

# Developments in Business Simulation & Experiential Exercises, Volume 8, 1981

## A GENERALIZED ALGORITHM FOR DESIGNING AND DEVELOPING BUSINESS SIMULATIONS

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### ABSTRACT

The design of business simulations is a complicated and time-consuming task. The time required and the degree of complexity could be greatly reduced by following certain basic procedures in an organized fashion. This paper attempts to outline some of the basic principles that could be applied in designing and developing a business simulation.

### INTRODUCTION

Business simulations have been used in collegiate education since 1956. During this time several hundred games have been designed and catalogued. However, many of these simulations were not designed for general use; and some that were are now outdated because of advances in computer technology. Among all the users of simulations only a small percentage have written general business simulations. Among ABSEL members less than 30 are authors of simulations, and many of these members are no longer active in business simulation design. Consequently, there is still a need to have more individuals involved in the design and development of business simulations. In order to interest more ABSEL members and others in simulation design, a more definitive presentation of business simulation design principles and fundamentals is necessary.

The basic principles of simulation design have not been fully set forth in writing. A number of papers at ABSEL conferences have been presented which touch upon aspects of simulation design [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]; however, taken collectively, these papers do not provide enough information to help the novice designer develop business simulations in an efficient manner. The designing and developing of simulations at this time appears to be primarily an art form, a creative skill based on intuitive feel rather than acquired knowledge. There is a pressing need to construct a science of simulation design and development.

This paper is an attempt to set forth some basic principles and concepts of business simulation design. While the fundamentals set forth in this paper were primarily derived from the writer's work with non-interactive business simulations, these fundamentals, nevertheless, apply equally to interactive business simulations. A previous paper by the writer [31] set forth the theoretical framework for noninteractive business simulations. This paper specifically deals with the more detailed mechanics of actual simulation design and development.

The writer has had published a relatively complex simulation, Introduction to Managerial Accounting: A Business Game. The design and development of this game was primarily the result of finding simulation design fundamentals at a trial-and-error basis. Through intensive analysis and reflection on this simulation writing experience, the writer has been able to develop a generalized algorithm for writing noninteractive simulations. Had such a step-by-step procedure been available to the writer at the beginning, the time and effort required to develop and write Introduction to Managerial Accounting: A Business Game

could have been greatly reduced.

### GENERAL STEPS OF SIMULATION DESIGN

The major steps of a generalized algorithm for designing noninteractive simulations can be outlined as follows:

1. Develop a general outline or scenario of the simulation.
  2. Translate this broad scenario into a set of financial statements and other desired reports.
  3. For each element of the financial statements (assets, liabilities, capital, revenue and expenses) create an equation which determines the ending balances or amounts.
  4. Construct the mathematical functions which give the simulation dynamics and realism necessary to achieve participants' acceptance.
  5. Construct the functional algorithms necessary to produce the decision values required by the financial statement equations.
  6. Assign specific values for all parameters and simulation constraints, mathematical functions, and functional algorithms.
  7. Write a computer program for processing decisions and producing simulation results.
- B. Write a student manual.

The above steps (general algorithm) indicate that the development of a general business simulation is a rather complicated process of determining the required financial statement equations, mathematical functions, and functional algorithms. The end result of the above eight steps is a rather large integrated mathematical model. The model is capable of processing an almost infinite number of variations in a set of decisions.

### DEVELOPMENT OF A BUSINESS SIMULATION SCENARIO

The design and development of a business simulation requires two main design structures: verbal and mathematical. The verbal structure ultimately becomes the student manual, and the mathematical structure becomes the computer program. Of course, these two design structures are highly interrelated. The term scenario then refers to the verbal description of the business reality which the simulation attempts to represent. The development of the simulation scenario outline requires decisions on the part of the simulation designer. Some of these decisions include:

1. Determination of Simulation Objectives--Simulation design objectives can be broadly classified as general and specific.

General - General design decisions include considerations of whether the simulation is to be used: a. to develop strategic planning skills, b. to develop quantitative skills, c. with graduate or undergraduate students, d. within business policy or other types of courses.

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Specific - Specific design decisions involve consideration of: a. type of business (manufacturing, retail, wholesale), b. type of simulation (functional, general management, or institutional), c. degree of complexity (simple, moderately complex, complex), d. Nature of desired student competition (interactive vs. noninteractive), e. type and number of decisions (marketing, finance, production).

2. Determination of Internal Structure of the Simulated Business--Given the above general and specific simulation design decisions, the internal structure of the simulated business must be considered next. This, in part, involves visualization of the company's financial statements format. The internal financial structure is largely determined by the decision as to simulation complexity which, in turn, largely directs the number and types of decisions.

3. Determination of Economic Environment-- To give the simulation an air of reality, an economic environment must be developed. This step will involve consideration of: a. type of industry (pure competition, monopolistic competition, monopoly, oligopoly), b. financial markets (stocks, bonds, mortgages), c. interest rates and banks, d. business cycle indices, e. suppliers of materials, f. labor unions and factory workers.

4. Determination of the Economic Environment-- The simulation must have its limits or otherwise it would be unmanageable. Constraints that provide necessary limits would include: a. limits on the amount of labor and wage rates, b. limits as to bank loans, stock shares, bond certificates, c. pricing and production limits, d. conditions for bankruptcy.

5. Determination of the Amount of Decision Information--Another critical consideration is the amount of explicit information needed for making good decisions. The less information provided, the more difficult it will be for students to use quantitative tools. On the other hand, too much information adds to game complexity and also limits intuitive decision-making and risk-taking.

6. Determination of Accounting Policies--The general design and scope of a business simulation must involve some consideration of accounting policies. Choices must be made among alternative depreciation and inventory costing methods. If the simulation scenario involves a manufacturing firm, then consideration must be given to the type of costing system that will be used. Variations in the costing system can cause different net income values to result. Other accounting problems involve the computation and reporting of income taxes. A frequent weakness of many simulations is oversimplification of accounting and tax problems.

The development of the scenario does not have to contain minute details at this point. The scenario outline is intended to be a guide to the remaining steps of the general simulation design algorithm.

### DESIGN OF OUTPUT DATA

The accomplishment of Step 1 creates a large number of interrelationships. These interrelationships must be completely recognized, understood, and documented. The output design is best facilitated by recognizing these relationships mathematically and presenting the dependent values of these mathematical equations as financial statement values.

If the simulated business is a manufacturing company, three financial statements must be designed in order to capture all the relationships and simulation features established in Step 1. These statements are: a. balance sheet, b. income statement, c. cost of goods manufactured statement.

In addition to the three items of output above, a fourth output item is generally desirable. This item may be called "other data" or "summary of results." It consists, for the most part, of unit data such as undelivered sales, sales orders, number of salesmen, number of salesmen quitting, units of inventory on hand, etc. An example of this output is shown in Exhibit IV.

The mechanics of this step involve the following procedure: a. Identification of all financial statement elements (e.g., cash, accounts receivable, sales, etc.), b. The identification of all desired nonfinancial statement data, c. Creation of variable names for each item of desired output. See Exhibits I - V for examples.

### DEVELOPMENT OF FINANCIAL STATEMENT EQUATIONS

After the financial statements are designed in format form, an algebraic equation for each financial statement must be developed. These equations provide financial statement values essential to the printing of financial statements. The financial statement equations alone do not provide all of the necessary values. Decision values (the terms of these equations) are dependent upon certain mathematical functions and functional algorithms. These mathematical functions and functional algorithms are discussed in the next step. The financial statement equation must recognize all financial statement interrelationships so that when all decision values are computed, assets will equal liabilities plus capital. The complexities of these financial statement interrelationships are illustrated in Exhibit VI. Financial statement equations must recognize all of the relationships indicated by the interconnected boxes.

A complete illustration of financial statement equations is presented in Exhibit V. Each equation of the balance sheet consists of the following components: a. Beginning value, b. Decision values (values computed from the mathematical functions and functional algorithms), c. parameters (constraining values built into the simulation. Income statement equations and cost of goods manufactured equations contain only items b and c.

The number of these equations varies with simulation complexity. Simulation complexity, as previously mentioned, is determined by the number of decisions and environmental factors built into the simulation.

### DEVELOPMENT OF MATHEMATICAL FUNCTIONS

In the real world of business there exists dynamic relationships between economic variables. Although the general relationships between many of these variables are well known, the impact of a precise change in one variable upon another can seldom be accurately predicted. For example, the general relationship between price and quantity has been abundantly illustrated in economic textbooks. However, it is doubtful that the demand curve for a given business has ever been quantified with any degree of precision. Similarly general relationships between advertising and sales, wage rates and production, salesmen commission rates and

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FINANCIAL STATEMENT EQUATIONS		REVENUE		EXHIBIT V
ASSETS		Sales	$S = CS + CHS$	
		Net sales	$NS = S - SR - SD$	
Cash	$CE = CI - CO$	EXPENSES		
Accounts receivable	$ARE = ARB + ARCS - ARC - ARWD$	Cost of goods sold	$CGS = FGB + TMC - FGE$	
Allow. for bad debts	$AFBDE = AFBDE + BDE - ARWD$	Finished goods (E)	$FGE = FGAFS - US$	
Materials	$ME = RMB + NP - MU$	Gross profit	$GP = NS - CGS$	
Finished goods	$FGE = FGB + TMC - CGS$	Selling	$SE = SSES + SCES + AES + OBES$	
Plant & equipment	$TPE = BVD + BVME$		$+ BDES + MSES + TES$	
Allow. for deprec.	$AFDE = AFDEB + OEE - DEWD$	General & admin.	$GAE = AEGA + PDGA + ESGA + SSGA + O$	
Buildings	$BE = BB$	Other	$OEI = IEO + ITO - II$	
Allowance for deprec., B	$AFBD = AFDB + DEB - DBWD$			
Investments	$INVSTE = INVBSTB + INVSTP - INVSTB$			
		NET INCOME		
LIABILITIES		Net income (after taxes)	$IAT = GP - CGS - SE - GAE - OEI$	
Accounts payable	$APL = APB + NMP - APP - SR - SD$			
Notes payable	$NPL = NPB + BL - NPP$			
Mortgages	$MPL = MPB + MPPA + MPI$			
Bonds payable	$BPL = BPB + BI - BR$			
Accrued income taxes pay.	$ITPE = AITP + AITPP$			
CAPITAL		COST OF GOODS MANUFACTURED		
Common stock	$CSE = CSB + CSI$	Materials used	$NP = RMP - PR - PD + FI$	
Premium on common stock	$PCSE = PCDB + PCSI$	Material avail. for use	$MAFU = MB + NP$	
Retained earnings	$REE = REB + NIAT - D$	Material used	$MU = MAFU - ME$	
Treasury stock	$TSE = TSB - TSP + TSI$	Direct labor	$DLC = DLCA + DLCD$	
		Manufacturing overhead	$TO = FMO + VMO + SVO$	
		Total manufacturing cost	$TMC = MU + DLC + TO$	

calls per month have been described but only in a general way.

If a business simulation is to be realistic, the same general relationships found in the real world must be found within the simulation. In order for a simulation to have the needed air of realism and dynamism, mathematical functions must be created to simulate these economic forces. Some of the desirable mathematical functions include: a. price and sales quantity, b. advertising and market potential, c. credit terms and sales, d. commission rates and calls per month e. salesmen's salaries and calls per month, F. wage rate and production rate.

To give an example, the relationship between price and quantity could be stated as:  $P_0 - K(P)$ .

For a real business, the exact nature of these relationships probably could never be identified and plotted graphically. At best the relationships could only be tested on a trial-and-error basis. However, a simulation designer must specify numerically these relationships; otherwise, the computer would have no quantitative basis whatsoever for computing consequences of different sets of decisions. Thus, in order to simulate reality the simulation designer must conceal or not make precisely known to the simulation participants the quantitative nature of the mathematical functions. This paradox of defining the mathematical functions exactly within the computer program but only vaguely to the participants creates a real challenge for the simulation designer. If the exact nature of these functions is learned too quickly then the uncertainty and risk of decision-making is lost, and the simulation then becomes a mere computational exercise.

After the design of financial statements, formulation of financial statement equations, and creation of mathematical functions, the next major step is to develop functional algorithms. Functional algorithms are step-by-step instructions for computing decision values from marketing, production, and financial decisions. The functional algorithms include the mathematical functions, and game parameters and constraints. Functional algorithms are needed for production, sales, credit, and finance.

### Production Algorithm

The first major computation that must be made in a business simulation is units manufactured. This value is critical to many Other computations. Until units manufactured is computed, the number of units sold and consequently sales proceeds cannot be calculated. The major purpose of the production algorithm is to take into account all of the factors that determine production. These factors include: a. number of production machines (units) in use, b. decisions as to overtime and second shifts, c. number of workers hired, d. material available for use, e. wage rates, F. production parameters and constraints.

A secondary purpose of the production algorithm is to compute related production values such as total labor hours, material inventories in units, etc.

### Sales Algorithm

A second major computation that must be made is sales orders. Given the sales orders and units available for sale, the actual number of units can be computed. Sales orders depend upon factors such as market potential, number of salesmen, salesmen compensation, credit terms, seasonal indices, number of territories or products. The major purpose of the sales algorithm is to correctly compute the impact of these factors on sales. In addition to computing sales orders, the sales algorithm computes secondary values such as undelivered sales, finished goods inventory, and cost of goods sold. In regard to finished goods inventory, this algorithm must take into account the inventory costing method; e.g., FIFO or LIFO.

### Credit Algorithm

The primary purpose of the credit algorithm is to take into account the effect of selling on credit. The major consequence of selling on credit is the creation of accounts receivable. If some cash sales are allowed, then this program determines the proportion of total sales that is credit. Since credit affects cash flow, this program must compute the amount of receivables in the current period. Furthermore, the selling on credit creates problems pertaining to

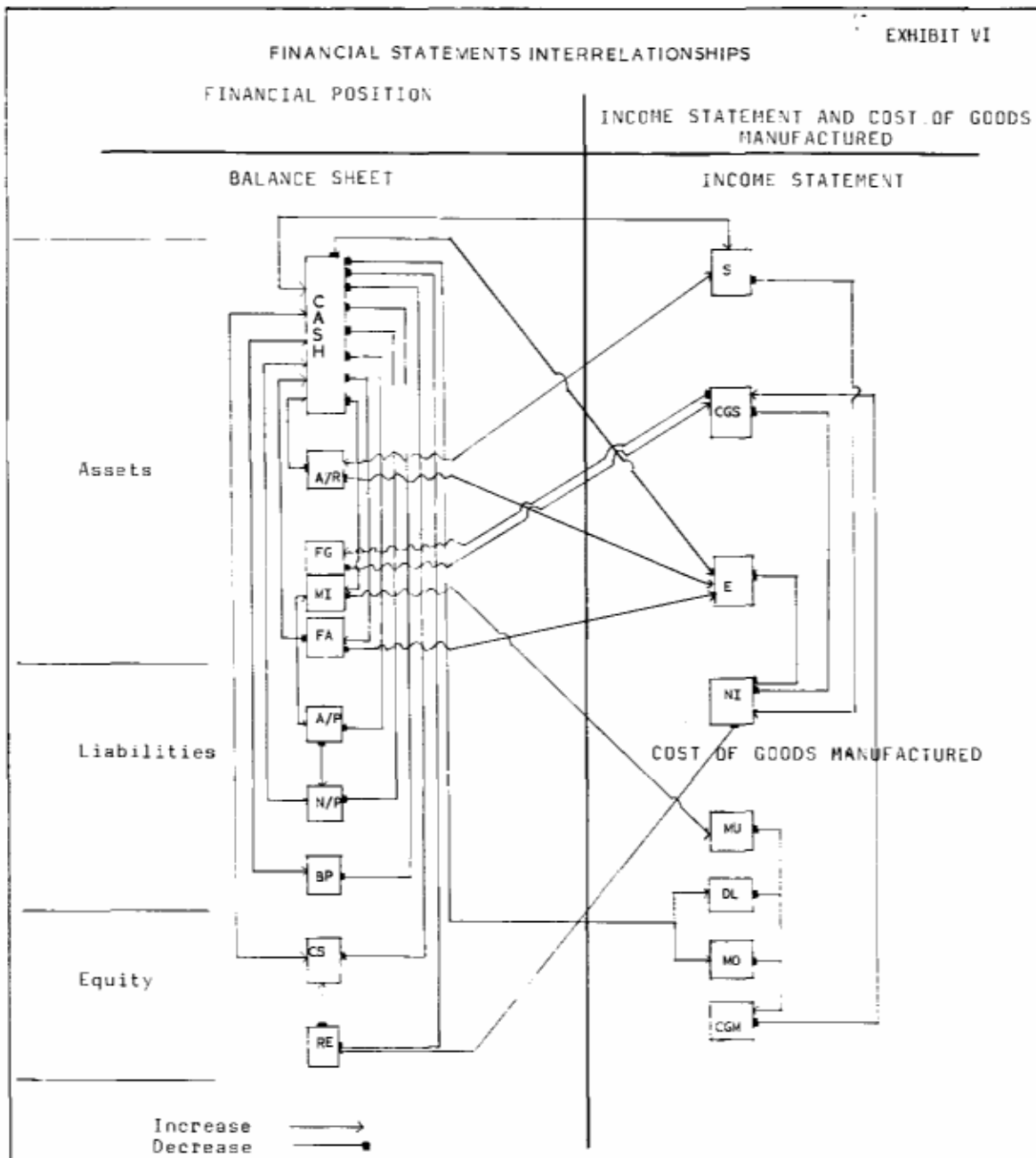
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COMPANY		EXHIBIT I	
INCOME STATEMENT			
FOR THE PERIOD ENDED _____			
Sales		S	
Cost of goods sold			
Finished Goods		FGB	
Cost of goods manufactured		CGS	
		CGFS	
Finished goods (EI)		FGE	
		CGS	
		GP	
Gross profit			
Expenses			
Selling			
Salesmen salaries	SSCS		
Salesmen commissions	SCCS		
Advertising	ACS		
Depreciation, bldg.	DBCS		
Bad debts expense	BDCS		
Managers' salaries	MSCS	TSE	
General and Administrative			
Accounting	AEGA		
Personnel dept.	PDCA		
Executive salaries	ESGA		
Secretarial salaries	SSGA	TGAE	
Other			
Interest expense	IED		
Interest income	II		
Income taxes	IYO	IOE	
Net income		NI	

COMPANY		EXHIBIT III	
Balance Sheet, _____			
ASSETS			
Current			
Cash		CE	
Accounts receivable	ARE		
Allowance for doub. accts.	AFDAE	NAR	
Materials		ME	
Finished goods		FGE	
Total Current Assets			TCA
Plant and Equipment			
Building	BE		
Allowance for deprec.	AFBD	BVD	
Machines and equipment	ME		
Allowance for deprec.	AFDE	BVME	
Total plant & Equip.			TPE
Investment			TVI
Total assets			TA
LIABILITIES			
Current			
Accounts payable	APE		
Notes payable	NPE		
Accrued income taxes payable	ITPE		
Total Current Liabilities			TCL
Long Term			
Mortgage payable	MPE		
Bonds payable	BPE		
Total long term liabilities			TLTL
Total liabilities			TL
STOCKHOLDERS' EQUITY			
Paid-in Capital			
Common stock (Auth. CSA; Issued TCSI)	CSE		
Premium on common stock	PCSE		
Total	TPIC		
RETAINED EARNINGS	REE		
Total stockholders' equity			TC
Total liabl. & Equity			TLSE

COMPANY		EXHIBIT II	
COST OF GOODS MANUFACTURED			
FOR THE PERIOD ENDED _____			
Materials Used			
Materials (BI)			MB
Materials purchases		RMP	
Purchases discounts	PD		
Purchases returns	PR		
Freight-in		TDR	
		FI	NP
Material(EI)		ME	RAU
			MU
Direct labor			
Cutting and assembly		DLCA	
Finishing		DLFD	TDL
Manufacturing overhead			
Fixed			
Cutting and assembly		FLCA	
Finishing department		FLFD	
Variable			
Utilities		VU	
Repairs and maintenance		VRM	
Supplies		VS	
Semi-variable			
Overtime premium		SVOP	
Purchasing and receiving		SVPR	
Total overhead			TO
Total manufacturing costs			TMC
Number of units manufactured			AP
Cost per unit			CPU

COMPANY		EXHIBIT IV	
SUMMARY OF OTHER DATA			
MARKETING			
Units sold		US	
Total demand		QD	
Undelivered sales		US	
Salesmen Quitting		SQ	
Salesmen hired		SH	
PRODUCTION			
Number of machines		NM	
Monthly production potential		MPPM	
Workers hired this month		WH	
Excess workers hired		EW	
Materials inventory (units)		MI	
Finished goods (units)		FGE	
FINANCIAL			
Credit terms this month		CT	
Earnings per share		EPS	
Market value per share		MVPS	
Number of bonds authorized		BA	
Number of bonds issued		BI	
Bonds issued this month		BIM	
Shares of stock authorized		SA	
Shares of stock issued this month		SI	
Number of shares of treasury stock		TSS	
RATIOS			
Current		CR	
Debt/Equity		DE	
Profit margin percentage		PM	
Contribution margin		CM	
ROI equity		ROIE	
ROI assets		ROIA	



bad debts. Bad debt expense and accounts receivable write-offs must be handled by this algorithm. If factoring of accounts receivable is allowed as a decision, then the complexities arising from this option must be properly analyzed and programmed. As in all of the functional algorithms, many of the computed values become decision values for the financial statement equations.

#### Finance Algorithm

The purpose of the finance algorithm is to take into account the impact of all the financial decisions. Basically, finance decisions either increase or decrease cash flow. Therefore, in this algorithm the consequences of issuing stocks, bonds, and bank notes must be computed. Furthermore, the effect retirement of stocks and bonds and payment of bank notes has on cash proceeds must be considered.

The major purpose of the functional algorithms (production, sales, credit, and finance) is to compute the decision values needed for the financial statement equations. Although the financial statement equations [discussed as Step 3 of the general algorithm for simulation design] could be dispersed throughout these functional algorithms, a more efficient procedure would be to collectively group all of these equations in a separate subroutine or program. In this separate program physical factors computed in the functional algorithms will be multiplied by cost factors to produce the decision values required by the financial statements equations. When the processing of the financial statements equations is completed the simulation program is then able to provide printouts for financial statements and other planned outputs.

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### ASSIGNMENT OF SPECIFIC PARAMETERS AND SIMULATION CONSTRAINTS

The design and development of a business simulation to this point has been algebraic and algorithm oriented. In the scenario development stage some or all of the simulation parameters and constraints were roughly considered. Now all simulation parameters and simulation constraints must be precisely determined and assigned to the proper equations and functional algorithms. Upon assignment of these values, a complete workable model for a business simulation has been constructed.

### DEVELOPMENT OF COMPUTER PROGRAM

The completed mathematical business simulation model is now ready for computer programming. This stage

- requires expertise in a computer language. In the writing of the program perhaps the most critical but most often neglected phase is the adequate documentation of the program. The major segments of the computer program will be:

MAINLINE--controls the order and direction in which program segments will be processed.

PRODUCTION--computes units manufactured and related values

SALES--computes total sales orders and related values.

CREDIT--computes the effect of credit terms.

FINANCE--computes values pertaining to the issue and retirement of stocks, bonds, and bond indebtedness.

FINANCIAL STATEMENT VALUES--computes final balances or amounts for financial statements equations.

FINANCIAL STATEMENTS--prints financial statements and other planned output data. This is the program for the output design.

After the program has been written in a computer language, the next phase is to test and debug the program. Many simulation designers will testify that this phase is more time consuming and frustrating than the design and writing stage.

### DEVELOPMENT OF THE STUDENT MANUAL

The basic outline of the student manual was determined in the scenario designing phase of simulation designment. In this step, the student manual is completely written down to all the fine points and details. Accurate and clear description must be made for all simulation data necessary to making decisions. Decision input forms and any other necessary forms to simplify simulation usage must be designed. Also, charts, graphs, tables, forms, etc., helpful in presenting and understanding simulation data should be provided. It is important that the student manual be well written. Many good and academically sound simulations have suffered seriously from the failure of the designer to write a good verbal description of the simulation and its objectives.

### SUMMARY

Design and development of a business simulation at best is a challenging and time consuming task. However, if the task of developing the simulation can be seen from a total project point-of-view and the various steps visualized in logical order, the time involved can be greatly reduced. The general

design program (algorithm) presented in this paper is intended to help the simulation designer achieve design efficiency.

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