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DEVELOPMENT OF A CORPORATE INFORMATION SYSTEM

by

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Summary

This paper develops a general analytical framework for the analysis and design of corporate planning models susceptible of (1) easy computer implementation as achieved by some existing report generating systems; while (2) integrating the analytically sophisticated techniques for optimizing the system's performance. The basic tree structure of any accounting system is introduced together with the associated "system matrix", and 'aggregate transactions' vector. This leads to a simple linear system representation of corporate accounts. A more detailed pro forma system is then used to study and compare existing corporate planning models. Fundamental criteria characterizing these models are found and illustrated with a few well known models. A corporate planning simulation language is then presented. Ongoing and future research on application of this methodology to sensitivity analyses and regression type studies in corporate planning are also sketched.

1. Introduction

Formalization of management decisions is now a favorite exercise of economists, management scientists, computer scientists and even practicing managers. Unfortunately, the result has been a host of apparently unrelated, and highly segmented contributions. Little attention has been given to the integration of these models into a comprehensive, easily accessible and computer implementable overall model of a firm. Undoubtedly, there are scores of computer packages purporting to implement a basic accounting structure to enable the manager to generate summary reports of his company at various target dates. But these models rarely attempt to integrate optimization methods or other analytical tools to evaluate company performance under alternative corporate policies. A successful integration of these features in a corporate planning model would enable the manager to make full use of the speed of execution, accuracy and convenience afforded by computers in other planning applications. This paper proposes a powerful self-contained framework to achieve this goal. Its usefulness is demonstrated by analyzing some representative corporate planning models, classifying them according to operational criteria and drawing general conclusions as to the level of detailed performance tracking and optimizing they provide the user.

The paper is organized around seven sections. Following this introduction, section 2 introduces the basic system (see[19]). This system is used: (1) to represent the state of a corporation as described in the standard accounting and financial literature (this representation provides a compact and computationally tractable procedure); (2) to record basic events in the corporation; (3) to update the corporate accounts accordingly; (4) to track the system's performance; and (5) to suggest alternative policies to achieve corporate objectives. A simple example is used to introduce the basic notions of the tree representation of a hierarchical system and its associated 'systems matrix' and the 'aggregate transactions vector'. The 'systems matrix', 'aggregate transactions vector' and 'systems state vector' form a linear system. This immediately allows the methods of linear systems and linear-quadratic Gaussian systems theory to be applied. A number of models in the literature such as the Holt-Muth-Modigliani-Simon (HMMS) model[7] and Lev and Pekelman[10] are thus encompassed in our general framework. Furthermore, it should be noted that this corporate financial accounting application is but one of many possible applications of this formalization. A non-exhaustive list of other applications includes cost accounting, national accounting, sales analysis by product, region etc., health care delivery systems and distribution systems. Alternative levels of disaggregation of the system are also suggested. This representation is then fully developed for the case of a corporate accounting system in section 3. With this 'pro forma system' we are able in section 4 to establish operational classification criteria for existing corporate planning models, e.g. (1) their level of 'vertical' and 'horizontal' detail, (2) their implicit or explicit time dimension, and (3) the analytical technique used for obtaining a solution. This framework leads us to some broad hypotheses regarding the feasible trade-offs in designing such models. Our approach is then applied to five corporate planning models representative of the existing literature (section 5). To further demonstrate the usefulness of these ideas, we outline their use in the development of a complete self-contained corporate planning language (section 6). A concluding section sketches some basic areas of ongoing and future research with particular reference to (1) the implications for regression-type methods in corporate planning and (2) sensitivity analyses in simulation and optimization models.

2. A Graphical-Algebraic Representation of Hierarchical Systems

Tree diagrams provide a well-known means for representing hierarchical systems. Clearly, double entry bookkeeping can be formalized by such a tree. Given some initial resources the basic distinction is between their sources on the one hand--owned or borrowed--and their uses on the other hand. The former are customarily known as the equity and liability of the corporation; while the latter constitute its assets. Together they form the firm's balance sheet which describes the state of the system. Changes in the system affect the levels of the balance sheet accounts. They are continuously updated to reflect events in the corporation. For performance evaluation, it is also useful to classify these events by their effects (inflows or outflows) on the state of the system. A standard classification is given in the 'Income Statement'.

These considerations can be summarized in a tree graph. The nodes describe elements in the classification scheme and the flows are represented by directed arcs connecting leaf nodes. Figure 1 represents a basic breakdown of corporate balance sheet. Obviously to affect a node requires a transaction connecting two leaf nodes in the subtree associated with that node. This means that a viable algebraic representation of this tree requires (1) a matrix with a positive and an offsetting negative entry to account for transactions affecting leaf nodes and (2) a vector with as many entries as there are conceivable links between leaf nodes. What is conceivable depends on the classification chosen and the legal bounds imposed upon the corporation. Certain transactions may not be feasible either from a legal or accounting viewpoint.

The 'Systems Matrix'

The effect on the leaf nodes can be summarized by the conventional node-arc 'incidence matrix'. If one also wants to represent the effect on higher order nodes in the tree structure, it suffices to add a row for each such node. Each transaction linking two leaf nodes defines a unique loop in the tree and will correspond to a column of the matrix. Thus a complete algebraic representation of the tree requires a (0,+1,-1) matrix with as many rows as there are nodes in the tree and as many columns as there are feasible transactions between leaf nodes. Finally we need to adopt a sign oonvention for the direction of the transaction. Our convention is to take debit entries--i.e. increases in the assets accounts or decreases in the equity/liability accounts--as positive and credit entries--i.e. decreases in the assets accounts or increases in the equity/liability accounts--as negative. The resulting matrix will henceforth be referred to as the $(m \times n)$ 'systems matrix', S. Corresponding to Figure 1:

$$S = \begin{array}{c} \\ A \\ L\&E \\ CA \\ FA \\ CL \\ LD \\ E \end{array} \begin{array}{c} \begin{array}{cccc} T_1 & T_2 & T_3 & T_4 \end{array} \\ \begin{bmatrix} +1 & 0 & +1 & +1 \\ -1 & 0 & -1 & -1 \\ +1 & -1 & +1 & +1 \\ 0 & +1 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

The 'Aggregate Transactions Vector'

As noted earlier, the states of the nodes of the systems are changed by transactions reflecting corporate decisions and activities. States are observed at discrete points--perhaps mandated by law. Between two observations (t,t+1) the amount of each type of transaction is recorded as a separate entry in the aggregate transactions vector, τ. For instance, in our previous example we could have $\tau^t \in \mathbb{R}^4$ where τ_1^t denotes the aggregate investment by the firm's owner(s) during the t^{th} period (transaction type T_1) etc.

The matrix multiplication $S \cdot \tau$ summarizes the change in the state of the system. Denoting by $b^t \in \mathbb{R}^m$ the state of the system (values associated with nodes in the tree), the transition equation for the system is:

$$b^{t+1} = b^t + S \cdot \tau^t \qquad (1)$$

With this simple graphical-algebraic representation of a system, we have a general method for (1) comparing existing corporate planning models, (2) establishing useful criteria for such comparisons, and (3) building a general corporate planning simulation language. We take up these issues in the following sections.

3. A 'Pro Forma' System

The Basic System for Financial Planning

In this section we focus on a more detailed system description for corporate planning. This greater disaggregation allows us to encompass existing corporate planning models in a single framework while it provides useful dimensions for comparing such models. Figure 2 gives the tree representation of a standard corporate financial reporting structure. Figure 3 gives a nonexhaustive list of the most common transactions occurring in a corporation.

At this point it should be noted that we have expanded the tree in Figure 2 to include the income statement classification scheme. As we can recall this describes which events lead to changes in the stock or balance sheet variables. For instance a cash sale of goods is associated with two transactions; namely, #1 and #5. The system consisting of the nodes corresponding to stock variables and nodes corresponding to a classification scheme for events can also be represented by a linear system as follows:

$$b^{t+1} = E \cdot b^t + S \cdot \tau^t \qquad (2)$$

Here the (expanded) state space corresponds to all nodes in the tree. The $(m \times m)$ E matrix is an $(m \times m)$ identity matrix except that diagonal elements corresponding to non-balance sheet accounts are set equal to zero in order to respect the flow nature of the income statement accounts.

Extensions of the Basic System for Other Classification Criteria.

This pro forma statement is broadly representative of the structure of financial accounts in today's corporation. The operation of a multidivision corporation can be represented using separate substructures for each division and relating them to a consolidated set of accounts. In this case, for instance, τ will be composed of as many sub-vectors as there are divisions. This example is but one of many subclassifications the user may want to consider in setting up his system. For instance he may want information concerning: (1) operations in the various regions in which the corporation operates, (2) sales by product, (3) product cost breakdowns--by expanding the tree beneath the working process account according to whichever product or process costing system is used (including standard costing systems), and (4) departmental costs or "responsibility accounting" in which a classification by departmental cost centers is used in parallel with the standard financial accounting structure.

As described later it is easy to automate the computer implementation of the basic tree structure together with the updating and reporting system. Further, it is very simple to modify the basic tree to test how alternative organizational structures and accounting conventions (historic cost vs replacement cost, etc.) affect the reported system performance.

Throughout the above discussion we have implicitly considered the recording of aggregate transactions in monetary units--dollars. The transactions information need not be specified always as a vector. It is possible to have a transaction matrix where every column represents the transaction values corresponding to a time subdivision (monthly, quarterly, weekly, same month last year, etc.) A two-column transaction matrix can also represent both the unit volume and \$ value of all transactions. In all the above mentioned cases, the state of the system and the system's equation will remain the same except for some minor modifications in the aggregation process.

4. A Classification Scheme for Corporate Planning Models

We now examine the fundamental criteria embodied in the basic pro forma system to differentiate among existing corporate planning models.

Referring to the basic tree given in Figure 2 below, we use four dimensions of classification:

1. The extent of the coverage of the model. This is measured by the number of elements used to describe the state, b, of the system and, correspondingly, the number of elements included in τ.

2. The time frame of the model: short-run vs. long-run.

3. The objective function considered in the model e.g. earnings-per-share (EPS), return-on-investment (ROI), etc.

4. The analytical techniques used, e.g. optimization (linear, non-linear), simulation, regression, etc.

These dimensions of classification enable us to compare existing models. An important point to note is that a choice on one dimension often confines the modeler to narrow ranges on another dimension. In that sense, these dimensions are not independent.

Extent and Level of Coverage

As in any tree graph the level of a node is measured by the number of arcs in a path from the root to that node. Here, higher levels are closer to the root node. In the tree structure, the user can opt for a given level and record events by their effect on all accounts at that level. Alternatively, his model could span a number of different levels in the tree or be narrowly concentrated at a given level. As we pointed out in developing the basic system of accounts, any amount of disaggregation can be chosen that suits the user's needs best. His choice will depend on the variables he uses in his objective function. This natural correspondence between the level, in the tree, of the variables in the model and the objective function is illustrated by Figure 4. Higher levels in the tree are associated with broad financial goals, e.g. EPS, ROI. As we move down to lower levels the goals are more narrowly confined to functional areas: marketing, production, inventory management, etc. This observation also suggests that the pro forma system can be used as a framework of integration of existing specialized planning models. It is interesting to note that traditional functional areas lead to a grouping of the tree nodes which spans several levels. This observation means that narrowly defined functional goals still require some aggregation to serve as objectives in formal corporate planning models. This aggregation requires some care, since the inputs of lower level models cannot always be used directly as inputs to higher-order models. For instance, many operations research models reason in terms of product marginal cost contributions to the firm's overall profit but do not recognize the full historic cost--especially overhead--in the solution. Some recent work[1] suggests a method for allocating fixed cost while retaining the solution reached by OR-type models. Inventory models are another case where the basic data used is not exactly consistent with that required as input to financial accounts. For instance, a large proportion of holding costs for inventory items is the opportunity cost associated with the dollars invested in inventory. Whenever lower level OR-type models are integrated with higher level financial-type models, care must be taken to allow for a consistent translation between the inputs and outputs at the different levels. With this proviso in mind some of the inputs from lower level models to higher level models are indicated in Figure 4. On the other hand, if higher level decisions are used to guide lower level policies the same variables become constraints on the local optimization problem.

Figure 5 shows groupings of nodes affected by several basic decision models which are usually treated as independent entities. Global optimization at the corporate level--if it is to be attained--requires explicit recognition of a number of dependencies. Here again the tree structure and the τ vector help the modeler see the interconnections which he has to deal with. For example in a corporate budgeting application all components of τ, except for those components associated with long-term funding (transaction #'s 413 to 416), are first estimated. This gives a projected cash flow which may trigger a readjustment of the elements of b circled with the label 'Funds Acquisition Policy'. An approach for measuring the interrelations between various models is suggested in section 7.

Choice of a Time Horizon

Another common characteristic which differentiates models is the time period over which the user is interested in observing and controlling the system. This feature is so obvious as to have become the sole criterion for classification of various planning models.[18] To be useful, however, it must be coupled with our other criteria, for they are not completely independent in practice as mentioned before. Examples of traditional categories on this dimension are the very short-run--e.g. the time to complete a production process; the short-run--from a day to one or several months;--the medium run--up to a year; and the long run--sometimes up to five or ten years. Given the need for various forecasts as we move into longer-run planning it is not surprising to find that models with a long-run horizon tend to be more aggregative both in terms of their level in the tree and their coverage of the basic accounts. This, no doubt, stems from a recognition that one stands to gain little and may lose in analytical tractability by seeking broad coverage since the addition of disaggregated lower level accounts only compounds the forecasts required for implementation. Thus it is reasonable to hypothesize that the longer time dimension models tend to have more restricted coverage (level and extent). Another aspect of the trade-off between these two dimensions is found in the variable chosen as a target in the model's objective function.

Choice of a Goal in the Objective Function

The existing corporate planning literature offers a large variety of goals to summarize the performance of the corporation. Examples include such criteria as EPS, ROI, Present Value of Discounted Cash-Flow, etc. Several models of investor's behavior have been used to justify the various objectives chosen.[9,15,16] Given the differing views found in the literature on this point, it is not surprising to encounter a diversity of goals in the objective functions adopted for corporate planning models. Here again, this choice of a variable is partly determined by (or, conversely, partly determines) the level and extent of coverage and the time frame chosen.

The Form of the Objective Function

The analytical technique used in the model depends largely on the above three criteria (coverage, time and goal), and the interrelations we have noted between them. Such techniques as mathematical programming, simulation and regression, are commonly encountered in these models. Overall greater analytical tractability carries a price: that of oversimplification and lack of detail.

These criteria and broad conjectures are illustrated by considering five different corporate planning models chosen for their diversity and to encompass the many options opened to the analyst.

5. Examples of Some Corporate Planning Models

The Models

For exposition the models are considered in descending level of the tree

Hamilton and Moses[5] (H&M) Optimization Model for Corporate Financial Planning typifies many capital budgeting models. Investment projects, with associated cash-flow requirements, are selected optimally to meet a set of corporate goals and constraints such as risk-preferences and credit limitations. As shown in Figure 6, the emphasis is on the sources of debt, equity and the type of debt acquired by the corporation, as well as the divisions in the long run.

The model allows for multiple divisions; however, all funding decisions are made at the corporate level. Mixed integer programming is used to obtain a solution. Some financial models attempt to integrate both financial and operating policies.

In the paper by Krouse[8] (K) the firm's short-term cash budgeting, long-term capital budgeting and related financing mix are simultaneously determined. Revenues are determined exogenously and the value of debt acquired, dividends paid and operating costs incurred are treated as decision variables in a stochastic control model meeting both short and long-term goals.

Pindyck[14] (P) discusses a financial simulation model which typifies the kind of model produced by many financial planning software packages. Sales forecasts are used to drive the model and to generate various operating transactions (components of τ). These, in turn, determine cash requirements. Management policies with respect to dividends, retained earnings, debt-equity ratio, etc. determine new debt and equity needs. Note that the simulation technique allows broader coverage but precludes conclusions concerning optimality of the resulting decisions.

Damon & Schramm[2] (D&S) focus on the interaction between the marketing, production and finance functions. Maximization of the net cash generated is chosen as the objective. Values of decision variables in all three areas are simultaneously determined by nonlinear programming.

The final example that will be discussed here is the HMMS[7] model that is employed in the short-run planning of production and employment. The analytical technique uses the well-known linear-quadratic systems model. Figure 10 illustrates the accounts that may be affected by the decisions taken in regard to production level and work-force. As shown therein a few nodes (accounts) of the pro forma tree structure have to be disaggregated to fully understand the impact of a lower level model and its decision criterion.

Some Observations Regarding the Models

A comparison of the transactions implied by different models is shown in Figure 11. In this figure we group the elements of τ, the aggregate transactions vector, in broad categories analogous to the grouping of accounts (nodes) in the tree depicted in Figure 5. This disaggregation of the transaction flows enables us to compare the variables included in the five models reviewed above. Further, as we move from HMMS to H&M we observe broad aggregations of transactions tracked separately in previous models. Of course, this is another way of recognizing that H&M operates at the highest level in the tree which requires tracing the impact of all transactions linking lower level nodes; whereas HMMS operates at the lowest level by focusing solely on production planning. Given the role of τ in changing the state of the system from one period to the next (see equations 1 - 2 above), a key step in planning consists in evaluating the components of τ that will meet the objectives set by the planner. Two approaches are often found in the planning literature 'top-down' and 'bottom-up'.

1. In top-down planning the transaction vector is estimated using historical or policy determined relationships between the decision variables (sales, production, earnings, etc.) and the various other elements of the transaction vector. For instance, in Pindyck's model 'sales' is used to compute all other transaction values. These estimated transaction values then become budgets to the corresponding functional units.

2. In bottom-up planning each functional unit will forecast its needs to achieve a broad corporate objective(s) and top management will determine a funding mechanism to satisfy these needs and also meet both the overall corporate objectives and the financial constraints.

A prevailing view among corporate planners is to incorporate both these approaches in the development of an integrated planning and budgeting mechanism. Thus we may note that τ is a link between corporate objectives and functional policies. (This dependency is also illustrated in Figures 4 and 5.) A useful distinction can be made between 'funding' transactions that represent the financing of the operations of a firm (sources of funds, e.g. equity, new debt, retained earnings) and 'operating transactions'--i.e. all others. Each transaction is the result of: (1) a decision taken by a unit (purchase X units of raw material on credit); (2) a policy set by top-management (pay Y% stock dividends); or (z) parameter(s) set by an external agency (pay τ % of earnings as taxes). Since the operating decisions/policies are interdependent, the values of the corresponding transactions in the transaction vector are interrelated. Hence the sequence used in computing the transaction vector is of special significance. Activities occur simultaneously at all levels of an organization thus posing a difficult computational problem. However in some cases it is reasonable to solve for subsets of the planning variables in an iterative manner. Thus some transaction values have to be estimated before evaluating the others. Examples of this are the 'funding' and 'operating' transactions. Evaluation of all operating transactions will yield an estimate of funds needed/in-excess, which can then be used to determine the funding transactions that represent the acquisition/disposition of those funds. In such cases, one needs to estimate τ^t in two or more iterations. Several methods for computing τ are feasible. The exact mechanism for the computation of τ^t depends on the strategy employed in planning. For instance, Krouse determines the level of assets, which is then used in the estimation of revenues and other transactions. In Pindyck's model the level of 'sales' is used in the estimation of operating transactions. Whatever strategy is used it is clear that our formulation of the systems logic allows us to readily focus on the relevant transactions. This is but one example of the economy and flexibility afforded by the system discussed in the next section.

6. Implications for Corporate Planning Simulation Packages

Most of the existing planning packages provide (1) facilities for accessing data files such as economic time series (national, regional and industry data), and financial and operating time series data for the corporation being studied; (2) a simulation language for stating the model and testing the effect of alternative decisions/policies; (3) a report generation system to project corporate financial statements under alternative policies. Well known examples of such systems are IBM's Scientific Time Sharing Corp (FPS),[4] or the SIMPLAN[17] system. To these basic components we add a 'system logic file'. Amongst other things our system can be used for:

- Projection of financial statements--balance sheets, income statements and sources and uses of funds.
- Sensitivity analysis of alternative future scenarios and of alternative corporate policies, accounting conventions and organizational structures.
- Development and analysis of budgets.
- Selection of optimal corporate policies based on analytical models or submodels.

The major systems components are the systems tree, systems matrices and the aggregate transaction vector. These building blocks represent readily modifiable 'schema' to state the logic of a corporate system. As explained in[19] it is easy to input and store definitions of the basic variables (nodes) to be controlled. A simple algorithm is used to generate the systems matrix S for any subset of nodes and the transactions required for a particular model. The system modifiability stems from the hierarchical structure which can be used as an intelligence to determine for instance what set of transactions is required for a given set of nodes to compute $S\tau$ and update b.

Another example of the system's flexibility is afforded by its application to more restricted, possibly function-based, scenarios ('sub-schemas'). Here all that is needed is the specification of the behavioral and/or policy assumptions, regression equation and optimal decision rules involved. Since all the accounting system logic can be pre-stored, alternative models can be economically stated, studied and modified. Summary reports are also readily obtained from pre-stored report generation routines.

Since the logic of the system is stored it is never necessary to replicate it for each planning model. This eliminates all lines of code which are concerned with accounting identities. An instance of the reduction in the problem statement required for computer implementation of the model is given by comparing our approach with that of Pindyck's model. In this case a conservative estimate of these savings in number of planning language statements is 40%.

7. Conclusion

In this section we indicate some directions of ongoing and future research. Firstly, many long range planning systems use regression techniques for projecting basic financial statements. A difficulty with this approach is in deciding what variables can be safely treated as exogenous and what variables should be considered endogenous. Of course, this issue always arises in econometric models, but here little theory exists to help the planner decide. The hierarchical structure suggests that one need not estimate nodes (stock variables), but only the elements of τ (flow variables). Stock variables can then be determined using the basic linear system.

Secondly, as mentioned before, our system can be used to study: (1) the percent contribution of τ_j in the value of b_i, denoted h_{ij}; and (2) the change in the value of node b_i resulting from a unit variation of τ_j from its expected value, denoted g_{ij}. The h_{ij} coefficients measure the relative contribution of the variables tracked in τ to the achievement of the objectives set by various models using these variables. Finally, the g_{ij} coefficients can be easily related to a classical dual variable interpretation when weighted by a measure of the cost of varying any b_i from management's target.

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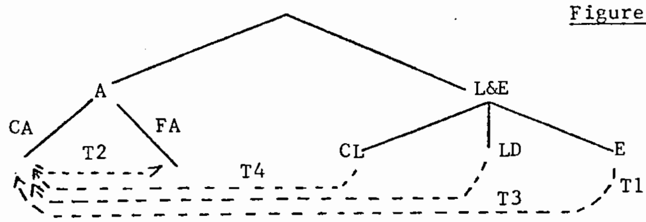

Figure 1

Legend

Balance Sheet

Current Assets (CA)
Fixed Assets (FA)
Current Liabilities (CL)
Long-term Debt (L)
Equity (E)

Transactions

T1 - investment in firm by owners
T2 - purchase of fixed assets for cash
T3 - long-term borrowing
T4 - short-term borrowing

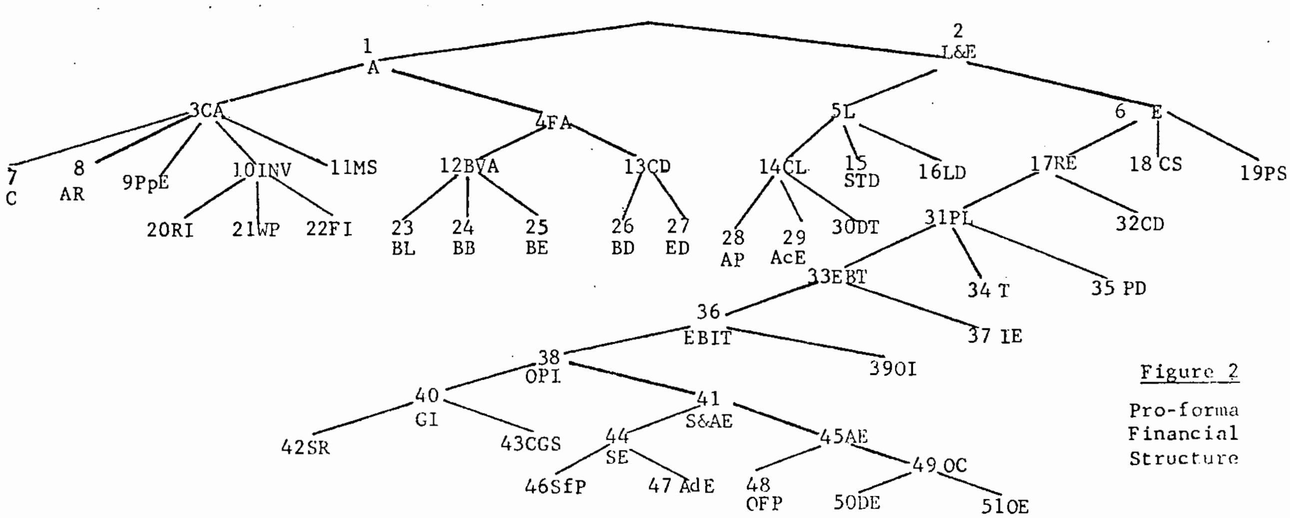

Figure 2

Pro-forma Financial Structure

Figure 2 (cont.) Legend

Acct. (Node)	Symbol	Description	Acct. (Node)	Symbol	Description	Acct. (Node)	Symbol	Description
1	A	Assets	18	CS	Common Stock	35	PD	Pref. Dividends
2	L&E	Liab. & Equities	19	PS	Preferred Stk.	36	EBIT	Earn. Bef. Int & Txs
3	CA	Cur. Assets	20	RI	Raw-Mat. Inv.	37	IE	Interest Exp.
4	FA	Fixed Assets	21	WP	Work-in-Process	38	OPI	Oper. Income
5	L	Liabilities	22	FI	Finished Gd. Inv.	39	OI	Other Income
6	E	Equities	23	BL	Bk-Value of Land	40	GI	Gross Income
7	C	Cash	24	BB	Bk-Value of Bldg.	41	S&AE	Sell. & Adm. Expense
8	AR	Accounts Rec.	25	BE	Bk-Value of Equip.	42	SR	Sales Revenue
9	PpE	Prepaid Exp.	26	BD	Bldg. Depreciation	43	CGS	Cost of Gds. Sold
10	INV	Inventory	27	ED	Equp. Depreciation	44	SE	Selling Expense
11	MS	Marketable Sec.	28	AP	Acct. Payable	45	AE	Adm. Expenses
12	BVA	Bk. Val. Assets	29	AcE	Accrued Expenses	46	SfP	Sales force Pay Exp
13	CD	Cum. Deprec.	30	DT	Deferred Taxes	47	AdE	Advertising Exp.
14	CL	Cur. Liab.	31	P/L	Profit/Loss	48	OfP	Office Payroll Exp.
15	STD	Short-term Debt	32	CD	Common Dividend	49	OC	Other Costs
16	LD	Long-term Debt	33	EBT	Earn. Before Taxes	50	DE	Depreciation Exp.
17	RE	Retained Earnings	34	T	Taxes	51	OE	Other Expense

Figure 3

A Typical List of Transactions

No.		Node No. (From),(To)	Acct. Entries Db/Ct	Trans. No.
1.	Cash Sales	42,7	C/SR	100
2.	Sales on Account.	42,8	AR/SR	101
3.	Sales Force Sal. Exp.	7,46	SfP/C	102
4.	Advertising Expense	7,47	AdE/C	103
5.	Cost of Goods Sold	22,43	CGS/FI	104
6.	Coll. of Acct. Rec.	8,7	C/AR	105
7.	Office Salaries Exp.	7,48	OfP/C	200
8.	Lab. Costs Pd. in Cash	7,21	WP/C	201
9.	Mat. Used This Period	20,21	WP/RI	202
10.	Overhead Pd. in Cash	7,21	WP/CD	203
11.	Misc. Overhead Exp. in the Cur. Prd, but Pd for in Prior Prds.	9,53	OE/PE	206
12.	Dep. Exp. in this Period	26,50	DE/BD	208
13.	Inventory Increase	21,22	FI/WP	209
14.	Cash Pur. of Inventory	7,20	RI/C	300
15.	Pur. of Inv. on Acct.	28,20	RI/AP	301
16.	Payment of Acct. Pay.	7,28	AP/C	302
17.	Equip. Bought for Cash	7/25	BE/C	303
18.	Pur. of Equip. on Acct.	28/25	BE/AP	304
19.	Sale of Equip. for Cash (at Cost)	28,7	C/BE	305
20.	Gain/Loss from Sale of Equipment	39,7	C/OI	306
21.	Dep. of Sold Equip. Cleared from Bks.	7/27	ED/C	307
22.	Rev. from Marketable Sec.	39,7	C/OI	400
23.	Interest Expense	7,37	IE/C	401
24.	Taxes Paid in Cash	7,34	T/C	402
25.	Adj. for Tax Difference	30,34	T/DT	403
26.	Deferred Taxes Pd. in Cash	7,30	DT/C	404
27.	Pref. Div. Pd. in Cash	7,35	PD/C	405
28.	Com. Div. Pd. in Cash	7,32	CD/C	406
29.	Com. Div. Pd. in Stock	18,17	RE/CS	407
30.	Repayment of Lgterm Debt	7,16	LD/C	408
31.	Repayment of Shtterm Debt	7,15	STD/C	409
32.	Proc. from Shtterm Loan	15,7	C/STD	410
33.	Pur. of Marketable Sec.	7,11	MS/C	411
34.	Proc. from Sale of Mktable Securities	11,7	C/MS	412
35.	Proc. from Issuance of Common Stock (at Par)	18,7	C/CS	413
36.	Proc. from Issuance of Com. Stock (in Excess of Par)	17,7	C/RE	414
37.	Proc. from Iss of Pref Stk	19,7	C/PS	415
38.	Issue of Longterm Debt	16,7	C/LD	416

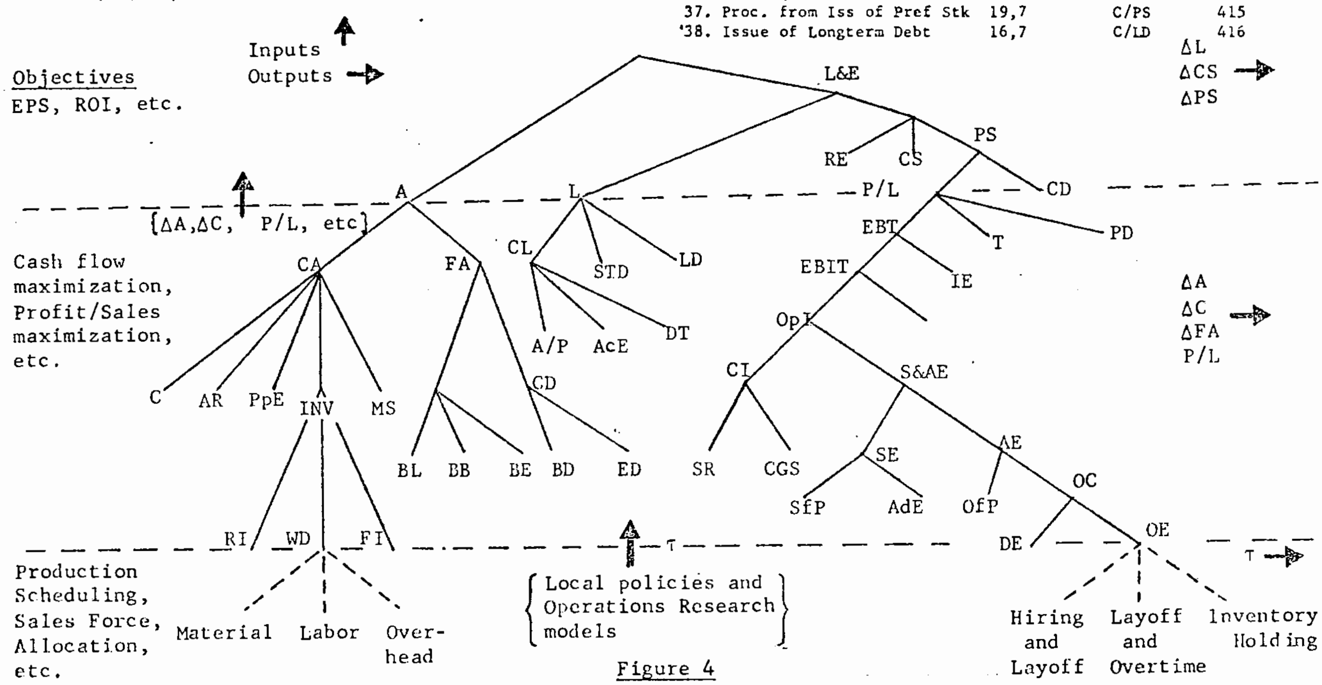

Figure 4

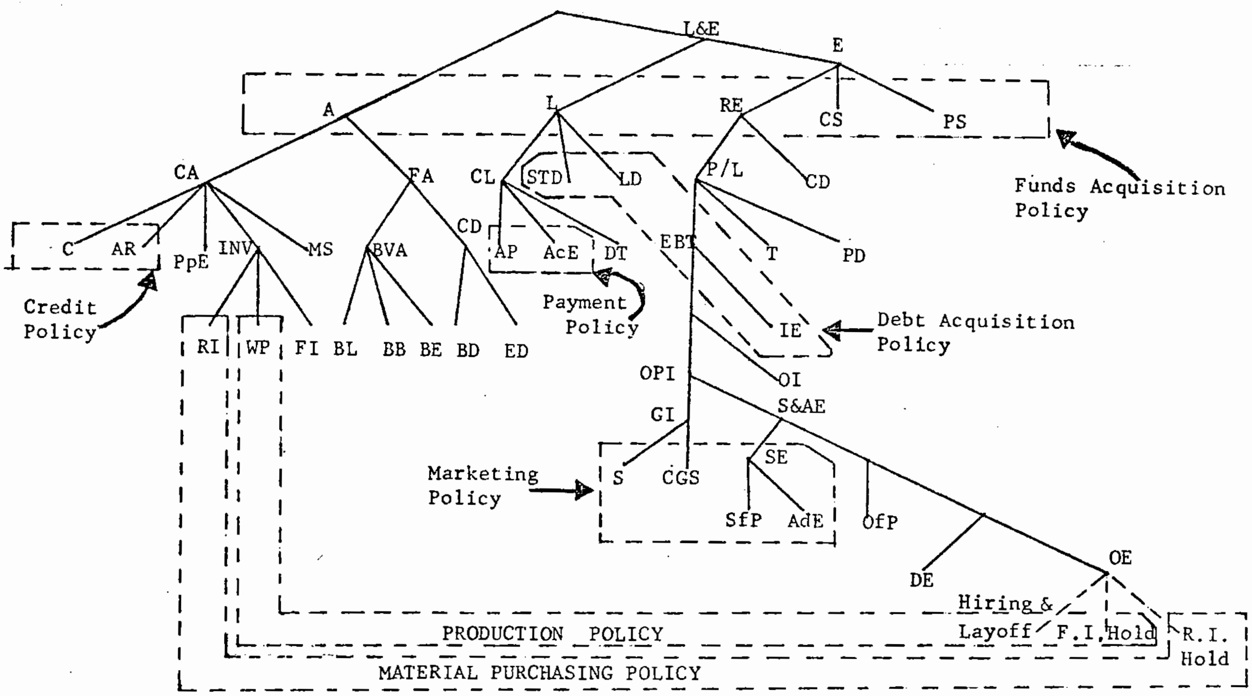

Figure 5

FIGURE 6

H&M

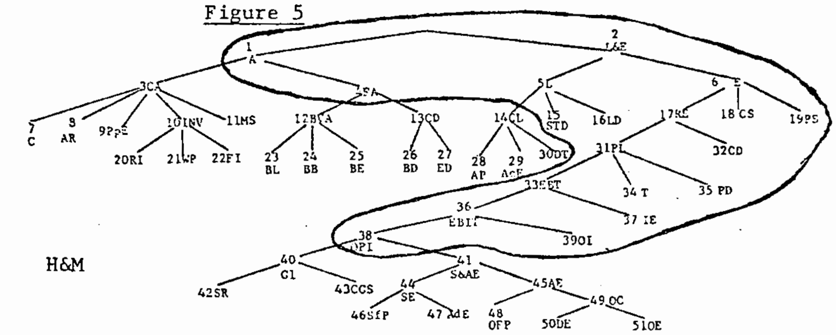

FIGURE 7

K

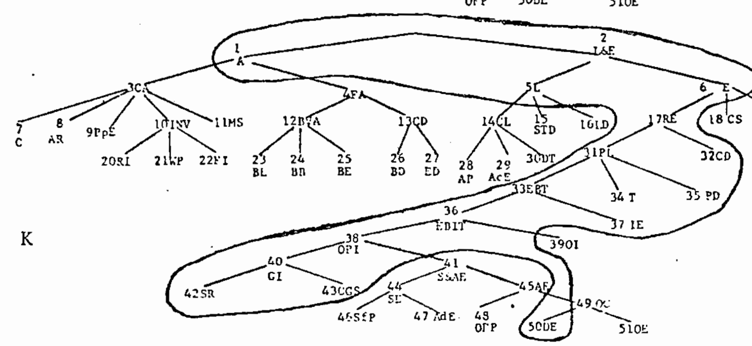

FIGURE 8

P

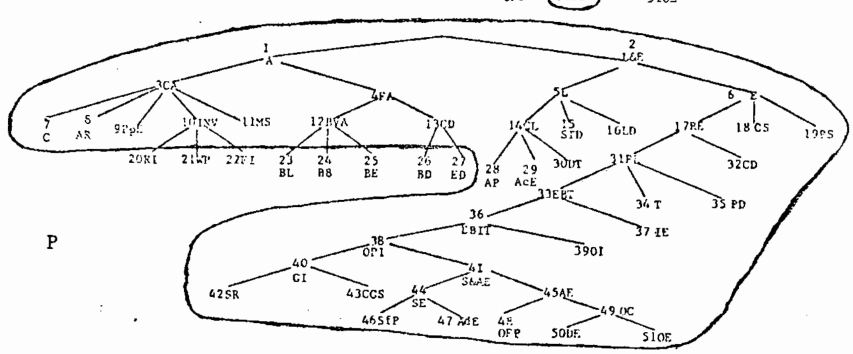

FIGURE 9

D&S

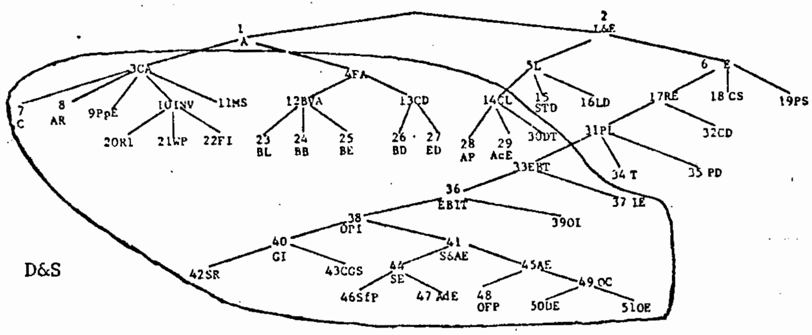

FIGURE 10

HMMS

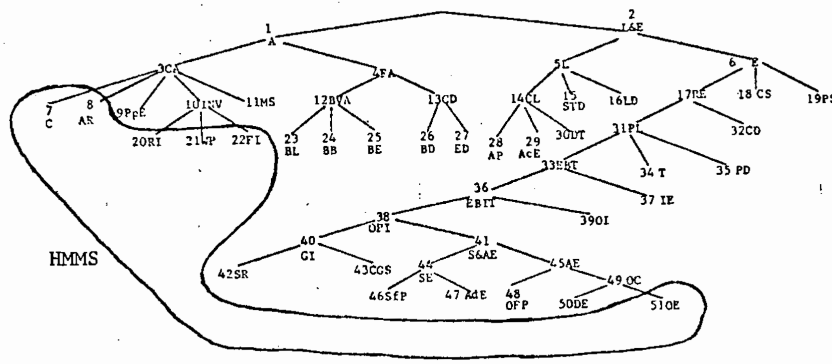

FIGURE 11

COMPARISON OF TRANSACTIONS IMPLIED BY DIFFERENT MODELS

	Trans. Flow		HMMS Fg (10)	D&S Fg (9)	P Fg (8)	K Fg (7)	H&M Fg (6)
FUNDS ACQUIS. AND DISPOSITION	7,16	LD					
	7,15	STD		7,15	7,15	7,15	1,15
	7,11	MS		7,11			
	11,7			11,7			
	15,7	STD		15,7	15,7		
	16,7	LD			16,7	16,1	16,1
	17,7	RE			17,7	17,1	17,1
	18,7	CS			18,7		18,1
	19,7	PS			19,7		19,1
FINANCIAL EXPENSES	7,37	IE		7,37	7,37	1,37	1,37
	7,34	T			7,34	1,34	1,34
	7,30						
	30,34						
	7,35	PD			7,35	1,35	1,35
	7,32	CD			7,32	1,32	1,32
	18,32						18,32
ASSET ACQUIS. AND DISPOSITION	7,28	NFA					
	28,25						
	28,7				7,12		
	39,7						
	7,27						
OTHER INCOME	39.7	OI		39,7			39,7
SALES TRANS-ACTIONS	42,7	S		42,7	42,7		
	42,8	AR		42,8	42,8		
	8,7	AR		8,7			
	22,43	CGS		22,43	10,43	42,1	38,1
			22,43			1,43	
PURCHASING AND PRODUCTION	7,20	RI		7,20			
	28,20	AP		28,20			
	7,28		7,21	7,28	7,10		
	7,21	WP	20,21-2	7,22	28,10		1,38
	20,21			7,22			
	21,22	FI		20,22			
SELLING AND ADMINISTRATIVE EXPENSES	26,50	DE		7,50	13,50	1,50	
	9,53	DE	7,51-1	7,53			
			7,51-2		7,49		
			7,51-3				
	7,48	OfE					
	7,47	AdE		7,44			
	7,46	SfE					

DISCUSSION PAPER NO. 304

DEVELOPMENT OF A CORPORATE INFORMATION SYSTEM

by

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Summary

This paper develops a general analytical framework for the analysis and design of corporate planning models susceptible of (1) easy computer implementation as achieved by some existing report generating systems; while (2) integrating the analytically sophisticated techniques for optimizing the system's performance. The basic tree structure of any accounting system is introduced together with the associated "system matrix", and 'aggregate transactions' vector. This leads to a simple linear system representation of corporate accounts. A more detailed pro forma system is then used to study and compare existing corporate planning models. Fundamental criteria characterizing these models are found and illustrated with a few well known models. A corporate planning simulation language is then presented. Ongoing and future research on application of this methodology to sensitivity analyses and regression type studies in corporate planning are also sketched.

1. Introduction

Formalization of management decisions is now a favorite exercise of economists, management scientists, computer scientists and even practicing managers. Unfortunately, the result has been a host of apparently unrelated, and highly segmented contributions. Little attention has been given to the integration of these models into a comprehensive, easily accessible and computer implementable overall model of a firm. Undoubtedly, there are scores of computer packages purporting to implement a basic accounting structure to enable the manager to generate summary reports of his company at various target dates. But these models rarely attempt to integrate optimization methods or other analytical tools to evaluate company performance under alternative corporate policies. A successful integration of these features in a corporate planning model would enable the manager to make full use of the speed of execution, accuracy and convenience afforded by computers in other planning applications. This paper proposes a powerful self-contained framework to achieve this goal. Its usefulness is demonstrated by analyzing some representative corporate planning models, classifying them according to operational criteria and drawing general conclusions as to the level of detailed performance tracking and optimizing they provide the user.

The paper is organized around seven sections. Following this introduction, section 2 introduces the basic system (see[19]). This system is used: (1) to represent the state of a corporation as described in the standard accounting and financial literature (this representation provides a compact and computationally tractable procedure); (2) to record basic events in the corporation; (3) to update the corporate accounts accordingly; (4) to track the system's performance; and (5) to suggest alternative policies to achieve corporate objectives. A simple example is used to introduce the basic notions of the tree representation of a hierarchical system and its associated 'systems matrix' and the 'aggregate transactions vector'. The 'systems matrix', 'aggregate transactions vector' and 'systems state vector' form a linear system. This immediately allows the methods of linear systems and linear-quadratic Gaussian systems theory to be applied. A number of models in the literature such as the Holt-Muth-Modigliani-Simon (HMMS) model[7] and Lev and Pekelman[10] are thus encompassed in our general framework. Furthermore, it should be noted that this corporate financial accounting application is but one of many possible applications of this formalization. A non-exhaustive list of other applications includes cost accounting, national accounting, sales analysis by product, region etc., health care delivery systems and distribution systems. Alternative levels of disaggregation of the system are also suggested. This representation is then fully developed for the case of a corporate accounting system in section 3. With this 'pro forma system' we are able in section 4 to establish operational classification criteria for existing corporate planning models, e.g. (1) their level of 'vertical' and 'horizontal' detail, (2) their implicit or explicit time dimension, and (3) the analytical technique used for obtaining a solution. This framework

framework while it provides useful dimensions for comparing such models. Figure 2 gives the tree representation of a standard corporate financial reporting structure. Figure 3 gives a nonexhaustive list of the most common transactions occurring in a corporation.

At this point it should be noted that we have expanded the tree in Figure 2 to include the income statement classification scheme. As we can recall this describes which events lead to changes in the stock or balance sheet variables. For instance a cash sale of goods is associated with two transactions; namely, #1 and #5. The system consisting of the nodes corresponding to stock variables and nodes corresponding to a classification scheme for events can also be represented by a linear system as follows:

$$b^{t+1} = E \cdot b^{t} + S \cdot \tau^{t} \qquad (2)$$

Here the (expanded) state space corresponds to all nodes in the tree. The $(m \times m)$ E matrix is an $(m \times m)$ identity matrix except that diagonal elements corresponding to non-balance sheet accounts are set equal to zero in order to respect the flow nature of the income statement accounts.

Extensions of the Basic System for Other Classification Criteria.

This pro forma statement is broadly representative of the structure of financial accounts in today's corporation. The operation of a multidivision corporation can be represented using separate substructures for each division and relating them to a consolidated set of accounts. In this case, for instance, τ will be composed of as many sub-vectors as there are divisions. This example is but one of many subclassifications the user may want to consider in setting up his system. For instance he may want information concerning: (1) operations in the various regions in which the corporation operates, (2) sales by product, (3) product cost breakdowns--by expanding the tree beneath the working process account according to whichever product or process costing system is used (including standard costing systems), and (4) departmental costs or "responsibility accounting" in which a classification by departmental cost centers is used in parallel with the standard financial accounting structure.

As described later it is easy to automate the computer implementation of the basic tree structure together with the updating and reporting system. Further, it is very simple to modify the basic tree to test how alternative organizational structures and accounting conventions (historic cost vs replacement cost, etc.) affect the reported system performance.

Throughout the above discussion we have implicitly considered the recording of aggregate transactions in monetary units--dollars. The transactions information need not be specified always as a vector. It is possible to have a transaction matrix where every column represents the transaction values corresponding to a time subdivision (monthly, quarterly, weekly, same month last year, etc.) A two-column transaction matrix can also represent both the unit volume and $ value of all transactions. In all the above mentioned cases, the state of the system and the system's equation will remain the same except for some minor modifications in the aggregation process.

4. A Classification Scheme for Corporate Planning Models

We now examine the fundamental criteria embodied in the basic pro forma system to differentiate among existing corporate planning models.

Referring to the basic tree given in Figure 2 below, we use four dimensions of classification:

1. The extent of the coverage of the model. This is measured by the number of elements used to describe the state, b, of the system and, correspondingly, the number of elements included in τ.

2. The time frame of the model: short-run vs. long-run.

3. The objective function considered in the model e.g. earnings-per-share (EPS), return-on-investment (ROI), etc.

4. The analytical techniques used, e.g. optimization (linear, non-linear), simulation, regression, etc.

These dimensions of classification enable us to compare existing models. An important point to note is that a choice on one dimension often confines the modeler to narrow ranges on another dimension. In that sense, these dimensions are not independent.

Extent and Level of Coverage

As in any tree graph the level of a node is measured by the number of arcs in a path from the root to that node. Here, higher levels are closer to the root node. In the tree structure, the user can opt for a given level and record events by their effect on all accounts at that level. Alternatively, his model could span a number of different levels in the tree or be narrowly concentrated at a given level. As we pointed out in developing the basic system of accounts, any amount of disaggregation can be chosen that suits the user's needs best. His choice will depend on the variables he uses in his objective function. This natural correspondence between the level, in the tree, of the variables in the model and the objective function is illustrated by Figure 4. Higher levels in the tree are associated with broad financial goals, e.g. EPS, ROI. As we move down to lower levels the goals are more narrowly confined to functional areas: marketing, production, inventory management, etc. This observation also sug-

The model allows for multiple divisions; however, all funding decisions are made at the corporate level. Mixed integer programming is used to obtain a solution. Some financial models attempt to integrate both financial and operating policies.

In the paper by Krouse[8] (K) the firm's short-term cash budgeting, long-term capital budgeting and related financing mix are simultaneously determined. Revenues are determined exogenously and the value of debt acquired, dividends paid and operating costs incurred are treated as decision variables in a stochastic control model meeting both short and long-term goals.

Pindyck[14] (P) discusses a financial simulation model which typifies the kind of model produced by many financial planning software packages. Sales forecasts are used to drive the model and to generate various operating transactions (components of τ). These, in turn, determine cash requirements. Management policies with respect to dividends, retained earnings, debt-equity ratio, etc. determine new debt and equity needs. Note that the simulation technique allows broader coverage but precludes conclusions concerning optimality of the resulting decisions.

Damon & Schramm[2] (D&S) focus on the interaction between the marketing, production and finance functions. Maximization of the net cash generated is chosen as the objective. Values of decision variables in all three areas are simultaneously determined by nonlinear programming.

The final example that will be discussed here is the HMMS[7] model that is employed in the short-run planning of production and employment. The analytical technique uses the well-known linear-quadratic systems model. Figure 10 illustrates the accounts that may be affected by the decisions taken in regard to production level and work-force. As shown therein a few nodes (accounts) of the pro forma tree structure have to be disaggregated to fully understand the impact of a lower level model and its decision criterion.

Some Observations Regarding the Models

A comparison of the transactions implied by different models is shown in Figure 11. In this figure we group the elements of τ, the aggregate transactions vector, in broad categories analogous to the grouping of accounts (nodes) in the tree depicted in Figure 5. This disaggregation of the transaction flows enables us to compare the variables included in the five models reviewed above. Further, as we move from HMMS to H&M we observe broad aggregations of transactions tracked separately in previous models. Of course, this is another way of recognizing that H&M operates at the highest level in the tree which requires tracing the impact of all transactions linking lower level nodes; whereas HMMS operates at the lowest level by focusing solely on production planning. Given the role of τ in changing the state of the system from one period to the next (see equations 1 - 2 above), a key step in planning consists in evaluating the components of τ that will meet the objectives set by the planner. Two approaches are often found in the planning literature 'top-down' and 'bottom-up'.

1. In top-down planning the transaction vector is estimated using historical or policy determined relationships between the decision variables (sales, production, earnings, etc.) and the various other elements of the transaction vector. For instance, in Pindyck's model 'sales' is used to compute all other transaction values. These estimated transaction values then become budgets to the corresponding functional units.

2. In bottom-up planning each functional unit will forecast its needs to achieve a broad corporate objective(s) and top management will determine a funding mechanism to satisfy these needs and also meet both the overall corporate objectives and the financial constraints.

A prevailing view among corporate planners is to incorporate both these approaches in the development of an integrated planning and budgeting mechanism. Thus we may note that τ is a link between corporate objectives and functional policies. (This dependency is also illustrated in Figures 4 and 5.) A useful distinction can be made between 'funding' transactions that represent the financing of the operations of a firm (sources of funds, e.g. equity, new debt, retained earnings) and 'operating transactions'--i.e. all others. Each transaction is the result of: (1) a decision taken by a unit (purchase X units of raw material on credit); (2) a policy set by top-management (pay Y% stock dividends); or (z) parameter(s) set by an external agency (pay τ % of earnings as taxes). Since the operating decisions/policies are interdependent, the values of the corresponding transactions in the transaction vector are interrelated. Hence the sequence used in computing the transaction vector is of special significance. Activities occur simultaneously at all levels of an organization thus posing a difficult computational problem. However in some cases it is reasonable to solve for subsets of the planning variables in an iterative manner. Thus some transaction values have to be estimated before evaluating the others. Examples of this are the 'funding' and 'operating' transactions. Evaluation of all operating transactions will yield an estimate of funds needed/in-excess, which can then be used to determine the funding transactions that represent the acquisition/disposition of those funds. In such cases, one needs to estimate τ^t in two or more iterations. Several methods for computing τ are feasible. The exact mechanism for the computation of τ^t depends on the strategy employed in planning. For instance, Krouse determines the level of assets, which is then used in the estimation of revenues and other transactions. In Pindyck's model the level of 'sales' is used in the estimation of operating transactions. Whatever strategy is used it is clear that our formulation of the systems logic allows us to readily focus on the relevant transactions. This is but one example of the economy and flexibility afforded by the system discussed in the next section.

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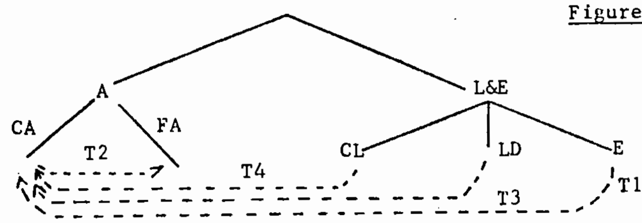


Figure 1

Legend

Balance Sheet

Current Assets (CA)
Fixed Assets (FA)
Current Liabilities (CL)
Long-term Debt (L)
Equity (E)

Transactions

T1 - investment in firm by owners
T2 - purchase of fixed assets for cash
T3 - long-term borrowing
T4 - short-term borrowing

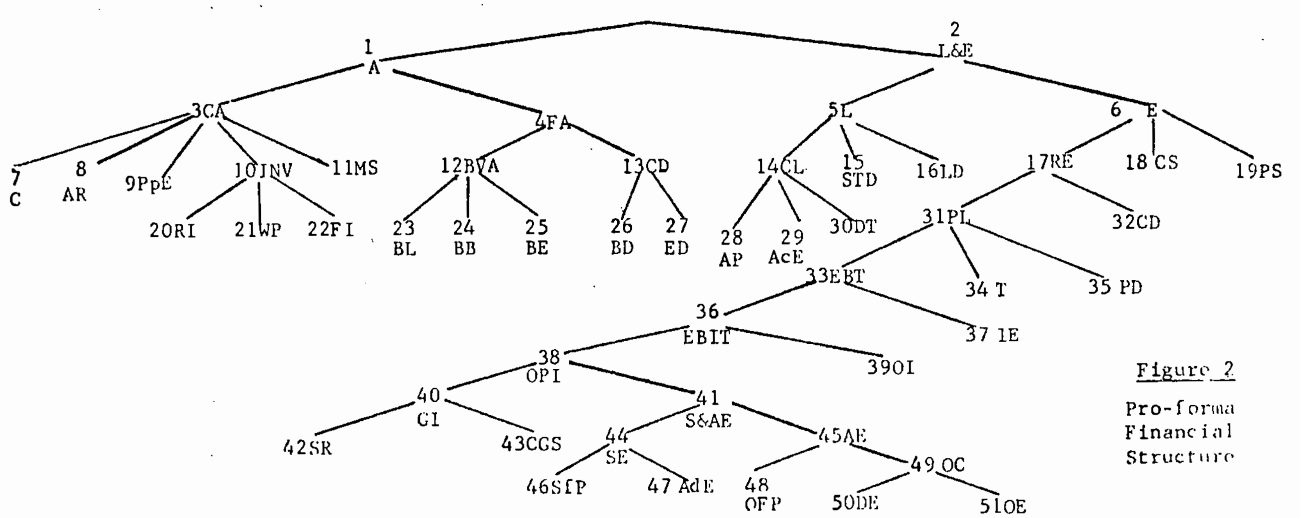


Figure 2

Pro-forma Financial Structure

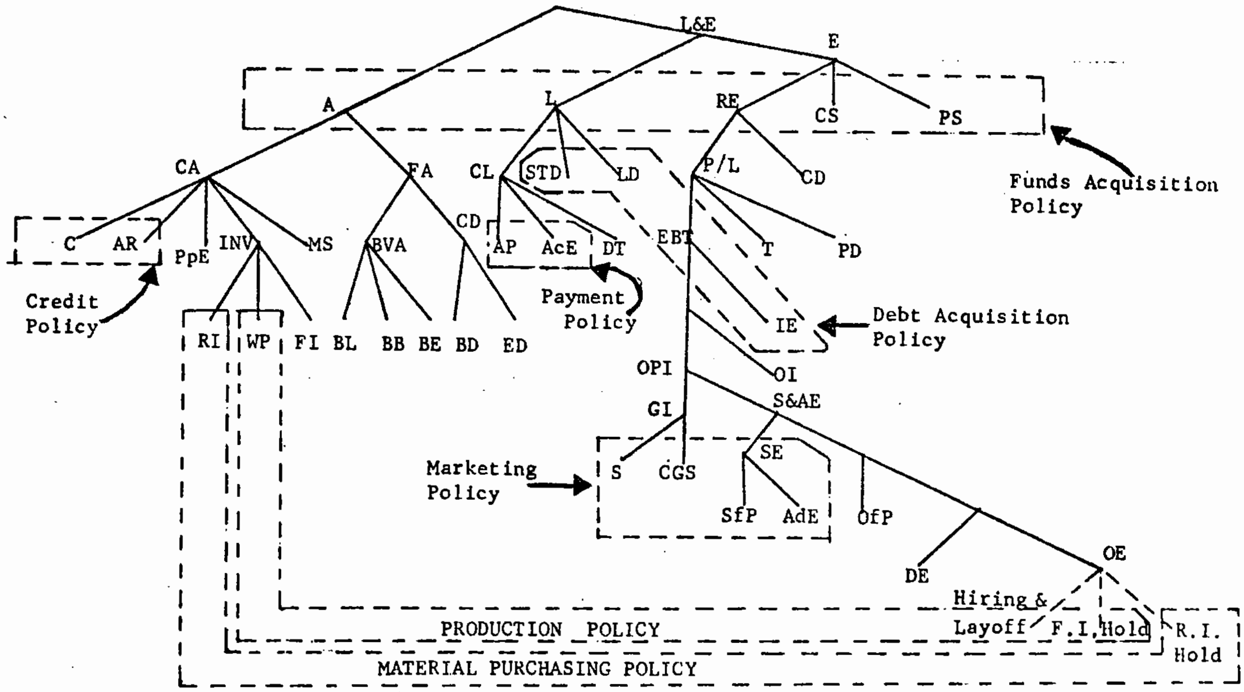
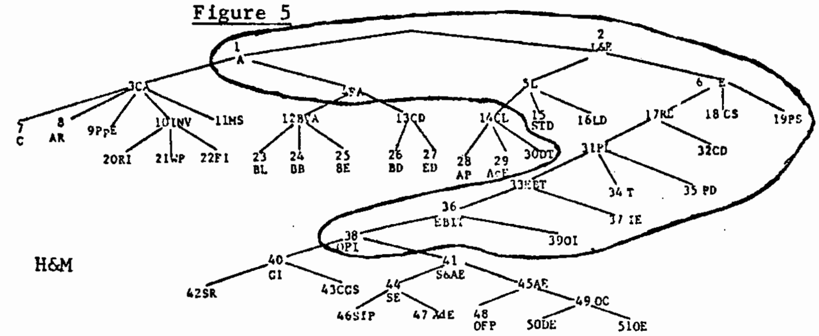


Figure 5

FIGURE 6



H&M

FIGURE 7

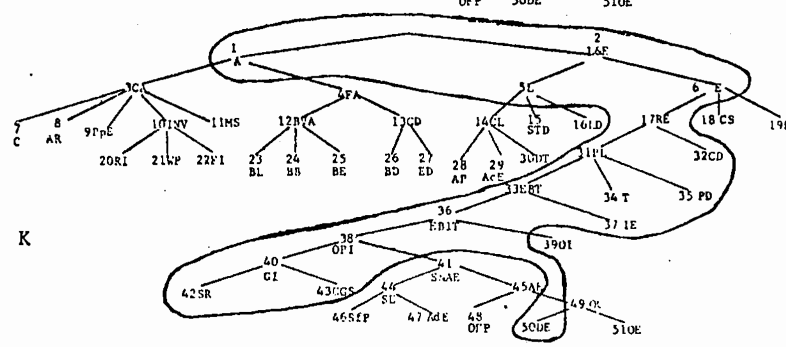


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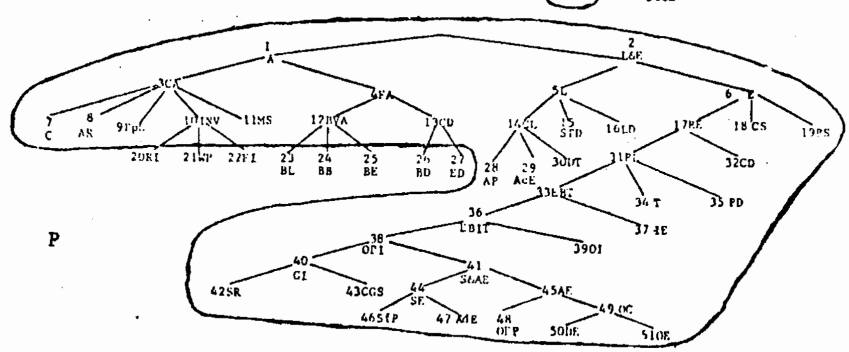
FIGURE 8



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