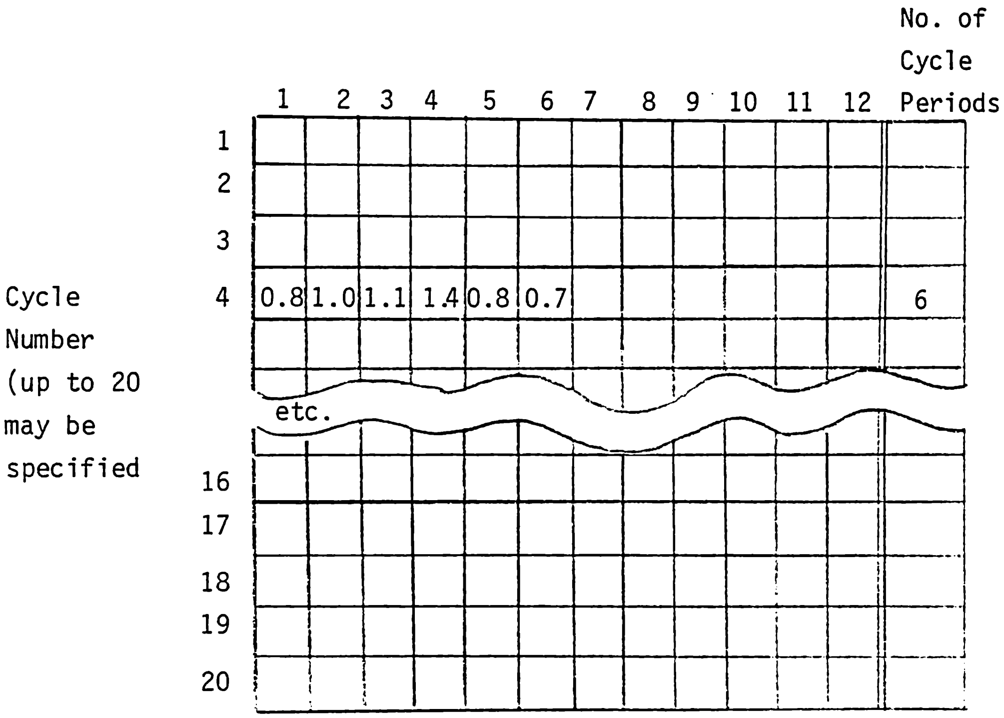
A pattern code of 12 denotes modulation with pattern option No. 12 and no cycling.

A pattern code of 1412 denotes modulation with pattern option No. 12 and cycle No. 14.

The Cycles Data Table (or Matrix)

This is used in conjunction with the Modulation Tables to superimpose user-specified cyclical influences on flows. Each cycle is specified as a row of the Table, and can be accessed by any row of any Modulation Table, by referencing its row number in the first two digit positions of the 4-digit modulation pattern code.

Periods of the Cycle
(maximum of 12 Periods permitted)



Cycle
Number
(up to 20
may be
specified

	1	2	3	4	5	6	7	8	9	10	11	12	No. of Cycle Periods
1													
2													
3													
4	0.8	1.0	1.1	1.4	0.8	0.7							6
etc.													
16													
17													
18													
19													
20													

FIGURE B.2: FORMAT OF THE CYCLES MATRIX

Cycles are specified by entering the relevant Indices (or Coefficients) in any selected row of the Table, for each period of the desired cycle in turn. Cycles of up to 12 periods in duration can be specified.

For example, in Figure B.2, Cycle No.4 has been specified to operate over 6 consecutive periods, (as per far right column), and the individual indices are as shown. Thus the flows of whatever linkage this cycle is brought to bear on (via a Modulation Table), will be multiplied by each index in turn, for successive periods, until 6 have elapsed, then a new 'run' of the cycle will commence using the first index again. Thus the cycle loops back on itself every 6 periods.

APPENDIX C

THE DELAY TABLES (MATRICES)

(For delaying the occurrence of flows for specified lengths of time, and releasing them according to a specified pattern of partial amounts, over a succession of periods, if desired)

(a) The Boxcar Delay

Flow Channel Number (matching the flow channels of the linkage to which the Table is attached)	Number of Time Periods of Delay (ahead of the Current Period)									Current Period (No Delay)
	+1	+2	+3	+4	+5	+6	+7	+23	+24	0
1										
2										
3	.15	.30	.20	.10	.10	.05				.10
4										
5										
6										
7										
8										
9										
10										

FIGURE C.1: FORMAT OF THE DELAY MATRICES

The above Table format is used to store two forms of Data as follows:

(1) The Delay Distribution Coefficients: Each row is entered with the 'split-up' proportions for spreading or distributing the flows in that channel, across the future time periods (i.e. those periods ahead of the current period), in accordance with the desired delay pattern.

For example, in Figure C.1, the entries shown in row 3 would release 10% of any period's flow in that same period (i.e. bypass the delay)

15% one period later, 30% two periods later, etc., until the remainder (=5%) is finally released 6 periods after the period in which the whole flow originally occurred.

(2) The Delayed Flow Initial Values (Transit Levels):

In some cases it is necessary to initialise future flow amounts to apply at the start of a model run. These 'opening future flow amounts' reflect the fact that account must be taken of the delayed components of past flows stored from periods prior to the point at which the model run commences.

Boxcar delays should not be applied to flows which are dependent upon (i.e. equated to) levels. The underlying concepts of Boxcar Delays are only applicable to flows which are equated to other flows, or base flows.

(b) The Exponential Delay

This type of delay is appropriate for flows which are dependent upon levels, more particularly levels to which they are attached as outflows. The only data which needs to be supplied for an Exponential Delay is the average delay period. The effect of this type of delay when assigned to an outflow which is dependent upon its own level, is to 'release' any given value of that level as flows which diminish or decay exponentially over a succession of time periods. The average duration of the delay overall is equal to the specified average delay period.

Thus for an outflow emanating from a Level which is its flow determinant, and with an Exponential Delay tagged to it with a delay period of 2, the following flow values would result, if in Period 1, the level had a value of 100, and there were no further inflows to it-

TABLE C.1: EXAMPLE CALCULATIONS FOR AN EXPONENTIAL DELAY

Variable	Time Period					
	1	2	3	4	5	6 ....etc..
Level at start of the Period	100	50	25	12.5	6.25	3.125
Outflow during the Period (after being delayed)	$\frac{100}{2}$ = 50	$\frac{50}{2}$ =25	$\frac{25}{2}$ =12.5	$\frac{12.5}{2}$ = 6.25	$\frac{6.25}{2}$ =3.125	$\frac{3.125}{2}$ =1.5625
Level at end of the Period	100-50 = 50	50-25 =25	25-12.5 =12.5	12.5 -6.25 =6.25	6.25 -3.125 =3.125	3.125 -1.5625 =1.5625

The outflow values can be seen to be steadily diminishing in a manner which is displayed graphically below. The weighted average delay duration is 2 periods.

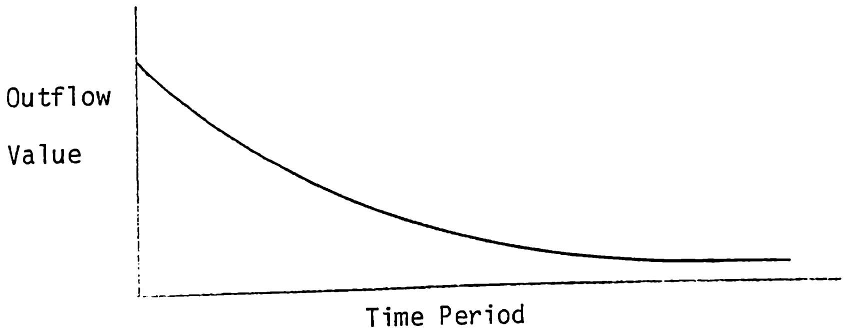


FIGURE C.2: THE EXPONENTIAL DELAY

Exponential Delays ignore the sign of values used. Thus negative values of any level would be treated as being positive.

(c) Boxcar Delays - Comparison with Conventional System Dynamics

In DYNAMO, using the BOXLIN function, the contents of each or any boxcar can be calculated independently from its own uniquely defined equation. Also flows may be 'taken off' from boxcars other than the bottom one, the contents of which are automatically discarded (Forrester, p. 84-85).

The BOXCYC function is a more specialised form of boxcar delay whereby the contents of each boxcar are sequentially updated using an exponential smoothing relationship, and re-cycled with the contents of the bottom boxcar being moved up to the top, rather than being discarded (Forrester, p. 446-448).

The basic procedure for effecting these delays in SSD is analogous to that used in conventional System Dynamics, viz., the setting up of a boxcar train with a defined shift interval. The contents of the 'boxes' comprising the train represent stored future flows, and the passage of time is reflected in the train by stepping the contents of the boxes, from one to the next, at the conclusion of each successive shift interval.

Simplifications made here in the use of the boxcar concept, are that the shift interval is automatically equated to the model solution interval (thus removing the need for interpolation) and flows are taken off from the bottom boxcar of the train only. Further, the calculation of the contents of each boxcar is structured to the extent that it is always computed as the sum of the incoming contents of the boxcar immediately above (if there is one) and the product of the flow being subjected to the delay (i.e. the input to the delay) and the delay distribution coefficient defined for the particular boxcar in question.

i.e. Boxcar Contents = (Contents of Boxcar Above) +
(Input to the Delay x Delay Distribution Coeff. for the Boxcar)

APPENDIX D

FLOW DEPENDENCY

The equations of any model are specified via the linkage specifications by defining a Flow Dependency Type for both the inflow(s) and outflow(s) of each linkage. This in effect equates the flow concerned to either another flow, a base flow, or a level. The flow, base flow, or level to which this flow is equated to thus acts as its determinant. Every flow of every linkage in a model must be assigned to a flow determinant. Possible determinants are therefore:

(1) Another flow (Inflow or Outflow of the same, or any other linkage).

(2) A Base Flow, tagged to the same, or any other linkage.

(3) A Level.

For multi-channel linkages, by definition the inflows and outflows become vectors, i.e. they consist of 'bundles' of flows, one per channel of the linkage. The equations associated with each of the above three types of flow dependency thus become vector equations. If, for example, the inflow of linkage No. 5 is given a "Level" flow dependency type, and equated to level No. 2 then:

$I(5,1) = L(2,1)$
and $I(5,2) = L(2,2)$
and $I(5,3) = L(2,3)$ etc., etc.

or more generally:

I(5,V) = L(2,V) for V=1,2,3 .....

Thus each individual flow element, or channel, is equated to the level element, or sub-level, of the same number. This one-to one correspondence applies regardless of whether the flow determinant is another flow, base flow, or level. For the purposes of this discussion of flow dependency the following notation is defined:

I(N,V) denotes the inflow of channel V, in linkage N
X(N,V) denotes the outflow of channel V, in linkage N
L(N.V) denotes the sub-level V, of level N
B(N,V) denotes the base flow V, of the Base Flow Table with Tag No. N.

(a) Dependency on Another Flow

Any flow, either inflow or outflow, can be equated to any other flow. For multi-channel linkages this results in a vector equation, with each channel being equated to its opposite number in the determining flow. Since the flows in any model are always calculated in linkage number order, the linkage numbering should always be done to ensure that no flow is equated to a flow of a higher linkage number. If this does occur, the flow concerned will be equated to the flow values of that higher linkage as calculated in the previous solution period. Thus the effect of equating a flow to a flow not yet calculated for any given solution period, is that the determining flow's previous period value is picked up instead.

Care should also be taken to ensure that any inequality between the number of flow channels defined for each respective flows in the relationship does not result in one or more of the channels of the flow being determined, not having a determinant. Obviously this will be the case if the number of channels of the former exceed those of the latter.

Two distinct types of relationship are possible when a flow is equated to another flow. These are:

(1) The determining flow is not of the same linkage. In this situation, the flow concerned is set equal to the determining flow, subject to any delay or modulation influences tagged against it. The following relationships, in general form, are possible:

I(N,V) = X(Z,V) ...D...M)
or X(N,V) = X(Z,V) ...D...M)
or I(N,V) = I(Z,V) ...D...M)
or X(N,V) = I(Z,V) ...D...M)

where D and M denote the (possible) presence of delay and (or) modulation flow influences.

....for flows of linkage N being determined by (or equated to) flows of linkage Z.

It should be noted that the sequence in which the delay and modulation influences are applied to any flow, are as shown (i.e. delay then modulate).

(2) The determining flow is of the <u>same</u> linkage. In this situation a transformation is required, either via a transformation table tagged to the linkage, or through the use of the 'sum' or 'identity' transformation classifications for Linkage Type (refer page 343). In this situation the flow concerned is set equal to its determining flow <u>multiplied</u> by the appropriate transformation table, then subjected to any delay or modulation influences tagged against it. The following relationships, in general form, are possible:

$$X(N) = I(N) \times T \ldots D \ldots M$$

or $$I(N) = X(N) \times T' \ldots D \ldots M$$

...for flows of linkage N, tagged with the transformation table T. Note that T' is the table T rotated about its diagonal. The above two equations respectively transform, for the linkage N, its inflows into outflows; and its outflows into inflows. Obviously for any given linkage only one, if any, of these equations would apply, as a <u>primal</u> model relationship.

Equations of the first type perform <u>product explosion</u>, being the calculation of resource input requirements,for given amounts of product output (Note: an <u>output</u> from a process is an <u>inflow</u> to a level. An <u>input</u> to a process is an outflow from a level).

Equations of the second type perform <u>resource implosion</u>, being the calculation of product unit costs associated with a given set of resource unit costs - if the inflows and outflows of the equation are replaced by their respective unit costs.

The equation thus becomes:

C(N) = K(N) x T' ...M where C(N) and K(N) denote the inflow and outflow unit costs of linkage N respectively.

Note that the delay influence does not apply to this relationship. Cost build-up equations of this kind constitute the 'dual' form of any model, and will be formed and evaluated automatically if the option to solve the dual form of the model is taken up in the GENCOM program. Obviously this option will only be exercised for models in which the unit cost concept is appropriate.

More generally, both of the flow equations identified above, utilise the 'flow directing' role of the transformation function.

(b) Dependency on a Base Flow

Any flow, either inflow or outflow, can be equated to a base flow specified in the form of a base flow table. The table concerned will be tagged to the flow via the Tag No. by which it is identified. The same table may also be tagged to other flows. For a multi-channel linkage, a vector equation results, with each flow channel being equated to its corresponding flow number in the base flow table. The following relationships, in general form, are possible:

I(N,V) = B(T,V) ...D...M
or X(N,V) = B(T,V) ...D...M

...for flows of linkage N tagged with the base flow table with

Tag No. T. As with flows dependent upon another flow, the equations are subject to any modulation or delay influences which may be tagged against the flow being determined.

Dependency on a base flow is appropriate for flows which cannot be satisfactorily equated to any flow, or level in the system. Such flows are in effect determined by purely external factors, and the base flow serves to provide a 'base' or initial value for the flow or flows concerned.

(c) Dependency on a Level

Any flow, either inflow or outflow, can be equated to any level in the system. For a multi-channel linkage, a vector equation results with each flow element or channel being equated to the sub-level of the same number. As with dependency on a flow, care should be taken to ensure that any inequality between the number of channels defined for the flow, and the number of sub-levels defined for the level, does not result in one or more channels of the flow not having a determinant. Clearly this results if the number of flow channels exceeds the number of sub-levels.

The following relationships, in general form, are possible:

$$I(N,V) = L(Z,V) \;\ldots D \ldots M$$

$$\text{or} \quad X(N,V) = L(Z,V) \;\ldots D \ldots M$$

...for flows of linkage N being equated to the level Z, with V denoting the channel No. of the former and the sub-level No. of the latter. As with the other dependency types discussed above, the equations may be subjected to any delay or modulation influences which might be tagged against the flow being determined.

It should be noted that for flows being made dependent on levels, the Boxcar Delay should not be used, as it is a device for spreading flows across future time periods, not levels. The Exponential Delay is more appropriate in these circumstances.

Care should also be taken to accommodate the effects of negativity in the determining level. If a flow is made equal to a negative-valued level, then the flow will be negative, unless it is being subjected to a delay, in which circumstance the sign will be ignored. In all other instances negative-valued levels will give rise to negative flows, unless the negativity is changed via modulation (e.g. specifying a change factor with a negative sign, in conjunction with one of the multiplicative modulation patterns).

(d) Mixed Dependency

The situation can arise, with multi-channel linkages, where the vector equation form of the three dependency types discussed above is unsatisfactory. Rather than each channel of the flow being equated to its 'opposite number' in the determining factor (another flow, base flow or level) each channel may need to be assigned its own unique determinant, i.e. to be equated to a specific flow channel, base flow number or sub-level number, quite independently of the other channels of the flow. The Mixed Dependency option allows each individual channel of a given flow to be equated to the nominated channel of any other flow, or the nominated element of any base flow table, or the nominated sub-level of any level. Thus any of the general relationships described earlier in this Appendix can be defined for any specific channel within the flow- resulting in a mixture of dependency types within the flow concerned. The only exception is the flow dependency situation involving transformation, as this concept is relevant only when flows are being treated as vectors. Nevertheless in a mixed dependency a flow channel can still be equated to another flow channel of the same linkage (either inflow or outflow), but there will be no multiplication by any transformation table regardless of whether or not one is defined.

When a mixed dependency situation exists, and flow channels are being equated to other flow channels within the same linkage, care must be exercised to ensure that this is done with due recognition of calculation sequence. The general rule is that if any channel is equated to another channel on the same side of the same linkage, the latter channel should have a lower number, if its value in the current solution period is to be picked up. This is because the channel equations are evaluated in numerical order, within any given linkage.

If any channel is equated to another channel on the other side of the same linkage then the former should be an outflow if current period flow values are required. The reason for this is that for any given linkage and solution period, inflows are calculated before outflows. The only exception to this sequence is where the inflow in total (all channels) is dependent upon its own outflow, in which circumstance the latter will be calculated first. In this case, if the outflow has a mixed dependency, none of the individual channels should be equated to any inflow channel of the same linkage, if current period flow values are required.

The general rule for any flow which is equated to another flow which has not yet been calculated for the current solution period, is that the latter's value as calculated in the previous solution period is picked up. If there is no previous solution period this value will be zero. This rule applies regardless of whether or not the equation occurs in the context of a mixed dependency.

For Mixed Dependency, the Flow Determinant Number (refer Table E.2, p.343) is in fact the Mixed Dependency Table Row No. This is the number of a specific row in this table which carries the codes specifying the dependency of each channel in the flow. Up to 10 rows can exist in this table. Each row used in the table must be uniquely assigned, i.e. used only once as a Flow Determinant No. The following example illustrates how this operates:

The inflow of linkage 5 is assigned a mixed dependency. Its Flow Determinant No. is given as 3. Thus row 3 of the Mixed Dependency Table will be set aside to store the individual dependency codes of the inflow channels of linkage

5. These channels (say 4 in total) are to be equated to determinants as follows:

I(5,1) = L(2,4) and the Dependency Code will be 1024

I(5,2) = I(4,1) and the Dependency Code will be 2041

I(5,3) = B(9,5) and the Dependency Code will be 0095

I(5,4) = X(1,7) and the Dependency Code will be 3017

Row 3 of the Mixed Dependency Table has now been assigned to the inflow of linkage 5 and cannot be used for any other mixed dependency relationship.

Note: the code structure used above is as follows:

From the left -

1st digit - 1=level, 2=inflow, 3=outflow, 0=base flow

2nd and 3rd digit - the level, linkage or base flow No.

4th digit - the sub-level, flow channel or base flow element No. (a "0" represents, 10)

All details relating to mixed dependency are prompted for during the running of the GENSPC program. These details are supplied as part of the specifications for any given linkage for which the mixed dependency option has been selected. For each channel a set of prompts occur which request -

(1) The Dependency Type for the channel (can be Base Flow, Inflow, Outflow, or Level)

(2) The Flow Determinant No. for the channel, being the specific

number of:-

the Base Flow (if Base Flow dependent) i.e. its Tag No.
the Linkage (if Inflow or Outflow dependent)
the Level (if Level dependent)

(3) The specific element number of the chosen Flow Determinant being -

the element number of the Base Flow Table concerned
or the channel number of the Inflow or Outflow,
or the sub-level number of the level concerned.

In the event of the Flow Determinant of any specific channel being a level, the total of all sub-levels within that level can be used to equate the channel to, instead of any specific sub-level of that level. This relationship is useful, for example, in situation such as those where a flow representing Interest on Bank Overdraft is to be calculated. This can be done by equating it to the amount of the overdraft, where that amount is given by the total of the Cash level, then modulating it to effect multiplication by the appropriate interest rate.

APPENDIX E

THE MODEL SPECIFICATION PROGRAM (GENSPC)

This program must be run to set up a new model, or to amend the basic structure of any model. The program can be accessed directly from the control program GENSIM, or from the Data Input program GENINP, or by using the command

RUN GENSPC (modified depending upon where the program
is stored)

(a) Purpose of the Program

The structure of any model must be specified in terms of:

(1) The type of Solution Interval (days, weeks. months, quarters or years)

(2) The total number of Levels

(3) The total number of Linkages

(4) The Specifications for each Level in terms of

- its Description
- its Dimension (i.e. No. of Sub-levels)
- its Type (Monetary or Physical)
- the Totalling Procedure for the Sub-levels
- the 'Re-set to Zero' Interval for the Level if applicable)
- the Sub-level (Element) Descriptions

(5) The Specifications for each Linkage in terms of

- its Type (i.e. usage of Flow Influences)
- the Level it flows into (referenced by No.)
- its Inflow Dependency Type
- the Number (Level, Linkage or Tag) of the Inflow Determinants)
- the relevant Tag Nos. of any Inflow Modulation

or Delay Tables

- the relevant Tag No. of a Transformation Table (if applicable)
- the Level the Linkage flows from (referenced by No.)
- its Outflow Dependency Type
- the Number (Level, Linkage or Tag) of the Outflow Determinants
- the relevant Tag Nos. of any Outflow Modulation or Delay Tables.

Details of the factors referenced in (1) to (5) above, are set out in Tables E.1 and E.2.

(b) The Program Files

The resultant model structure is stored on the following disk files for access by the other programs of the system. (The file-name MODEL is used purely for illustration and would be replaced by the name of the particular model concerned).

MODEL .ONE for Level Specs
MODEL .TWO for Linkage Inflow Specs and Linkage Type
MODEL .THR for Linkage Outflow Specs and Level Totalling Procedure
MODEL .FOU for No. of Levels, No. of Linkages, Solution Interval Type, Level and Sub-level Descriptions

(c) The Program Structure

Refer Figure E.3

TABLE E.1 LEVEL SPECIFICATIONS

(Note: All Levels are referenced to by their Number in GENSPC)

Level Specification Factor	Explanatory Comments
Level Description	Up to 30 Characters allowed
Level Dimension	The Number of Elements (orSub-levels) defined for the Level. Up to 10 elements are allowed.
Level Type	Whether measured in Monetary or Physical units. Also whether negative values are allowable (=unbounded) or not (= lower bound of zero) 1 = Monetary Unbounded (negative values allowed) 2 = Monetary Bounded (negative values not allowed) 3 = Physical Unbounded (negative values allowed) 4 = Physical Bounded (negative values not allowed)
Level Total Type (Summation Procedure)	The manner in which Elements (Sub-levels) are totalled if at all. Options are: S=Sum of Elements P=Sum of the Product of Element value times Element Unit Cost N=No Summation Required SCF=Sum of Elements with the sum carried forward regardless of any zero-ising of the Level.
Zeroising Interval	The number of solution periods which are allowed to elapse before all elements of the Level are re-set back to zero. Since the Levels are accumulators, this is effectively the accumulation interval of the Level. A response of zero results in the Level never being re-set to zero.

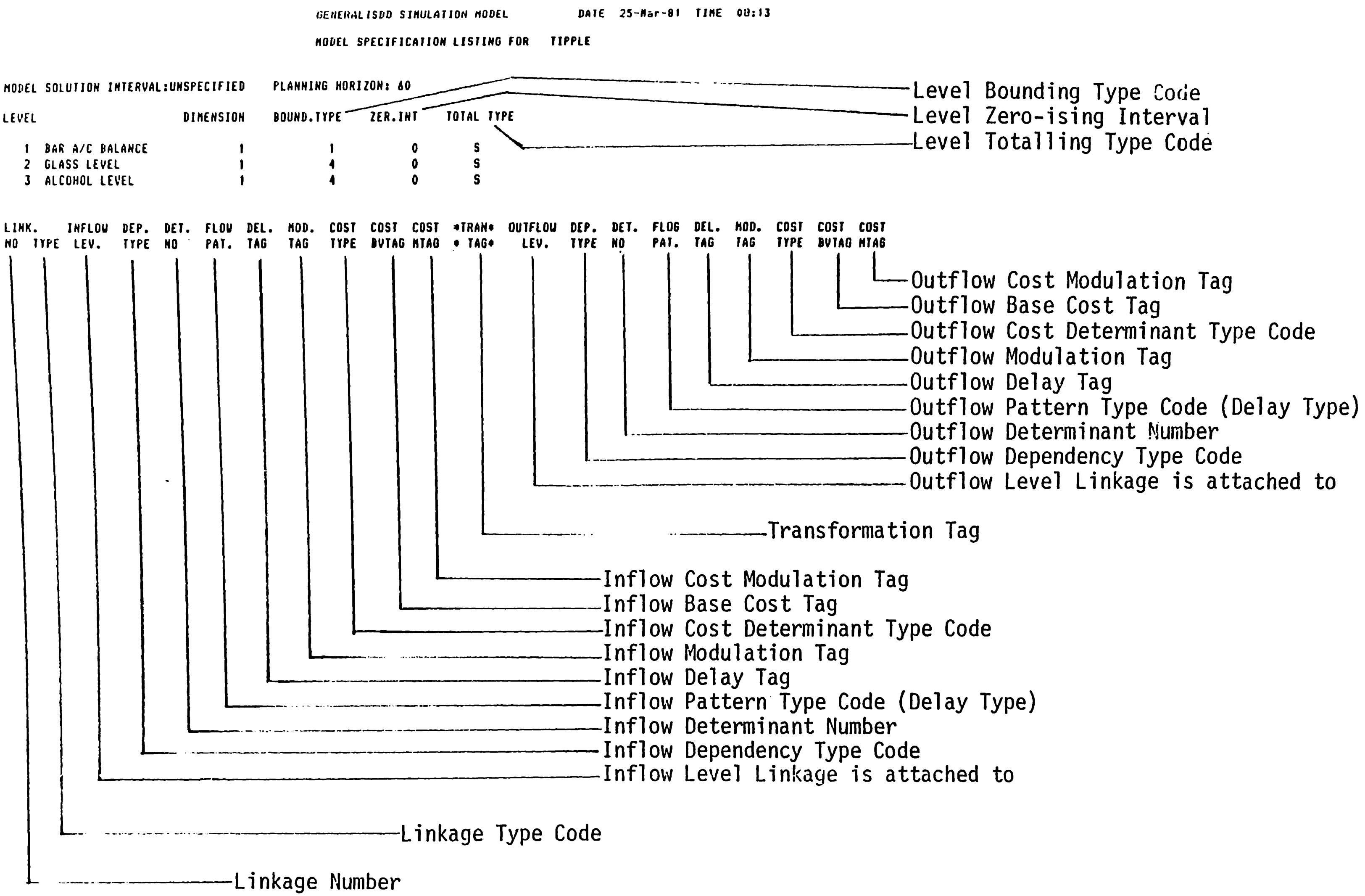
TABLE E.2: LINKAGE SPECIFICATIONS

(Note: All Linkages are referenced to by their Number in GENSPC, and the numbering sequence must follow the desired order of computation. For each Linkage, Inflow Specs are entered then the Outflow Specs.)

Linkage Specification Factor	Explanatory Comments
Linkage Type	Each Linkage is classified according to the nature of its flow influences. Classification codes are: IC = Identity Transformation & No Modulation II = " " " Inflow " IX = " " " Outflow " IF = " " " Full Flow " SC = Sum Transformation & No Modulation SI = " " " Inflow " SX = " " " Outflow " SF = " " " Full Flow" GC = General Transformation & No Modulation GI = " " " Inflow " GX = " " " Outflow " GF = " " " Full Flow " Note: Identity Transformation 'ties' each Inflow Element (Channel) to its corresponding Outflow Element (Channel) & vice versa. Sum Transformation sums all Inflow Elements (Channels) into each Outflow Element (Channel) and vice versa. General Transformation allows the user to specify the Inflow-Outflow relationship via a Transformation Table
Level In (for Inflow) and Level Out (for Outflow)	The respective Numbers of the levels which the Linkage Inflow flows into, and the Linkage Outflow flows out from.
Flow Dependency Type (for both Inflow and Outflow respectively)	Possible Dependencies and their respective codes are: E = Externally Dependent, on a Base Flow L = Level Dependent I = Inflow Dependent X = Outflow Dependent M = Mixed Dependency, each flow element has its own individual dependency
Determinant Flow or Level Number (for both Inflow and Outflow respectively)	The Number of the Flow, or Level which the Inflow (or Outflow) of this Linkage has been defined as being dependent upon- If Externally Dependent - enter the relevant Base Flow Tag No. If Level Dependent - enter the relevant Level No. If Inflow Dependent or Outflow Dependent - enter the relevant Linkage No. If a Mixed Dependency - enter an unused Mixed Dependency Table row No. (must be between 0 and 10)

TABLE E.2: LINKAGE SPECIFICATIONS (continued)

Linkage Specification Factor	Explanatory Comments
Flow Pattern (for both Inflow and Outflow respectively)	The type of response of the flow to its determinant. Possible response patterns and their codes are: I = Instantaneous (i.e. no delay) B = Boxcar Delay (i.e. discrete spread across a number of time periods) E = Exponential Delay (i.e. the response decays exponentially over time)
Modulation Tag No. (may apply to either or both Flows)	The Number of the Modulation Table (Matrix) which has been defined to apply to the flow.
Cost Dependency (may apply to either or both Flows)	Relevant only where the concept of flow unit cost applies. Possible options are: E = the Flow Unit Cost is to be defined as a Base Unit Cost vector 0 = the Flow Unit Cost is to be calculated if this concept is applicable, and ignored otherwise.
Base Cost Tag. No. (may apply to either or both Flows)	The Number of the Base Unit Cost vector which has been defined to apply to the flow.
Transformation Tag No. (applies only to Linkages for which a general transformation is necessary to relate the Inflow to the Outflow, or vice versa)	The Number of the Transformation Table (Matrix) which has been defined to apply to the Linkage.



```
                                GENERALISDD SIMULATION MODEL          DATE  25-Mar-81  TIME  08:13

                                MODEL SPECIFICATION LISTING FOR   TIPPLE

MODEL SOLUTION INTERVAL:UNSPECIFIED    PLANNING HORIZON: 60

LEVEL                      DIMENSION   BOUND.TYPE   ZER.INT   TOTAL TYPE

  1  BAR A/C BALANCE            1            1          0        S
  2  GLASS LEVEL                1            4          0        S
  3  ALCOHOL LEVEL              1            4          0        S

LINK.    INFLOW  DEP.  DET.  FLOW  DEL.  MOD.  COST  COST  COST  *TRAN*  OUTFLOW  DEP.  DET.  FLOG  DEL.  MOD.  COST  COST  COST
NO  TYPE  LEV.   TYPE  NO    PAT.  TAG   TAG   TYPE  BVTAG MTAO  * TAG*   LEV.    TYPE  NO    PAT.  TAG   TAG   TYPE  BVTAO MTAG
```

FIGURE E.1: <u>LAYOUT OF THE MODEL SPECIFICATIONS LISTING GENERATED BY THE GENLIS PROGRAM</u>

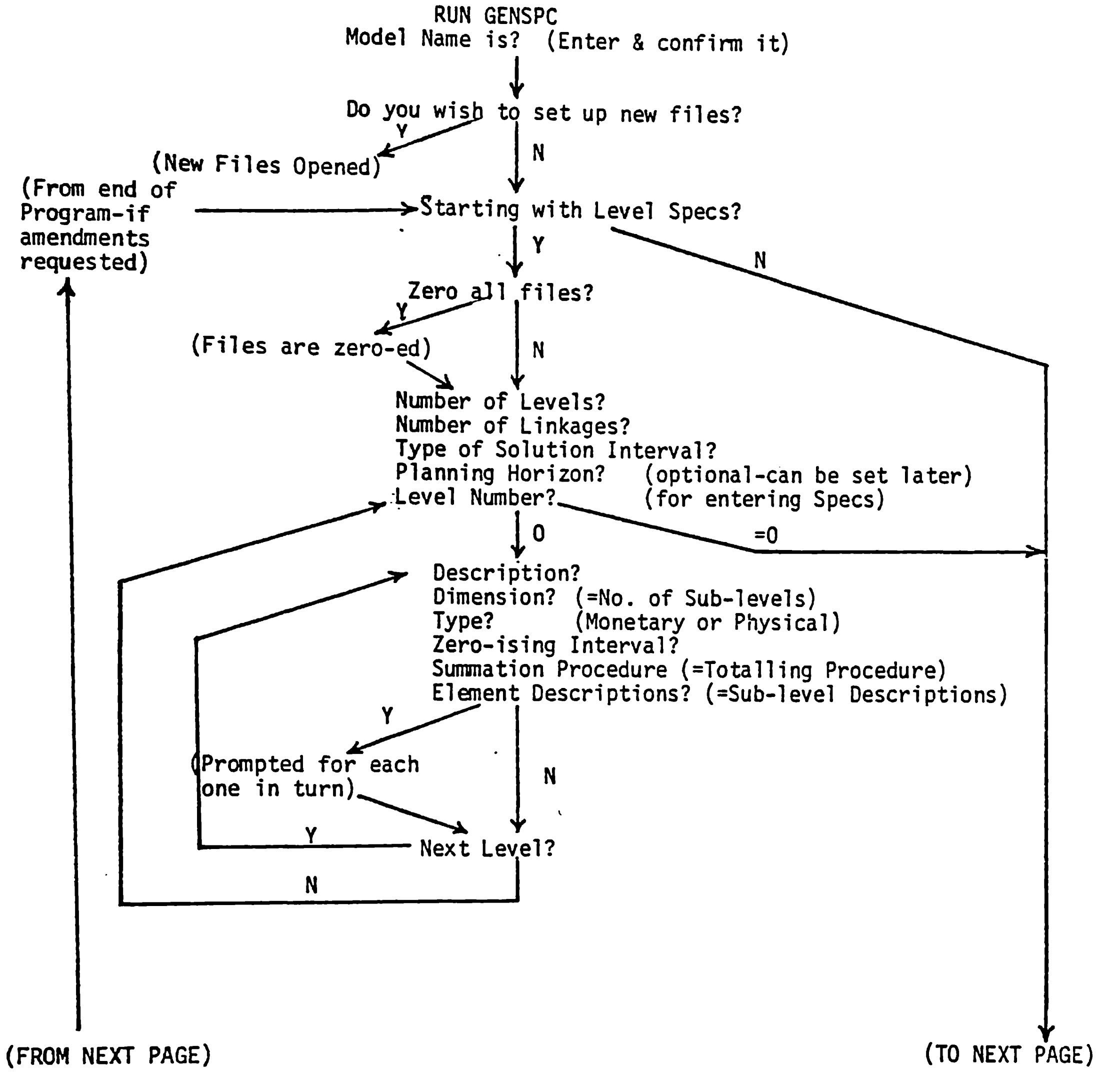


FIGURE E.2: <u>CHART OF GENSPC PROMPTS</u>

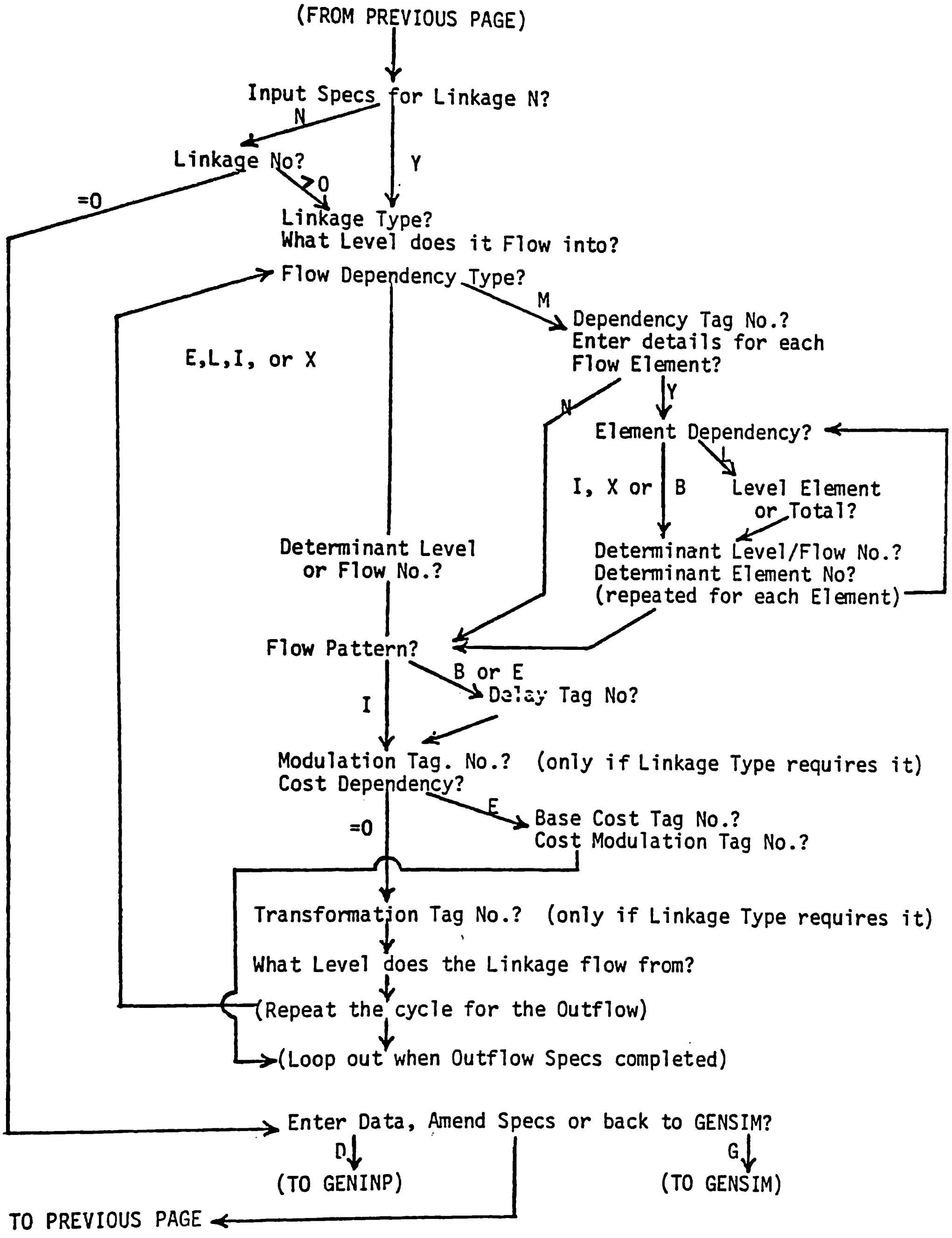


FIGURE E.2: CHART OF GENSPC PROMPTS (continued)

APPENDIX F

THE MODEL DATA INPUT PROGRAM (GENINP)

This program must be run to enter the data for a new model, or to amend any data item of an existing model. The program can be accessed from the control program GENSIM, or from the specifications program GENSPC, or by using the command

```
RUN GENINP  (Modified depending upon where the program
                  is stored)
```

(a) Purpose of the Program

The data for any model must be entered in terms of:

(1) The initial values (i.e. opening balances) of each level element (sub-level). For financial models credit balances (liabilities) must be entered as negative amounts. For models utilising the costing feature, Average Unit Costs must be supplied for the elements of levels defined in physical units which are to be costed (e.g. finished stocks as a level would need to have defined the average unit costs of the units held in the opening balances).

(2) The Base Flows, where these have been defined, must be given values. Any one Base Flow may be shared by more than one linkage, in which case its value(s) need only be entered once, rather than re-entering it in connection with any other linkages utilising it.

(3) The Transformation Tables (Matrices), where these have

been defined, must be entered. As with Base Flows, they are entered and accessed by nominating the Linkage No. to which they are 'tagged', and where a Table is shared by more than one linkage, it need only be entered once.

(4) The Modulation Tables (Matrices), where these have been defined, must be entered. They are entered and accessed in the same manner as Transformation Tables. Also more than one linkage may share the same Modulation Table.

(5) The Delay Tables (Matrices), where these have been defined, must be entered, and they are entered and accessed in the same manner as Transformation Tables. Delays should <u>not</u> be shared by more than one linkage if they are the boxcar type, as the boxcar contents (delay transit levels) are unique to each flow, and determined by that flow. These transit levels must be assigned 'opening balances' which can be determined manually or automatically by the GENINP program. The latter option necessitates specifying the total amount of 'stored' flow to be spread across the delay, in respect of each flow channel. Refer to Appendix C for details.

(6) The Cycles Table (Matrix) must be entered if any Modulation Tables have been defined utilising cycles. Only the row numbers corresponding to those used in the modulation pattern code to reference cycles need be entered (e.g. a pattern code of 600 means row 6 of the Cycles Table will be used for the cycle data and it must

therefore be entered accordingly).

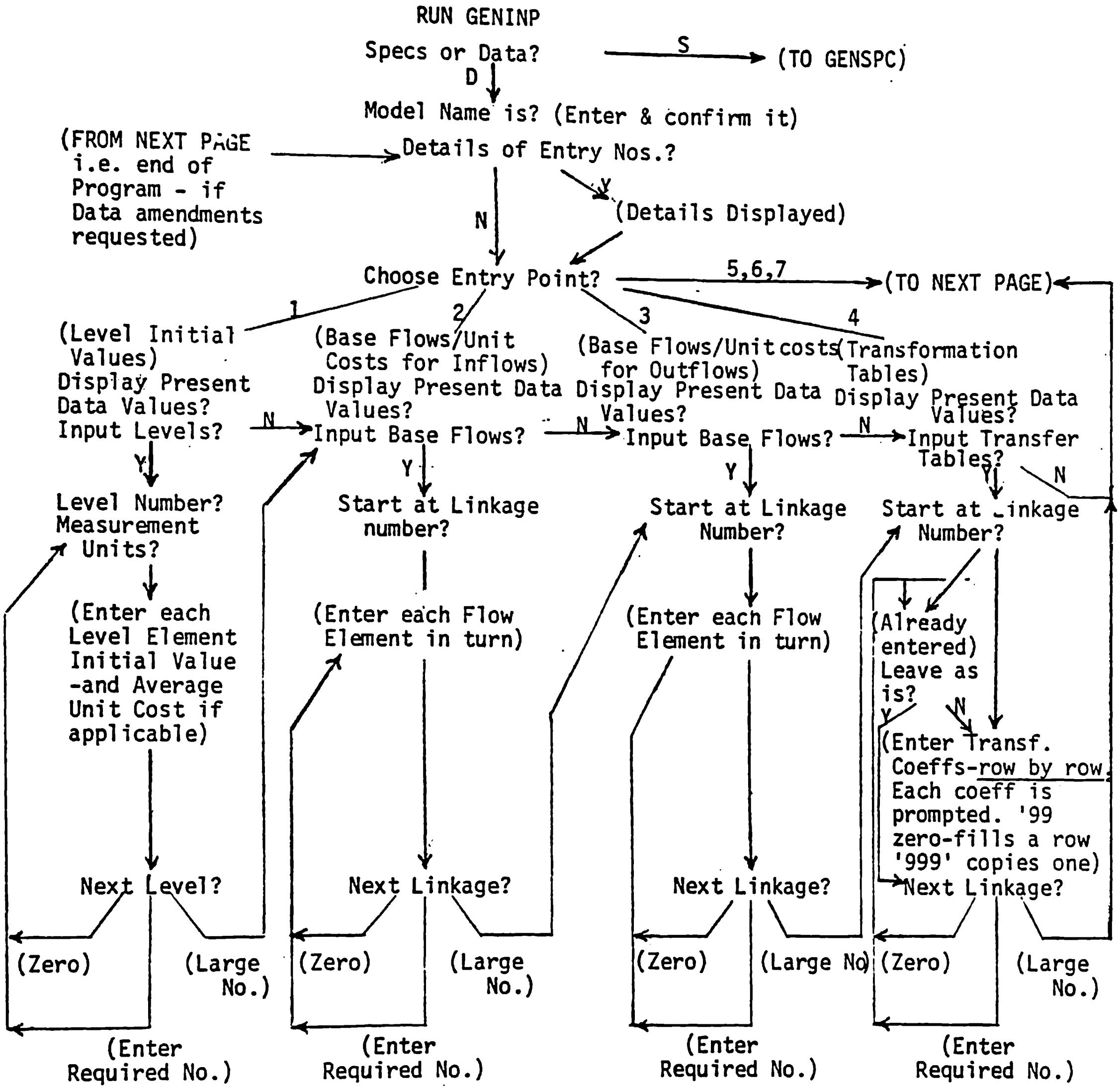
(b) The Program Files

Input Files:	MODEL .ONE MODEL .TWO MODEL .THR MODEL .FOU	Contents as defined in Appendix E
Output Files:		
	MODEL .ONE	Contents as defined in Appendix E plus the Transformation Tables, Mixed Dependency Codes, Boxcar Delay Tables (Distribution Coeffs) Base Flow Tables, Cycles Tables, and Level Measurement Units.
	MODEL .TWO	Contents as defined in Appendix E plus No. of Boxcar Delay Coeffs. in each row of each Table, Average Unit Costs associated with opening Level values, and Outflow Base Cost Tables.
	MODEL .THR	Contents as defined in Appendix E plus the Exponential Delay Table and the Inflow Base Cost Tables.
	MODEL .FOU	Contents as defined in Appendix E plus the Modulation Tables, and Boxcar Delay Tables (Transit Levels)
	MODEL .FIV	Contains temporary arrays associated with the automatic calculation of Delay Transit levels.

NOTE: GENINP can not be run for any model unless that model's structure has been defined using GENSPC.

(c) The Program Structure

Refer Figure F.1.



NOTE: The prompt 'Next Linkage' can be responded to in three ways-

(1) Carriage Return (i.e. zero) to access the next linkage

(2) Entry of the required linkage number, or

(3) Entry of a large invalid number to finish and move to the next Entry Point.

FIGURE F.1: CHART OF GENINP PROMPTS

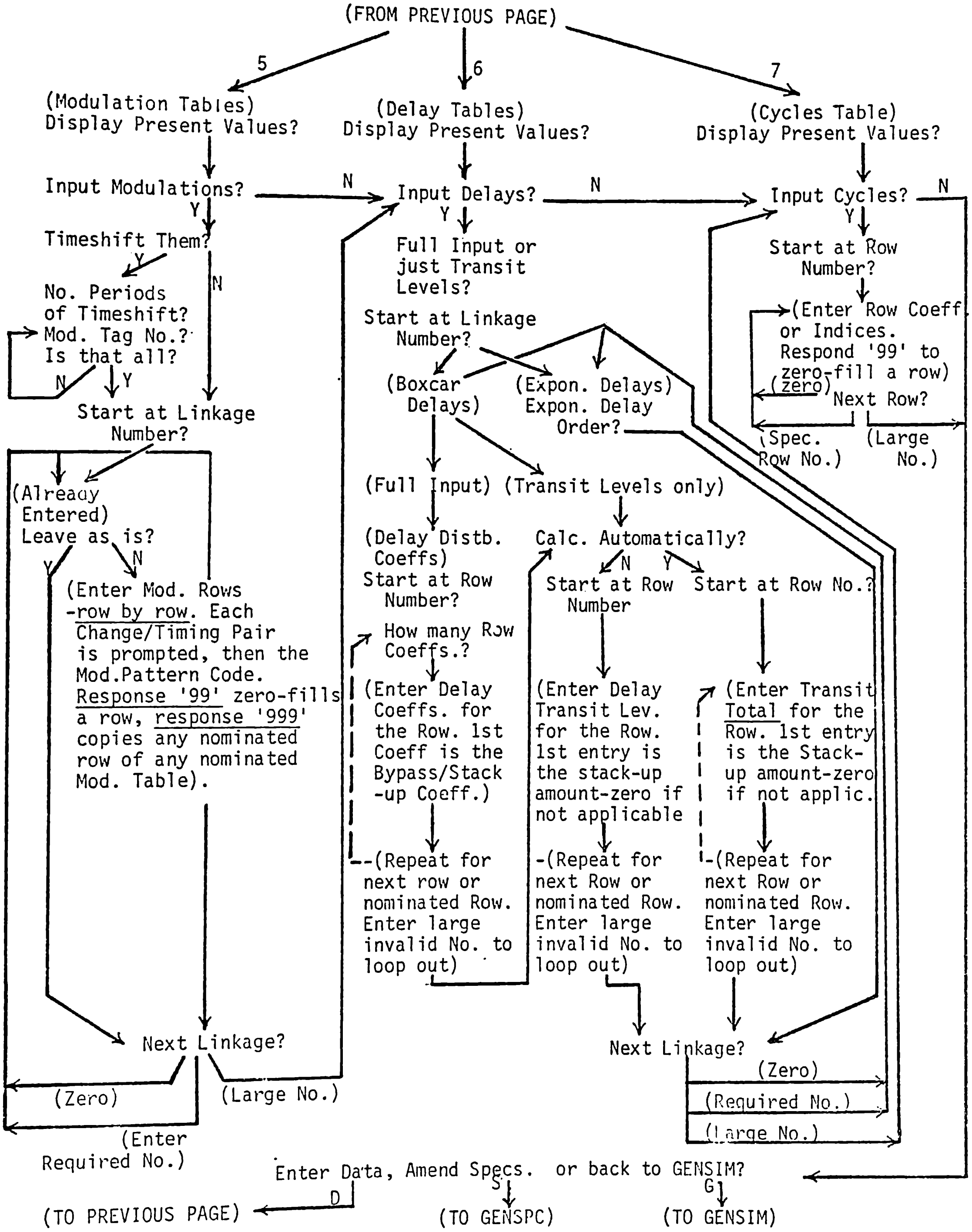


FIGURE F.1: CHART OF GENINP PROMPTS (continued)

APPENDIX G

THE MODEL SPECIFICATIONS AND DATA LISTING PROGRAM (GENLIS)

This program must be run to generate a listing of either the model specifications and (or) the model data. The program can be accessed from the control program GENSIM, or by using the command

```
RUN GENLIS  (Modified depending upon where the program is
                stored)
```

(a) Purpose of the Program

The format of any model listing is specified in terms of:

(1) Whether the required listing is to consist of specifications (i.e. the model structure), or data (i.e. the model level initial values and data tables), or both.

(2) If a specifications listing is required, whether it is to consist of a full listing, or only the specifications of a selected linkage.

(3) If a data listing is required, whether it is to consist of a full listing, or only selected aspects of the model data base.

The resultant listing is stored on the disk file MODEL .LST (where the term 'MODEL ' is purely illustrative, and would be replaced by the name of the particular model concerned).

(b) The Program Files

Input Files:	MODEL .ONE MODEL .TWO MODEL .THR MODEL .FOU	Contents as defined in Appendices E and F
Output File:	MODEL .LST	Contains Model Structure Specifications in terms of Levels, Linkages and Flow Dependencies, together with all Model Data Tables - presented in report form.

(c) The Program Structure

Refer Figure G.1

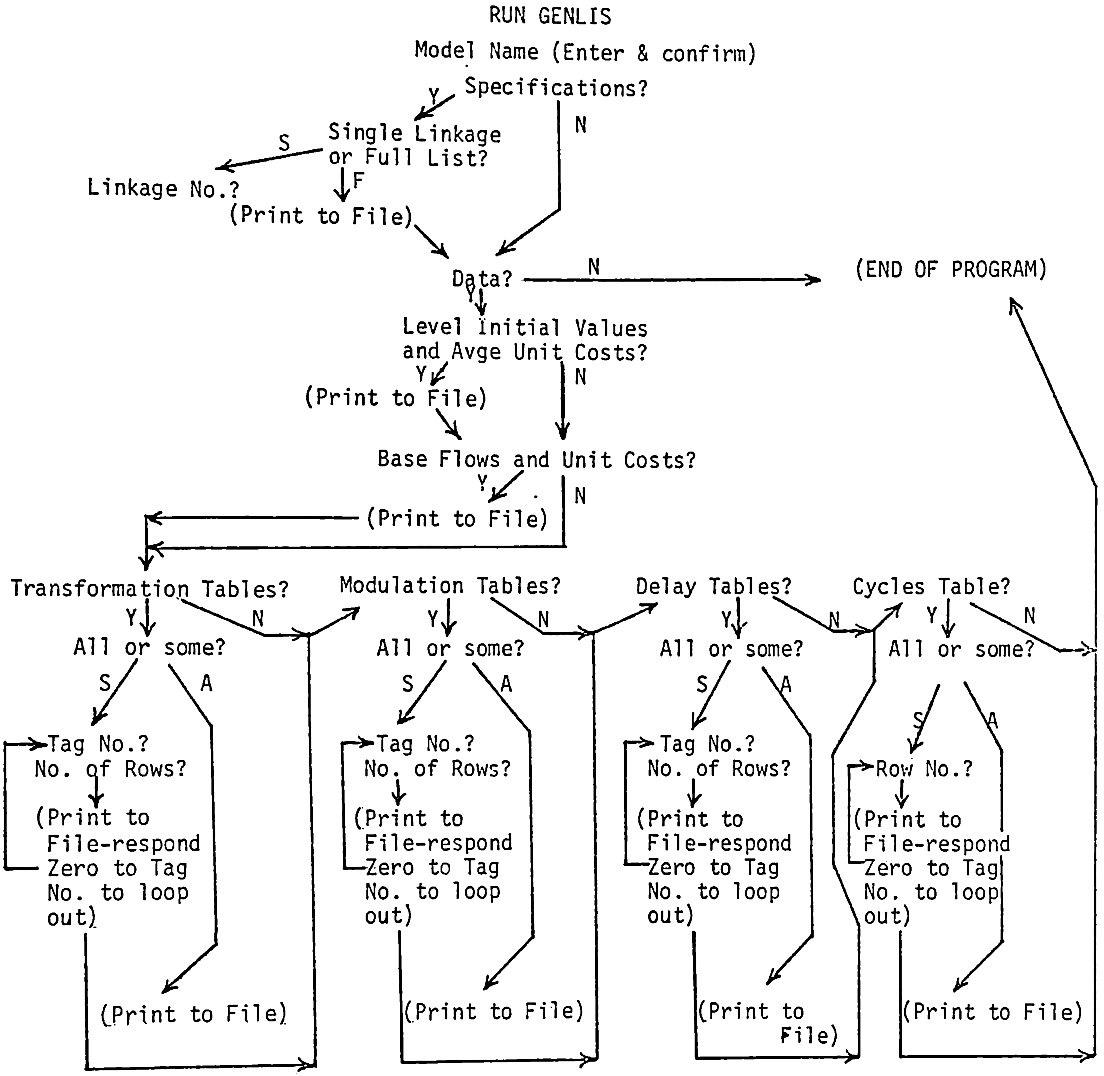


FIGURE G.1: CHART OF GENLIS PROMPTS

APPENDIX H

THE MODEL EDITING PROGRAM (GENEDT)

This program must be run if it is desired to perform an edit check of either the model specifications or the model data (or both). The program can be accessed from the control program GENSIM, or run directly by using the command

RUN GENEDT (Modified depending upon where the program
is stored)

(a) Purpose of the Program

All error conditions diagnosed by this program are 'non-fatal' i.e. the model computations will still proceed. Generalisation about specifications errors is difficult in that what is unacceptable in one particular model may be deliberately designed into another. An example of this is the failure to fully define a linkage in terms of it being attached to a level at both ends. There may be either no defined inflow level, or no defined outflow level, through oversight or because of the 'open' nature of the model.

Data errors by their nature cannot all be catered for in any edit program, and thus there can be no substitute for a careful visual check of the model data. GENEDT is, however, capable of detecting certain data errors such as complete failure to enter a data table, or a specific data item having a value outside certain user-specified limits, or the presence of data values in a particular table which are inconsistent with the proper use of that table. For example, each cycle series (i.e. row) of the Cycles Table should never have more non-zero data items in it than the stated periodicity (or length) of the cycle.

In summary form, the basic method of operation of the GENEDT program is as follows:

(1) Model specifications editing is performed in respect of the model linkages, with each linkage in turn being scanned, first in terms of its inflow, then in terms of its outflow. The error conditions which are tested for, are summarised in Table H.1.

(2) Model data editing is performed in respect of the Data Tables, which can be edited sequentially, by type, or selectively, by type. The type catagories are:

1. Base Flow Tables for Inflows
2. Base Flow Tables for Outflows
3. Transformation Tables
4. Modulation Tables
5. Delay Tables
6. Cycles Table

The user is required to specify data limits, in the form of upper and lower bounds, for the Transformation Tables, the Modulation Table Change Factors, and the Delay Table Distribution Coefficients. The error conditions which are tested for are summarised in Table H.2.

(b) The Program Files

The Input Files to GENEDT are those created by GENSPC and GENINP (i.e. MODEL.ONE, MODEL.TWO, MODEL.THR. and MODEL.FOU). No Output Files are created by GENEDT, all error messages are displayed at the terminal.

(c) The Program Structure

Refer Figure H.1.

TABLE H.1: MODEL SPECIFICATIONS ERROR MESSAGES

Error Message	Comment
Linkage (Number) Inflow/Outflow	
... is hanging loose.	Has no defined level attached.
... is connected to an undefined level.	
... has an illegal determinant Flow No,	No linkage of that number has been defined.
... has an illegal determinant Base Flow No,	No base flow with that Tag No. has been defined.
... has an illegal Level No.	No level of that number has been defined.
... has more elements than its determinant.	It is being equated to a level or flow which has more sub-levels, or flow channels that it has.
... has an illegal flow dependency type classification .	It has not been made dependent on one of the possible flow determinants (Base Flow, Level, Inflow, Outflow, or Mixed).
... should have a Delay Tag No.	Has been given an exponential or boxcar delay for its flow pattern, but no Delay Table Tag No.
... should not have a Delay Tag No.	The reverse of the above.
... has an allocated Delay Tag No.	A Delay Table is being shared by more than one flow. This is not desirable with Boxcar Delays.
... has an illegal Delay Tag No.	No Delay Table with that Tag No. has been defined.
... should have a Transformation Tag No.	The linkage has been classified as GC, GI, GX or GF but no Transformation Tag Number has been assigned to it.
... should not have a Transformation Tag No.	The reverse of the above.
... has an illegal Transformation Tag No.	No Transformation Table with that Number has been defined.
... should have a Modulation Tag No.	The linkage has been classified as having a modulated flow, but no Modulation Tag Number has been assigned to it.
... should not have a Modulation Tag No.	The reverse of the above.

TABLE H.1: continued

Error Message	Comment
Linkage (Number) Inflow/Outflow ...	
... has an illegal Modulation Tag No.	No Modulation Table with that Number has been defined.
... should have a Base Cost Tag No.	The flow has been defined as having an external cost dependency, but no Base Cost Tag has been assigned to it.
... should not have a Base Cost Tag No.	The reverse of the above.
... has an illegal Base Cost Tag No.	No Base Cost with that Tag Number has been defined.
... has an illegal Cost Modulation Tag No.	No Modulation Table with that Tag Number has been defined.
... has not been assigned a flow determinant.	Every flow must be equated to one of the possible determinants (Base Flow, Level, Inflow, Outflow, or Mixed).
... has an illegal flow pattern classification.	Every flow must have its response to its determinant designated as either Instantaneous, Delayed (Boxcar) or Delayed (Exponentially).
... has an allocated Transformation Tag No,	A Transformation Table is being shared by more than one linkage.
... has an allocated Base Cost Tag No.	A Base Cost Table is being shared by more than one flow.
... of a Physical/Monetary Linkage with no Inflow Base Cost Table.	Normally a linkage connecting a Physical level to a Monetary level will need to have its outflow in physical units and its inflow converted to monetary units, via multiplication by unit costs, which if not calculated (using the costing module of GENCOM), would need to be specified via a Base Cost Table.
... of a Monetary/Physical Linkage with no Inflow or Outflow Base Cost Tables.	Similar situation to the above, in this case with the connection being from a Monetary to a Physical level.

TABLE H.1: continued

Error Message	Comment
Linkage (Number) Inflow/Outflow...	
... of a Physical/Physical Linkage with a Base Cost Table Tag.	Normally the concept of unit cost if it applies to such a linkage would be such that unit costs would be calculated via the costing module of GENCOM, and not via a Base Cost Table.
... of a Monetary/Monetary Linkage with a Base Cost Table Tag.	Normally the concept of unit cost would not apply to such a linkage.
... is dependent on a flow of a higher linkage number.	This would result in the flow concerned being related to the value of its determinant flow as calculated in the previous solution interval, instead of the current one.

TABLE H.2: MODEL DATA ERROR MESSAGES

Error Message	Comment
Base Flow for Inflow (No.) Element (No.) is zero.	This may or may not be intentional.
Base Flow for Outflow (No.) Element (No.) is zero.	This may or may not be intentional.
Transformation Table (No.) Row (No.) Column (No.) entry is out of bounds.	The Value of the entry in that Row Column position of the Table is outside the limits specified for Transformation Tables.
Transformation Table (No.) has its entries all zero.	Generally this will be the case if provision of the data for the Table has been overlooked.
Modulation Table (No.) Row (No.) Change Factor is out of bounds.	The value is outside the limits specified for Modulation Table Change Factors.
Modulation Table (No.) Row (No.) Timing Factor is out of bounds.	A period has been entered as a Timing Factor which is beyond the time span covered by the planning horizon of the model.
Cycles Table Row (No.) is all zeros.	Generally this will be the case if a cycle series being called on by a Modulation Table, has not been entered.
Cycles Table Row (No.) has non-zero coefficients not equal to Cycle periodicity.	The number of non-zero entries in the row does not equal the stated length of the cycle defined for that row.
Delay Table (No.) Row (No.) Coefficient (No.) is out of bounds.	The value of the coefficient is outside the limits specified for Delay Tables.
Delay Table (No.) Row (No.) sum of distribution coefficients equal ---	This message will appear if the sum of the coefficients entered in any row of a Delay Table of distribution coefficients does <u>not</u> equal 1. This relationship usually applies, as the purpose of such a Table is to 'spread' the flow of any given period across future time periods in accordance with the proportions entered as delay coefficients.

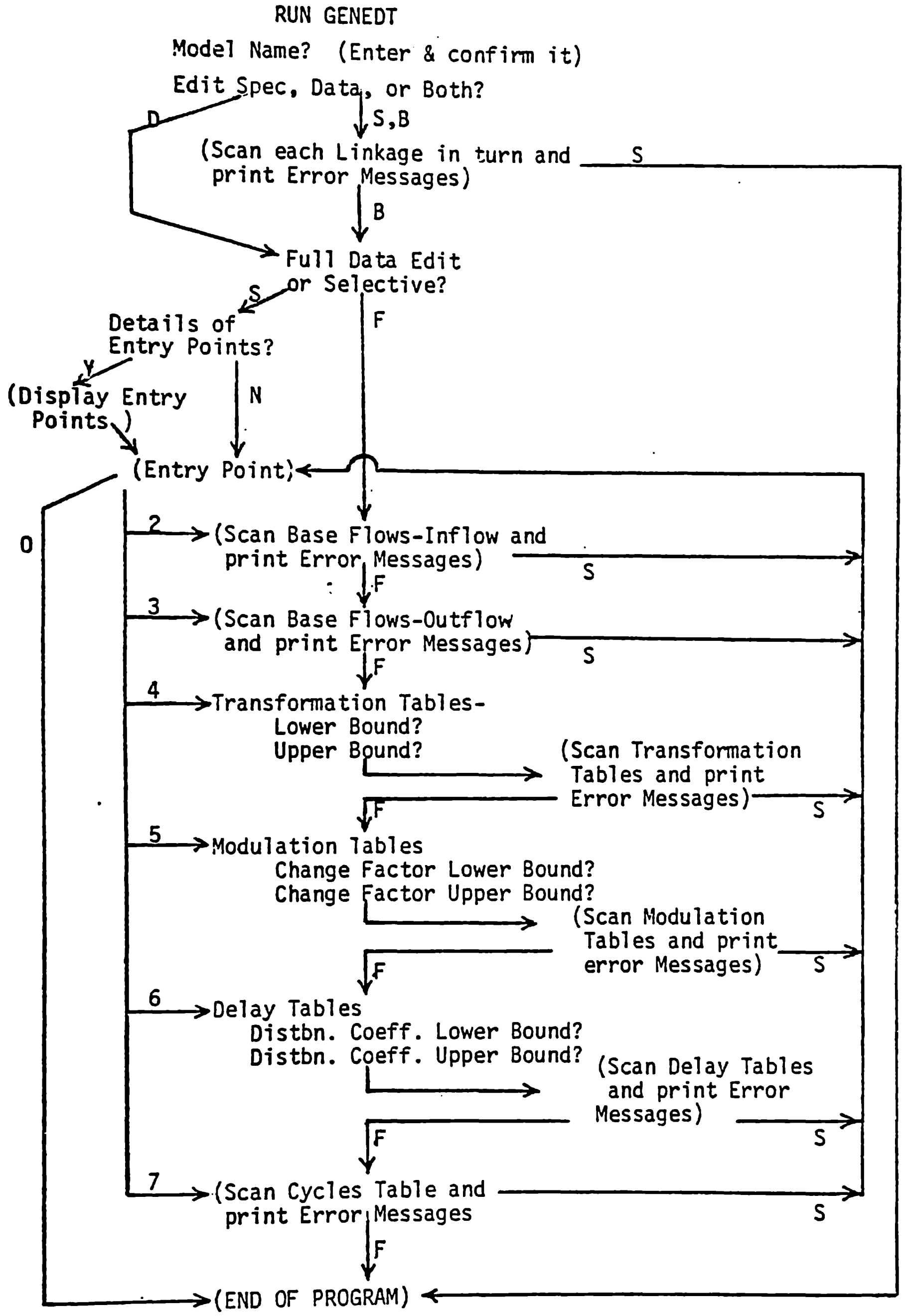


FIGURE H.1: CHART OF GENEDT PROGRAM PROMPTS

APPENDIX I

THE MODEL COMPUTATION PROGRAM (GENCOM)

This program must be run in order to perform the model computations. The program can be accessed from the control program GENSIM, or run by using the command

RUN GENCOM (Modified depending upon where the program is stored)

(a) Purpose of the Program

The model computations are performed according to run specifications which are prompted for at the start of the program. These specifications consist of:-

(1) A Planning Horizon, i.e. the number of solution intervals, or time periods over which the model computations are to be performed. Up to 60 periods can be covered in any one model run. A planning horizon of 1 or 2 should be used during the early stages of model testing and validation.

(2) The starting Period to be applied to the Cycles Table. This must be a number between 1 and 12 (the maximum length of any cycle) and represents the period within the Cycles Table at which all cycles will be commenced during the first solution period of the model. For the majority of situations this start period will be 1 (i.e. all cycles commence with their first element at the start of the model run), but for some model uses, e.g. short term forecasting, the first period of

the model run may be one which 'breaks into' the cycles at say their 4th period. Commencing a model run in April, with a monthly solution interval, and 'seasonal' cycles based on the months of the calendar year, would necessitate this choice of start period for the cycles.

(3) The use (or non-use) of the dual form of the model. Any model in which the concept of flow and level unit cost has been defined (through the use of at least one Base Cost Table) <u>must</u> be run using this form of the model. The dual form permits calculation of flow unit costs, and level average unit costs, where these concepts are appropriate. Thus -

(i) Flow Unit Costs associated with the flows along linkages linking Monetary levels to Physical levels, Physical levels to Physical levels, and Physical levels to Monetary levels- will be calculated each solution interval.

(ii) Level Average Unit Costs associated with all Physical levels will be calculated at the end of each solution interval.

These calculations will be performed using those equations from the Dual Form Equation Library which are appropriate to the circumstances (refer to Appendix D for details).

(4) The use (or non-use) of the Tracer. This facility exist primarily to facilitate model testing and validation. In general the Tracer should be run for <u>all</u> linkages, for the first <u>one or two</u> solution intervals, during this phase of

model building. Tracer details are given in Figure I.2. Basically its function is to provide a record of all aspects of flow (and flow unit cost) calculations, as a model debugging aid.

It is important to note that only the results of the *level calculations* (i.e. sub-level values, level totals, and sub-level average unit costs - if applicable) are stored permanently on a disk file. These values are stored for each period of the model planning horizon. The results of all *flow calculations* (i.e. flow values and flow unit costs - if applicable - are not stored beyond the period in which they occur. They are merely temporary variables in the model, a means to the end of determining levels. A permanent record of flow values and flow unit costs can only be created via the Tracer, or by accumulating them in levels - which of course is the definition of a level in fact. In the context of a financial model, only account *balances* are stored permanently, not the *transaction flows* which give rise to them.

(b) *The Program Files*

The following disk files are used by GENCOM. (The file-name MODEL is used purely for illustration, and would be replaced by the name of the particular model concerned).

Input Files:	MODEL .ONE MODEL .TWO MODEL .THR MODEL .FOU	Contents as described in Appendices E and F

Output File:	MODEL. OUT	Contents are sub-level Values Level Totals, and Sub-level Average Unit Costs (where applicable) for each level and each period of the planning horizon.

(c) Computational Details of the Program

Figure I.1 shows the broad structure of the GENCOM program in terms of the major segments and the logic of their interrelationship within the iterative sequence of computations for 'solving' the flow equations and level equations successively for each solution period of the planning horizon. The detailed structure and logic of each program segment is set out in Figures I.3 to I.9 inclusive.

The following system variables, constituting the core elements of the package, are defined in the program-

(i) The Level Variables

L(N,V)	denotes the Vth element (Sub-level) of the Nth level for V=1,2,...,10.
L(N,11)	denotes the assigned dimension (number of Sub-levels in use) of the Nth level.
L(N,12)	denotes the type classification (physical or monetary) of the Nth level.
L(N,13)	denotes the level zero-setting frequency to be observed for the Nth level.
A(N,V)	denotes the average unit cost of the Vth level element (Sub-level) for V=1,2,...,10.

(ii) The Inflow Variables

I(N,V)	denotes the Vth element (channel) of the Nth linkage's inflow, for V=1,2,...,10.
I(N,11)	denotes the number of the level to which the inflow side of linkage N is attached.
I(N,12)	denotes the type of dependency defined for the inflows of linkage N.
I(N,13)	denotes the identifying number of the factor (inflow, outflow, base flow, or level) which the inflows of linkage N are equated to.
I(N,14)	denotes the flow pattern (instantaneous or delayed) defined for the inflows of linkage N.
I(N,15)	denotes the identifying number (Tag No.) of the delay tables assigned to the inflows of linkage N.
I(N,16)	denotes the identifying number (Tag No.) of the transformation table assigned to linkage N.
I(N,17)	denotes the identifying numbers (Tag Nos.) of the modulation tables assigned to the inflows of linkage N.
C(N,V)	denotes the unit cost of the Vth inflow of the Nth linkage for V=1,2,...,10.
C(N,11)	denotes the identifying number (Tag No.) of the cost modulation table assigned to the inflow unit costs of the Nth linkage.
C(N,12)	denotes the identifying number (Tag No.) of the base unit cost vector (table) assigned to the inflow unit costs of the Nth linkage.

(iii) The Outflow Variables

The system variables defined for the linkage outflows are as defined for the inflows, except that the variable name X(N,V) replaces the name I(N,V), for V=1,2,...,17, and K(N,V) replaces C(N,V), for V=1,2,...,12.

(iv) The Transformation Tables

TO(T2,I,J)	denotes the transformation coefficient in the Ith row and Jth column position of the transformation table (matrix) identified with the Tag No. T2. Note that this table is restructured as a two dimensional array in the GENCOM program.

(v) The Modulation Tables

MO(T3,M,V)	denotes the Mth modulation factor (either a flow change or timing factor) applicable to the Vth flow channel, of the modulation table (matrix) identified with the Tag No. T3. Note that this table is restructured as a two dimensional array in the GENCOM program.
SO(P2,E)	denotes the Eth cycle index of the P2th cycle series which is accessable through the modulation function.

(vi) The Delay Tables

DO(T1,M,V)	denotes the Mth delay coefficient applicable to the Vth flow channel, of the delay distribution table (matrix) identified with the Tag No. T1.
D1(T1,M,V)	denotes the Mth delay transit level (boxcar) value of the delay transit level table identified with Tag No. T1.

Note that both the the above tables are restructured as two dimensional arrays in the GENCOM program.

(vii) The Base Flow and Base Flow Unit Cost Tables

BO(T,V)	denotes the base flow applicable to the Vth flow channel (either inflow or outflow) and identified with the Tag No.T.
CO(T,V)	denotes the base flow unit cost applicable to the Vth inflow and identified with the Tag No. T.
KO(T,V)	denotes the base flow unit cost applicable to the Vth outflow and identified with the Tag No. T.

(viii) The Program Control and Housekeeping Variables

F$	denotes the model name
N	denotes the level number, or linkage number
S(I)	denotes the total number of model levels (for I=1), the total number of model linkages (for I=2), the type of solution interval (for I=3), and the planning horizon (for I=4).
V	denotes the sub-level number (in the case of the level variables) and the flow channel number (in the case of the flow variables).
L1	denotes the output array for the disk storage of all computed level values over the full planning horizon of the model.

A1	denotes the output array for the disk storage of all computed level average unit costs, over the full planning horizon of the model.

Temporary variables defined within the GENCOM program for the handling of key system variables are as follows -

P	denotes the model solution period counter.	
L9,A9, and D9	denote storage arrays for the initial values of all levels, level average unit costs, and delay transit levels respectively.	
K9	denotes the unit cost-build-up requirement indicator for activating the dual form of the model).	
Y$,I$	denote the requirement indicators for the model tracer and the model interrupt facilities respectively.	
L1	is equated to L(N,11) for those levels attached to inflows.	
L2	is equated to L(N,11) for those levels attached to outflows.	
A1	is equated to I(N,11) or X(N,11)	(Refer section (i) and (iii) above for details. The choice depends upon which type of flow is being computed.
A2	is equated to I(N,12) or X(N,12)	
A3	is equated to I(N,13) or X(N,13)	
A4	is equated to I(N,14) or X(N,14)	
T1	is equated to I(N,15) or X(N,15)	
T2	is equated to I(N,16) or X(N,16)	
T3,T4	are equated to I(N,17) or X(N,17)	
M1	denotes the temporary variable name for flows to be modulated.	
Y	denotes the temporary variable name for flows to be delayed.	
J5	denotes the temporary variable name for the start period assigned to the modulation cycles table.	

(d) General

As with conventional System Dynamics, in SSD modelling the term integration is taken to mean accumulation (see Coyle, 1977, p.28). Thus inflows and outflows accumulate into (and out from) levels. The method of integration (or accumulation) used is the same as that used in conventional System Dynamics except that-

(i) The value of DT is always set at 1.0. For most corporate modelling applications this would correspond to a time span of less than 2% of the overall planning horizon (e.g. DT = 1 month for an overall planning horizon of 60 months. DT could of course be set at 1 week or even 1 day if the circumstances warranted it).

(ii) For any given level, its value as a net accumulation of flows at the end of any solution interval, is derived from the balancing relationship-

Closing Level Value = Opening Level Value +
1.0 x (Sum of Inflows to the Level -
Sum of Outflows from the Level)

The values for the 'Sum of Inflows' and 'Sum of Outflows' are each obtained by scanning, for each and every level in the model, all model linkages and accumulating their respective flow values (for the solution interval under consideration) if they are attached to the level concerned (either on their inflow side or their outflow side). The computational logic associated with this is detailed in Figure I.3.

Numerical instability can of course arise from a mismatch between the choice of DT and the structure of one or more of the delays defined for any given model. This phenomenon will usually be immediately apparent from the large positive or negative values being assumed by one or more levels. GENCOM automatically warns of negative values being assumed by any level which has been designated by the model-builder as a non-negative type of level. Also the relatively infrequent occurrence, in SSD modelling, of feed-back loops with delays embedded in them lowers the risk of numerical instability. This aspect arises from the more open nature of SSD models compared to those encountered in conventional System Dynamics.

Nevertheless care must be taken in structuring both exponential and boxcar delays to prevent them from generating abnormally large outputs (relative to the levels which they affect) in any one solution period. In general careful alignment of delay structures with what is observed in the real-world system being modelled, will ensure avoidance of this problem.

REFERENCE

Coyle, R.G., 1977. Management System Dynamics. John Wiley and Sons Inc., 463p.

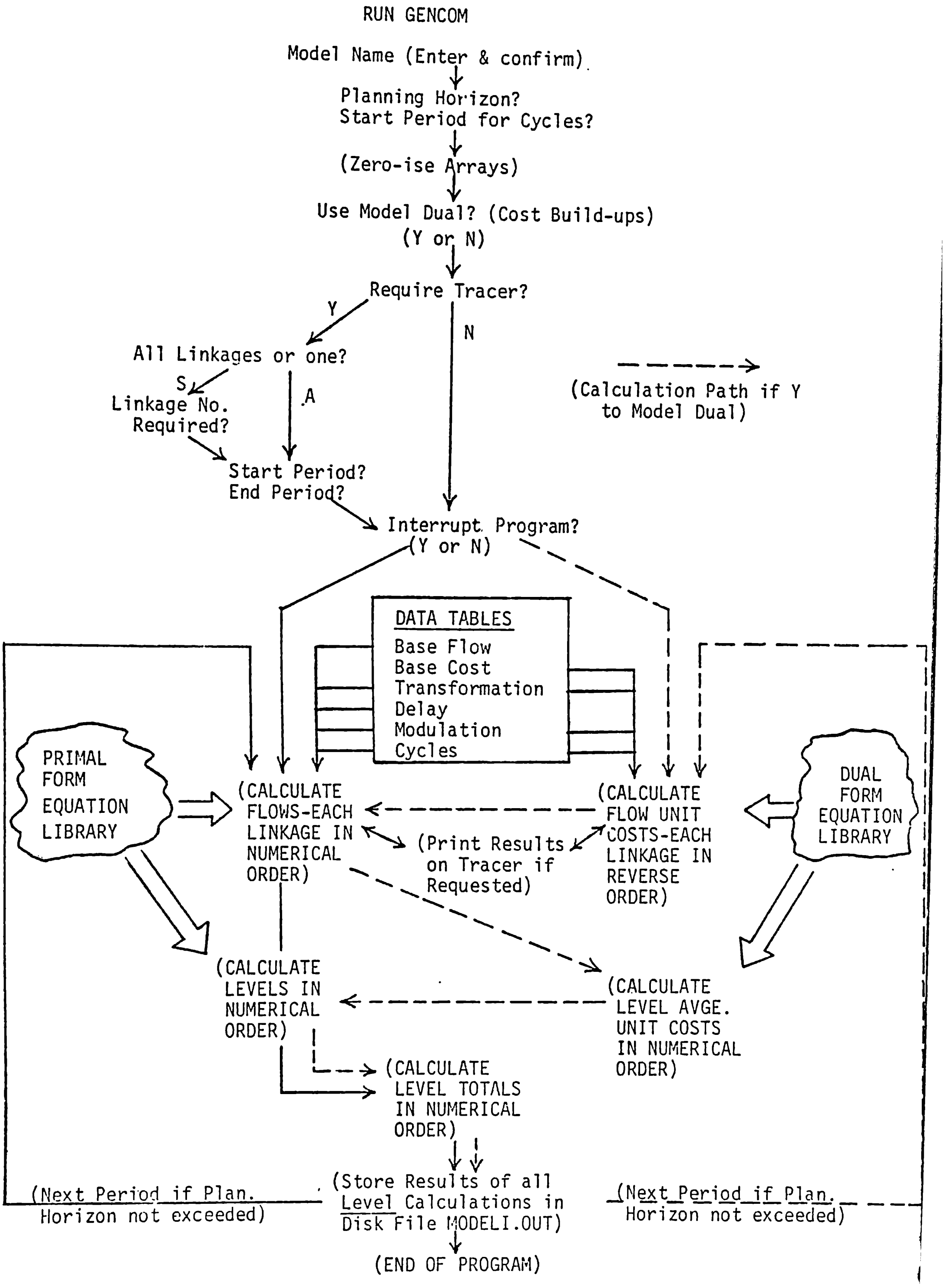
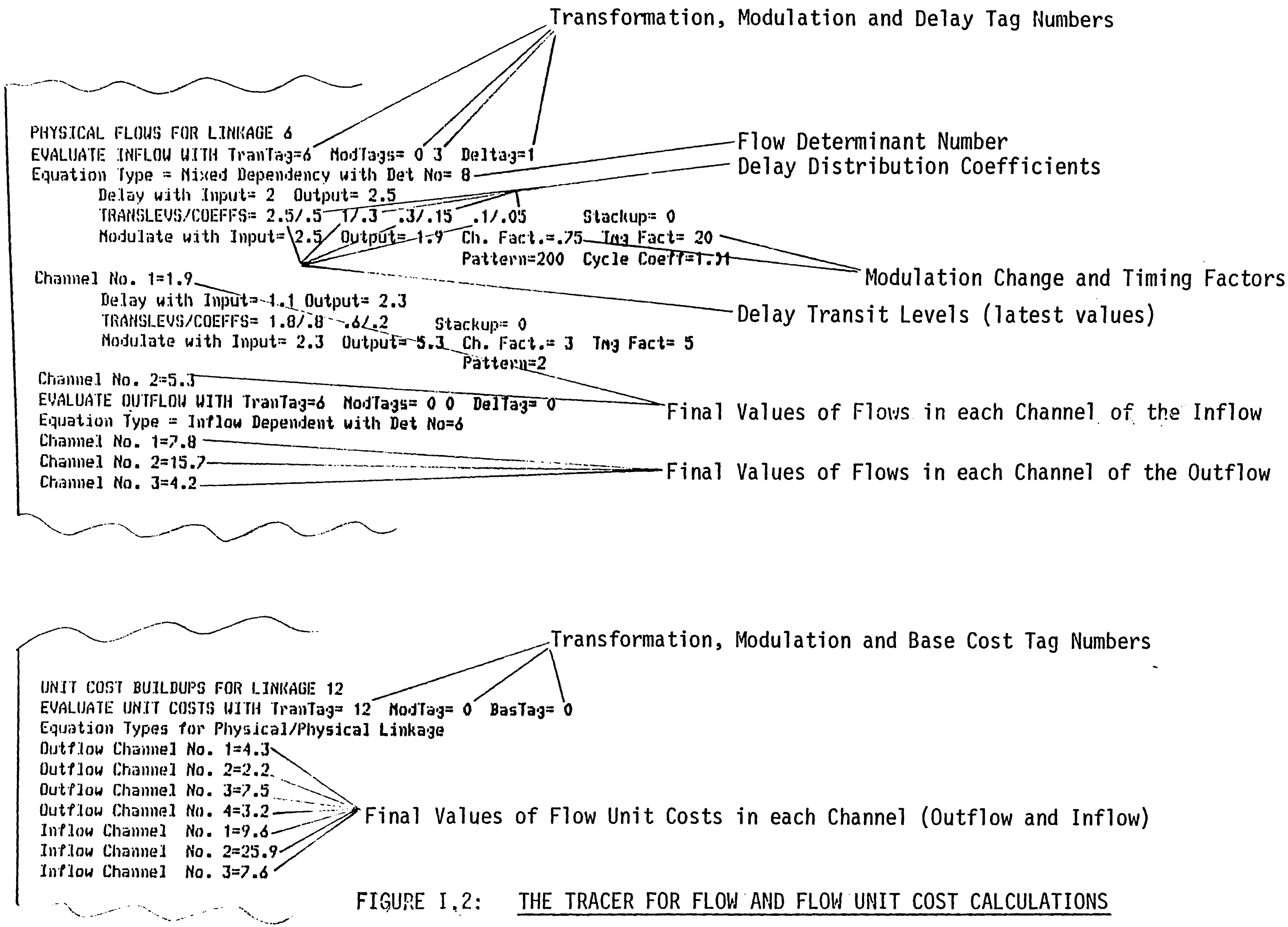


FIGURE I.1: CHART OF PROMPTS AND LOGIC FOR THE GENCOM PROGRAM



```
PHYSICAL FLOWS FOR LINKAGE 6
EVALUATE INFLOW WITH TranTag=6  ModTags= 0 3  Deltag=1
Equation Type = Mixed Dependency with Det No= 8
        Delay with Input= 2  Output= 2.5
        TRANSLEVS/COEFFS= 2.5/.5  1/.3  .3/.15  .1/.05      Stackup= 0
        Modulate with Input= 2.5  Output= 1.9  Ch. Fact.=.75  Tng Fact= 20
                                               Pattern=200  Cycle Coeff=1.11
Channel No. 1=1.9
        Delay with Input= 1.1 Output= 2.3
        TRANSLEVS/COEFFS= 1.8/.8  .6/.2     Stackup= 0
        Modulate with Input= 2.3  Output= 5.3  Ch. Fact.= 3  Tng Fact= 5
                                               Pattern=2
Channel No. 2=5.3
EVALUATE OUTFLOW WITH TranTag=6  ModTags= 0 0  DelTag= 0
Equation Type = Inflow Dependent with Det No=6
Channel No. 1=7.8
Channel No. 2=15.7
Channel No. 3=4.2
```

```
UNIT COST BUILDUPS FOR LINKAGE 12
EVALUATE UNIT COSTS WITH TranTag= 12  ModTag= 0  BasTag= 0
Equation Types for Physical/Physical Linkage
Outflow Channel No. 1=4.3
Outflow Channel No. 2=2.2
Outflow Channel No. 3=7.5
Outflow Channel No. 4=3.2
Inflow Channel  No. 1=9.6
Inflow Channel  No. 2=25.9
Inflow Channel  No. 3=7.6
```

FIGURE I.2: THE TRACER FOR FLOW AND FLOW UNIT COST CALCULATIONS

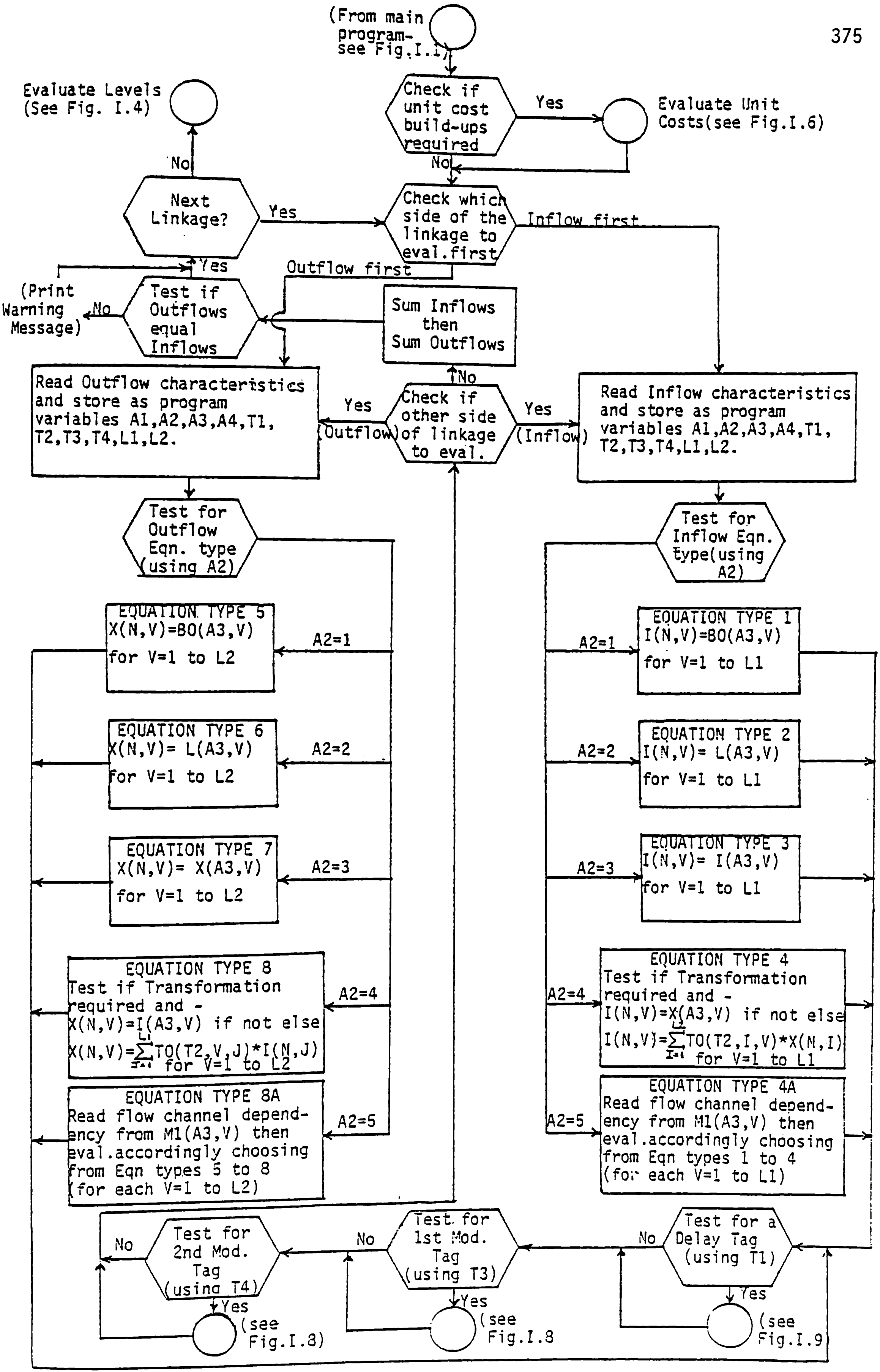


FIGURE I.3: FLOWCHART OF THE FLOW CALCULATION LOGIC (Note:Linkages are evaluated in numerical order)

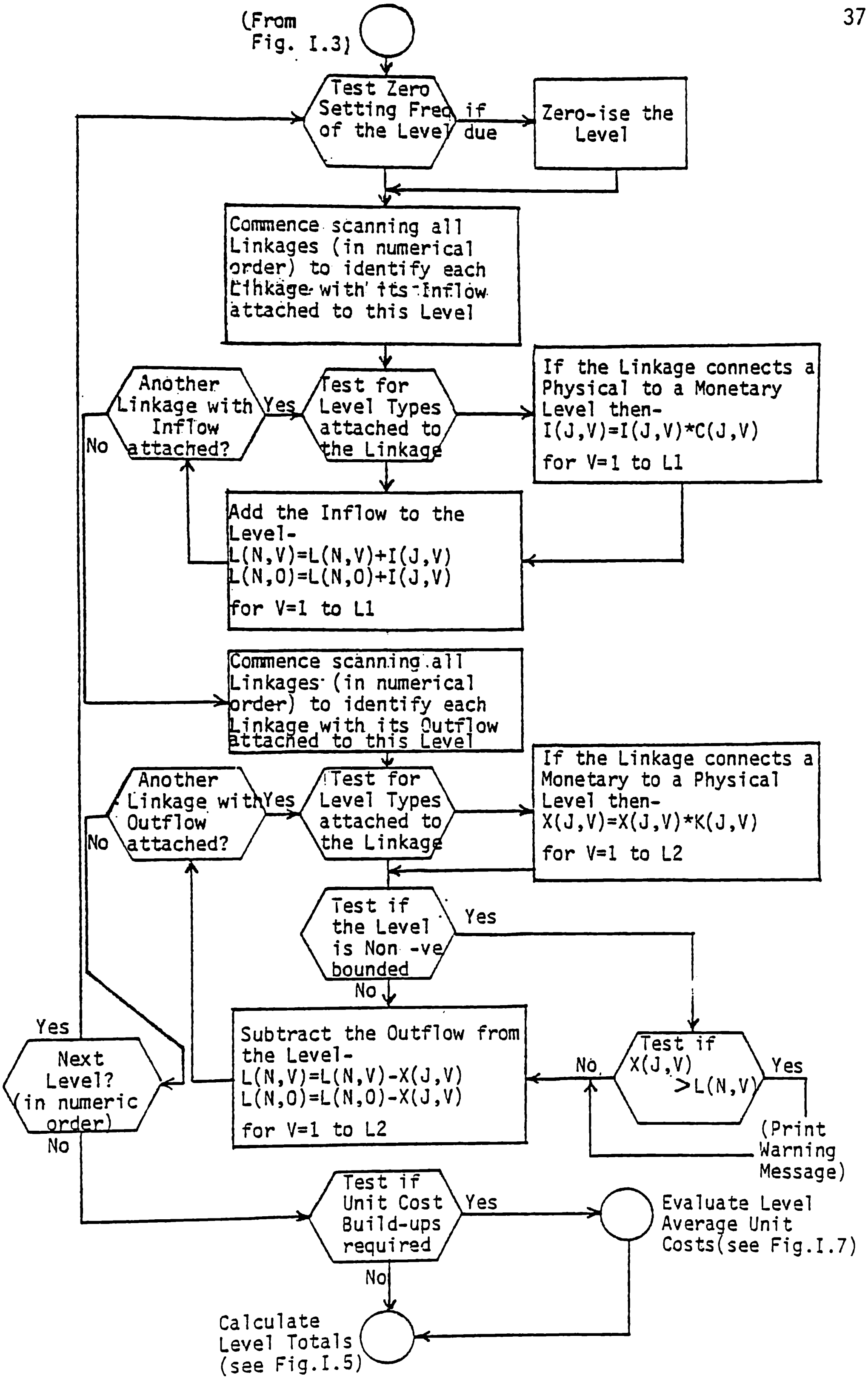


FIGURE I.4: FLOWCHART OF THE LEVEL CALCULATION LOGIC

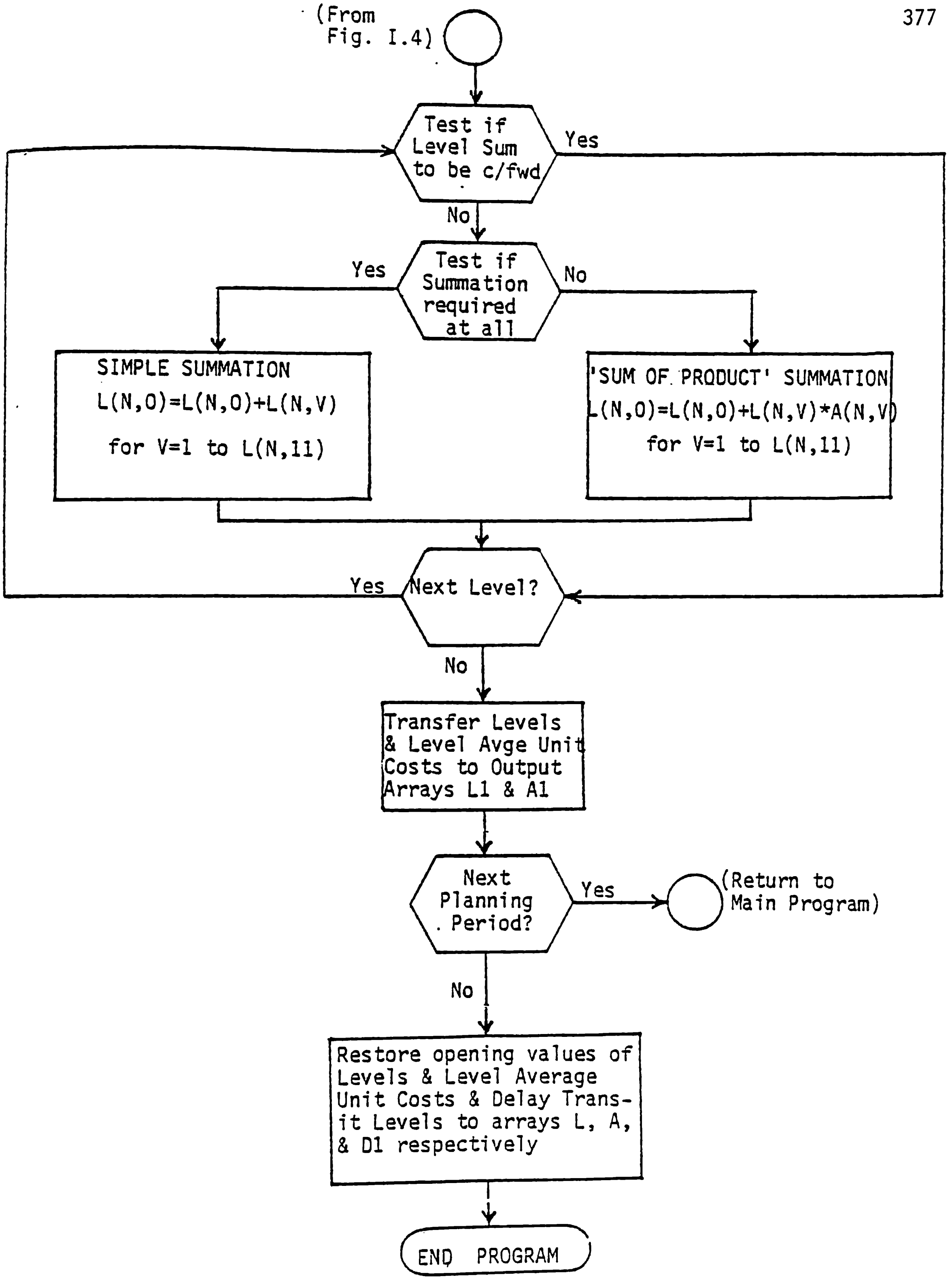


FIGURE I.5: FLOWCHART OF THE LEVEL TOTALLING LOGIC

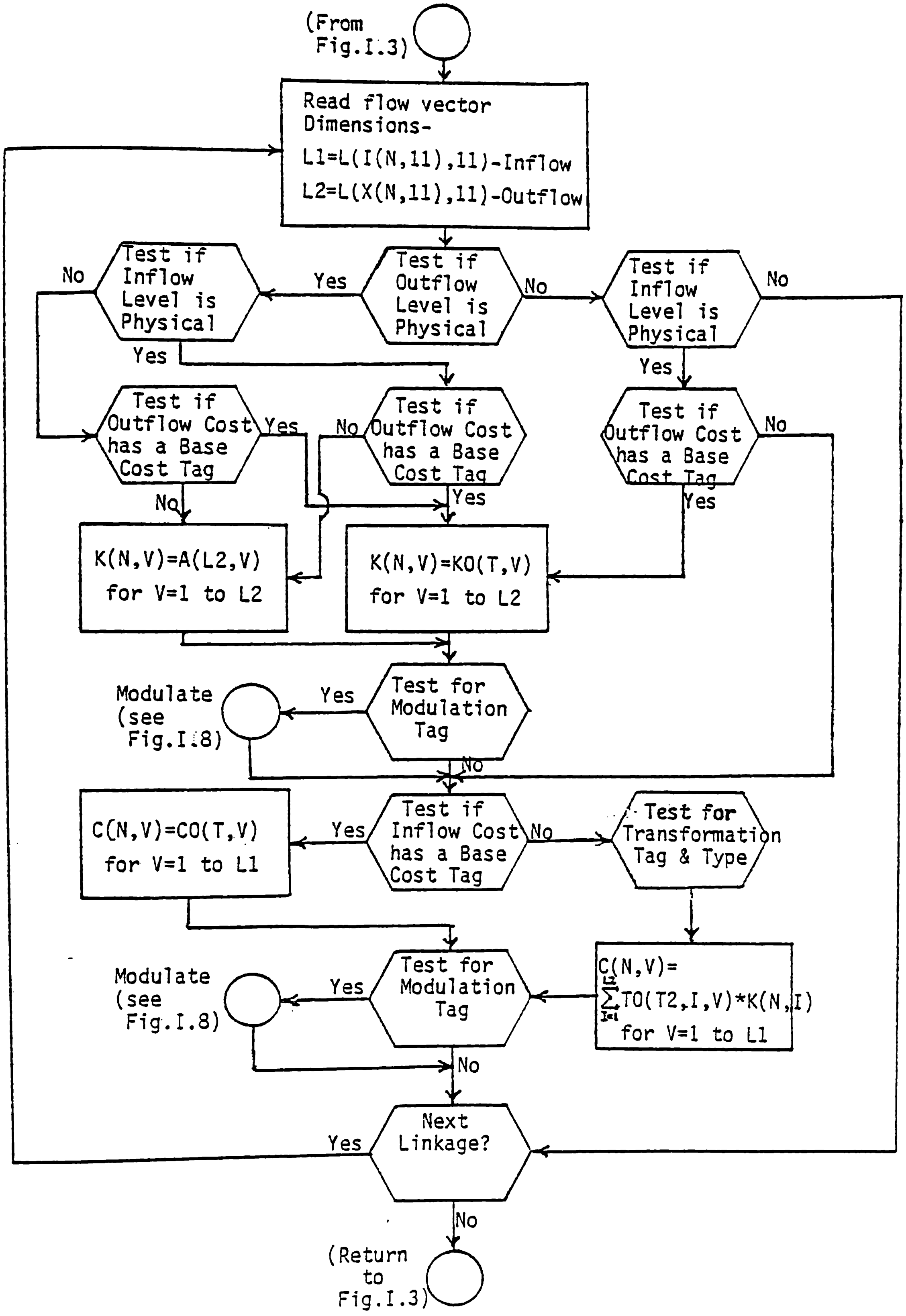


FIGURE I.6: FLOWCHART OF THE FLOW UNIT COST CALCULATION LOGIC

(Note: Linkages are evaluated in reverse numerical order)

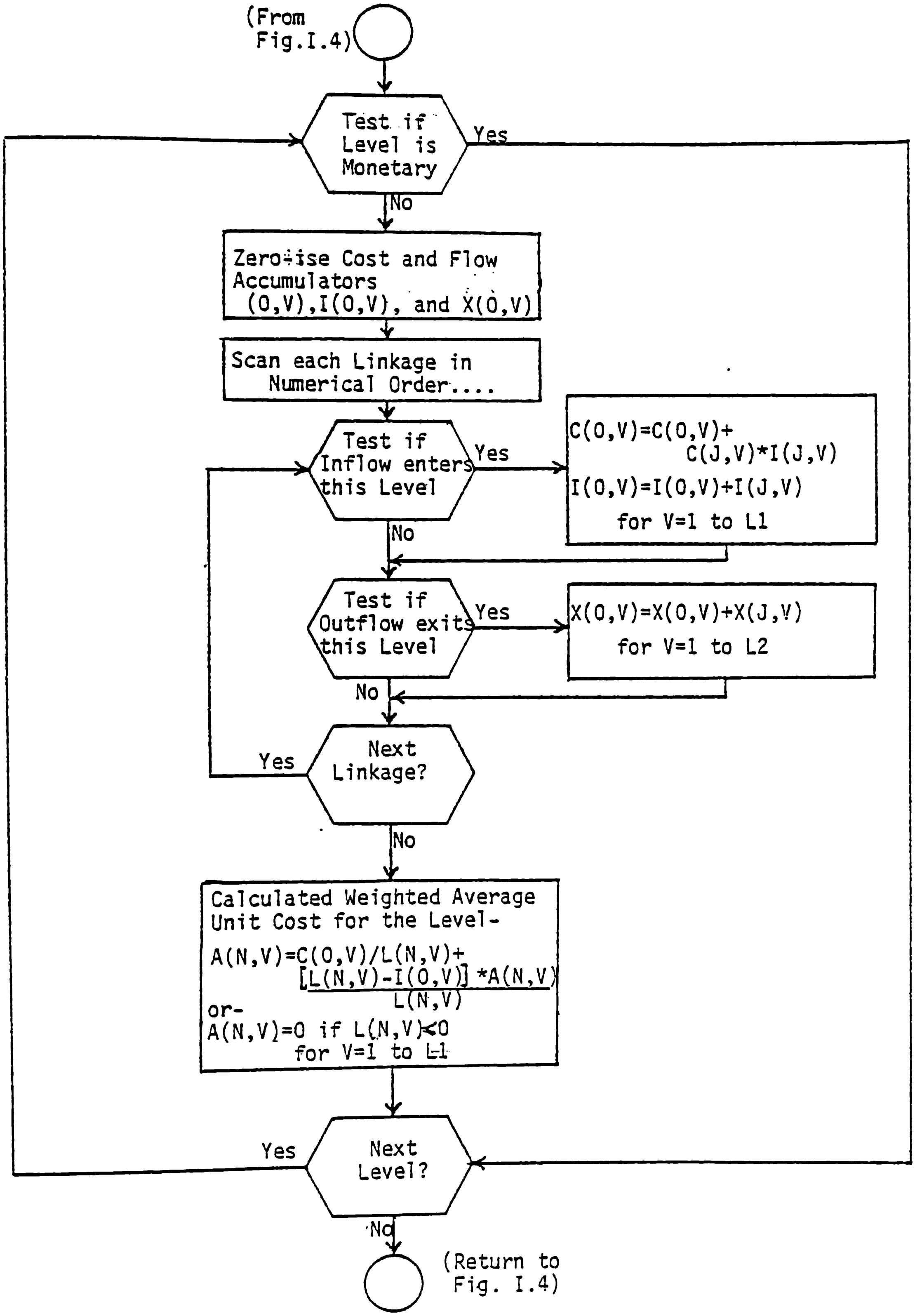


FIGURE I.7: FLOWCHART OF THE LEVEL AVERAGE COST CALCULATION LOGIC

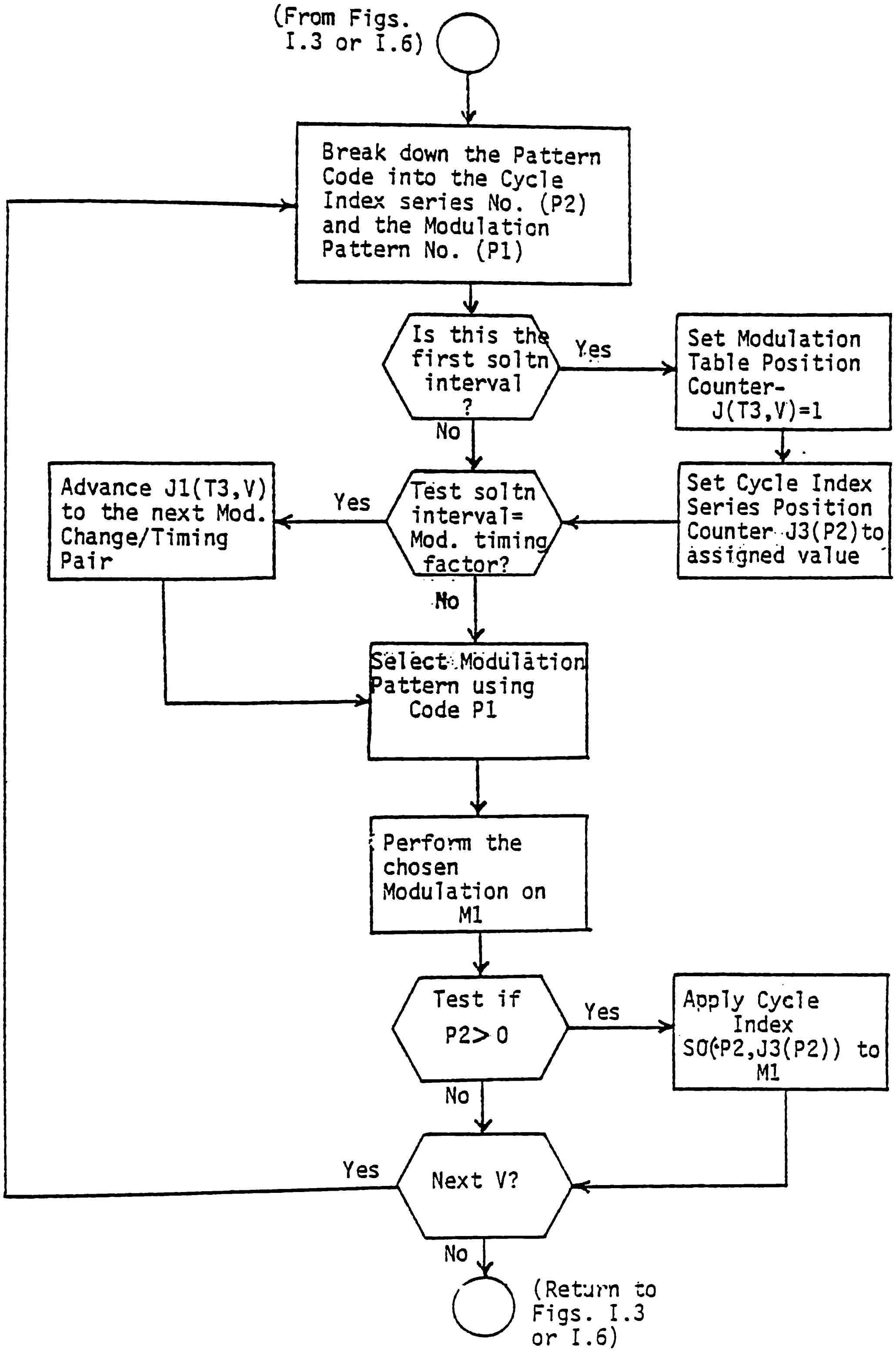


FIGURE I.8: <u>FLOWCHART OF THE MODULATION FUNCTION LOGIC</u>

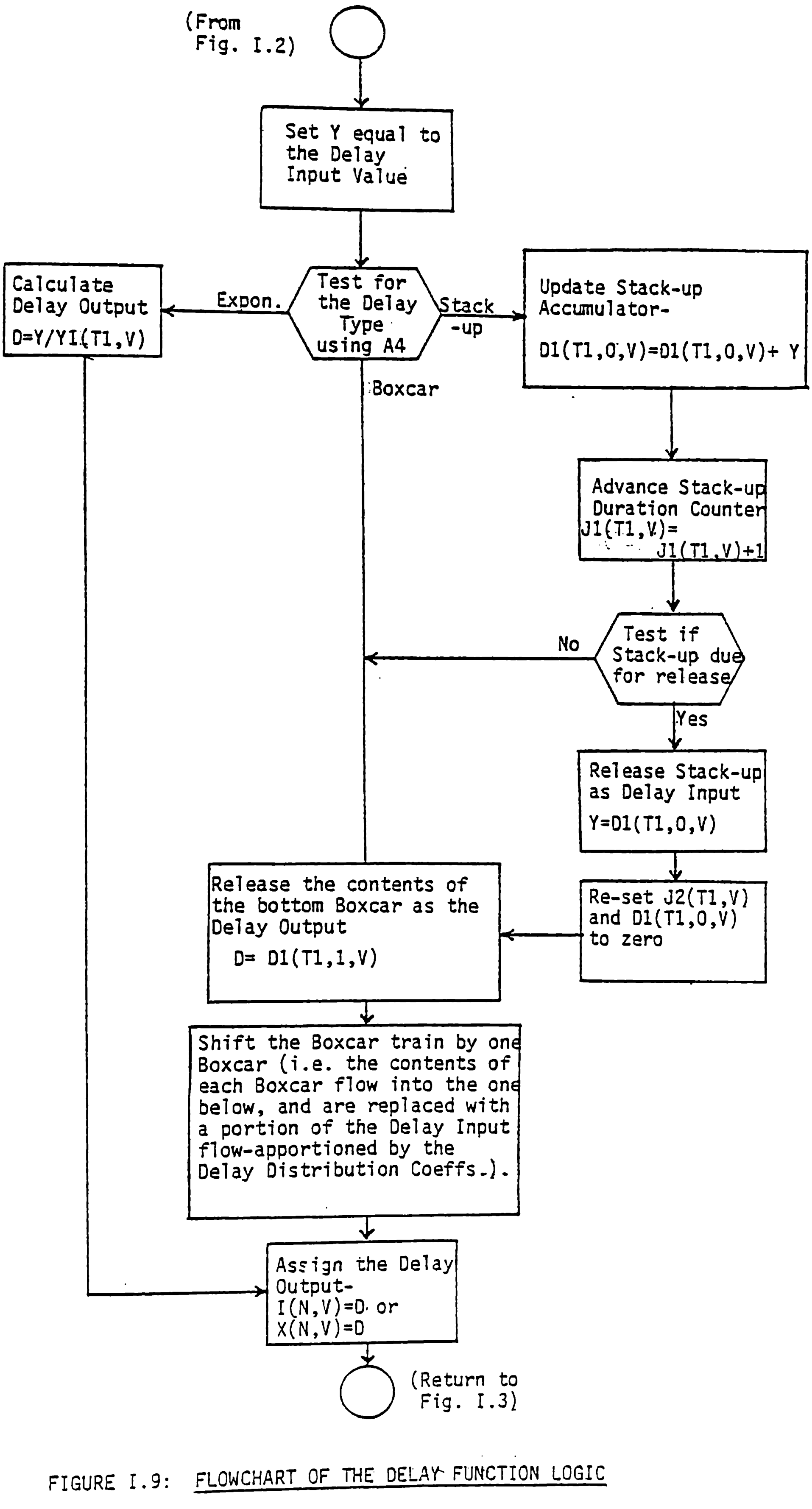


FIGURE I.9: FLOWCHART OF THE DELAY FUNCTION LOGIC

APPENDIX J

THE REPORT GENERATING PROGRAM (GENREP)

This program must be run to generate any report associated with a particular computational run of any given model. The program can be accessed from the control program GENSIM, or run by using the command

RUN GENREP (Modified depending upon where the program is stored)

(a) Purpose of the Program

A report associated with any model run can be produced in either tabular or graphical form. Tabular reports consist of a standard format whereby the columns are used to designate time periods, and the rows (or report lines) are used to designate the factor to be reported (either a level or a performance factor). Graphical reports consist of a format whereby time periods constitute the horizontal axis and specified performance factors and levels can be graphed using the vertical axis for their respective period values.

Any report must be set up in terms of:-

(1) Whether or not it is to constitute a consolidation of the results of more than one model. In the case of their being only one model no consolidation is involved.

(2) Whether or not a listing of the report specifications which

are currently on file, is required. All specifications for report lines, performance factors, and graphs are stored permanently on disk files, and can be displayed if desired.

(3) Whether or not it is desired to change the report heading. Generally this is only necessary for the first report run of a model.

(4) Whether or not the files for the performance factor specifications are to be zero-ised. This should be done for the first report run of a model, or if it is desired to completely re-specify the performance factors.

(5) Whether or not it is desired to specify any performance factors. Up to 40 such factors can be defined, and within this limit the factors can be added to and (or) amended as required. Performance factors are combinations of level values built up in terms of addition, subtraction, or division.

(6) Whether or not it is desired to specify the report formats. This covers:-

1. The type of report required (i.e., Tabular, Graphical or both types).

2. The reporting frequency as regards time periods (i.e. are results required for each period, or only every 2nd, 3rd or 4th period etc.)

3. The report listing sequence (i.e. the specification of

the report lines, for tabular reporting.

The above must be specified for the first report run, but not for subsequent runs unless variations in format are required.

(7) The report run description (up to 32 characters to identify the particular report run concerned).

(8) The report line numbers to start and end the report. This applies only to tabular reports and permits selective printing of report segments.

(9) Whether or not the level values on tabular reports are to be printed out fully (i.e. all sub-levels) or whether only the level totals are required.

(10) How many report columns (i.e. time periods) are required on the tabular reports and what those specific time periods in fact are (if they have not already been specified, or it it is desired to amend them).

(11) After the specified report has been generated further report runs may be made which are appended to the report file resulting in multiple reports, of varying formats if desired, all stored on the one disk file MODEL .LSR. The file name MODEL is purely illustrative and would be replaced by the name of the particular model concerned.

It should be noted that GENREP cannot be run for a model unless the output file from GENCOM has been created for that model - i.e. a computational run of the model has taken place. Furthermore, if any aspect of a model's structure or data is changed (using GENSPC or GENINP) then GENCOM must be re-run before reports incorporating the effects of those changes can be generated.

(b) The Program Files

The following data files are used by GENREP (the File name MODEL is used purely for illustration purposes).

Input Files:	MODEL .ONE MODEL .TWO MODEL .THR MODEL .FOU	Contents as described in Appendices E and F
	MODEL .OUT	The file of computed level and average unit cost values created by GENCOM.
	MODEL .TXT	Holds the text explaining the use of the level numbers and performance factor numbers for specifying report lines, and the code system for performance factor specification.
	MODEL .R7	Contains the performance factor Numerator codes and scaling factors.
	MODEL .R8	Contains the performance factor Denominator codes and the upper and lower bounds for the vertical axis of each graph.
	MODEL .R9	Contains the tabular report line codes, the report columns (time periods) and the performance factor Numerator-Denominator time lags.

	MODEL .R10	Contains a temporary array for graph printing and the level element (i.e. Sub-level) descriptions.
	MODEL .R11	Contains a temporary array for performance factor calculation and the performance factor descriptions.
	MODEL .R12	Contains the performance factor codes to be graphed, the report heading, report type, and frequency, and the number of performance factors which have been defined. Also contains the report column headings.
Output File:	MODEL .LSR	Contains the generated report or reports if multiple reporting has been requested.

(c) Performance Factor Specification

The procedure, and coding system for defining performance factors is described below. Up to 40 such factors may be defined. They can be defined as combinations of up ten level totals or sub-level values (or a mixture of both) combined using addition and (or) subtraction - constituting a Numerator. If a ratio is desired as a performance factor, then a Denominator can be set up to go with the above-mentioned Numerator. This Denominator can be a combination of up to 10 level totals or sub-level values, in exactly the same manner as described for the Numerator. Note that multiplication is not possible in either the Numerator or the Denominator.

In order to construct the formulae for performance factors, in terms of Numerator and (if desired) Denominator, a simple coding system is used as follows:-

(1) Levels to be incorporated into any Numerator or Denominator are referenced by a 4-digit code number. The first two digits from the left are the level number (only the right-hand digit of this pair need be used if the level number is less than 10). The second pair of digits are the level element (i.e. Sub-level) number. If the level total is required rather than any specific Sub-level value, then two zeros are used for this second pair of digits. Thus:-

403	Means Level 4, Sub-level 3
1910	Means Level 19, Sub-level 10
500	Means Level 5 total

To make up the formula for either a Numerator or Denominator each code is prefixed by an appropriate sign - either "+" or "-". As each individual code is prompted for separately only the latter sign need be explicitly entered, positive values are assigned automatically.

(2) If no Denominator is required (i.e. the factor is not a ratio) then no entry is made for the first Denominator code prompt and the program will loop out of that segment.

Any performance factor may have a Numerator and Denominator which do not relate to the same time period, in that the values picked up for the levels specified in the Denominator may be lagged 1 or more periods behind those picked up for the Numerator. Thus growth rates can be set up as performance factors by specifying an identical set of components for both Numerator and Denominator, then lagging the latter. For example, if an annual growth rate is required, and the model solution period is 1 month a time lag of 12 would be chosen.

The final component to specify for any performance factor is its scaling coefficient. If no scaling is required, 1 is entered. If a ratio is to be converted to a percentage 100 is entered. Fractional amounts can also be entered as scaling coefficients.

(d) Report Line Specification

The procedure for specifying report lines is as follows:

(1) If a level is to be reported on the line then the level number is entered. The values of all sub-levels will be printed out one below the other if the 'full values' option is selected.

(2) If a performance factor is to be reported on the line then the performance factor number is entered, prefixed by 1. Thus if performance factor No. 4 is required enter 104. If performance factor 23 is required, enter 123.

(3) If an average unit cost is to be reported then the level number associated with that cost, is entered, prefixed by 2. Thus if the average unit costs associated with level No. 7 are required, then enter 207. If those associated with level 19 are required, enter 219. The average unit costs associated with all sub-levels will be printed out

one below the other if the 'full values' option is selected as in (1) above.

(4) If a space of one line is required on the report then enter 999 in response to the report line prompt.

(5) If a new page is to be started, enter -999 in response to the report line prompt.

(e) The Program Structure

Refer Figure J.1.

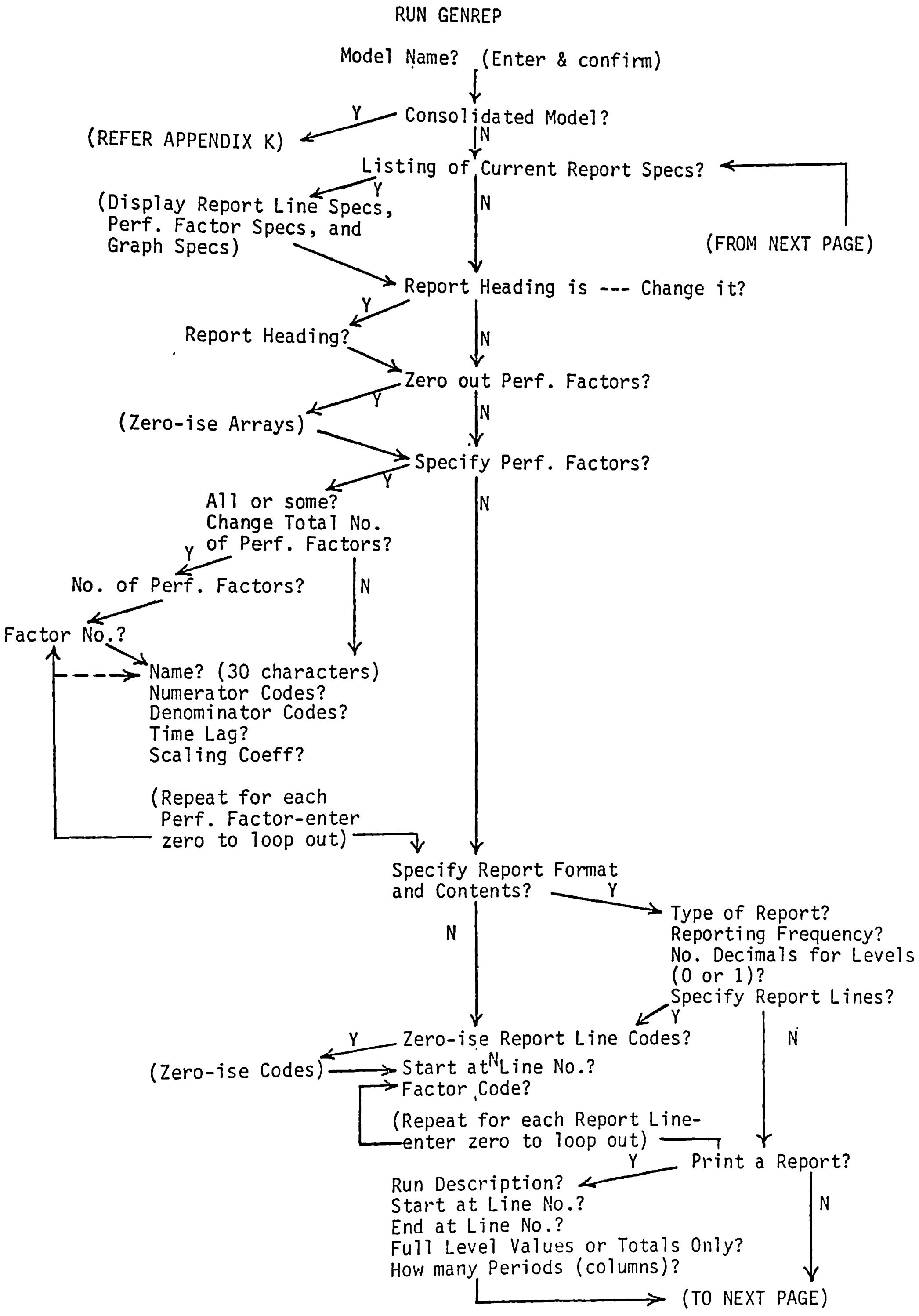


FIGURE J.1.: CHART OF GENREP PROMPTS

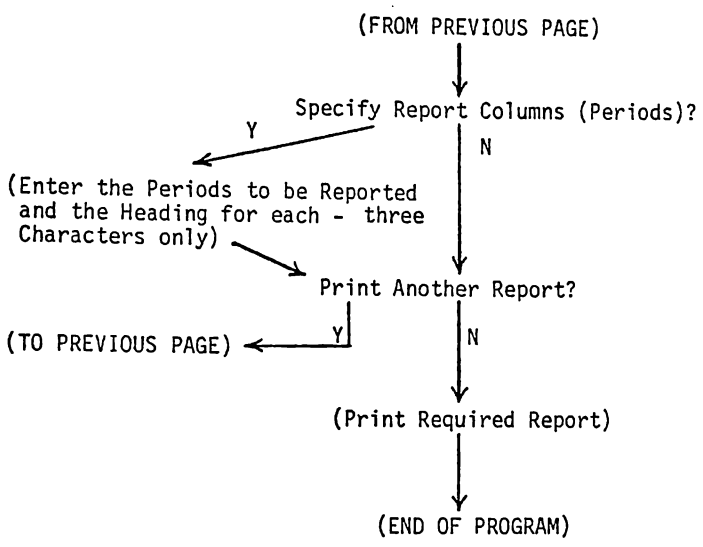
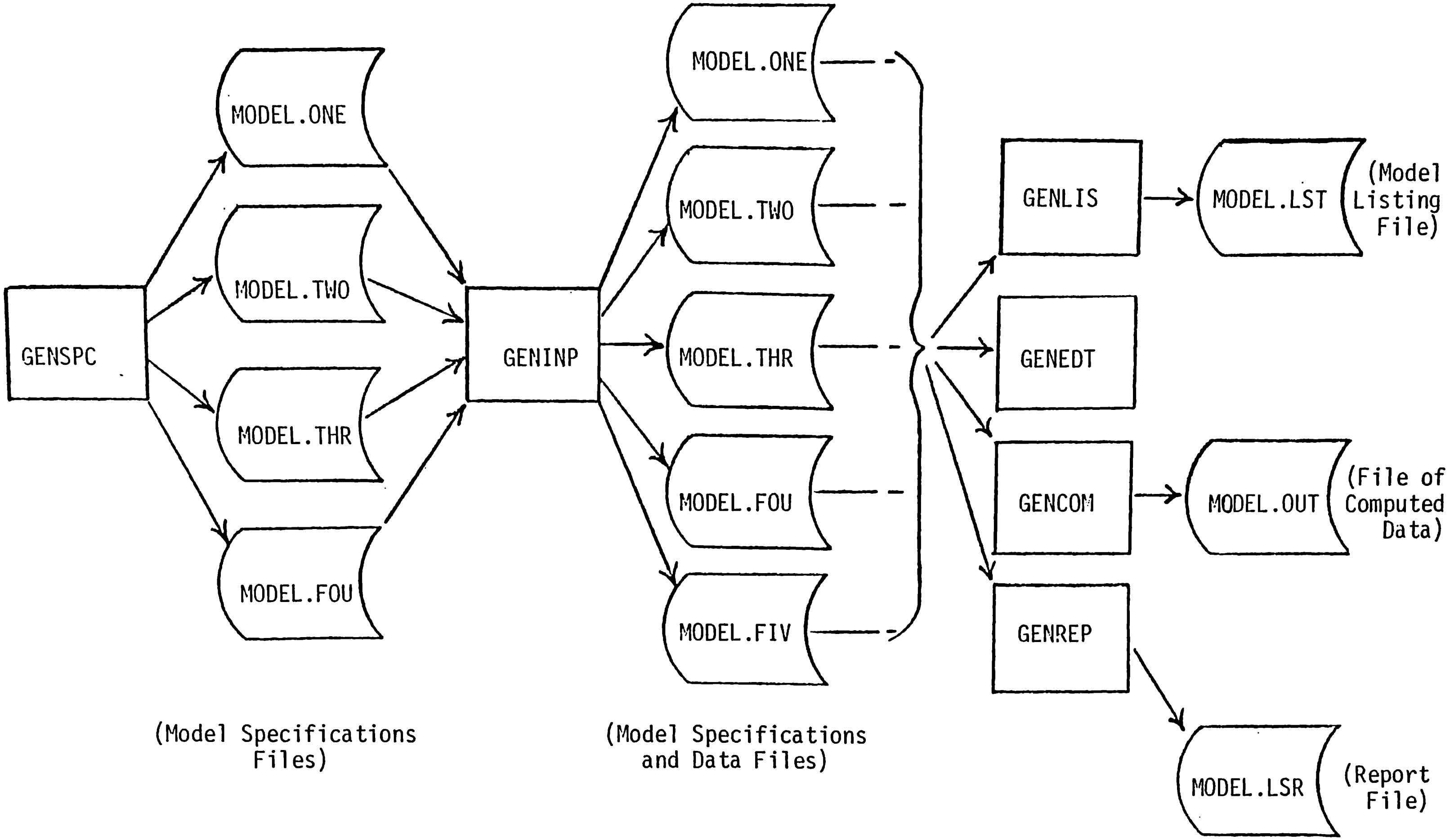


FIGURE J.1: CHART OF GENREP PROMPTS (continued)

APPENDIX K - GENSIM SYSTEM: PROGRAMS AND DISK FILES



APPENDIX L

SPECIFICATIONS AND DATA LISTING FOR THE SIMPLE FINANCIAL MODEL

```
                                 GENERALISED SIMULATION MODEL         DATE  28-Apr-81  TIME  21:17

                                 MODEL SPECIFICATION LISTING FOR   MODEL1


MODEL SOLUTION INTERVAL:MONTHS (12 PER YEAR)    PLANNING HORIZON: 12

LEVEL                    DIMENSION    BOUND.TYPE    ZER.INT    TOTAL TYPE

   1  CAPITAL                 1            1           0          S


   2  CASH                    1            1           0          S


   3  CREDITORS               1            1           0          S


   4  FIXED ASSETS            1            2           0          S


   5  DEBTORS                 1            2           0          S


   6  STOCK                   1            2           0          S


   7  ACCUM. PROFIT           1            1           0          S



 LINK.    INFLOW  DEP.   DET.  FLOW  DEL.  MOD.  COST  COST  COST  *TRAN*  OUTFLOW  DEP.  DET.  FLOW  DEL.  MOD.  COST  COST  COST
 NO  TYPE  LEV.   TYPE   NO    PAT.  TAG   TAG   TYPE  BVTAG MTAG  * TAG*   LEV.   TYPE  NO    PAT.  TAG   TAG   TYPE  BVTAG MTAG

  1  IX     5   OUTFLOW   1    INST.   0     0           0     0      0       7   EXOG.   1   INST.   0     1           0     0
  2  II     7   OUTFLOW   1    INST.   0     2           0     0      0       6  INFLOW   2   INST.   0     0           0     0
  3  II     6     EXOG.   3    BOXC.   3     3           0     0      0       3  INFLOW   3   INST.   0     0           0     0
  4  II     7     EXOG.   4    INST.   0     4           0     0      0       3  INFLOW   4   INST.   0     0           0     0
  5  IC     2   OUTFLOW   5    INST.   0     0           0     0      0       5  INFLOW   1   BOXC.   5     0           0     0
  6  IC     3     LEVEL   3    EXPON   6     0           0     0      0       2  INFLOW   6   INST.   0     0           0     0
  7  IX     7   OUTFLOW   7    INST.   0     0           0     0      0       4   LEVEL   4   INST.   0     7           0     0
  8  IX     2   OUTFLOW   8    INST.   0     0           0     0      0       1   EXOG.   8   INST.   0     8           0     0
  9  II     4     EXOG.   9    INST.   0     9           0     0      0       2  INFLOW   9   INST.   0     0           0     0
```

Continued.......

```
                                    GENERALISED SIMULATION MODEL       DATE 28-Apr-81
                                    MODEL DATA LISTING FOR   MODEL1

                    ----  LEVEL INITIAL VALUES & COSTS  ----

LEVEL
   1 CAPITAL             Initial Values    -100
   1                     Unit Costs        0.00
   2 CASH                Initial Values      -5
   2                     Unit Costs        0.00
   3 CREDITORS           Initial Values     -10
   3                     Unit Costs        0.00
   4 FIXED ASSETS        Initial Values      60
   4                     Unit Costs        0.00
   5 DEBTORS             Initial Values      15
   5                     Unit Costs        0.00
   6 STOCK               Initial Values      40
   6                     Unit Costs        0.00
   7 ACCUM. PROFIT       Initial Values       0
   7          .          Unit Costs        0.00

                    ----  BASE FLOW & BASE UNIT COSTS  ----

LINKAGE
   1 BASE FLOW NO.  1        12.800
   3 BASE FLOW NO.  3         7.700
   4 BASE FLOW NO.  4         1.000
   8 BASE FLOW NO.  8         0.000
   9 BASE FLOW NO.  9         0.000

                    ---- MODULATION TABLES (MATRICES) ----
MODULATION PATTERN CODES (IN FAR RIGHT COLUMN) ARE AS FOLLOWS:-
.        THE FIRST TWO DIGITS ARE THE CYCLE SERIES ROW NUMBER IF CYCLICAL EFFECTS ARE BEING SUPERIMPOSED
         FOR THE LAST TWO DIGITS (Before the Decimal Point)-
              00=Mult. each Period < or = Stated Period          01=Mult. in the Stated Period only
              02=Addn. each Period < or = Stated Period          03=Addn. in the Stated Period only
              04=Clips Back to Stated Upper Bound                05=Clips Up to Stated Lower Bound
              06=1 ==> 0 on Stated Upper Bound                   07=1 ==> 0 on Stated Lower Bound

LINKAGE  TAG

   1      1
CREDITORS       1.0000   5.0000   1.0300   6.0000   1.0700   9.0000   1.1100  36.0000   0.0000   0.0000   0.0000   0.0000 100.0000

   2      2
CREDITORS       0.6900   4.0000   0.6800   8.0000   0.6700  12.0000   0.6600  24.0000   0.6500  36.0000   0.0000   0.0000   0.0000

   3      3
               1.0000   3.0000   1.0500   6.0000   1.1000   9.0000   1.1500  12.0000   1.2800  24.0000   1.4000  36.0000   0.0000

   4      4
CREDITORS       1.0000  12.0000   1.1000  24.0000   1.2100  36.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000 200.0000

   7      7
               0.0110  36.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   8      8
               5.5000   7.0000 -20.0000  28.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   3.0000

   9      9
              12.0000   5.0000  12.0000  11.0000   6.0000  18.0000  20.0000  24.0000  10.0000  32.0000   0.0000   0.0000   3.0000
```

Continued.......

```
                        ---- DELAY TABLES (MATRICES) ----

LINKAGE TAG

   3      3 DELAY DISTRIBUTION COEFFS
                          0.00    0.20    0.50    0.30      0.00*

   3      3 DELAY TRANSIT LEVELS
                          6.00   10.70    3.50    2.00      0.00*

   5      5 DELAY DISTRIBUTION COEFFS
                          0.60    0.20    0.10    0.10      0.00*

   5      5 DELAY TRANSIT LEVELS
                          8.82    3.53    1.76    0.88      0.00*

   6      6 EXPONENTIAL DELAY PERIODS
                          1.10

                        ------------ CYCLES TABLE (MATRIX) -------------

CYCLE 1   0.6000  0.8000  1.0000  1.2000  0.8000  0.8000  1.0000  1.4000  1.5000  1.2000  1.0000  0.7000 12.0000
CYCLE 2   2.0000  1.8000  1.8000  0.9000  2.0000  2.0000  2.0000  2.1000  2.2000  2.2000  0.8000  0.8000 12.0000
```

APPENDIX M

SPECIFICATIONS AND DATA LISTING FOR THE EXTENDED FINANCIAL MODEL

```
                                 GENERALISED SIMULATION MODEL        DATE  30-Apr-81  TIME  12:54

                                 MODEL SPECIFICATION LISTING FOR   MODEL2


MODEL SOLUTION INTERVAL:MONTHS (12 PER YEAR)    PLANNING HORIZON: 12

LEVEL                    DIMENSION    BOUND.TYPE    ZER.INT    TOTAL TYPE

  1  CAPITAL                   2           1           0          S
       1    DEBT CAPITAL
       2    EQUITY CAPITAL

  2  CASH                      6           1          12          SC
       1    COLLECTIONS
       2    PAYMENTS
       3    INTEREST
       4    CAPITAL EXPEND.
       5    BORR/REPAYMENTS
       6    TAX PAYMENTS

  3  OTHER LIABS.              4           1           0          S
       1    TRADE CREDITORS
       2    SUNDRY CREDS.
       3    RESERVES
       4    TAX PROVN.

  4  FIXED ASSETS              3           2           0          S
       1    LAND & BLDGS.
       2    FURN & EQPT.
       3    MOTOR VEHICLES

  5  DEBTORS                   1           2           0          S
       1    SUNDRY DEBTORS

  6  STOCK                     4           2           0          S
       1    TELEVISION
       2    REFRIGERATORS
       3    OTHER BROWN
       4    OTHER WHITE

  7  ACCUM. SALES              4           1          12          S
       1    TELEVISION
       2    REFRIGERATORS
       3    OTHER BROWN
       4    OTHER WHITE
```

Continued.......

```
 8 ACCUM. EXPENSES          4          2          12        S
     1    INTEREST
     2    DEPRECIATION
     3    FIXED EXPENSES
     4    VAR. EXPENSES

 9 ACCUM. C.O.S.            4          2          12        S
     1    TELEVISION
     2    REFRIGERATORS
     3    OTHER BROWN
     4    OTHER WHITE

10 PROFIT CALC.            10          1          12        N
     1    SALES
     2    TV C.O.S.
     3    FRIG. C.O.S.
     4    BROWN C.O.S.
     5    WHITE C.O.S.
     6    INTEREST
     7    DEPRECIATION
     8    EXPENSES
     9    GROSS MARGIN
    10    NET PROFIT

11 TAX CALC.                6          1          12        N
     1    BT PROFIT
     2    LOSSES C/F
     3    TAX. DEPN.
     4    ACTUAL DEPN.
     5    OTHER ALLCES
     6    TAXABLE PROFIT


LINK.    INFLOW  DEP.   DET.  FLOW  DEL.  MOD.  COST  COST  COST  *TRAN*  OUTFLOW  DEP.   DET.  FLOW  DEL.  MOD.  COST  COST  COST
NO  TYPE  LEV.   TYPE   NO    PAT.  TAG   TAG   TYPE  BVTAG MTAG  * TAG*   LEV.   TYPE   NO    PAT.  TAG   TAG   TYPE  BVTAG MTAG

 1  SX     5   OUTFLOW   1   INST.   0     0             0     0      0       7   EXOG.    1   INST.    0     1            0     0
 2  II     9   OUTFLOW   1   INST.   0     2             0     0      0       6  INFLOW    2   INST.    0     0            0     0
 3  GI     6     EXOG.   3   BOXC.   3     3             0     0      3       3  INFLOW    3   INST.    0     0            0     0
 4  GI     8     MIXED   1   INST.   0     4             0     0      4       3  INFLOW    4   INST.    0     0            0     0
 5  GC     2   OUTFLOW   5   INST.   0     0             0     0      5       5  INFLOW    1   BOXC.    5     0            0     0
 6  GI     3     LEVEL   3   EXPON   6     6             0     0      6       2  INFLOW    6   INST.    0     0            0     0
 7  GX     8   OUTFLOW   7   INST.   0     0             0     0      7       4   LEVEL    4   INST.    0     7            0     0
 8  GX     2   OUTFLOW   8   INST.   0     0             0     0      8       1   EXOG.    8   INST.    0     8            0     0
 9  GI     4     EXOG.   9   INST.   0     9             0     0      9       2  INFLOW    9   INST.    0     0            0     0
10  GX     8   OUTFLOW  10   INST.   0     0             0     0     10       2   MIXED   10   INST.    0    10            0     0
11  GC    10     MIXED   2   INST.   0     0             0     0     11      10  INFLOW   11   INST.    0     0            0     0
12  GI    11     MIXED   3   INST.   0    12             0     0     12      11  INFLOW   12   INST.    0     0            0     0
13  GI    11     MIXED   3   INST.   0  1314             0     0     13       3  INFLOW   13   INST.    0     0            0     0
```

Continued........

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                    --------------- MIXED DEPENDENCY CODES --------------

THE MIXED DEPENDENCY CODE STRUCTURE IS AS FOLLOWS:-
          FIRST DIGIT...........0=Base Flow Dependent     1=Level Dependent
                                2=Inflow Dependent        3=Outflow Dependent
          SECOND & THIRD DIGITS...The Relevant Level or Flow Number
          FOURTH DIGIT............The Relevant Element Number

                                   DEPENDENT FLOW ELEMENT NUMBER
                          1         2         3         4         5         6         7         8         9        10

LINKAGE 4 INFLOW      11020         0        43      2011         0         0         0         0         0         0

LINKAGE 10 OUTFLOW        0         0      1011         0         0         0         0         0         0         0

LINKAGE 11 INFLOW      2011      2021      2022      2023      2024      2101      2072      3042         0         0

LINKAGE 12 INFLOW      3110      3126       103      2072       105      3126         0         0         0         0

LINKAGE 13 INFLOW      3110      3126       103      2072       105      3126         0         0         0         0
```

Continued.......

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                                              GENERALISED SIMULATION MODEL      DATE 30-Apr-81
                                              MODEL DATA LISTING FOR   MODEL2

                     ----  LEVEL INITIAL VALUES & COSTS  ----

LEVEL
   1 CAPITAL         Initial Values    -60    -40
   1                 Unit Costs       0.00   0.00
   2 CASH            Initial Values     00     -5      0      0      0      0
   2                 Unit Costs       0.00   0.00   0.00  0.000   0.00   0.00
   3 OTHER LIABS.    Initial Values     -7     -3      0      0
   3                 Unit Costs       0.00   0.00   0.00   0.00
   4 FIXED ASSETS    Initial Values     45     10      5
   4                 Unit Costs       0.00   0.00   0.00
   5 DEBTORS         Initial Values     15
   5                 Unit Costs       0.00
   6 STOCK           Initial Values     17     12      8      3
   6                 Unit Costs       0.00   0.00   0.00   0.00
   7 ACCUM. SALES    Initial Values      0  0   0      0      0
   7                 Unit Costs       0.00   0.00   0.00   0.00
   8 ACCUM. EXPENSES Initial Values      0      0      0      0
   8                 Unit Costs       0.00   0.00   0.00   0.00
   9 ACCUM. C.O.S.   Initial Values      0      0      0      0
   9                 Unit Costs       0.00   0.00   0.00   0.00
  10 PROFIT CALC.    Initial Values      0      0      0      0      0      0      0      0      0      0
  10                 Unit Costs       0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
  11 TAX CALC.       Initial Values      0      0      0      0      0      0
  11                 Unit Costs       0.00   0.00   0.00   0.00   0.00   0.00

                     ----  BASE FLOW & BASE UNIT COSTS  ----

LINKAGE
   1 BASE FLOW NO.  1      4.800     3.400     2.200     0.800
   3 BASE FLOW NO.  3      3.300     2.300     1.500     0.600
   4BASE FLOW NO.  4      1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   8 BASE FLOW NO.  8      0.000     0.000
     BASE FLOW NO.  9      0.000     0.000     0.000
  12BASE FLOW NO.  10      0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
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Continued.......

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                        ---- TRANSFORMATION TABLES (MATRICES) ----

LINKAGE  TAG                            INFLOWS

  3       3           TELEVISION          OTHER BROWN
                              REFRIGERATORS       OTHER WHITE
    TRADE CREDITORS        1.00     1.00     1.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00
    SUNDRY CREDS.          0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    RESERVES               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    TAX PROVN.             0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00

  4       4           INTEREST            FIXED EXPENSES
                              DEPRECIATION        VAR. EXPENSES
    TRADE CREDITORS      0 0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    SUNDRY CREDS.          1.00     1.00     1.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00
    RESERVES               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    TAX PROVN.             0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00

  5       5           COLLECTIONS         INTEREST            BORR/REPAYMENTS
                              PAYMENTS            CAPITAL EXPEND.     TAX PAYMENTS
  . SUNDRY DEBTORS         1.00     0.00     0.00     0.00     0.00     0.00     0.00   0 0.00     0.00     0.00

  6       6           TRADE CREDITORS     RESERVES
                              SUNDRY CREDS.       TAX PROVN.
    COLLECTIONS            0.00 .   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    PAYMENTS               1.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    INTEREST               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    CAPITAL EXPEND.        0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    BORR/REPAYMENTS        0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    TAX PAYMENTS           0.00     0.00     0.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00

  7       7           INTEREST            FIXED EXPENSES
                              DEPRECIATION        VAR. EXPENSES
    LAND & BLDGS.          0.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    FURN & EQPT.           0.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
    MOTOR VEHICLES         0.00     1.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00

  8       8           COLLECTIONS         INTEREST            BORR/REPAYMENTS
                              PAYMENTS            CAPITAL EXPEND.     TAX PAYMENTS
    DEBT CAPITAL           0.00     0.00     0.00     0.00     1.00     0.00     0.00     0.00     0.00     0.00
    EQUITY CAPITAL         0.00     0.00     0.00     0.00     1.00     0.00     0.00     0.00     0.000   00.00
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Continued........

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9      9                 LAND & BLDGS.        MOTOR VEHICLES
                                     FURN & EOPT.
 COLLECTIONS                 0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 PAYMENTS                    0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 INTEREST                    0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 CAPITAL EXPEND.             1.00       1.00       1.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 BORR/REPAYMENTS             0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 TAX PAYMENTS                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00

18     10                 INTEREST              FIXED EXPENSES
                                     DEPRECIATION          VAR. EXPENSES
 COLLECTIONS                 0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 PAYMENTS                    0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 INTEREST                    1.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 CAPITAL EXPEND.             0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 BORR/REPAYMENTS             0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 TAX PAYMENTS                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00

11     11                 SALES                 FRIG. C.O.S.0         WHITE C.O.S.          DEPRECIATION          GROSS MARGIN
                                     TV C.O.S.             BROWN C.O.S.          INTEREST              EXPENSES              NET PROFIT

 SALES                       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 TV C.O.S.                   0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 FRIG. C.O.S.                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 BROWN C.O.S.                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 WHITE C.O.S.                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 INTEREST                    0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 DEPRECIATION                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 EXPENSES                    0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 GROSS MARGIN                1.00      -1.00      -1.00      -1.00      -1.00       0.00       0.00       0.00       0.00       0.00
 NET PROFIT                  1.00      -1.00      -1.00      -1.00      -1.00      -1.00      -1.00      -1.00       0.00       0.00

12     12                 BT PROFIT             TAX. DEPN.            OTHER ALLCES
                                     LOSSES C/F            ACTUAL DEPN.          TAXABLE PROFIT
 BT PROFIT                   0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 LOSSES C/F                  0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 TAX. DEPN.                  0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 ACTUAL DEPN.                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 OTHER ALLCES                0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 TAXABLE PROFIT              1.00       1.00      -1.00       1.00      -1.00       1.00       0.00       0.00       0.00       0.00

13     13                 BT PROFIT             TAX. DEPN.            OTHER ALLCES
                                     LOSSES C/F            ACTUAL DEPN.          TAXABLE PROFIT
 TRADE CREDITORS             0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 SUNDRY CREDS.               0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
 RESERVES                    1.00       0.00       0.00       0.00       0.00      -1.00       0.00       0.00       0.00       0.00
 TAX PROVN.                  0.00       0.00       0.00       0.00       0.00       1.00       0.00       0.00       0.00       0.00
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               ---- MODULATION TABLES (MATRICES) ----
MODULATION PATTERN CODES (IN FAR RIGHT COLUMN) ARE AS FOLLOWS:-
     THE FIRST TWO DIGITS ARE THE CYCLE SERIES ROW NUMBER IF CYCLICAL EFFECTS ARE BEING SUPERIMPOSED
     FOR THE LAST TWO DIGITS (Before the Decimal Point)-
          00=Mult. each Period < or = Stated Period        01=Mult. in the Stated Period only
          02=Addn. each Period < or = Stated Period        03=Addn. in the Stated Period only
          04=Clips Back to Stated Upper Bound              05=Clips Up to Stated Lower Bound
          06=1 ==> 0 on Stated Upper Bound                 07=1 ==> 0 on Stated Lower Bound

LINKAGE  TAG

   1      1
TELEVISION       1.0000   3.0000   1.0250   6.0000   1.0650   9.0000   1.1050  12.0000   1.2140  24.0000   1.3430  36.0000 100.0000
REFRIGERATORS    1.0000   3.0000   1.0300   6.0000   1.0700   9.0000   1.1100  12.0000   1.2200  24.0000   1.3500  36.0000 100.0000
OTHER BROWN      1.0000   3.0000   1.0400   6.0000   1.0800   9.0000   1.1210  12.0000   1.2320  24.0000   1.3630  36.0000 100.0000
OTHER WHITE      1.0000   3.0000   1.0350   6.0000   1.0750   9.0000   1.1150  12.0000   1.2260  24.0000   1.3570  36.0000 100.0000

   2      2
TELEVISION       0.6900   4.0000   0.6800   8.0000   0.6700  12.0000   0.6600  24.0000   0.6500  36.0000   0.0000   0.0000   0.0000
REFRIGERATORS    0.6900   4.0000   0.6800   8.0000   0.6700  12.0000   0.6600  24.0000   0.6500  36.0000   0.0000   0.0000   0.0000
OTHER BROWN      0.6900   4.0000   0.6800   8.0000   0.6700  12.0000   0.6600  24.0000   0.6500  36.0000   0.0000   0.0000   0.0000
OTHER WHITE      0.6900   4.0000   0.6800   8.0000   0.6700  12.0000   0.6600  24.0000   0.6500  36.0000   0.0000   0.0000   0.0000

   3      3
TELEVISION       1.0000   3.0000   1.0450   6.0000   1.0950   9.0000   1.1440  12.0000   1.2740  24.0000   1.3930  36.0000   0.0000
REFRIGERATORS    1.0000   3.0000   1.0500   6.0000   1.1000   9.0000   1.1500  12.0000   1.2800  24.0000   1.4000  36.0000   0.0000
OTHER BROWN      1.0000   3.0000   1.0600   6.0000   1.1110   9.0000   1.1610  12.0000   1.2920  24.0000   1.4140  36.0000   0.0000
OTHER WHITE      1.0000   3.0000   1.0550   6.0000   1.1050   9.0000   1.1560  12.0000   1.2860  24.0000   1.4070  36.0000   0.0000

   4      4
INTEREST        -0.0083  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
DEPRECIATION     1.0000  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FIXED EXPENSE    1.0000  12.0000   1.1000  24.0000   1.2100  36.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000 200.0000
VAR. EXPENSES    0.0500  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   6      6
TRADE CREDITO    1.0000  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
SUNDRY CREDS.    1.0000  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
RESERVES         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
TAX PROVN.       1.0000  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000 400.0000

   7      7
LAND & BLDGS.    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
FURN & EQPT.     0.0083  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
MOTOR VEHICLE    0.0167  60.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
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Continued........

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  8      8
DEBT CAPITAL       5.5000    7.0000  -20.0000   28.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    3.0000
EQUITY CAPITA      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  9      9
LAND & BLDGS.      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
FURN & EQPT.      12.0000    5.0000    6.0000   18.0000   20.0000   24.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    3.0000
MOTOR VEHICLE      6.2000   11.0000   10.0000   32.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    3.0000

  10     10
COLLECTIONS        0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
PAYMENTS           0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
INTEREST          -0.0100   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
CAPITAL EXPEN      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
BORR/REPAYMEN      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAX PAYMENTS       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  12     12
BT PROFIT          1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
LOSSES C/F         0.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000  604.0000
TAX. DEPN.         0.5000   12.0000    0.7000   24.0000    0.9000   36.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    2.0000
ACTUAL DEPN.       1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
OTHER ALLCES       1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAXABLE PROFI      1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000  700.0000

  13     13
BT PROFIT          1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
LOSSES C/F         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAX. DEPN.         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
ACTUAL DEPN.       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
OTHER ALLCES       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAXABLE PROFI      0.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000  505.0000

  13     14
BT PROFIT          1.0000   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
LOSSES C/F         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAX. DEPN.         0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
ACTUAL DEPN.       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
OTHER ALLCES       0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
TAXABLE PROFI      0.4500   60.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
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                    ---- DELAY TABLES (MATRICES) ----

LINKAGE TAG

  3      3 DELAY DISTRIBUTION COEFFS
   TELEVISION                0.00    0.20    0.50    0.30      0.00*
   REFRIGERATORS             0.00    0.20    0.50    0.30      0.00*
   OTHER BROWN               0.00    0.20    0.50    0.30      0.00*
   OTHER WHITE               0.00    0.20    0.50    0.30      0.00*

  3      3 DELAY TRANSIT LEVELS
   TELEVISION                2.55    4.55    1.49    0.85      0.00*
   REFRIGERATORS             1.80    3.21    1.05    0.60      0.00*
   OTHER BROWN               1.20    2.14    0.70    0.40      0.00*
   OTHER WHITE               0.45    0.80    0.27    0.15      0.00*

  5      5 DELAY DISTRIBUTION COEFFS
   SUNDRY DEBTORS            0.60    0.20    0.10    0.10      0.00*

  5      5 DELAY TRANSIT LEVELS
   SUNDRY DEBTORS            8.82    3.53    1.76    0.88      0.00*

  6      6 EXPONENTIAL DELAY PERIODS
   SUNDRY DEBTORS              1.10
                               1.10
                               1.00
                               1.00
                    ------------ CYCLES TABLE (MATRIX) -------------

CYCLE 1   0.6000  0.8000  1.0000  1.2000  0.8000  0.8000  1.0000  1.4000  1.5000  1.2000  1.0000  0.7000 12.0000
CYCLE 2   1.1000  1.0000  1.0000  0.9500  1.1000  1.1000  1.2000  1.2500  1.2000  1.2000  0.5000  0.4000 12.0000

CYCLE 4   0.0000  0.0000  0.6700  0.0000  0.0000  0.0000  0.0000  0.0000  1.0000  0.0000  0.0000  0.0000 12.0000
CYCLE 5   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  1.0000 12.0000
CYCLE 6   1.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 12.0000
CYCLE 7   0.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000 12.0000
```