"AN APPLICATION OF SIMULATION MODELS TO CORPORATE PLANNING PROCESSES"

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A family of timeshared computer models written in APL have been developed in an effort to link the functional areas for communication, planning and control purposes. The models incorporate the concepts and tools of simulation, forecasting, long-range planning and probabilistic budgeting. Developed in a short time span and at low cost, they are widely used at XEROX in both corporate and region offices in both the U.S. and Canada. Under development is a system of statistical and econometric models. The paper discusses the approaches used to design, implement and involve the functional managers in building and utilizing the models.

INTRODUCTION

We have developed and are utilizing a series of deterministic simulation models to assist us in financial planning for Xerox (XCL) and additionally as a step in the development of corporate planning models.

The purpose of this paper is to describe how we use the models in our planning process, the types of models we utilize, the initial implementation procedure and how we maintain the models in a changing internal/external environment.

These models are on a timeshared (T/S) computer, were developed by the functional users, and are written in APL. They access an extensive series of on line data bases which mechanically interact with batch system data bases.

Not at issue is whether or not simulation is of value. We accept and have demonstrated to ourselves that it can make a significant contribution. Rather, we are essentially concerned with applications to which simulation models can make an economic contribution and how to implement them in a way that managers (without a management science background) will be able to incorporate them into their planning and decision-making processes.

The definitions of models and simulation are two popularly raised questions when working with corporate managers. Models are representations of systems which themselves are too large to be brought into a laboratory or otherwise experimented on in their natural environment (Ackoff 1970). Models can be classified as physical (ships in tow tanks), graphic, symbolic representations (algebraic equations) of the system; or a specified procedure for the evaluation of some criterion such as expenses or profit (Schweyer) that depend on other operating conditions subject to control by management.

Simulation is the manipulation of a model in such a manner as the "properties" of the system can be studied. In the sense I'm using it, simulation is an experiment or manipulation of a model that reproduces XCL operations (a functional component or the whole firm) as it moves through time. The manipulation may be by hand, computer, or by a combination of man and computer working together. The simulation models we have worked with to date have been essentially of the latter type (man-machine) although we have built some forecasting models that can 'stand alone' under strict computer control. We simulate systems (such as the operations of XCL) because we want to understand how they work, determine the factors that influence their behavior and observe how they react to changes in their environment as an aid to planning, forecasting, and other decision processes.

SIMULATION MODELS BEING USED IN FINANCIAL PLANNING AT XCL

It is most important to realize that we do not have a planning model as such, rather, we have a series of models which are changing as we learn more about our business and as we learn more about how models can assist us in improving our planning and decision-making capabilities.

Simulation models have been previously (Gershefski 1971) classed into three types - budget compilers, simple mathematical models, and large complex integrated models. We use all three types and variations in between.

Our first simulation model was of the simple mathmatical type, it was developed in crude operational form within 1 calendar month with the expenditure of less than $3000.00. This model was built to assist us in the development of our rolling 12 -month forecast of our business, a task which is performed monthly and is used in resource planning, profit planning, as a control device, and in the development of our operating plan. Prior to the model, this activity required about 4 man-weeks of analyst level effort.

This initial model was operated through a terminal where the analyst and manager (generally both) controlled 30 variables (such as growth rates, product trading relationships, productivity, etc.) and obtained a forecast of 300 output variables per month for 12 months (such as order forecasts, inventory changes, resource requirements, revenue, expense and profit contribution, etc.) (Seaberg 1972). This initial system can be seen in Chart 1 (Initial Simulation System). On this chart you can see the interrelationship of the timeshared data base with the in-house batch systems. Initially the data was keyboard entered into the T/S data base; now, there are mechanical (data tape) transfers .

To summarize our initiation to simulation models, one could say that it started with a recognition that a computer model could be of significant assistance in obtaining a more timely and consistent forecast of XEROX operations at a significant reduction in cost (4 man-weeks to 2 man-machine days) and infinitely more flexibility in varying assumptions and observing the simulated outcome on activity, revenue, expense variables.

We classified this initial model as a simple model. While it simulated our marketing function in a fair amount of detail, our distribution, service (support) and financial functions were handled in highly aggregated and simplistic procedures (although in more detail than the manual procedure which the model replaced). The model did however, stress key interrelationships in both our financial and operating structures and for this last reason we later used this particular simulation model for the basis of a model designed to assist in long range studies and projections.

Our long range planning cycle (10 years) begins with a projection of current trends of key variables. Management then may change these key variables consistent with what they feel to be desired directions (objectives and goals) and the models are then executed to determine the effects on operations and the resulting financial implications.

INTEGRATED MODELS

The requirement for increased model complexity becomes apparent as we begin examining causal factors; the interrelationships within, as well as between the functional areas; and for the development of operating plans and budgets.

Beginning with our simple model, we, together with the functional areas, enlarged the models to describe in more detail, their operations and the financial procedures of XCL. From this effort we derived more complex, integrated models for use in forecasting, planning, and simulating procedural changes (operations or financial) and for special one-time or infrequent studies such as pricing reviews, promotional campaigns, and facility locations analysis. As can be expected these large models have both many more input variables (compensation levels, trends by employee group, freight rates by destination and point of origin, etc.) and outputs (an entire operations and financial plan). These larger models tend to be operated primarily by analysts supporting the functional manager.

It is difficult if not impossible in both planning and forecasting to avoid looking outside the firm to the external environment. Typically and in the case of XCL many of these relationships are not clearly defined and even more rarely quantifiable. However, these forces cannot be ignored and must (even if only implicit) be incorporated in a forecast and plan. Typically we find that these exogenous factors for planning purposes, are assumed not to change or at most, that changes in them will have only a minimal impact on the firm. However, on a hind-sight basis it is nearly always demonstratable that environmental forces both economic (up or downswing) and social (riots) did have an influence on the firm (generally earnings). It becomes increasingly important to provide an explicit as possible a mechanism to incorporate these influences in our planning process.

To this challenge we are developing other models and information links to be incorporated into our planning system. Partial to-date results from these efforts include a series of statistical and econometric models and data bases.

ECONOMETRIC MODELS

To date, we have focused primarily on the development of "search-analysis-display" timeshared programs to examine econometric series (GNP, unemployment, interest rates) and XCL DATA (sales, profits) and applying the statistical concepts of regression analysis (single, multiple and stepwise), find and determine relevant relationships. The Service Bureau (which supports APL) provides an economic data base of 6000 series maintained by Statistics Canada (CANSIM) which in turn is the central agency in Canada for funnelling economic data from originating government agencies (agriculture, commerce, etc .).

A major problem we encountered in doing this type of project is organization of the data such that both corporate and economic series can be retrieved quickly and stored on a comparable basis for use in the analytical models. This is a major problem since these are on-line models and the analyst wants to spend only minimal time retrieving and structuring data so that it is in comparable form. We overcame this obstacle and an example is demonstrated on Chart 2 (A Procedure for Structuring Data Series With Timesharing).

Through the terminal the user specifies both the economic series (CANSIM code) and the XCL data which the computer retrieves from the files.

Another series of programs shapes the data according to information entered through the terminal by the analyst covering such things as time periods to be utilized, lead and lag relationships, and the identification of dependent and independent variables. Other programs then take over and check for data completeness, deletion of any extraneous data, and that the data is structured properly for the analysis programs.

We have obtained national economic forecasts from the Institute of Policy Analysis, University of Toronto and these forecasts also reside on-line for use with the planning and simulation models. A sample output of an economic analysis and projection related to XCL data is contained on Chart 3. While this analysis results from a multiple regression analysis, we are developing more sophisticated models (to be covered in Future Projects section). These print programs can also be used by market research to show market or geographical profiles at a point in time or how they are changing over time in addition to comparison with economic variables.

STATISTICAL MODELS

As we were completing our initial simulation models, it was becoming apparent that a variety of statistical forecast models would significantly enhance the value of the simulation models especially if they were equipped with an override capability to allow the manager to easily add information affecting the outcome not contemplated in statistical analysis. These statistical models were designed to be used for estimating input variables with both the planning and forecasting (12 month rolling outlook) simulation models as well as on a stand alone basis.

Late in 1971, exponential smoothing models were made operational. Three models were included in the general model - seasonal, single and double. Optimization procedures are an integral part of the models and are used to compute demand levels, trends, seasonals, and the alpha weighting factors. A tracking system for both previous actuals and forecasts is included to continually (over time) determine the optimal forecasting model (criteria is the minimum absolute deviation - MAD). In addition to the MAD, a forecastability index is also produced (actual performance ÷ standard deviation). Chart 4 shows a typical output of these models.

The effect of introducing this set

of statistical models was something only short of fantastic. The forecast MAD was decreased by an average of 30% and in some instances by 50%. The other significant effect was a significant reduction in the time to prepare a reliable forecast since now the simulation models could be operated with minimal human intervention. It is significant to point out that if managers massage the statistical forecasts to incorporate special knowledge, such as sales campaigns, inventory constraint, (a man-statistical-simulation interface) the MAD decreases by a further 10 per cent indicating the importance of managerial involvement and his insight into the process. I would point out that the computer based simulations models without the statistical models predicted about as well as the purely manual models (the great benefit of course being time and human effort savings). This is, of course, because the initial simulation models were designed directly from the manual process they were to replace.

For use with the statistical models a series of curve fit programs are available. We have found these in many instances to be excellent (although naive) forecast models for some econometric series. Chart 5 shows one way in which we use them in our planning process.

We are currently developing other statistical forecasting techniques which will be covered in the future projects section.

BUDGET COMPILERS

Once we have a set of simulation results from the XCL operations models we execute a set of budget compiler models that allocate resources to organizational units and programs. The output includes budgets and pro-forma financial statements. Most of the budget model input variables are directly taken from the results of the operating and financial simulation models. A few input variables are controlled separately such as depreciation write-off assumptions and allocation rates for overhead expenses. As in the other simulation models a manual override capability exists for any last minute "management directions" .

THE ROLE OF MODELS IN THE CONTROL FUNCTION

An important role of the above models and their data bases has been the derivation of a series of "control" models. The establishment of a control system is one important component of the planning process that provides a feedback mechanism to assure that objectives/goals are being achieved. Chart 6 shows how the feedback system works.

As actual performance data is obtained, it is incorporated in the forecasting simulation models (through the statistical analysis models) which in turn are a feedback loop to the planning models.

In the control function, a discrepancy between actual observations and previously defined objectives (Plans) is generally the stimulus to trigger management action. The statistical forecasting models (discussed above) utilizing actual performance data, projects trends and in addition do a comparison against plan. These "actual-forecast-plan" relationships are made available either through routine or exception reports. While these control models are passive in the sense that they do not trigger action by themselves to correct perceived deviations, they do provide the manager with the exception information which, when coupled with the simulation models, provides the manager with an adaptive mechanism for positive action. Over the past two years each of our functional areas have made extensive use of the simulation models in this control context.

UPDATE AND REVISIONS OF PLANS

Planning is a continuing process. At various time intervals a plan must be adopted as the basis for objectives and resource allocation at which time it becomes an Operating Plan. However, every plan is based on assumptions, and if the assumptions contain gross defects, then we have an invalid plan which can be worse than no plan at all (especially from the viewpoint of credibility). It may then be necessary within the operating cycle to revise and update the Plan. The models are used in this process which in turn stimulates changes to the long range plans which are then simulated and adjusted for this change in current direction.

THE PLANNING SYSTEM WE ARE USING

This next chart (chart 7) puts together all of the various models we have been discussing above (APL in Business--System at 28 months). As is suggested by the chart we have to a very large degree modularized the models so that they could be used interchangeably or on a stand alone basis. The data base contains operating plans, long range plans, forecasts, current and historic operating results. About 99% of the data is either derived from the models or in the case of actual operating data, is mechanically fed from batch systems. The models to the left of the Data Base are the models discussed in this paper.

The special studies are models that have been developed by the functional areas for use in additional analysis of the data and "one-time-only" projects. 95 percent of these programs are written (in APL) directly by the functional department.

The Reporting System indicated in the upper right hand side is a series of programs to format the data or information in a variety of user defined ways. A unique function within the APL system allows the user to develop some basic reports in just a few seconds. Elaborate reports take longer. This is particularly useful with the simulation models as frequently a unique problem is being examined and the manager or analyst does not want to wade through predetermined general reports to observe the effects of a particular set of simulation outputs. In addition this flexible report writing procedure makes it very easy to change report formats .

One of the chief advantages of this type of an overall system is that it links together the historical and future data, and all of the parts of the business so that the business can at the same time be viewed as an integrated whole or be broken down into its various components. Through the simulation models , it can be readily ascertained how a decision in one functional area will reverberate through the system and affect other functional areas and the firm as a whole. These effects can be simulated and shown in seconds or minutes rather than hours or days for a whole series of alternatives. Through the use of "base cases", variable sensitivity analysis is quickly calculated.

FUTURE PROJECTS

In the same sense that planning is an on-going process so are these models and data bases. We find that solutions to one problem generally result in additional questions or demonstrate a lack of understanding of other processes. For us this means that our models must change to answer new questions and to handle problems and alternatives not previously considered. Little, probably best described this process as an "analysis-education-decision process" where man in working with models updates his intuition as he understands more about the problem and the models assist in this process by interrelating the factors for him (Little 1970).

We process model changes on an on-going basis by changing, discarding and recreating, or at the same time both enlarging some models (to account for added complexities) and adding simplifying models for summary level analysis.

We are also continuously researching new capabilities in order to learn more about our business, its environment, and to assist in developing better ways of doing business.

On Chart 7 the asteriks represent some of the projects with which we are currently involved.

ECONOMIC DATA ANALYSIS

As previously indicated, we already have both historical and forecasted data for several economic series and a broad set of statistical routines for analysis. Currently under development are I/O models to develop industry and geographic forecasts, models to combine both economic and market research data (potentials, penetration growth rates). From this will come (hopefully) information for better resource allocation, identification of growth areas and a measure of the influence of environmental data on our business.

PROBABILISTIC FORECASTING

We are already doing statistical variance analysis as a part of our statistical and feedback models discussed earlier and this provides us with the capability of applying confidence intervals to our statistical forecasts in addition to the point estimates.

We are currently working on the capability of doing risk analysis utilizing "Monte Carlo" simulation methods (AMA 1972). The objective here is to integrate modeling, probability theory and simulation for investment analysis.

SENSITIVITY ANALYSIS

Currently we have the capability of measuring the sensititivity of inputs by changing an input variable, re-simulating and mechanically measuring the change in output variables against a previously defined "base case". This method while it is operational - it is crude. We are enhancing the existing capability with likelihood information for the input variables.

THE IMPLEMENTATION PROCEDURE

We became involved with simulation and models when we were able to demonstrate to ourselves and management that this alternative provided us with better forecast and planning procedures than the manual systems they replaced (more timely and economical as well). Each new application must pass this same test. As was indicated earlier, our initial model cost us under $3000 which included computer costs, systems analysis support and the time of our own staff.

From the models inception, other functional areas were asking us to change input variables and simulate the effects. We were immediately requested to incorporate additional features to enhance and generalize the use of the model for them.

There are several important contributing factors to this happy state. We have already discussed three important ones - usefullness, economy, and timeliness. There are other significant factors:

Interactiveness-the ability to change assumptions and obtain instantaneous results. The terminal and models essentially become an extension of the manager or analyst.

Direct Involvement -There are no third parties or intermediary obstacles to work through (coding sheets, keypunch routines or programmers), just the manager and the terminal.

APL Language -APL is extremely macro oriented and knowledge of only a few commands allows the user considerable "programming" capability. Our Management Sciences group (in the U.S. have found APL to save resources over conventional languages (Fortran, COBOL, BASIC) of from 5-15: 1 (Redwood 1972 and Schengilii 1971).

Timeliness -To implement useful models. The combination of terminals, on-line data bases and APL allowed models to be developed and implemented in the time that it would take to write the specifications in a more conventioanl language on a batch system.

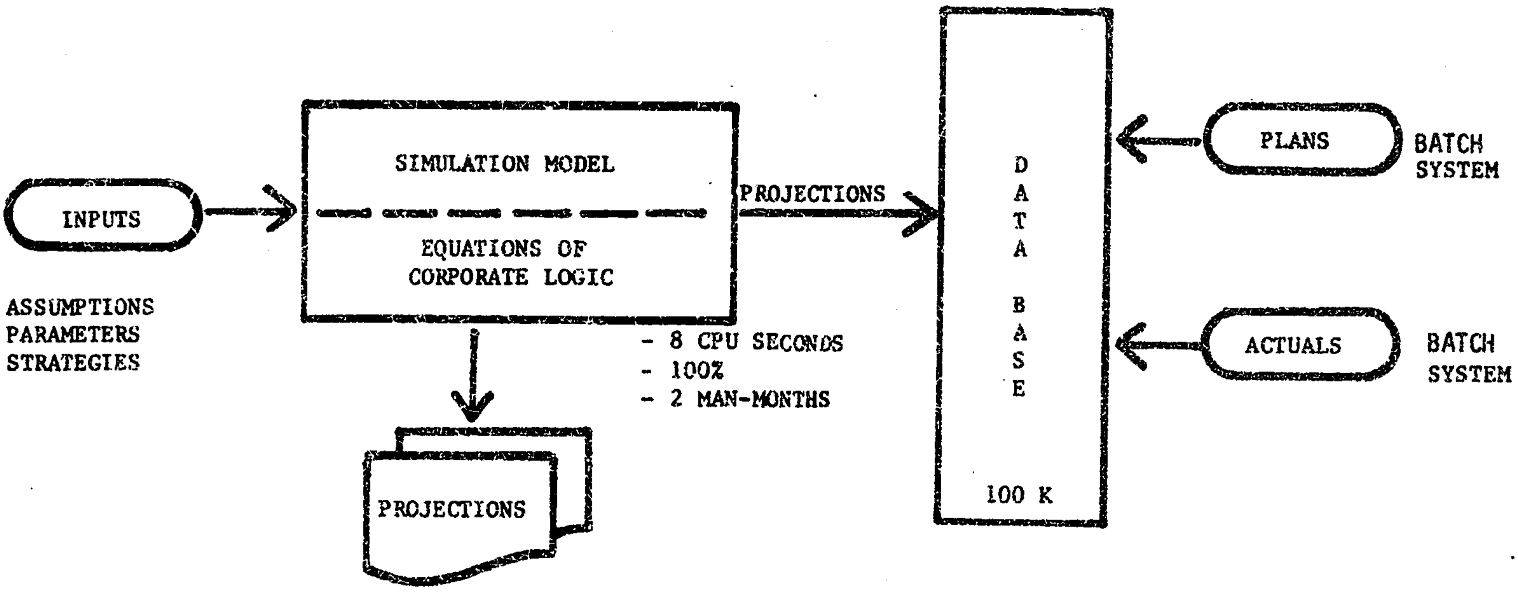
User Involvement -Because of all the above, it put a modelling capability directly in hands of the user - given that he has analytical ability or orientation.

All of the above models have been developed by my staff complemented with one full time consultant from the timesharing vendor and myself - a total of five. None of us have worked full time on modelling, the models have evolved as part of performing our overall responsibility. We estimate our total investment in these systems to be under $30K to date.

We have worked sufficiently long with these kinds of modelling applications to observe their effects on two other important work related aspects resource requirements and job satisfaction. We have saved considerable cost by using computer based models rather than strictly manual approaches. We estimate it would require several magnitudes of manpower increases to achieve the same level of output - a significant increase in efficiency. Each analyst has a low-cost terminal which they have come to rely upon in all phases of analysis and problem solving. The average usage is 50 hours per month per analyst. The range of APL programming capability ranges from poor to very good. However, to operate the models no programming ability is required, but I do require of the analysts, knowledge of how to access files and use the computer in a calculator mode. The use of timeshared models gives each of the analysts greater responsibility and scope than would be possible in a manual environment which has generally resulted in a much greater level of job satisfaction.

In conclusion we have found timeshared simulation models to be imminently successful in our planning processes. We use them as an augment to the manager in assisting him in planning and decision processes by providing the capability of an instantaneous data retriever, analyzer and projector. The models have been adopted in the U.S. as well, further attesting to their usefullness in these processes (Redwood) plus other uses. We have as well adopted the simulation models to our smallest divisions which demonstrates that computer based simulation models are economically viable in small as well as large business.

INITIAL SYSTEM



SIMULATION INPUTS (N30)	SIMULATION OUTPUT (N300)
GROWTH RATES	ORDERS BY PRODUCT LINE
TRADE ASSUMPTIONS	INVENTORIES
INVENTORIES - BEGINNING	PERFORMANCE DATA
COMPENSATION STRATEGIES	RESOURCE REQUIREMENTS
SEASONALITY PATTERNS	PROFORMA FINANCIAL STATEMENTS

CHART 1

ILLUSTRATION

CHART 2

SAMPLE OF AVAILABLE OPTIONS FOR STRUCTURING
ECONOMIC/BUSINESS DATA FOR STATISTICAL ANALYSIS

TERMINAL COMMANDS AND RESPONSES	ACTIVITY DESCRIPTION
FREQUENCY 13 F-CODE? 13 □: QA COMPLETE	CHANGES FREQUENCY OF ECONOMIC SERIES 13 FROM QUARTERLY TO ANNUAL.
LAG←0 1 ¯1 R←1965 1970 MATLAG 13 14 15 COMPLETE	RETRIEVES ECONOMIC SERIES 13, 14 AND 15 FOR THE TIME PERIOD 1965 TO 1970 (INCLUSIVE) WITH SERIES 13 CONCURRENT, SERIES 14 LEADING ONE PERIOD, SERIES 15 LAGGING ONE PERIOD (INDICATED BY VARIABLE LAG).
Q←1 2 3 R←1 PCCHANGE R COMPLETE	CHANGE ROW DATA OF ALL SERIES (INDICATED BY VARIABLE Q) TO A PERCENTAGE CHANGE OF THE PREVIOUS PERIOD.
R←3 ADDTIME R COMPLETE	ADD THE VARIABLE TIME, WITH THE 3RD OBSERVATION AS THE ORIGIN, TO THE MATRIX OF ECONOMIC SERIES.

R (RESULT MATRIX FROM ABOVE ACTIVITIES)

BASE YEAR	GNP	GOVERNMENT EXPENDITURE	GROSS CAPITAL FORMATION	TIME
1966	8.82	11.34	10.27	¯2
1967	8.16	11.19	11.83	¯1
1968	8.62	12.52	7.00	0
1969	9.05	15.51	8.62	1
1970	5.30	¯97.53	10.05	2

THE MATRIX R IS IN A USABLE FORMAT FOR ANY STATISTICAL ANALYSIS.

CHART 2

CHART 3

ILLUSTRATION

MULTIPLE REGRESSION OF FIRM DATA WITH ECONOMIC SERIES

ANNUAL *STARTYEAR* 1959 *PREDICT ALL* *CLIM* 0 *SIGNIFICANCE* 1 *PITEST* 3	INPUT VARIABLES

DV REGRESS IV - PROGRAM EXECUTION

MULTIPLE REGRESSION OF SALES AGAINST GNP AND CORPORATE PROFITS

COEFFICIENTS		*ST. ERROR*	*T VALUES*	*VARIABLES*		
A	-84.659			*DV*	1	*SALES*
B1	0.049	0.001	52.083	*IV*	40012	*GNP*
B2	-0.143	0.011	-12.573	*IV*	30867	*CORPORATE PROFITS*

STATISTICS:

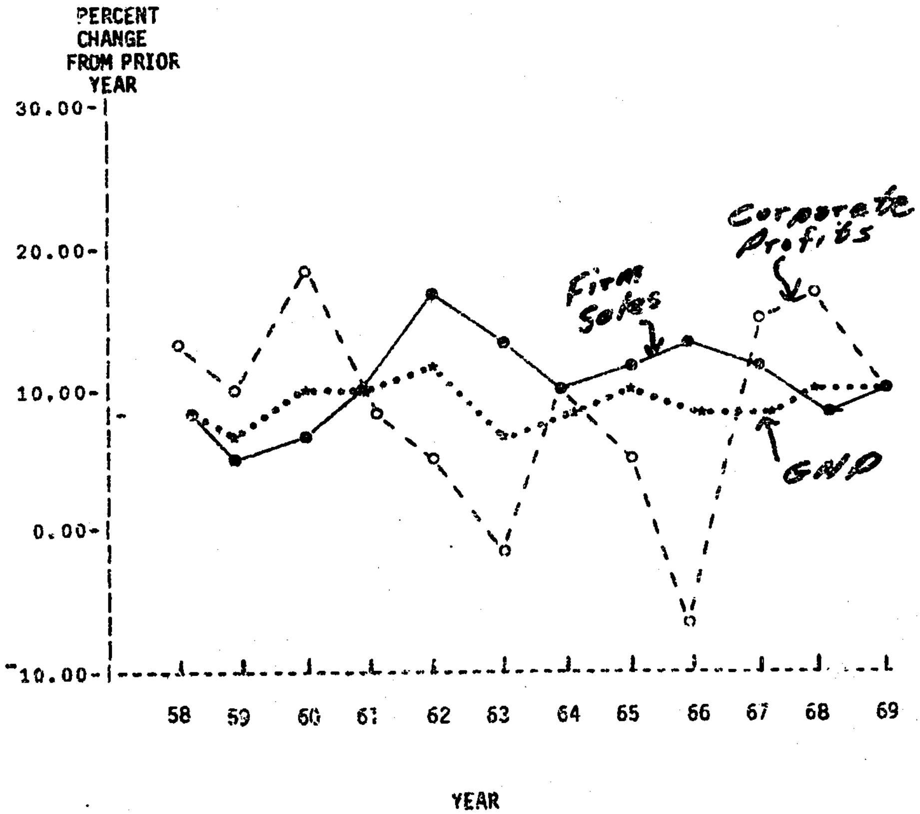
R2	0.999	*R*	1.000	*K*	0.025
R2	0.999	*R*	1.000	*K*	0.027
SE	15.006	*SE*	15.916	*DW*	2.180
F	5554.629	*DF*	2.000	*DF*	7.000

PREDICTIONS:

			RESIDUAL	
	ACTUAL	*FORECAST*	*AMOUNT*	*PERCENT*
1959	1233.0	1242.6	-9.6	-0.8
1960	1344.0	1326.4	17.6	1.3
1961	1408.0	1411.1	-3.1	-0.2
1962	1497.0	1484.0	13.0	0.9
1963	1645.0	1658.0	-13.0	-0.8
1964	1909.0	1928.4	-19.4	-1.0
1965	2149.0	2158.7	-9.7	-0.4
1966	2368.0	2340.0	28.0	1.2
1967	2633.0	2632.0	1.0	0.0
1968	2986.0	2990.9	-4.9	-0.2
AVERAGE (ABOVE)			11.9	0.7
OVERALL AVERAGE			11.9	0.7

PREDICTION INTERVAL TEST

1969	3354.0	3201.5	152.5	4.8
1970	3650.0	3468.3	181.7	5.2
1971	4035.0	3802.6	232.4	6.1
AVERAGE (ABOVE)			188.9	5.4



NOTE: ACTUAL & FORECAST DATA ARE HYPOTHETICAL DATA

AN ILLUSTRATION

FORECASTING WITH EXPONENTIAL SMOOTHING

MINIMIZING ESTIMATES-WEIGHTS BY P/L
NO/MAN

MODEL	Da	Ta	Sa	DEMAND	TREND	MAD
1	.2	.5	.5	68	-2.00	13.8
2	.2	.2		79	-3.00	11.3
3	.1			71	69.00	11.5

ORDERS
JUL OUTLOOK

	PERFORMANCE							OUTLOOK			ACTUAL-OUTLOOK				
		JUN			YTD										
MODEL	PI	ACT	OUT	MAD	ACT	OUT	MAD	JUL	AUG	SEP	Q1	Q2	Q3	Q4	FYPC
1	2.74	144	155	11	888	883	42	146	152	162	419	469	460	334	121.36
2*	3.89	144	153	9	888	877	30	148	147	146	419	469	441	334	119.99
3	3.70	144	173	29	888	911	35	150	149	148	419	469	447	334	120.42

MODEL--1=SEASONAL
2=SINGLE
3=CABLE
*=OPTIMUM

α = OPTIMUM ALPHA (TIME) WEIGHTING FACTOR
D = DEMAND COMPONENT
T = TREND COMPONENT
S = SEASONALITY COMPONENT
MAD = MEAN ABSOLUTE DEVIATION

CHART 4

ILLUSTRATION

USE OF CURVE FIT PROGRAMS TO DEVELOP DATA FOR ECONOMIC FORECAST

GPP CURVEFIT TIME

GROSS PROVINCIAL PRODUCT FOR ONTARIO (1957 - 1969)

		LINEAR		PARABOLA		CUBIC		QUARTIC		EXPONENTIAL	
	ACTUAL	FORECAST	DELTA	FORECAST	DELTA	FORECAST	DELTA	FORECAST	DELTA	FORECAST	DELTA
1957	13784	11134	23.6	13846	-0.5	13973	-1.4	13776	0.1	12566	9.7
1958	14060	12701	10.7	14057	0.0	14057	0.0	14189	-0.9	13544	3.8
1959	14829	14268	3.9	14515	2.2	14446	2.7	14637	1.3	14599	1.6
1960	15300	15836	-3.4	15219	0.5	15127	1.1	15234	0.4	15735	-2.8
1961	16010	17403	-8.0	16170	-1.0	16089	-0.5	16067	-0.4	16960	-5.6
1962	17016	18970	-10.3	17367	-2.0	[illegible]	-1.8	17194	-1.0	18280	-6.9
1963	18699	20537	-9.0	18811	-0.6	18811	-0.6	18644	0.3	19703	-5.1
1964	20303	22104	-8.1	20501	-1.0	20548	-1.2	20420	-0.6	21237	-4.4
1965	22477	23671	-5.0	22439	0.2	22519	-0.2	22497	-0.1	22890	-1.8
1966	25342	25239	0.4	24622	2.9	24714	2.5	24822	2.1	24672	2.7
1967	27103	26806	1.1	27052	0.2	27122	-0.1	27313	-0.8	26592	1.9
1968	29566	28373	4.2	29729	-0.5	29729	-0.5	29861	-1.0	28662	3.2
1969	32493	29940	8.5	32653	-0.5	32526	-0.1	32329	0.5	30893	5.2
AVG ERROR			7.4		0.9		1.0		0.7		4.2

COEFFICIENTS	A	B	C	D	E
LINEAR	11134.0	1567.2			
PARABOLA	13846.4	87.7	123.3		
CUBIC	13973.3	-71.9	157.9	-1.9	
QUARTIC	13776.2	439.9	-52.0	26.0	-1.2
EXPONENTIAL	4.1	NS			

ORIGIN: *OBSERVATION - 1*

NS=NOT SIGNIFICANT

CHART 5

ROLE OF MODELS IN THE CONTROL FUNCTION

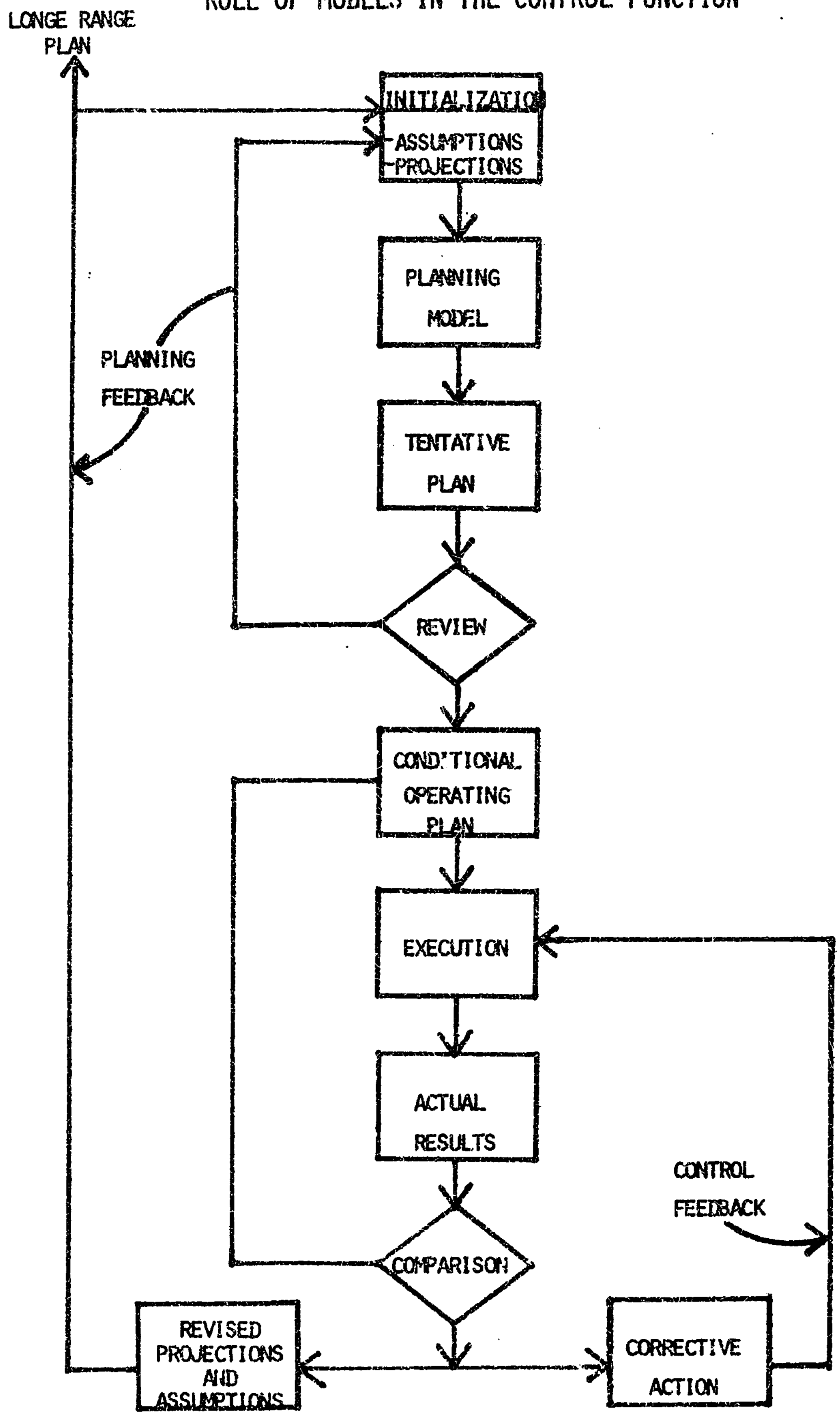
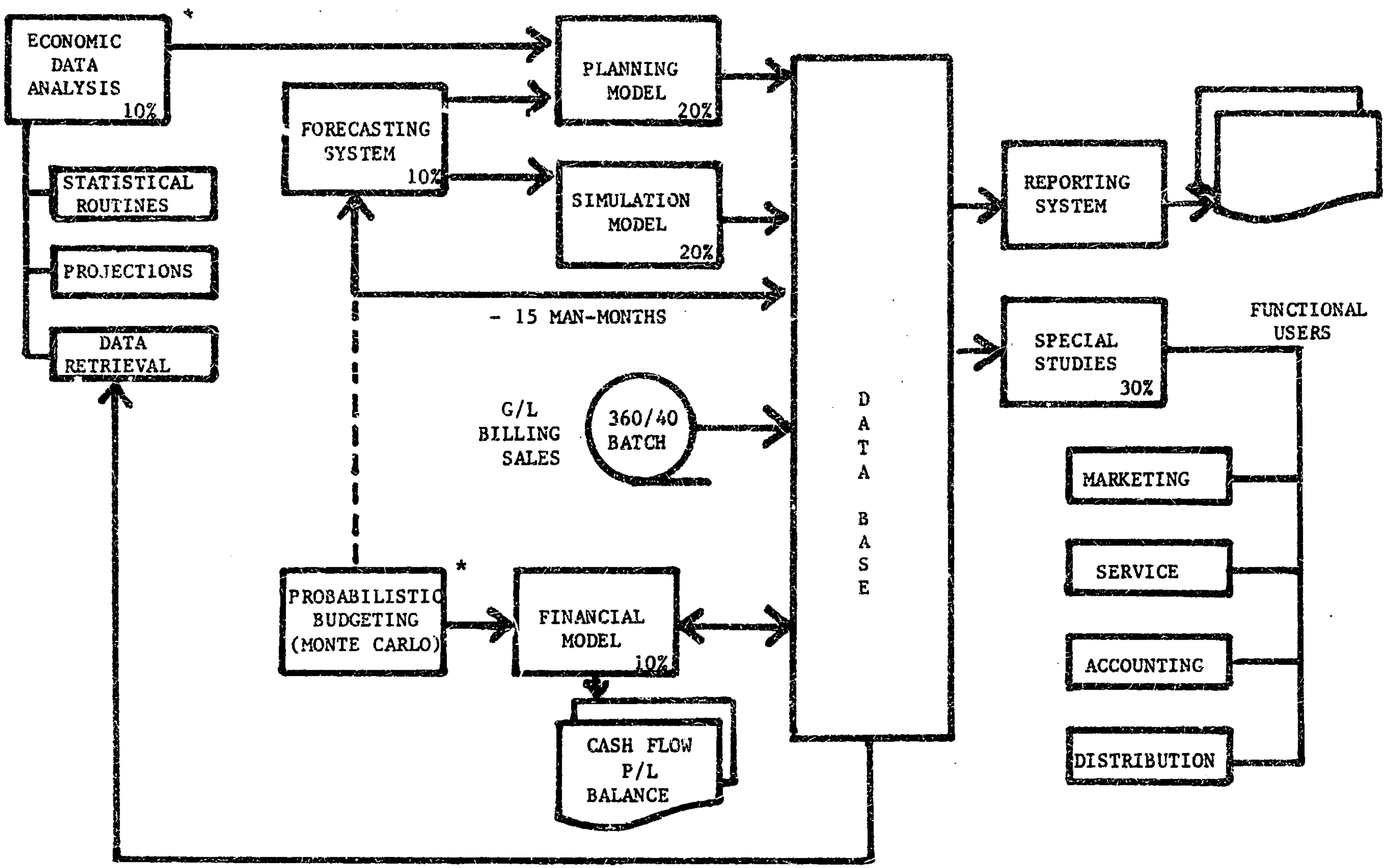


CHART 6

SYSTEM AT 28 MONTHS



* UNDER DEVELOPMENT

CHART 7

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