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Computer models are coming into greater use in large companies today. The question is: are they coming into great enough use? Or is the "black box" phobia still preventing their full utilization. Here's the case history of one successful application.

COMPUTER MODELS: 'BLACK BOX' OR MANAGEMENT-ORIENTED?

by Michael C. Luecke
CIBA-GEIGY

To meet the challenge of an increasingly complex business environment, modern companies are developing computer models in growing numbers. This recent trend has been inevitable for two reasons: (1) The constantly improving methods of management science, with greater reliance on sophisticated quantitative techniques; and (2) The rapidly increasing speed and capacity of large computers which make the new methods feasible. Consequently, models are finding new applications in nearly every facet of business in which management decisions are based primarily upon quantifiable or generated data —i.e., where rational analysis can replace intuition.

New probability techniques like risk analysis, for example, permit management to use simulation models which automatically take the consequences of risk—or uncertainty—into account for various uncertain input data. Older methods like linear programing are enjoying a resurgence of popularity outside the traditional areas of application such as production; "optimization" models are now feasible for solving a broad spectrum of business problems. Sensitivity analysis, which provides management with quick answers to critical "What if?" questions (e.g., optimistic and pessimistic variations of key input parameters) is often incorporated in simulation models. A time-shared computer terminal is commonly used to achieve an "interaction" between manager and computer in sensitivity analysis. Large "on-line" corporate models are also emerging in greater numbers.

Why, then, do so many "good" computer models meet a premature death—on a shelf—through lack of use or interest? Too often the answer lies not with the technical design of the model itself but with the "black box" image the model gives to the decision maker. Shelving a technically sound model —or not using it to fullest advantage—is particularly tragic when one considers the important role such models can play in the decision-making process, not to mention the considerable time and expense normally required to develop these models.

The purpose of this article is to: (1) Shed some light on the common pitfalls which prevent most companies from getting the payoff they should from computer models; (2) Present some guidelines on how to develop a successful model; and (3) Illustrate the guidelines with a case study.

Why models fail

If a manager cannot understand a computer model, naturally he will not have full confidence in it. The obvious result: the manager will be reluctant to use the model for important decision-making. It is crucial, therefore, that future models shrug off the "black box" image so that they will be more readily—even enthusiastically—accepted *and used* by management.

Is it any wonder that management is slow to embrace any decision-making tool which is often delivered to them with one or more of the following characteristics:

- Explanations are in technical jargon and computerese.
- Printouts appear in cluttered, cryptic format difficult to interpret.
- Only a specialist can use the model.
- Input data must be translated in terms of the model's abstract or inflexible input format.
- Modifications are difficult when changes are necessary.
- Documentation is poor—no single person "understands" the entire model.
- Fictitious or unrealistic input data were used during the test phase.
- The model is more sophisticated (and complicated) than necessary.

Despite the technical competence of the model builders, most models being developed contain several of the negative characteristics listed above, at least to some degree.[1] In other words, these models are not management oriented. But whose fault is the "black box" image—the model builders' or management's? The blame can usually be shared by both.

Guidelines for the model builder

Although usually a specialist, the model builder can easily overcome most of the major problems by following these guidelines:

Jargon—Ordinary English can replace much of the technical jargon to convey the basic ideas to management. For instance, why should management be less impressed by the term "external factors" than "exogenous variables"?

Printout—A model is often judged by the appearance of its printout. Clear, well-organized output "report" formats—without the cryptic abbreviations—require very little additional computer coding. Computer graphics are also easy to program if a plotter is available. The payoff: the printout is suitable for presentation, and nearly any manager in the company can interpret the results!

Use—The model should always be programed with the user in mind. The user instruction manual should be comprehensive, including examples, so that a nontechnical person can easily use the model. User seminars may be given to supplement training. Depending upon the model's application, it can be cataloged on disk or tape in the computer library, accessible to numerous authorized users.

Input—The model's input data should be in a flexible form which is familiar to the user. For example, if sales volume is always expressed in pounds companywide, why use tons for the model input?

Modifications—The model should always be programed in building blocks, or "modules," using submodels and subroutines as much as possible. The modular approach permits enormous advantages in flexibility and also cuts total development time. In addition, any data subject to change should be programed as input to the model. As an extreme (but actual) example, one large model did not handle the "date" as input—i.e., the model had to be "re-programed" each new day the model was run! Finally, a generalized model is much more versatile (and useful) than a model developed for one narrow application.

Documentation — The computer program should be well documented *as it is developed*, and kept up-to-date as revisions and personnel turnovers occur.

Testing—Depending on the type

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[1] Schrieber, Albert N., *Corporate Simulation Models*, Seattle, University of Washington, 1970.

of model, it should be tested using "live" input data, if possible. Otherwise, validate the model with realistic test data submitted by management.

Sophistication—Keep the model as basic and simple as possible. Unnecessary sophistication, however impressive, will only hinder development and may cause problems later.

Remember that the finished product, while meeting management's technical requirements, must nevertheless be "sold" to management. Some of the most vital elements of this "marketing" job include: (1) correct "packaging" (e.g., easy to understand printouts and documentation); and (2) good "promotion" (e.g., nontechnical, dynamic presentation). In short, deliver the model with management's perspective clearly in mind.

Guidelines for management

What steps can management take to ensure that it gets a useful product from the model builders? First, management should *actively* participate in the model's design phase, giving the model builders a clear definition of its requirements. Management participation is especially important if the model is a "topdown" type; interaction and feedback are essential. Management should never delegate "carte blanche" responsibility for the model's overall design to a specialist. Second, management should try to keep informed on the new quantitative methods, learning at least the basic concepts and terminology. This learning process is not just going "halfway" with the specialists —it is a necessary part of executive development. Finally, management must realize that models, particularly corporate models, usually require several man-years by highly qualified (and expensive) specialists to develop and implement. Total development cost can easily exceed $100,000 for a single model —and this is precisely the reason that the end result should not be a "black box" on a shelf.

Shortly after its merger in 1970, CIBA-GEIGY's Basel, Switzerland, headquarters began an improved formal planning program for its extensive multinational operations. As a part of this program, management recognized the great need for a tailormade, sophisticated capital investment simulation model to assist in project evaluation, capital budgeting, and investment strategy decisions. Both risk analysis and sensitivity analysis were desired as methods; both internal rate of return (DCF) and Net Present Value were preferred as the primary yardsticks of financial performance. Since capital investment decision making was decentralized, the model would need to be universal in scope for implementation and use by subsidiaries around the world. Although standard investment procedures had been established, the model would have to be versatile enough to accommodate the various local tax laws, depreciation methods, investment grants, etc. In addition, management wanted a model that would be easy to use and interpret—i.e., no "black box."

Designing the model

The author was assigned the challenging task of building the model to management's requirements within one year's time. It was decided very early in the design stage to follow the "modular" approach so that four different versions of the basic model could be easily assembled and implemented as "packages," depending on the user's application and/or hardware capability:

- Sensitivity model, using timeshared terminal
- Sensitivity model, using printer and computer graphics
- Risk model, with computer graphics
- Risk model, without computer graphics.

Due to its modular design, individual subroutines of the different versions could be programed and

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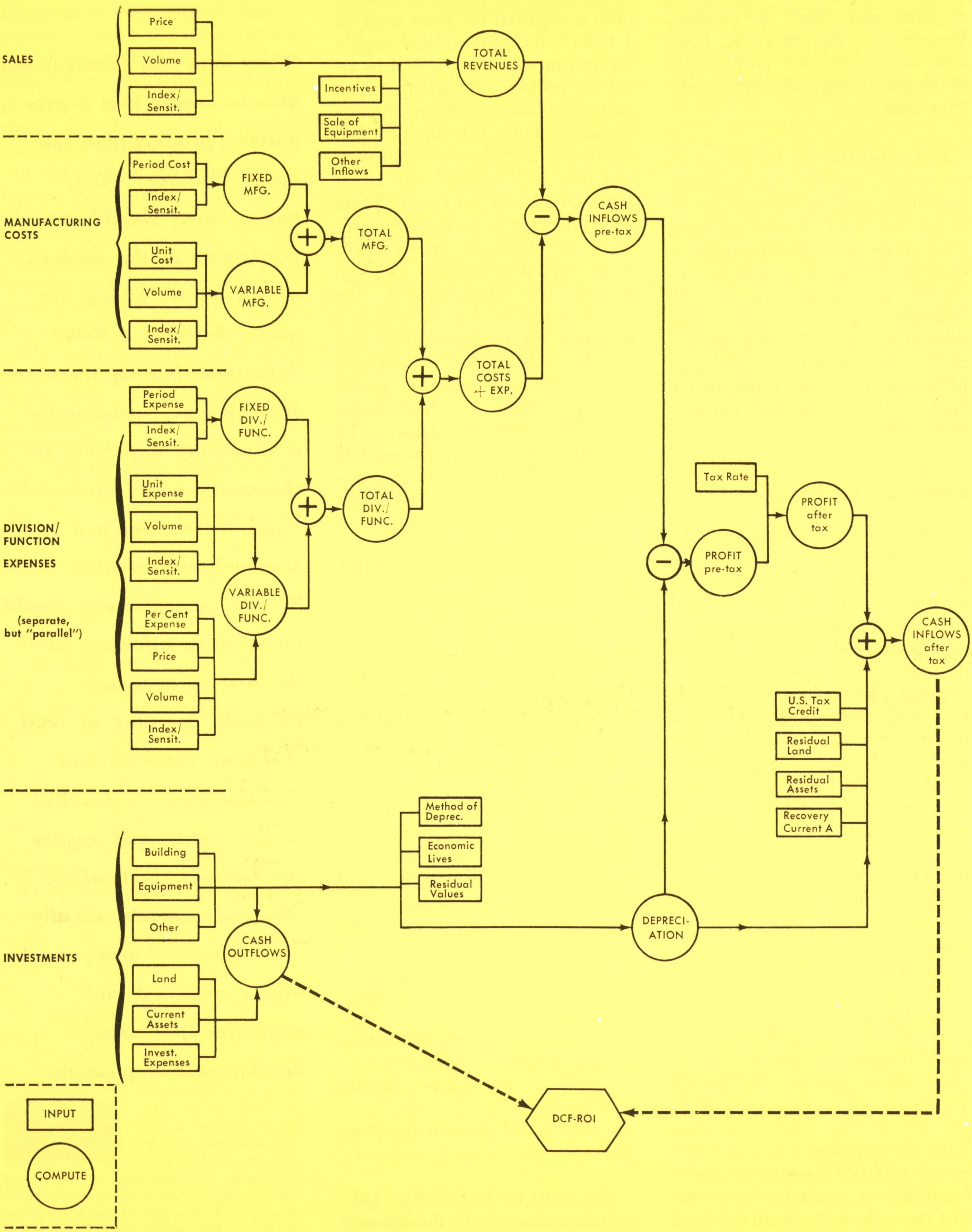
EXHIBIT I

GENERAL FLOW CHART OF MODEL



debugged independently, speeding the total development time. In fact, the sensitivity models were already operational while the final subroutines of risk analysis were still being debugged.

What the model can do

It was decided to make the model as flexible and general as possible to ensure maximum use. Some of the model's major capabilities include:

- Acceptance of nearly any type or size of investment project.
- Flexible handling of a wide variety of input data (up to 75 different types of variables).
- The various input data can be input on a quarterly, yearly, or constant basis over the life of the investment.
- Options include: five economic indexes (e.g., inflation); three methods of depreciation; two tax methods.
- Up to 67 key input parameters can be varied singly or in any combination in sensitivity analysis.
- The eight most "risky" input parameters can assume a wide

EXHIBIT 2

OUTPUT RESULTS FROM SINGLE SENSITIVITY RUN

CIBA-GEIGY PRIVATE DATA

CAPITAL INVESTMENT SIMULATION MODEL

OUTPUT DATA

PROJECT: DEMONSTRATION RUN
DATE: JULY 4, 1971
CURRENCY: LIRA

SUMMARY OF PROFITABILITY ANALYSIS	RUN NO. 0
INTERNAL RATE OF RETURN ON INVESTMENT (AFTER TAXES)	16%
NET PRESENT VALUE (000) (AFTER TAX) AT COST OF CAPITAL OF 10.00%	3368.
PROFITABILITY INDEX (AFTER TAX)	152.
PAY-BACK TIME & DATE (AFTER TAX) AT COST OF CAPITAL OF 10.00%	27 QUARTERS/1979, QUARTER 3
PAY-BACK TIME & DATE (AFTER TAX) UNDISCOUNTED	21 QUARTERS/1978, QUARTER 1
MAXIMUM NET CUMULATIVE CASH OUTFLOW (000) & DATE (AFTER-TAX, UNDISCOUNT.)	−6248./1973, QUARTER 4
BREAKEVEN DATE (TOTAL REVENUES = TOTAL EXPENSES) (BEFORE-TAX, ST.-LINE)	1974, QUARTER 1
RETURN ON SALES (BEFORE TAX, ST.-LINE)	53.5%

CIBA-GEIGY PRIVATE DATA

CAPITAL INVESTMENT SIMULATION MODEL

OUTPUT DATA

PROJECT: DEMONSTRATION RUN
DATE: JULY 4, 1971
CURRENCY: LIRA

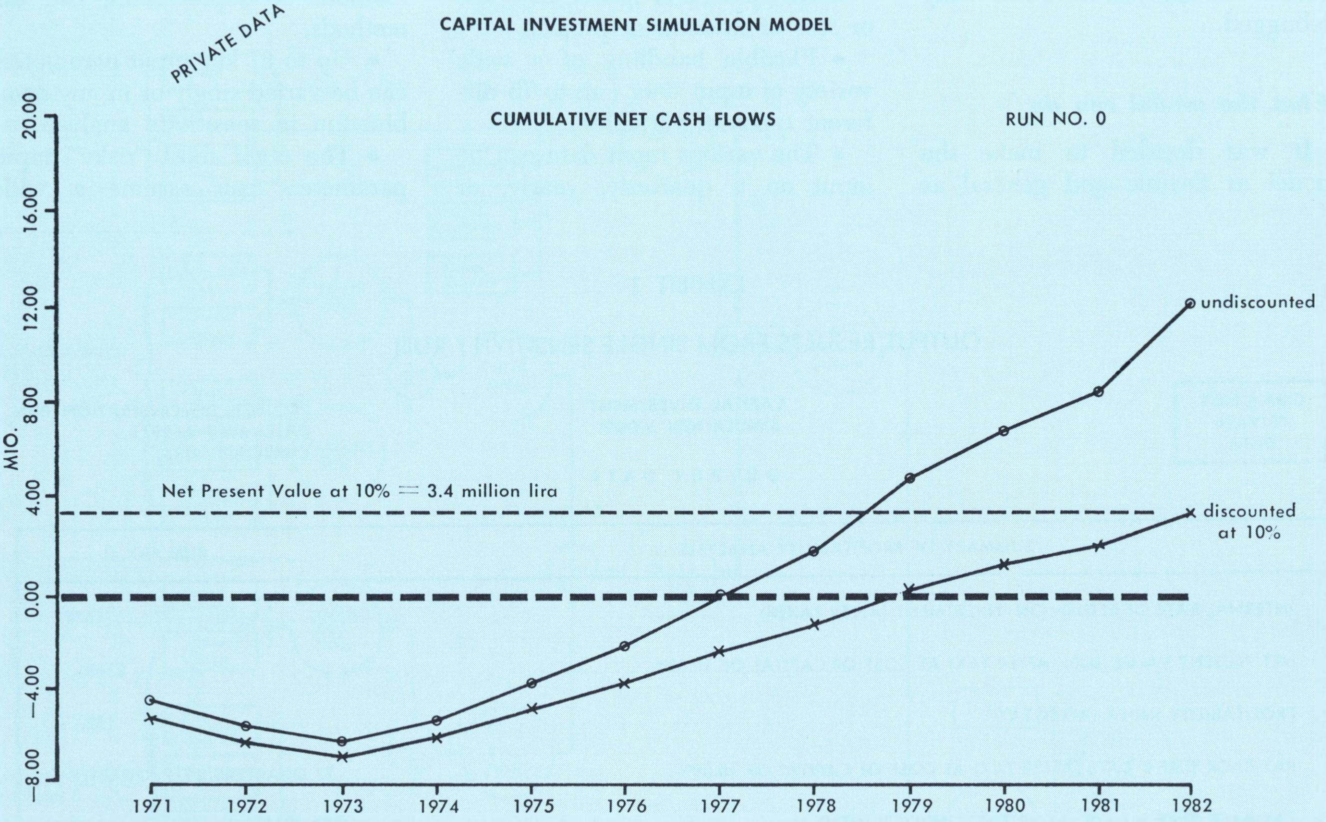
ANNUAL PERFORMANCE — RUN NO. 0

YEAR	TOTAL REVENUES (000)	TOTAL EXPENSES (000)	PROFIT (PRE-TAX)(1) (000)	NET CASH FLOWS (2) (000) DISCOUNTED: AT 16.%	AT 10.0%	AT 0%
1971	0.	700.	−700.	−5620.	−5189.	−4590.
1972	200.	1072.	−872.	−1038.	−1023.	−1000.
1973	983.	1585.	−602.	−597.	−620.	−658.
1974	3039.	1828.	1211.	739.	816.	951.
1975	4040.	2001.	2040.	1035.	1216.	1562.
1976	3974.	1794.	2180.	870.	1091.	1548.
1977	4002.	1368.	2634.	986.	1319.	2068.
1978	4039.	1589.	2450.	766.	1094.	1896.
1979	5553.	1343.	4210.	1070.	1631.	3123.
1980	3788.	1202.	2587.	575.	936.	1980.
1981	3029.	881.	2149.	411.	714.	1669.
1982	1325.	442.	883.	732.	1383.	3682.
TOTAL	33973.	15803.	18170.	−73.	3368.	12229.

(1) USING STRAIGHT-LINE DEPRECIATION
(2) USING DECLINING-BAL (AFTER-TAX)

EXHIBIT 3

COMPUTER GRAPHICS FOR SENSITIVITY RUN



range of alternative values, with corresponding probability weights in risk analysis. (The model is flexible enough to treat these parameters as mutually independent or interdependent in the Monte Carlo simulation.)

• Sensitivity and risk analysis can be used together to test "shifts" in critical input parameters.

A general flow chart of the basic model is shown in Exhibit 1 on page 20.

Using the model

Management can submit all relevant input data associated with an investment project by filling in a specially designed questionnaire. This questionnaire is "keyed" to card layout sheets for easy keypunching of input data. The model is programed to automatically print out all the input data involved, in labeled format, along with the final results. In other words, management knows *exactly* what input data the computer processed, lending greater credibility to the results.

A user instruction manual was written in step-by-step fashion and filled with examples. Although sophisticated, the model is simple to use and interpret—even a secretary can run the model and get the correct result. User seminars have proved helpful. The model is now being implemented worldwide.

The basic output results from a *single* sensitivity run of a typical investment project are illustrated in Exhibit 2 on page 21. The "report" format is suitable for presentation and is extremely easy to interpret. The various yardsticks of performance are printed out in the top table; a "pro forma" income statement with net cash flows from the entire project is printed out in the lower table.

A computer-generated graph of the cumulative net cash flows over the life of the investment is shown in Exhibit 3 above for the single sensitivity run. The cumulative flows are plotted in two curves: undiscounted and discounted at cost of capital. The dramatic effect of a 10 per cent rate over an 11-year horizon is illustrated.

A graphical summary of a *complete set* of sensitivity runs is displayed in Exhibit 4 on page 23. This example shows the results of a "classical" sensitivity analysis—i.e., only *one* input variable is changed for each run. CIBA-GEIGY executives favor this graph due to its simplicity in identifying the critical input variables in the sensitivity analysis. Those variables whose curves are most horizontal or "flat" are most sensitive to change; conversely, those variables whose curves are most vertical or "steep" are least sensitive to change. The non-linear relationships inherent in sensitivity analysis are clearly evident.

The basic output results of risk analysis are depicted in Exhibit 5 on page 24. It is interesting to note that this sample risk analysis and the sample sensitivity analysis shown previously were generated from *the same investment project.* The great advantage of risk analysis in capital investment studies is apparent. In risk analysis, the computer makes hundreds of different DCF calculations (iterations), each based on a random selection of the eight "risky" input variables—according to their probabilities, or chances, of occurrence. (The selection process is like spinning a roulette wheel—i.e., Monte Carlo simulation.) An internal rate of return on investment(DCF-ROI) and net present value (not shown) are computed for each random *combination,* or set, of input data involved. The output result of risk analysis is a probability distribution ("Risk Profile") of all the possible outcomes (i.e., return-on-investment results). The cumulative "Risk Profile" (graph, upper left, page 24) gives management ***a clear picture of the risks*** associated with each possible return on investment (i.e., the chance of exceeding a given return). The ordinary "Risk Profile" (graph, upper right, page 24) is the probability distribution and the basis for the cumulative "Risk Profile." This distribution is approximately normal or bell shaped in this case.

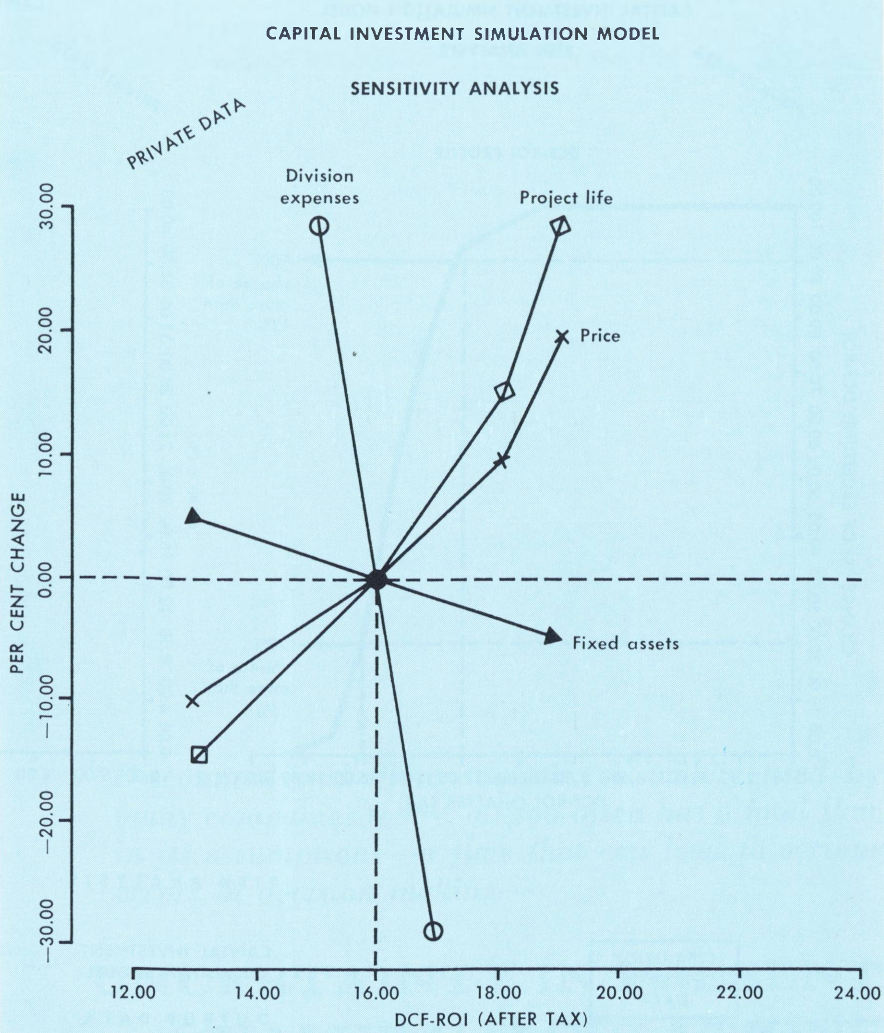
The table shown in the lower half of Exhibit 5 contains the various statistical calculations of the risk analysis results. In this case, 500 iterations were performed, and the risk profiles shown reflect a graphical summary of the 500 different return-on-investment calculations. The main statistical measures are: (1) the average value ("Expected Value") of the 500 results; and (2) the statistical variation ("Standard Deviation") of the 500 results. Basically, the greater the standard deviation, the greater the degree of risk associated with the project.

Sensitivity analysis, on the other hand, does not explicitly take risk into account and can only give management a rough idea of "optimistic" and "pessimistic" outcomes. For high-risk investment projects, risk analysis will often give the decision maker a dramatically improved picture of the odds of making a high return—or a low return. Another benefit of risk-based decision making is that management can rank numerous alternative investment proposals according to *degree of risk* as well as return on investment.[2]

There is no doubt that computer models will be developed in increasing numbers, and that a manager is more than willing to use a model as a decision-making tool—if he has confidence in the model and can understand it. Otherwise, there is a good chance that the model will eventually become a "black box" on a shelf. It has been demonstrated that a management-oriented model can be developed by following a few common-sense guidelines. The model builder is not solely responsible for developing a successful model—management must play an active role. The end result will be a model which is not only technically sound, but effectively used.

EXHIBIT 4

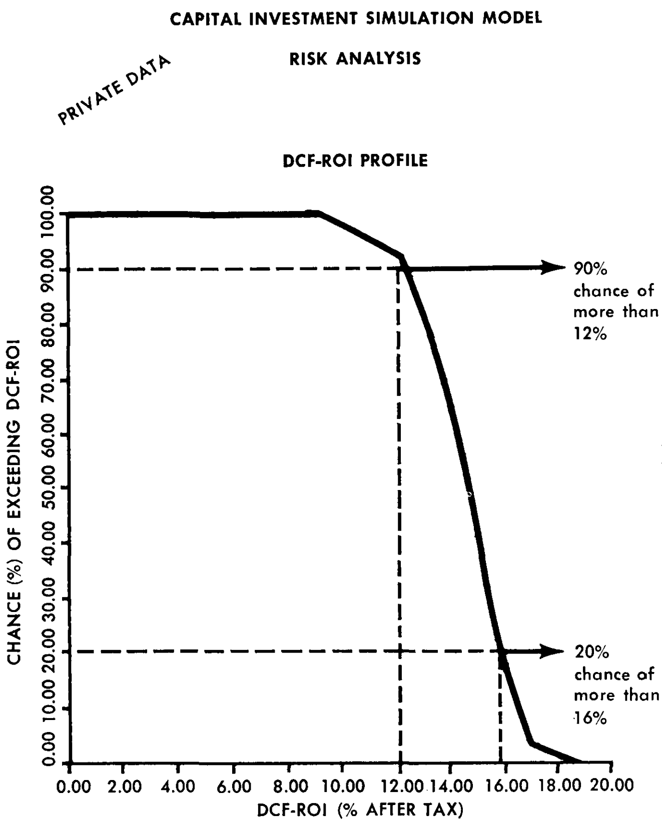
GRAPHICAL SUMMARY FOR SET OF SENSITIVITY RUNS

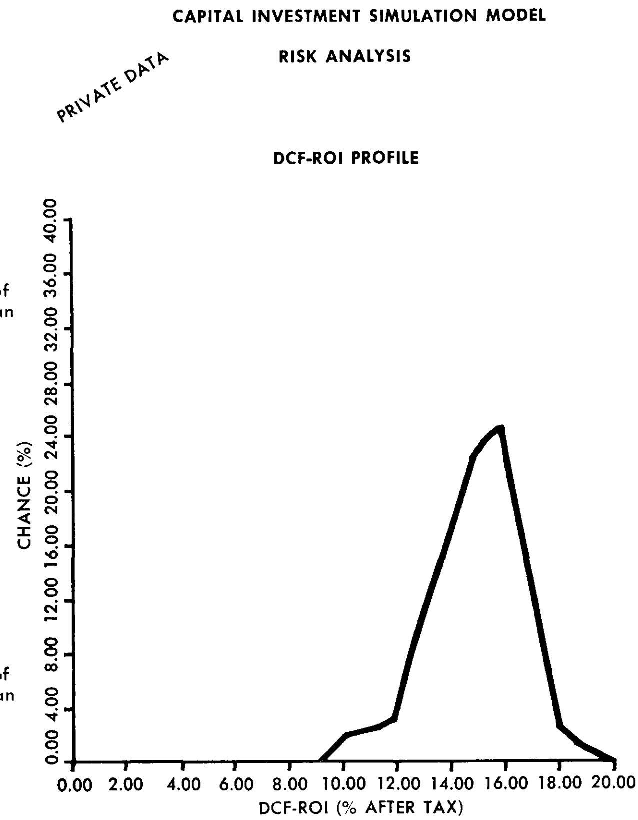


[2] This "Efficiency Frontier" concept is developed by David Hertz in "Investment Policies That Pay Off," *Harvard Business Review,* Jan.-Feb., 1968. For a more detailed explanation of risk analysis in general, also refer to this article as well as the earlier article by Hertz, "Risk Analysis in Capital Investment," *Harvard Business Review,* Jan.-Feb., 1964.

EXHIBIT 5

COMPLETE RISK ANALYSIS RESULTS





RISK ANALYSIS

CIBA-GEIGY PRIVATE DATA

CAPITAL INVESTMENT SIMULATION MODEL

OUTPUT DATA

PROJECT: DEMONSTRATION RUN
DATE: JULY 4, 1971
CURRENCY: LIRA

INTERNAL RATE OF RETURN ON INVESTMENT (% AFTER TAXES)		
MOST PROBABLE VALUE		16. (1)
AVERAGE VALUE		15.5(2)
STANDARD DEVIATION (SIGMA)	11.2%/	1.7(3)
95% CONFIDENCE LIMITS	15.3-	15.6(4)
SAMPLE SIZE, THIS RUN		500 (5)
RESULT WITHOUT RISK ANALYSIS		16. (6)

(1) MODE.

(2) ARITHMETIC MEAN ('EXPECTED VALUE' OF THIS ANALYSIS).

(3) ⅔ OF ALL VALUES FALL WITHIN + & — ONE SIGMA OF THE AVERAGE, IF THE DISTRIBUTION IS NORMAL (GAUSSIAN).

(4) 95% SURE THAT 'TRUE' AVERAGE VALUE LIES WITHIN THESE LIMITS, IF DISTRIBUTION OF MEANS IS NORMAL (GAUSSIAN).

(5) TOTAL NO. OF ITERATIONS BY COMPUTER.

(6) WITH ALL INPUT DATA FIXED (I.E., DETERMINISTIC RATHER THAN PROBABILISTIC ANALYSIS).