A METHODOLOGY FOR FINANCIAL MODELLING

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ABSTRACT
This paper describes a methodology for constructing financial planning models using a computer package developed by the author. The package itself is designed to provide general management with a flexible and easy-to-use modelling facility capable of supporting the development of dynamic simulation models of both financial and non-financial systems.

A brief summary of the nature of the methodology, and its underlying concepts is presented initially, followed by an application. First a simple form of financial model is developed, followed by an extended version of the same model. The Appendices contain details of the two computer programs used in setting up the models, together with output from a run of the simple version.

1. THE PACKAGE

1.1 Introduction

The GENSIM package[1] consists of a set of six functionally oriented computer programs written in the 'BASIC' language, for use on a Digital PDP 11/70 computer, in an interactive mode. These six programs, and the way in which they inter-relate, are depicted in Figure 1. It is important to note that GENSIM is a package as distinct from a high level computer language such as DYNAMO[2]. The practical ramifications of this are that the model builder is not required to do any programming, or to translate the model relation-ships into lines of code. Models are constructed, tested, amended and operated by the user, in response to clearly worded prompts from the computer terminal.

1.2 The Framework of GENSIM

The general framework upon which the package is based, is essentially an amalgamation of two system approaches to the modelling of complex organisations. These two approaches are System Dynamics[3] and Input-Output Analysis[4].

System Dynamics constitutes a powerful tool for the construction of dynamic, aggregated continuous flow models of a broad cross-section of complex real world systems, in situations where system growth and stability characteristics are of critical importance. It characteristically views organisations, or systems as comprising information feedback loops embedded in a web of levels interconnected by flows. These levels and flows can be defined to represent, respectively, the accumulations and movements of orders, materials money, equipment, personnel and information. The management process is seen as being a process of influencing levels by regulating flow rates, on the basis of information feedback over a series of small time increments or solution intervals.

Input-Output Analysis utilises the power of matrix algebra to represent the quantitative aspects of multi-sector organisations. The term 'sector' can be used to refer to a product type or group, a resource type or group, a process stage, a company division, or a market sector. The concept of an array arises if, for example, the product sales volumes of each of a series of products are considered as a group. This becomes the product sales array, or vector, which when multiplied by the product unit price vector, yields the product revenue vector.

If the defined product types of the above example are produced from more than one resource, the concept of a resource requirements vector arises. Furthermore, if the amounts of each resource type consumed per unit of product type are known, they can be grouped into a 'doubles chart', or two-dimensional array, which constitutes a matrix. Multiplication of the product sales vector by the resource consumption matrix yields the resources requirements vector. This particular calculation has an extremely useful dual form, in that the multiplication of the resources unit cost vector by the same matrix, transposed, yields the product unit cost vector.

The GENSIM package is based on the concepts of *both* System Dynamics and Input-Output Analysis. Specifically, the concepts of levels and flows of the former, are coupled with the concept of arrays, and the use of matrix algebra to manipulate them, which are an integral part of the latter. Systems are subjected to a 'world view' which perceives them in terms of 'vectorised' levels and flows. Furthermore, any one flow vector can be transformed into another, by matrix multiplication. In order to do this, and to relate flows and levels, it is useful to think of flows taking place along flow channels, or linkages. A linkage links one level to another. Since flows have a direction, each linkage has an inflow side, and an outflow side, (refer Figure 2.).

If the levels are defined as vectors (comprising sub-levels) then the flows entering and leaving each level will be vectors of the same dimension as the level which they enter, or leave. Thus the linkages become multi-channel, with the inflow side not necessarily having the same number of channels as the outflow side. The concept of flow directing, or switching, thus arises. Matrix multiplication can be used to perform this function, i.e., to

1. The term GENSIM is an acronym for 'Generalised Simulation System'.
2. The computer language developed for the construction of System Dynamics models.
3. See Forrester (1961).
4. See Butterworth and Sigloch (1971).

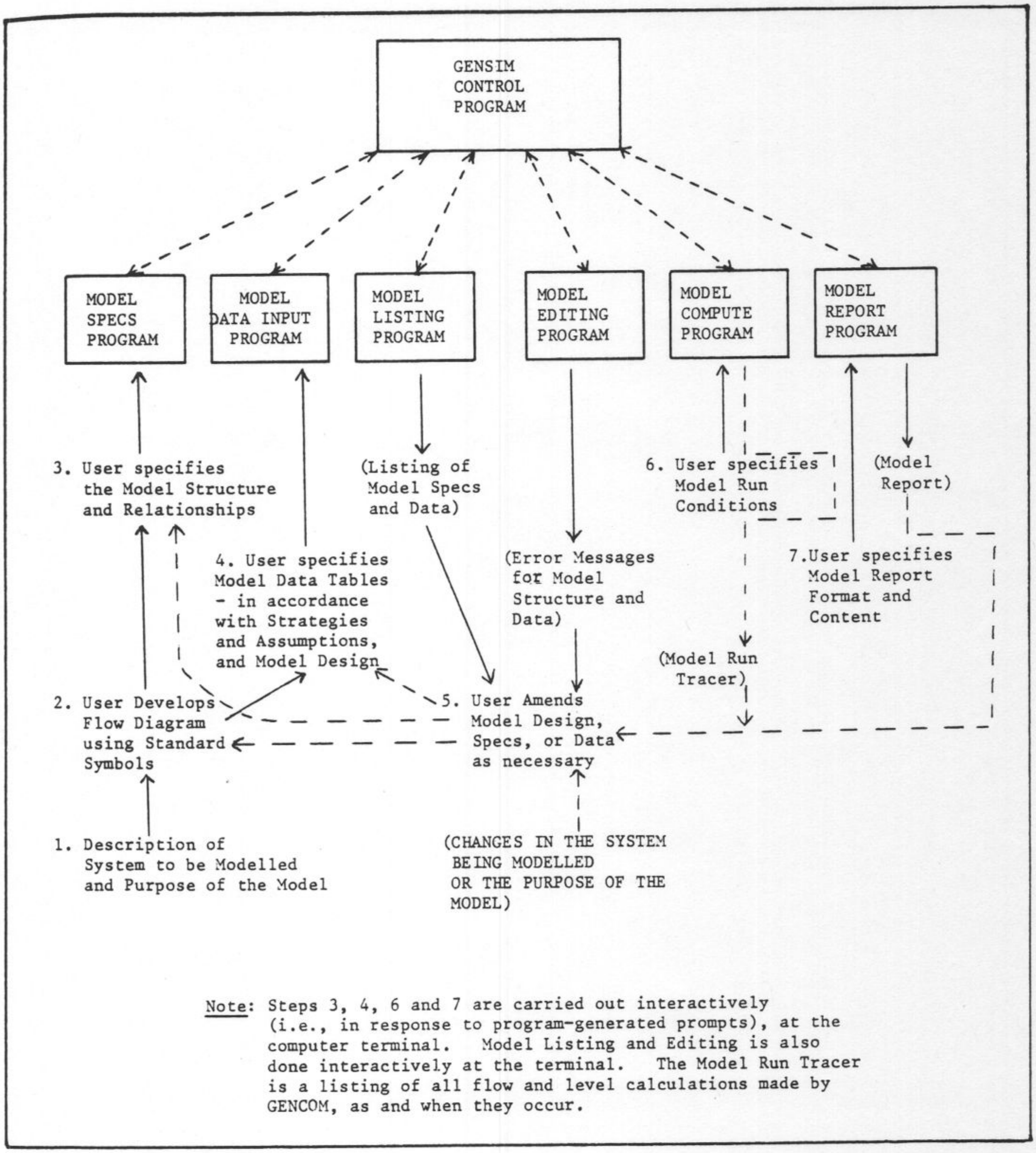

Figure 1. The GENSIM Programs and Their Use

transform an inflow into an outflow, or vice versa, in either the flow directing, or flow consumption context. Flow transformation, via a transformation matrix can therefore be regarded as a type of flow influence.

Two other types of flow influence are catered for in the GENSIM package. These are user-specified time-varying influences (modulations) and time lags (delays). Figures 3 and 4 show how these fundamental concepts interrelate.

1.3 The Accounting Significant of the GENSIM Framework

All of the foregoing concepts can readily be related to the

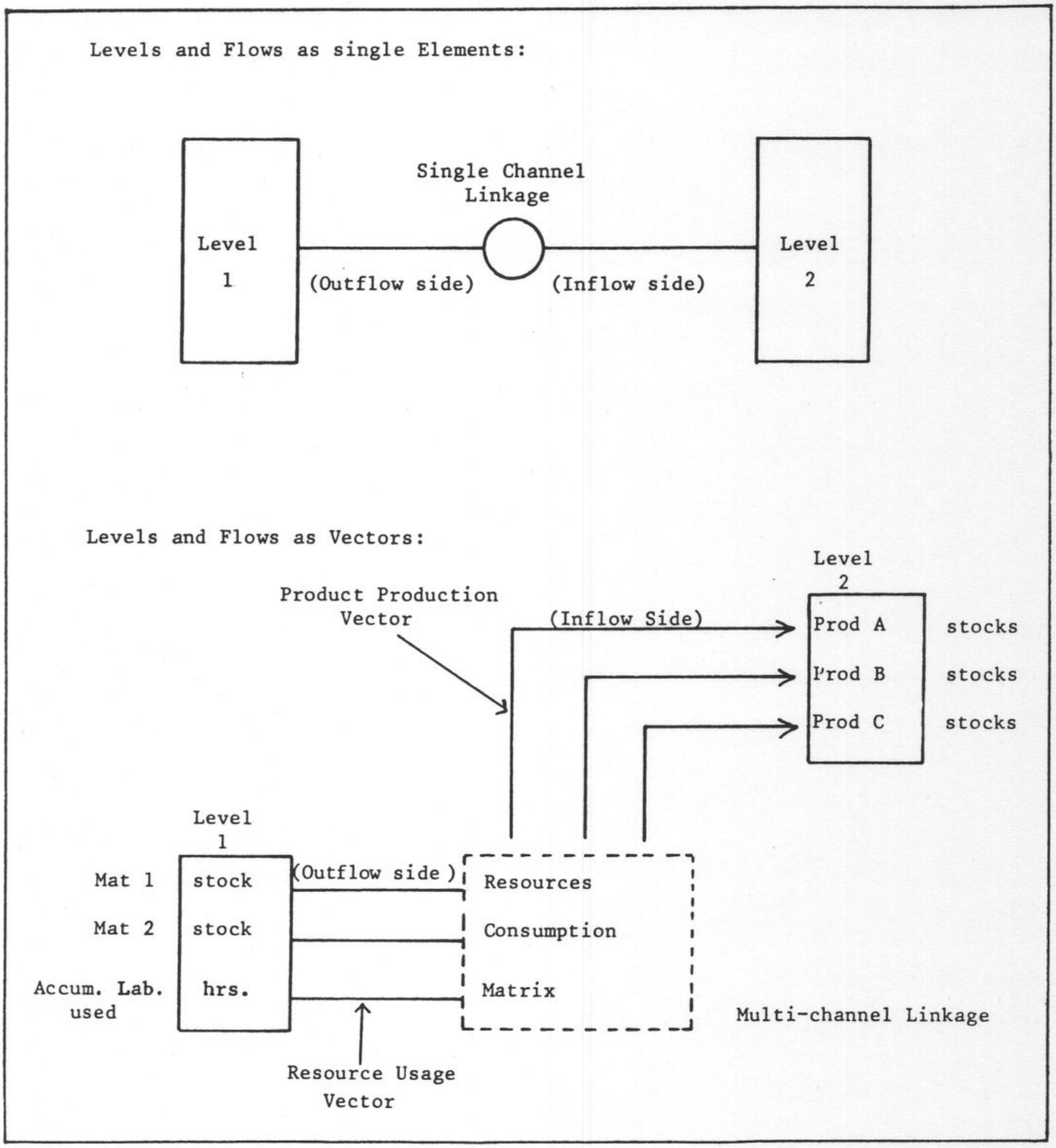

Figure 2. The Level and Flow Concepts

established concepts of Accounting. Account balances are levels, and transactions are flows. Transactions affect, or determine account balances in the same way that flows affect, or determine levels. The Accounting principle of double-entry can be re-stated to the effect that every linkage has an inflow and an outflow side to it, and that inflows must equal outflows[5].

5. Obviously not a requirement for non-financial flows which may be defined in a financial model.

The convention followed in GENSIM, as far as financial models are concerned, is that inflows constitute debits, and outflows constitute credits. Thus levels which are negative in value represent credit balances, and those which are positive represent debit balances. The basic concepts of the package can now be summarised as follows:

(1) Levels and flows are the basic building blocks of

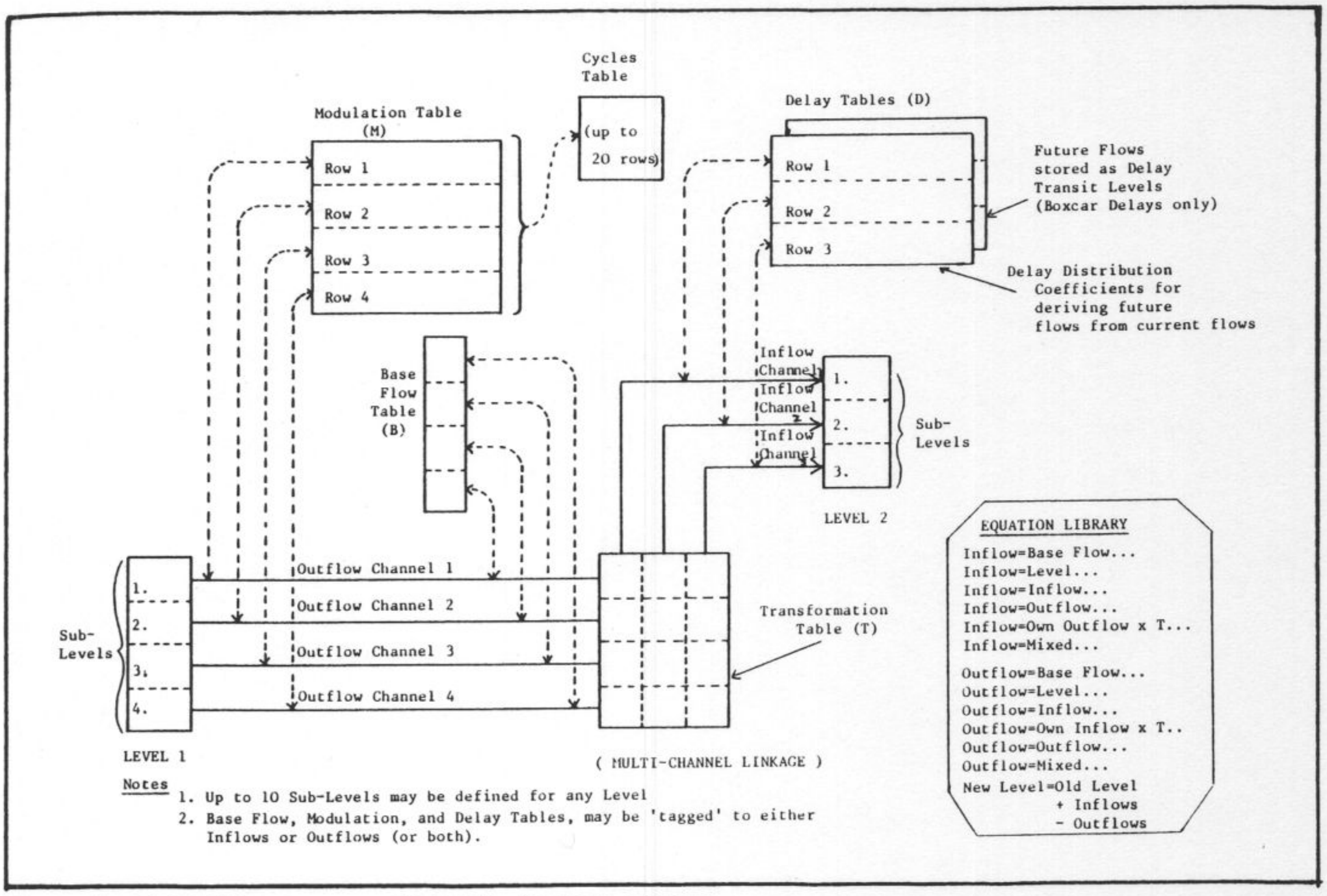

Figure 3. The Modelling Concepts of GENSIM (PRIMAL FORM)

GENSIM models, and the grouping of like factors can be accommodated by vectorisation.

(2) Flows occur along linkages. Each linkage has an inflow and outflow side to it.

(3) Levels are determined by flows. Flows are determined by equating them to flow determinants, which can be other flows, externally specified 'base' flows, or levels.

(4) Flows can also be subjected to influences, of which there are three types–

Transformations, which are flow directing, or flow consumption influences, effected by Transformation Tables (matrices), which transform an inflow into an outflow of the same linkage, or vice versa.

Modulations, which are user-specified, time varying influences, e.g. growth rates, stored in Modulation Tables.

Delays, which are time-lag influences whereby flows can be stored, in Delay Tables, for release in later periods.

(5) The calculations for any model proceed according to a sequence whereby for each solution period, flows are calculated to enable the calculation of levels using the simple balance relationship–

$$\text{Level Value at Period End} = \text{Level Value at Period Start} + \text{Inflows} - \text{Outflows}$$

– for any given level.

2. THE METHODOLOGY

2.1 General

The art of constructing mathematical simulation models is still in its developmental stages, with formalised methodologies existing only in some of the specialised applications areas. None of these methodologies can be said to be enjoying widespread acceptance and use in the construction of models for general management.

In practical terms, by far the most formidable obstacle in model building is the *abstraction process* of translating the relevant structural elements of the real world system into mathematical terms. Forrester's Industrial Dynamics and IBM's General Purpose Simulation System[6] (GPSS) were among the first computer-based modelling systems to appear with procedures aimed at formalising the abstraction process, at least in part. In both instances this formalisation is achieved with the use of Flow

6. See IBM World Trade Corporation (1970).

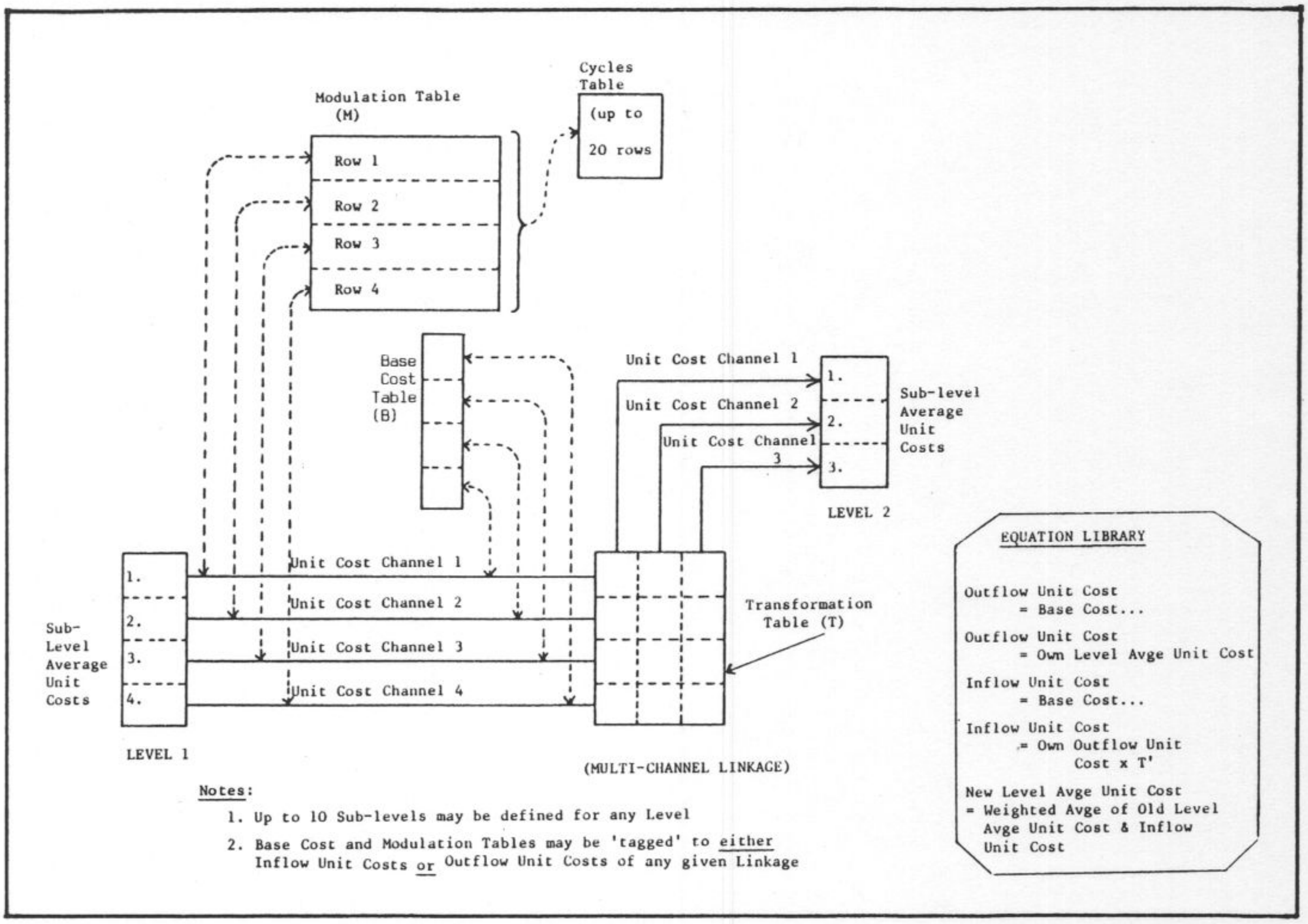

Figure 4. The Modelling Concepts of GENSIM DUAL FORM)

Diagramming as an essential intermediate step in the process. In both instances a precise set of rules and symbols is defined for the construction of these diagrams.

System Dynamics, the modelling approach which has evolved from Industrial Dynamics, is designed to support the construction of highly aggregated continuous flow models, focussing on the growth and stability characteristics of the system being modelled. GPSS is designed to support the construction of disaggregated discrete-event models focussing on the utilisation of facilities. Perhaps the fact that neither of these approaches are in widespread use as general management tools arises from the fact that organisations must be managed in a manner which recognises *both* continuous flow and discrete-event behaviour, together with varying degrees of aggregation and measures of system behaviour beyond merely growth, stability and facility utilisation.

The GENSIM package is designed to provide general management with a versatile, easy-to-use modelling facility which is capable of meeting the requirement for aggregational flexibility, and performance measurement in terms of profitability, growth, stability and productivity. It takes full advantage of modern computing technology, in particular the advent of inter-active computing, while the general systems concepts upon which the methodology is based permit formalisation of the model abstraction process through the use of flow diagramming and high level software support. As with traditional System Dynamics, the flow diagram is seen as being an indispensible bridge between the real world and the final mathematical form of the model.

As a highly structured and fully interactive package, GENSIM allows the model building effort to be concentrated on model abstraction, and model maintenance. The methodology focusses on the use of simple conventions and building blocks capable of capturing the highly structure mechanistic relationships of any organisation in the most efficient and flexible manner. The less structured 'fuzzy. relationships[7] which so often undermine the model building effort, can be set aside, if desired, to be reflected in the model as user specified external influences. The model development effort can thus be significantly reduced, while simultaneously increasing the scope for managerial involvement, and the chances of model acceptance.

2.2 Constructing a Model Using GENSIM

The steps involved in constructing a model using the package are summarised in Figure 1. The key step in the

7. Often those associated with information feedback loops.

process is that of constructing the flow diagram. During this step the model builder must:

(a) Assign a determinant to each flow, i.e., equate it to either another flow, a user-specified base flow, or a level.

(b) Identify the flow influences to be recognised in the model, and 'tag' the flows accordingly.

(c) Ensure that the final flow diagram constitutes the simplest, most logical, and most flexible representation of the 'plumbing' of the real world system.

The remainder of this paper deals with the application of the methodology to the problem of constructing financial models. A simple financial model is developed first, and then extended by vectorising its levels and flows, and adding new levels and flows, to result in a more comprehensive and powerful model.

3. A SIMPLE FINANCIAL MODEL

3.1 The System to be Modelled

The system comprises the financial aspects of a small retail business, and it is intended to construct a model embracing these aspects, which produces projected balance sheets on an annual, quarterly, or monthly basis, over a planning horizon of three years. The solution interval for this model is one month, and the projections will therefore span thirty-six months.

3.2 System Description in Terms of Levels and Flows

To retain simplicity in this purely illustrative example, all levels (and therefore flows) are defined as scalars, i.e., no vectorisation. The system is described in terms of levels which span all of the main asset and liability types, together with their associated flows (transaction types). These are as set out in Table 1., as are the flow influences defined for the model.

The flow diagram developed from this information is depicted in Figure 5. This graphical form of the model utilises a standard set of symbols whereby levels are represented by rectangles, and flow linkages as arrows. The linkages are 'tagged' where appropriate with the specific Data Tables associated with the particular flow influences to be exercised. The simple set of symbols used here is sufficient for the flow diagramming of all models developed using the system, regardless of size and complexity.

3.3 Setting up the Model Structure and Data Files

The GENSPC program is used to set up the model structure as per Figure 5. This is done at the computer terminal in response to prompts which are set out in Appendix 1. The GENINP program is then used to enter the model data – in this case the level opening balances, the Base Flow Tables B1, B3, B4, B8 and B9; the Modulation Tables M1, M2, M3, M4, M7, M8, and M9; and the Delay Tables D5 and D6. The computer terminal prompts associated with this phase are set out in Appendix II.

Normally specification of the model structure and data would be followed by the use of the GENLIS and GENEDT programs to respectively list the model structure and data, and perform edit checks on same.

3.4 Computing the Model

This is performed with the GENCOM program. Sample

TABLE 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 Inflows	
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 Inflows	
Linkage 4 Inflow	User specified via Base Flow B4	Modulated by M4 = Expenses Growth Coeff. and its Pattern of Change
Outflow	Linkage 4 Inflows	
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 Inflows	
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/Repayment 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	

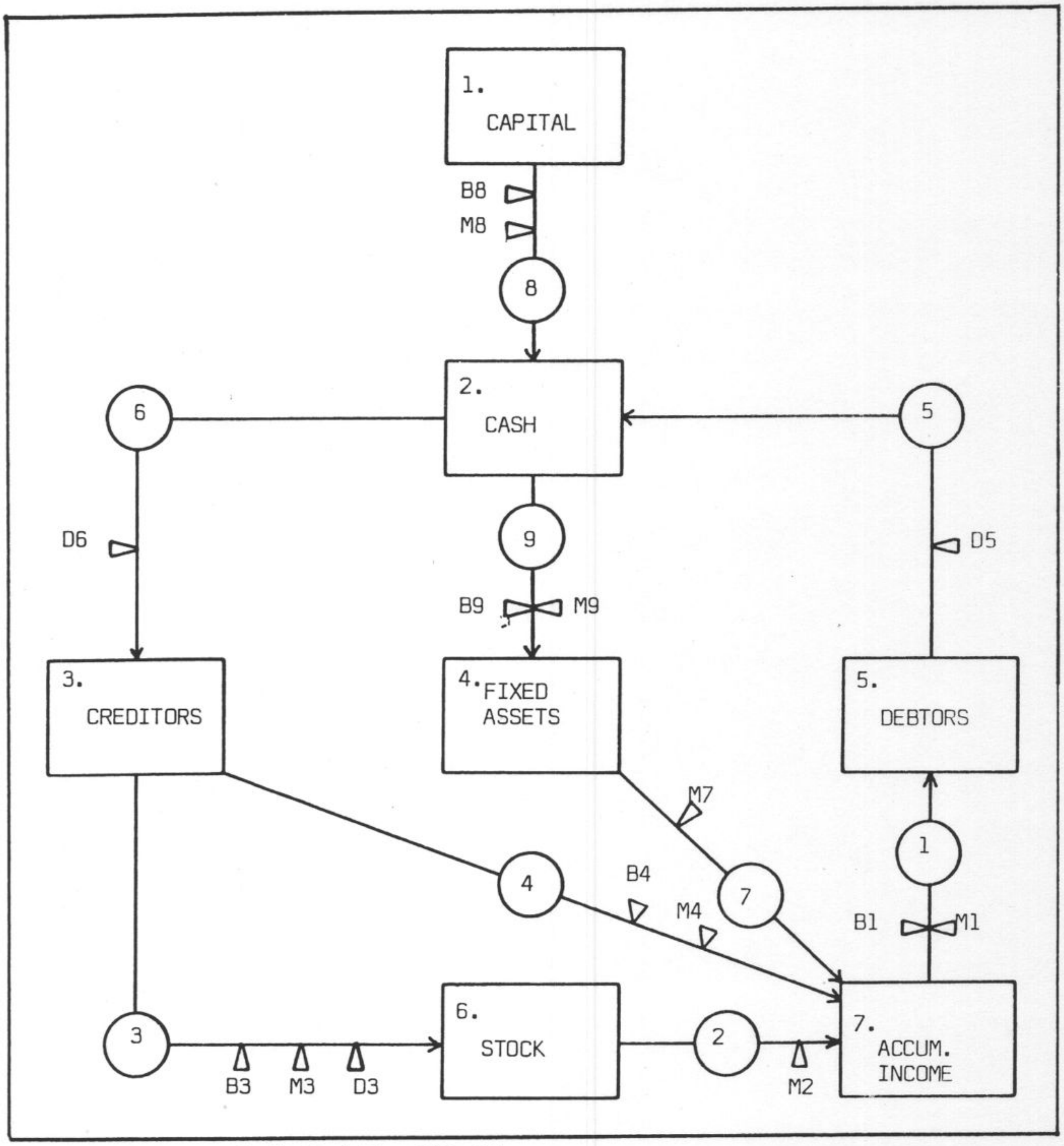

Figure 5. Flow Diagram for the Simple Financial Model

output from a full run of the model over the thirty-six month planning horizon is shown in Appendix II. Quarterly balance sheets are shown for the three years, produced from the file of computed data by the GENREP program. This program could be re-run to produce the monthly balance sheets from the same file of computed data, for whatever segment within the three year horizon if desired.

As all model structural specifications and data is permanently stored on disk files, computational and report re-runs can be made as circumstances dictate. In the case of the former, any aspect of the model structure or data can be accessed and changed selectively using the appropriate program, as part of a systematic 'what-if' dialogue.

4. THE EXTENDED FINANCIAL MODEL

4.1 Scope of the Extension

The extension takes the form of greater dis-aggregation of the existing levels and flows (through the vectorisation of the former to recognise sub-levels, or sub-accounts), and the defining of some new levels to permit the generation of profit and cash flow statements, and also to encompass tax calculation. The net result is a model capable of pro-

TABLE 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. Refrigerator
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 Circulation

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

jecting complete balance sheets, profit and cash flow statements. The planning horizon of three years, and the solution interval of one month remain unchanged.

4.2 System Description in Terms of Levels and Flows

All of the levels and flows of the simple model retain their identity with the exception of level 7, which is replaced with the three new levels (7, 8 and 9) – for the accumulation of sales, expenses, and cost of sales respectively. These are of course, the three principal determinants of net profit. Linkage 10 is added to permit the separate computation of interest as an expense related to borrowing, and levels 10 and 11, together with their associated linkages 11, 12 and 13, are brought in to permit the

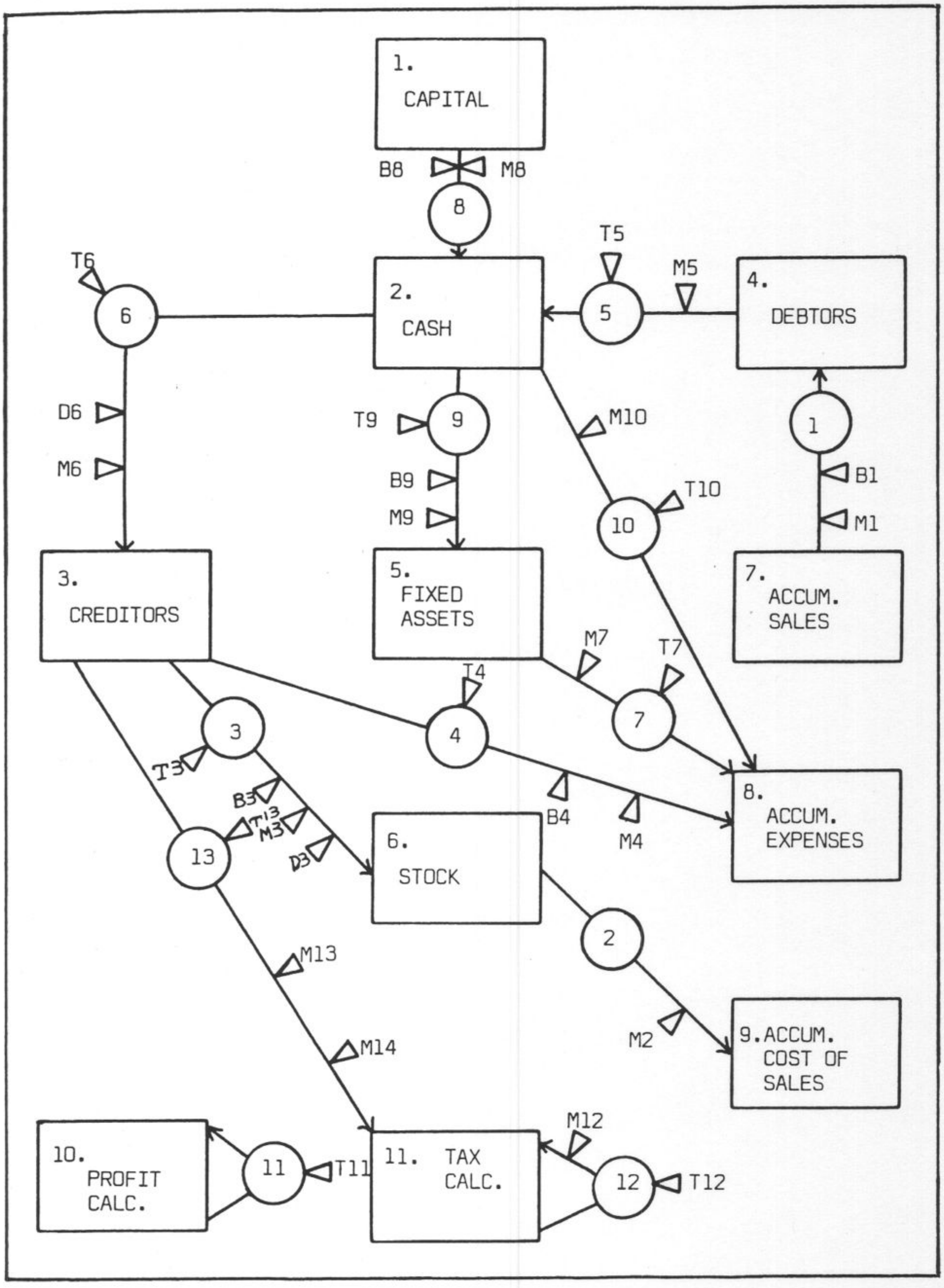

Figure 6. Flow Diagram for the Extended Financial Model

calculation of profit and tax.

As far as the vectorisation is concerned, the sub-level definitions resulting from this, are set out in Table 2. For the linkages 1 through to 9 the flow determinants and influences are as defined for the simple model – with the exception of the linkage 4 inflow, which is given a 'mixed dependency', to allow each of the expense categories resulting from vectorisation, to have its own unique determinant. The inflows of the new linkages 11, 12 and 13 are also assigned mixed dependencies, for the same reason. The outflows of all of these linkages are determined by their own inflows. Linkage 10 has a mixed dependency for its outflow (to 'tie' its flow channel for interest to the debt capital sub-level of level 1. Its inflow is determined by this outflow. The flow diagram for the extended model is depicted in Figure 6, using the same set of symbols defined in Figure 5. The fact that the levels have been vectorised does not need to be shown on the flow diagram. The basic structure of the model can still be conveyed without this unnecessary complication.

4.3 Implementing the Extension

This is done via the GENSPC and GENINP programs respectively using the structural and data files already created for the simple model. The structural changes associated with the extension (i.e., vectorisation, and the addition of new levels and flows) must be entered first using GENSPC, in order to generate the appropriate prompts in GENINP to request the necessary new data. The model can then be listed and edited, computed and reported on, in the same manner as described for the simple model.

5. CONCLUSION

This paper has shown that the GENSIM computer package, together with its underlying general systems concepts, provides a modelling methodology capable of being applied to the problem of constructing financial models for general management use. The use of the flow diagram, constructed from simple symbols in an uncomplicated way, as a bridge between reality and the model, should assist greatly in transforming the 'black box' view of models held by the majority of line managers (the real model users), into a 'glass box' view. This enlightenment possibility must be further enhanced by the fact that the methodology results in very open models, reflecting the mechanistic relationships, whilst unashamedly relegating the others to the status of user-specified influences.

It should be apparent, from the discussion of the package and methodology, that corporate planning models embracing both financial and non-financial factors can be constructed. In particular the complex physical flows associated with multi-product multi-process manufacturing systems can be modelled in both their primal and dual forms[8]. Also quasi-financial factors such as the levels and flows associated with customer and supplier orders can be explicitly represented in situations where their effect is significant.

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8. See Craig (1979) for an account of a production planning model in which both the primal (explosion of product volumes into resource input requirements), and dual (implosion of resource unit costs into product unit costs) forms of the model are computed.

APPENDIX 1. The GENSPC Program for Specification of Model Structure

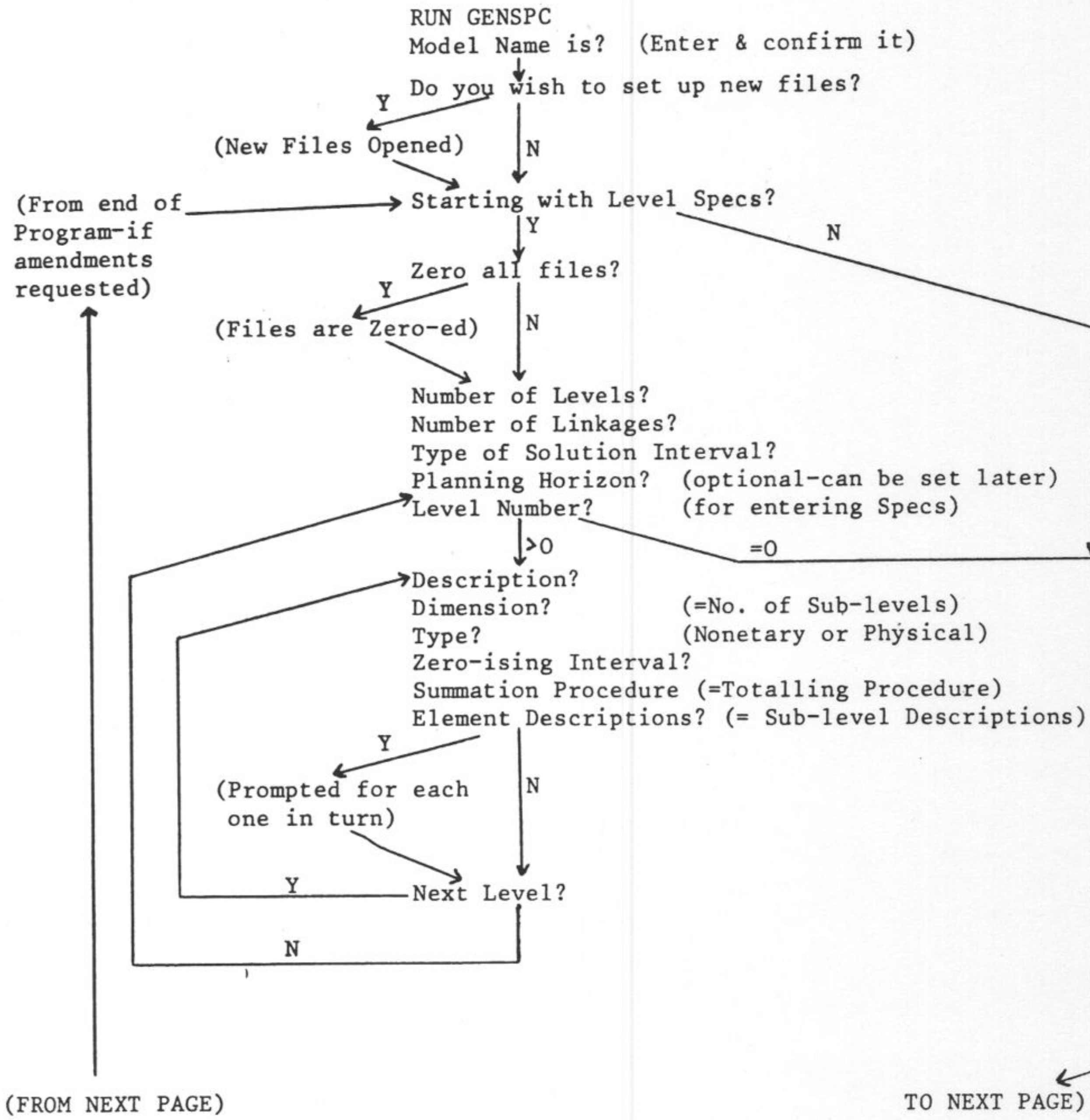
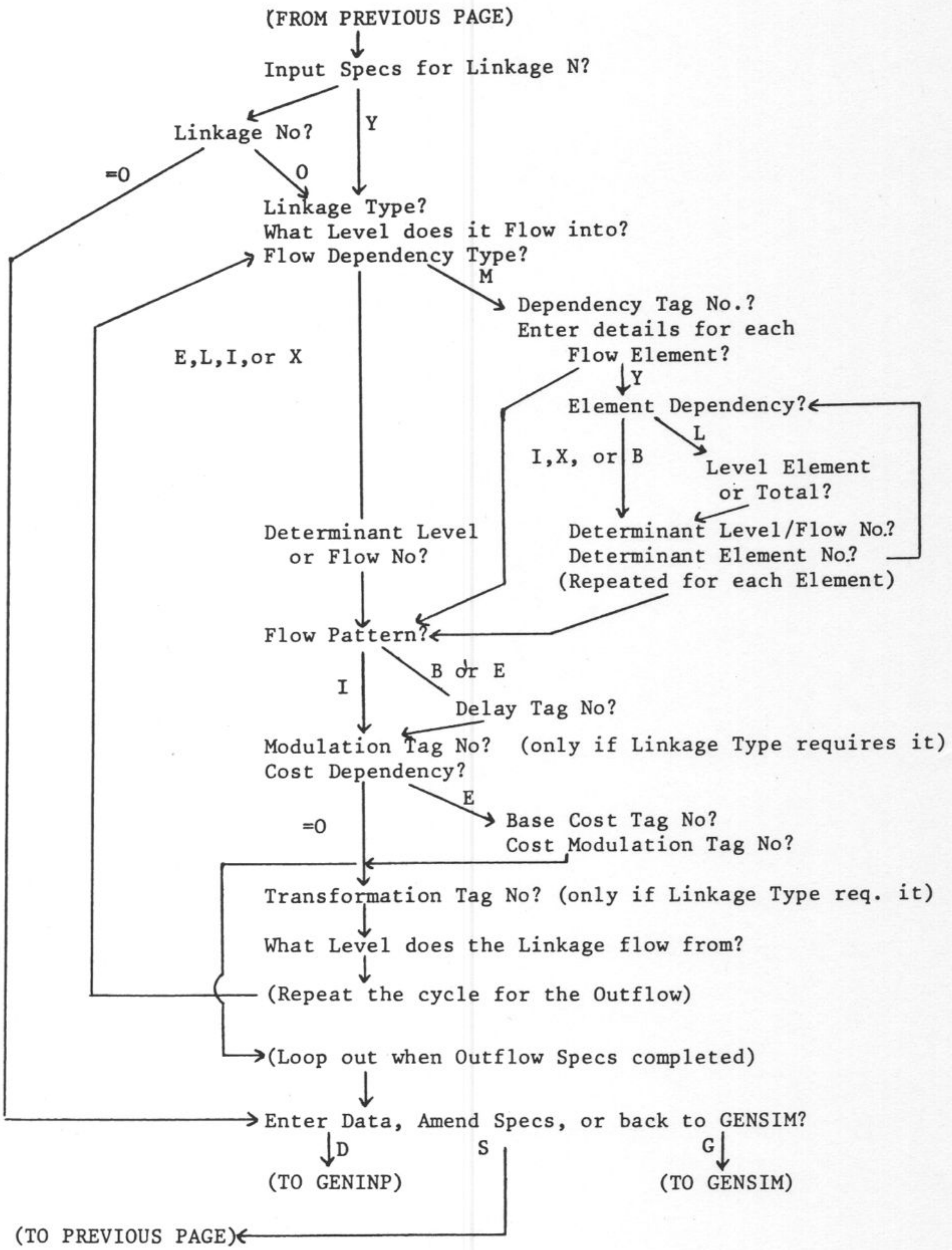


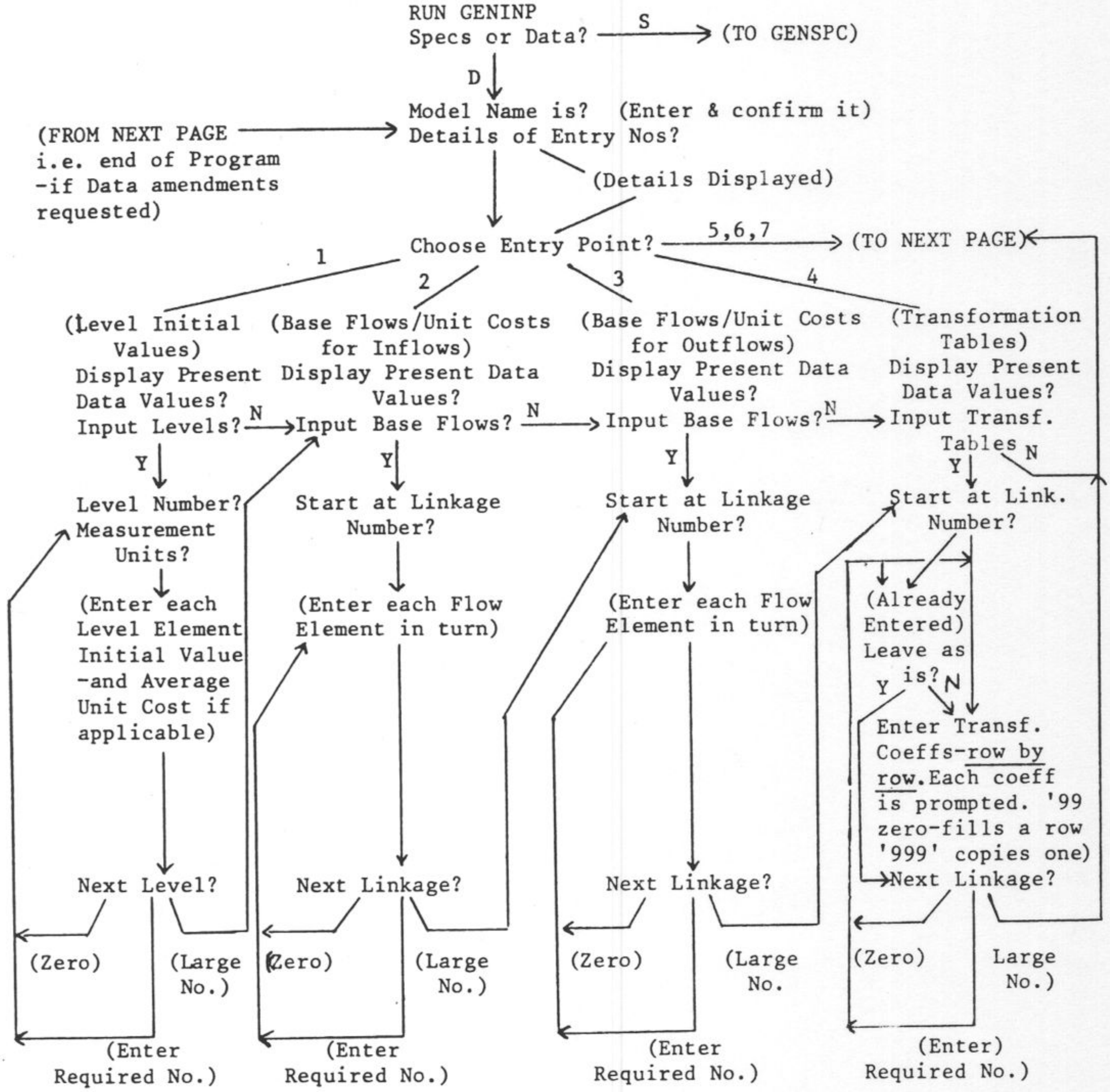
Chart of GENSPC Prompts

APPENDIX 1 Continued . . . . . .



<u>Chart of GENSPC Prompts (Continued)</u>

APPENDIX II. The GENINP Program for Entering Model Data



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.

<u>Chart of GENINP Prompts</u>

APPENDIX II Continued . . . . . .

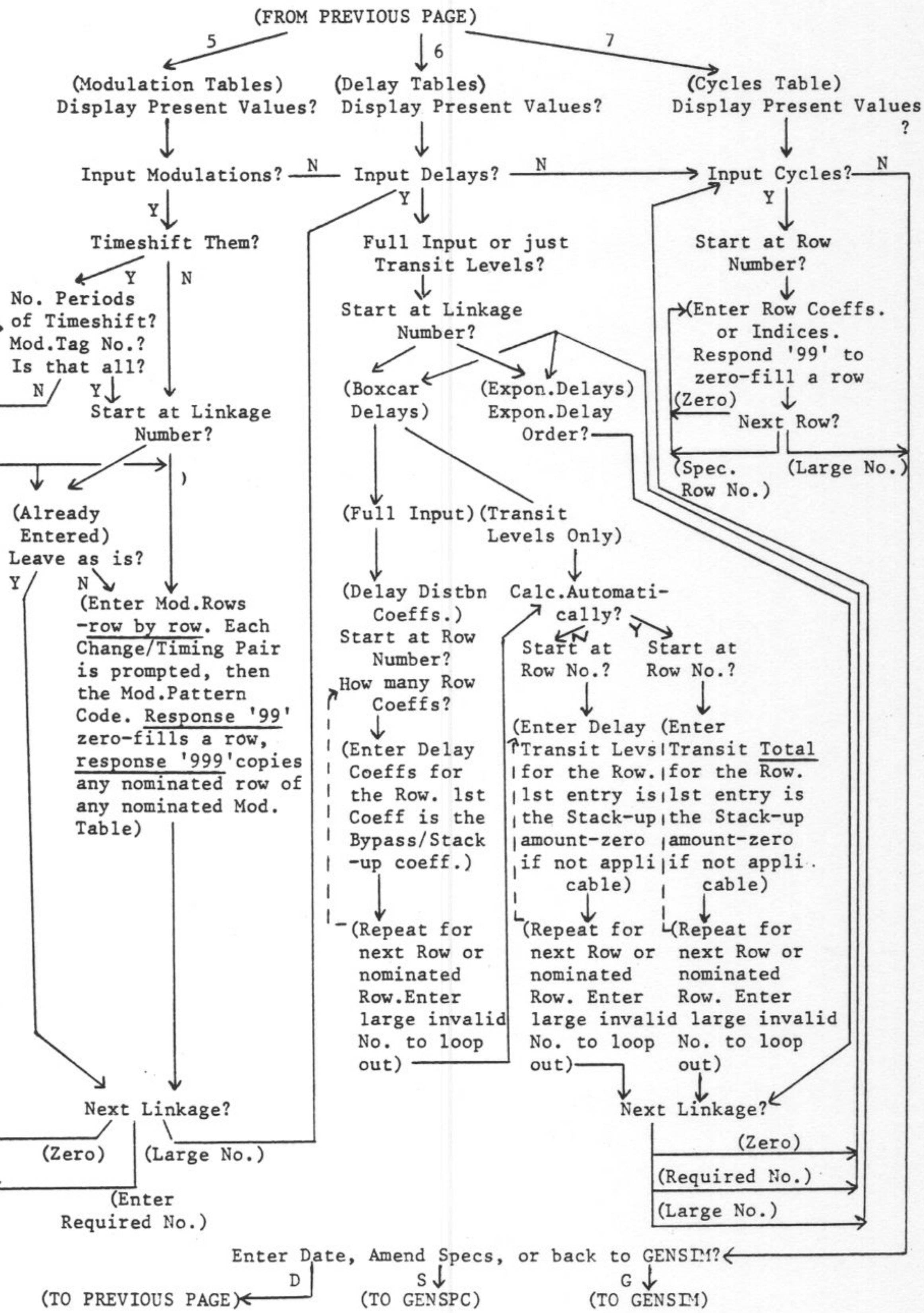


Chart of GENINP Prompts (Continued)

APPENDIX III (a)

GENERALISED SIMULATION SYSTEM - VERSION 2 *** SIMPLE FINANCIAL MODEL
RUN SAMPLE
RESULTS FOR MONTH ENDING:-

DATE 24-Jun-79

DESCRIPTION	UNITS	0 1978	3	6	9	12 1979	15	18	21	24 1980	27	30	33	36 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	-0.8	-3.0	-9.7	-15.5	-18.0	-22.1	-30.8	-37.7	-40.6	-45.4	-55.5	-63.2
TOTALS FOR CREDITORS		-10.0	-8.0	-10.7	-11.4	-10.3	-12.1	-13.3	-13.5	-11.8	-13.4	-14.5	-14.8	-12.9
TOTALS FOR CASH		-5.0	-9.4	-15.0	-3.8	-0.5	-0.8	-2.5	2.5	-1.7	-2.7	-17.8	-21.9	-4.0
TOTAL LIABILITIES	$'000	-115.0	-118.2	-128.8	-130.4	-131.8	-136.4	-143.4	-147.3	-156.7	-162.3	-163.3	-177.7	-165.6
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	43.2	44.0	36.6	37.8	42.8	46.8	41.2	44.6	50.8	55.3	49.3	53.2
TOTALS FOR DEBTORS		15.0	17.0	16.8	28.0	18.5	20.5	20.0	32.0	20.4	22.7	22.1	35.4	22.5
TOTAL ASSETS	$'000	115.0	118.2	128.8	130.4	131.8	136.4	143.4	147.3	156.7	162.3	163.3	177.7	165.6

APPENDIX III (b)

GENERALISED SIMULATION SYSTEM - VERSION 2 *** SIMPLE FINANCIAL MODEL
RUN SAMPLE

DATE 24-Jun-79

ITEM: 5 DEBTORS (—) 6 STOCK (---)