5-1970

Uncertainty in Capital Investment Analysis

Kenneth Krock

UNCERTAINTY IN CAPITAL INVESTMENT ANALYSIS

by

Kenneth W. Krock

B. S. in Industrial Management, The Ohio State University 1966

An Independent Study
Submitted to the Faculty
of the
University of North Dakota
in partial fulfillment of the requirements
for the Degree of
Master of Science

Minot Air Force Base, North Dakota

May
1970

This Independent Study submitted by Kenneth W. Krock in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

Advisor

Resident Administrator

Director, Special Air Force Programs

Permission

Title UNCERTAINTY IN CAPITAL INVESTMENT ANALYSIS

Department College of Business and Public Administration

Degree Master of Science

In presenting this independent study in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my independent study work or, in his absence, by the Chairman of the Department or the Dean of the College in which my independent study work was done. It is understood that any copying or publication or other use of this independent study or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my independent study.

Signature Kenneth W. Krock

Date 29 May 1970

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Little attention is given to uncertainty in capital investment models typically used in business. Contributing to this deficiency has been the fact that managers have only limited information concerning how to consider uncertainty in analyzing investments. This report is an investigation of both popular techniques and newer techniques which do incorporate uncertainty in capital investment analyses. Traditional capital budgeting methods, including some commonly recommended in business textbooks, are evaluated in this study, and criticized for their avoidance of the risk element. Library research provides the basis for the descriptions and evaluations of various analysis methods which have been developed to deal specifically with uncertainty. Special emphasis is placed on the use of probability analysis, computer simulation, and utility theory in capital budgeting. The advantages and limitations of these and other concepts are demonstrated with examples throughout the paper. This report concludes that probability distributions are more meaningful than traditional best estimates in considering uncertainty. Monte Carlo simulations are concluded to be generally very accurate and economical devices for analyzing uncertain ventures. While the merits of using expected utility values are realized in this study, the complexity of utility theory prevents it from being recommended as a practical tool for management. However, the utility concept appears to offer the greatest potential for further research in the area of uncertainty in capital investment analyses.

CHAPTER I

INTRODUCTION

Purpose and Scope of Study

Little attention is given to uncertainty in most commonly accepted capital investment models. In any business, risk[1] is an especially important factor since investment decisions must be based on predicted returns in an indefinite future. In many cases a higher risk investment yields a higher rate of return, yet little consideration is given to uncertainty in techniques typically used for investment decision making.

It is probable that managers' expectations have not been fully realized due to the fact that uncertainty has not been fully considered. At the present time, managers have only limited information concerning how to consider risk in analyzing investment alternatives. Probably many managers are not aware of the various techniques which do incorporate uncertainty in capital investment analysis.

In this chapter the need to consider uncertainty in capital investment analysis is examined. Investment analysis methods typically used in business are evaluated to determine

---

[1] No attempt is made in this report to distinguish between uncertainty and risk. The terms are used interchangeably to describe those situations in which the decision maker has at least some idea about the probability of future events.

both their merits and shortcomings. This chapter explains that even those techniques described in some textbooks as "theoretically correct" fail to consider the insecurity of future operations.

The second chapter of this study describes how the traditional methods of capital investment analysis can be adjusted to allow for risk. The discussion includes such concepts as conservative forecasts, inflated cut off rates, and risk-adjusted rates of return. While these methods do at least recognize uncertainty, they still have some limitations. These limitations are pointed out. Steps that can be taken to change or reduce risk are also discussed in Chapter II.

Various techniques which describe uncertain investments with probability distributions are explained in Chapter III. Among these are expected value calculations and Monte Carlo simulations. The feasibility of small firms using computers and the advantages of including variance estimations in expected values are also examined in Chapter III.

Chapter IV investigates the influence of individual preference on investment decision making. Utility theory is introduced as a tool permitting an analyst to make decisions consistent with his manager's attitude toward risk. The practicality of the utility concept is examined from various points of view.

The findings of this study are summarized in Chapter V. Realizing the impact of uncertainty on capital investment, analysis is emphasized in a review of capital budgeting models available to management. The author's recommendations and conclusions are enumerated in this fifth and final chapter.

Shortcomings of Typical Procedures

Because long term investments in plants or equipment require large capital outlays and long payback periods, management should employ extreme caution in analyzing investment alternatives. William Haynes contends that the following six steps must be accomplished in a complete evaluation of any capital investment:

1. The search for investment opportunities.
2. A forecast of the changes in cash flows that will result from each investment.
3. A method of computing the cost of capital which will take into account the availability of funds.
4. A method of converting the changes in future cash flows into a common unit that will reflect the discounting principle.
5. The selection of the most profitable investments.
6. A post audit of the results of previous investments.[2]

While this list makes no mention of uncertainty, it is typical of procedures commonly presented in business textbooks. The discounting principle is stressed, but the problem of risk is ignored. In reality, determining the appropriate discounting factor will itself involve

---

[2]William Warren Haynes, Managerial Economics, Analysis and Cases (Homewood, Illinois: The Dorsey Press, Inc., 1963), p. 525.

estimations. Uncertainty cannot be ignored as long as there are such variables as changing capital structures, fluctuating money markets, and inflation.

To say that Dr. Haynes' procedure is typical of those actually used in business would be an overstatement. Many managers disregard even the discounting principle when making investment decisions. Several surveys have been conducted to determine which methods, if any, are most frequently used in actual firms. A study of sixty small firms disclosed that explicit methods involving the discounting principle were never used in analyzing capital investments.[3] The most frequently used techniques found in a study by Walter W. Heller were payback and qualitative judgment.[4] It appears that managers are either dubious of the precise calculations commonly recommended for capital budgeting, or that they are not aware of the value of explicit reasoning.

"A high degree of 'experienced judgment' is needed in weighing uncertainty elements against profitability potentials,"[5] but judgment is not enough. Explicit

---

[3]Martin B. Solomon, Jr., Investment Decisions in Small Business: Theory and Practice, quoted by Haynes, Ibid., p. 534.

[4]Walter W. Heller, "The Anatomy of Investment Decisions," Harvard Business Review, quoted by Haynes, Managerial Economics, p. 535.

[5]Victor H. Brown, "Rate of Return: Some Comments on its Applicability in Capital Budgeting," in Contemporary Issues in Cost Accounting, ed. by Hector R. Anton and Peter A. Firmin (Boston: Houghton Mifflin Co., 1966), p. 429.

computations are needed so that analysts, managers, and stockholders can better communicate with one another. In a large organization, one man's opinion is of little value unless he can illustrate in black and white that his proposal is profitable.

Even if a manager realizes the importance of explicit reasoning, it is easy to understand why he might be reluctant to use many of the investment analysis techniques recommended by business educators. It has been proven that different firms using identical approaches to profitability measurement will compute different rates of return from precisely the same data.[6] Experience has proven that a dynamic business environment has seldom produced returns exactly as predicted. Contributing to the disappointing results of commonly accepted investment models has been their failure to make any allowance for uncertainty.

The surveys mentioned earlier support Joel Dean's observation that payoff, or payback, "is unquestionably the most widely used measure of investment worth."[7] Payback, which is the length of time within which the summation of a project's net earnings are expected to pay off the initial investment, is the simplest and most easily understood capital investment selection criterion.

---

[6]Ross G. Walker, "The Judgment Factor in Investment Decisions," Harvard Business Review (March-April, 1961), p. 96.

[7]Joel Dean, "Measuring the Productivity of Capital," Harvard Business Review (January-February, 1954), p. 123.

For most corporations, however, payback has several obvious deficiencies:

1. Payback tends to overweight the importance of liquidity as a goal of the capital-expenditure program. No firm can ignore needed liquidity. But most can achieve it by means that are more direct and less costly than sacrificing profits by allowing payback to govern the selection of capital projects.
2. It ignores capital wastage. By confining analysis to the project's gross earnings (before depreciation) it takes no cognizance of its probable economic life.
3. It fails to consider the earnings of a project after the initial outlay has been paid back. By concentrating on liquidity, it ignores the vital matter of what the life pattern of the earnings will be.[8]

The argument that payback has the advantage of allowing for uncertainty by favoring short term investments over what may be riskier, longer term proposals is not completely valid. Payback uses single value estimates of cash flows which are typically treated as assured values. Because the calculations are based on uncertain estimates, who is to say that a proposal with a possible payback period of four years would always be preferred to a proposal with a certain payback period of five years? Obviously, if the four year proposal also had a much higher probability of loss, it would not be prudent to base the decision solely on the payback criterion.

The shortcomings of the payback method cause it to be recommended only as a secondary consideration in capital

---

[8] _Ibid._, p. 124.

budgeting. Authors of typical business textbooks recommend either of two "theoretically correct" techniques to analyze capital investments.[9] The present value method and the discounted rate of return are recommended because they both incorporate the discounting principle and therefore represent the "true" rate of return.

The first and simplest of these two methods of evaluating investments is present value, sometimes called present worth. This technique discounts future earnings, both cash flows and salvage value, by the cost of capital. The result is not a rate of return, but rather a value of future earnings in terms of present dollars. If the present value exceeds the initial investment, the project is financially worthwhile.

While the present value method appears simple, determining the appropriate cost of capital to use can be a complex matter. Because a firm's capital structure and borrowing costs change, uncertainty is necessarily a part of the cost of capital computations. Uncertainty presents itself again in "making the empirical projections that are needed to get the three basic determinants of project worth: (a) earnings, (b) economic life, and (c) amount of capital tied up."[10]

---

[9] Haynes, Managerial Economics, p. 529.

[10] Dean, Productivity of Capital, p. 125.

Present value assumes that generated cash flows will be reinvested at the external rate of return which is the cost of capital. The other theoretically correct technique, the discounted rate of return, assumes that cash flows are reinvested at the internal rate of return which is the rate generated by the investment itself. It is apparent, then, that these two methods, both based firmly on the discounting principle, will sometimes produce different results.

The discounted rate of return is defined as "the rate of discount which when applied to the future cash flows will equate their sum to the supply price of the asset."[11] The definition is cumbersome and so is the calculation, especially when cash flows vary from year to year. This probably explains why the technique is so seldom used in actual business.

The discounted rate of return provides the analyst with a rate which is often more helpful than a net present value when comparing alternatives of varying magnitudes. The discounted rate of return is difficult to compute in addition to having the same general disadvantages as the present value method. Both techniques make no allowance for uncertainty.

Many other capital budgeting tools, such as MAPI and the accountant's rate of return, have certain advantages

---

[11] Haynes, Managerial Economics, p. 530.

and disadvantages which are discussed in numerous accounting and finance texts. It will suffice here to say that all these popular techniques have serious limitations including a total avoidance of uncertainty analysis. The shortcomings of all the methods typically used in business make clear the manager's dilemma in selecting an explicit technique to analyze capital investments. Methods which simply and accurately make allowances for risk are needed for better investment decision making.

CHAPTER II

ALLOWING FOR RISK WITH TRADITIONAL METHODS

Risk Adjustments

Adjustments are necessary to make popular methods of capital investment analysis more realistic. While risk adjustments may be nothing more than guesses, they are always made either explicitly or implicitly. Joel Dean recommends that uncertainty allowances be made explicitly for the sake of objectivity.[12] Failing to do so merely disguises the risk element in the decision-making process.

Allowances for risk can be introduced in any of three stages in a capital investment analysis. Adjustments can be reflected in the forecasted inputs, in the rate-of-return calculations, or in the interpretation of the results.

Adjusting the Inputs

Conservative forecasting is a popular way to make simple uncertainty allowances. With this procedure, the decision maker creates a safety buffer by reducing forecasted profits to a less optimistic level. Extreme discipline is mandatory to prevent personal prejudices from causing inconsistent treatment of alternative investments.

---

[12] Joel Dean, Capital Budgeting (New York: Columbia University Press, 1951), p. 30.

Complications can set in when an organization has several levels in its forecasting hierarchy. Forecasters at the lower echelons may increase their estimates in anticipation of cuts higher in the organization. If this occurs, a guessing game can develop to the extent that actual sales estimates are obscured beyond any useful recognition.

Advanced forecasting models demonstrate how adjustments for anticipated demand cycles mushroom out of perspective by the time they filter up through the retailer, wholesaler, and so on, to the chief forecaster.[13] When forecasts must pass through several levels of management, original predictions may be adjusted several times depending on the number of implicit variables that are not explained. The result can be an unwarrantable exaggeration of the risk factors.

Another more refined way of allowing for uncertainty is to "apply a probability multiplier (e.g., .90, .85, .80 and so on) to the estimated earnings of each project for each year."[14] A smaller multiplier is used for more distant years to reflect increasing uncertainty. This method makes fine discrimination possible among years as well as among alternative investments.

---

[13]Jay Wright Forrester, Industrial Dynamics (Cambridge: M.I.T. Press, 1961), pp. 137-186.

[14]Dean, Capital Budgeting, p. 31.

Some of the best investment opportunities may be lost if conservative forecasts or reduced earnings estimates are emphasized. If either of these input adjustments are used to explicitly express uncertainty, allowances for risk should not be made again in the actual rate-of-return computations. Doing so would double the impact of the risk consideration. Every effort should be made to make forecasts as accurate as is economically possible, with the realization that uncertainty can never be completely eliminated.

Adjusting the Calculations

An alternative to adjusting the inputs is incorporating uncertainty into present value or rate of return calculations. Simple present value computations are based on the concept that a dollar today is worth more than a dollar tomorrow. This relationship should not be confused with the concept that a bird in the hand is worth two in the bush. In other words, the discounting principle should not be confused with the concept of uncertainty. The fundamental present value technique makes no allowance for risk.

Present value permits future dollars to be compared with today's dollars. Therefore, some allowance must be made for the possibility that estimated future cash flows may never, in fact, materialize. One way of incorporating a risk allowance into the present value criterion is to use a discount factor somewhat higher than the cost of capital. This type of adjustment is logical only when a very special assumption is found to be valid. The assumption is that "the probability of a dollar of estimated cash actually materializing will decrease each year by a fixed percentage of the probability in the preceding year."[15] The rate of interest used determines the amount of the percentage decrease through the years. Therefore, use of the risk adjusted present value technique is justified only in the limited number of cases where this special assumption actually exists.

The application of present value discount factors to preliminary estimates of cash flows is generally not an acceptable way of adjusting for risk. "In the special situations in which this technique is an acceptable means of adjusting for risk, the resultant discounted cash flows should not be referred to as present values but as expected cash flows adjusted for risk."[16] That portion of the discounting factor representing the risk adjustment should be clearly distinguished from that portion representing the return.

Empirical adjustments can also be made with other capital budgeting criterion including the discounted rate of return. While these techniques are usually fairly simple and easy to understand, they are not always justified. Adjusting the factors influencing the outcome of a decision

[15]Harold Bierman, Jr. and Seymour Smidt, The Capital Budgeting Decision (New York: The Macmillan Company, 1960), p. 54.

[16]Ibid., p. 55.

can result in serious difficulties. When the variables are adjusted to reduce the probability of making a bad investment, the chances of making a good investment are also reduced.[17]

Adjusting the Results

Very similar to calculations adjustments is the selection of higher cut off rates for high-risk ventures. In other words, some managers feel that an incentive in the form of a higher expected rate of return is necessary for a higher risk proposal to be acceptable. With inflated cut off rates, the decision maker still does not explicitly know the odds of achieving the expected return.

One alternative is to completely ignore uncertainty in forecasting and in computing rates of returns. Allowances for risk can then be applied in the final review "by merely exercising general judgment without any attempt to modify the earnings estimates or by adjusting the rates of projects in some systematic way for differences in uncertainty."[18]

The surveys cited in the first chapter of this report suggest that informal judgment is one of the more popular methods actually used in business. Contributing to this has been the fact that existing procedures for considering

---

[17]David B. Hertz, "Risk Analysis in Capital Investment," Harvard Business Review (January-February, 1964), p. 98.

[18]Dean, Capital Budgeting, p. 30.

risk "have tended either to provide management with only a portion of the information required for a sound decision or they have assumed the availability of information which is almost impossible to obtain."[19]

Changing Risk

Investment decision making is simplified by reducing the degree of uncertainty connected with a proposal. Obtaining more information prior to making a decision is one way of decreasing uncertainty. The information gained through extensive sampling, as a part of market research, must be weighed against the added expenses. The expected net gain increases with sample size up to the optimum where the cost of sampling increases at a faster rate than the expected value of sample information. Fortunately, improvements in electronic data processing are making more sampling economically possible.

Risks may be spread by product diversification, especially when a firm sells products which compete with one another or products which react differently to changes in the economy. A company with a diversified product mix can chance failure on a new product because profits on other products provide financial support. Newman and Logan contend that this argument has been overworked in actual

---

[19]Frederick S. Hillier, "The Derivation of Probabilistic Information for the Evaluation of Risky Investments," Management Science (April, 1963), p. 443.

practice: "Companies have gone into lines they were unqualified to manage, thereby increasing their risks far more than spreading them."[20]

Management can take definite steps to reduce some business risks. Although these actions are not the primary concern of this study, they do at least deserve mentioning. The risks of accidental injury, for example, can be minimized by an aggressive safety program. Some raw materials permit the concept of hedging to be employed as a guard against unstable markets. Leasing should be a consideration when machine obsolescence is a potential hazard. A continuing program of research and development can alleviate the risk of obsolescence. Insurance offers protection against losses from some of the major hazards facing any production operation.

The most knowledgeable manager can never completely eliminate uncertainty from capital investment analysis. Traditional methods adjusted for risks appear inadequate. Management needs better tools to more accurately account for the unavoidable problem of risk in capital budgeting. Concepts developed to deal specifically with uncertainty will be examined in the following chapters.

---

[20] William H. Newman and James P. Logan, Business Policies and Central Management (Cincinnati: South-Western Publishing Co., 1965), p. 119.

CHAPTER III

ALLOWING FOR UNCERTAINTY WITH PROBABILITY ANALYSIS

Probabilities in Forecasting

One deficiency of all the concepts discussed thus far has been the use of single value estimates in both forecasts and calculations. Traditional methods make no mention of the likelihood that the best estimates will occur in reality. There is no attempt to distinguish the estimates as means, medians, or modes. These shortcomings can be corrected by using probability distributions with a stated mean and standard deviation. Variance, represented by the standard deviation, tells the manager how confident he can be that the expected value will actually occur. This is important because many executives, if given the option, would prefer an investment with a relatively certain rate of return over another investment with the same expected rate of return but a larger variance.

Probability concepts can be easily introduced into capital investment forecasts. The simplest way is to adjust for possible contingencies by estimating a most probable, a reasonably pessimistic, and a reasonably optimistic forecast. Then the three forecasts are weighted "using the best information available or using standard weights such as 50 per cent for the most probable and 25 per cent for the optimistic and pessimistic predictions."[21] The sum of the three weighted forecasts is the expected monetary value as shown in Table 1.

TABLE 1

EXPECTED MONETARY VALUE*

Optimistic assumptions	$350.00	.20	$ 70.00
Most probable	250.00	.50	125.00
Pessimistic assumptions	150.00	.30	45.00
	Expected monetary value		$240.00

*Source: Harold Bierman, Jr. and Seymour Smidt, The Capital Budgeting Decision (New York: The Macmillan Company, 1960), p. 130.

If the standard weights suggested by Bierman and Smidt are used, the forecaster may be incorrectly assuming normality. Although this assumption is sometimes required, the decision maker wants the estimated distribution of cash flows to be as descriptive of reality as possible. Estimates can sometimes be improved by having the forecaster sketch a probability distribution to describe his predictions. Similar improvement can result from having the forecaster select a most descriptive distribution from a series of probability

[21]Bierman and Smidt, The Capital Budgeting Decision, p. 129.

distributions commonly used by statisticians. Portraying the forecast with some classical distribution can simplify subsequent analysis.

A forecaster's narrative description can sometimes be converted into a probability distribution useful for uncertain investment decisions. Assume, for example, that a forecaster predicts that the mean sales of some product will be 250 units. He also feels that there is a 50-50 chance that sales could be less than 200 units or more than 300 units. With this description it is possible to construct a normal distribution to represent his expectations. The mean of the distribution is already known to be 250 units. Now all that is needed for a complete description of this distribution is the standard deviation.

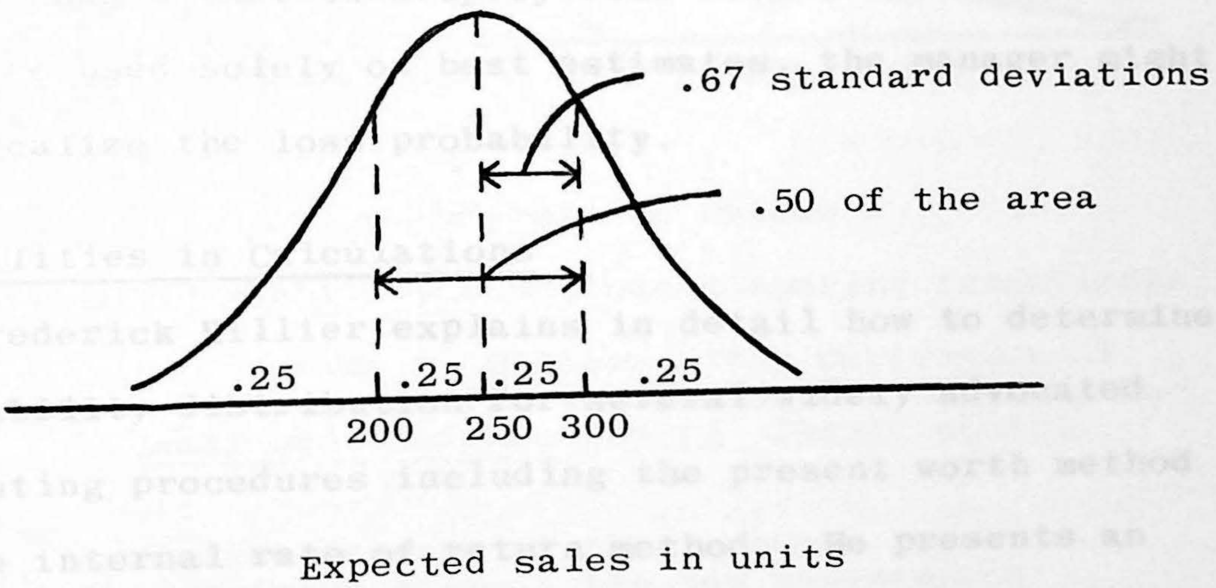

Fig. 1.--Distribution drawn from forecast

Source: Harold Bierman, Jr., Charles P. Bonini, Lawrence E. Fouraker, and Robert K. Jaedicke, Quantitative Analysis for Business Decisions (Homewood, Illinois: Richard D. Irwin, Inc., 1965), p. 96.

Figure 1 approximates the fit of a normal curve to the forecaster's estimates in this example. Because this is a normal distribution, roughly one half the area lies within $\pm$ .67 standard deviations of the mean. From the figure it is apparent that .67 standard deviations on either side of the mean is equal to 50 units. Therefore, if .67 standard deviations equals 50 units, one standard deviation must equal 75 units.

When a probability distribution can be described in terms of a mean and a standard deviation, the decision maker is much better equipped to cope with uncertainty. In the example just discussed, if a manager knows that sales below 150 units will lead to bankruptcy, he can reference a normal-curve table and determine that there is a 9% chance that bankruptcy will occur. If the decision had to be used solely on best estimates, the manager might never realize the loss probability.

Probabilities in Calculations

Frederick Hillier explains in detail how to determine a probability distribution for several widely advocated discounting procedures including the present worth method and the internal rate of return method. He presents an interesting example to illustrate the importance of determining probability distributions for alternative investments. His example contrasts a safe, conservative investment A with a risky but promising venture B. He describes investment A as having an expected rate of return of 18.5% with a standard deviation of about 4%. The mean rate of investment B is 25% and its standard deviation is about 20%. Figure 2 shows the approximate probability density functions of the rates of return for the two investments.

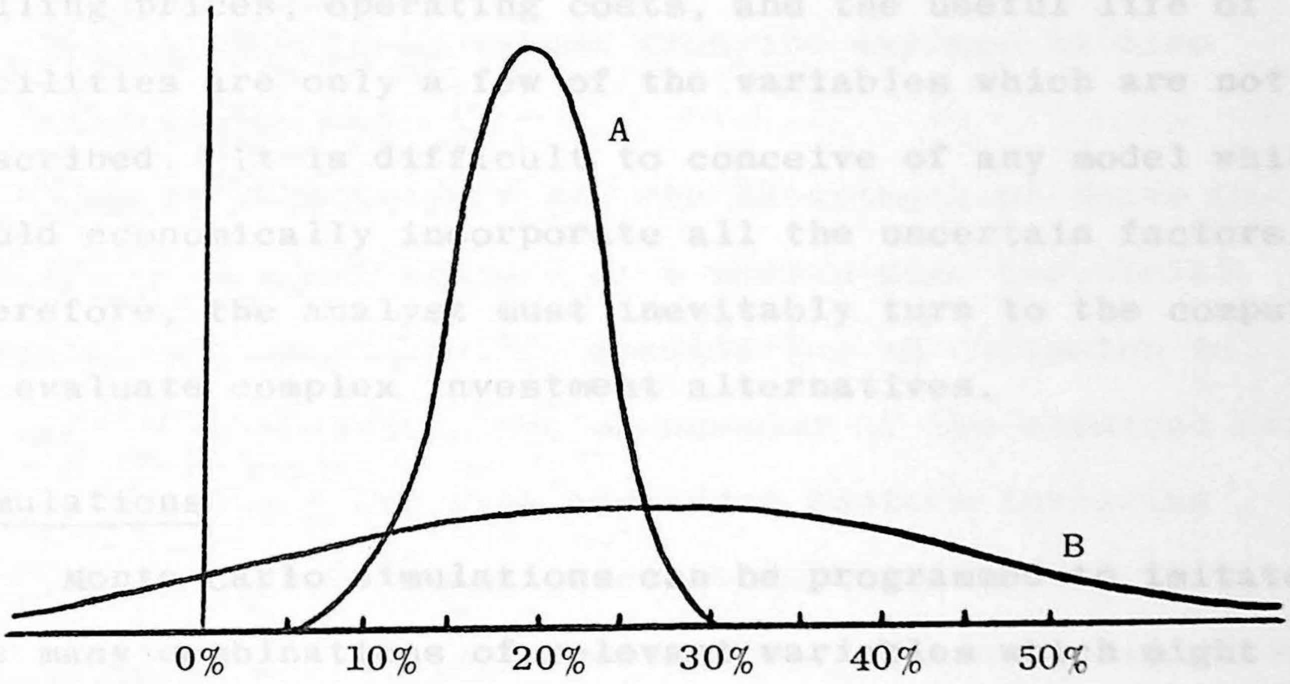

Fig. 2.--Probability functions comparing investments.

Source: Frederick S. Hillier, "The Derivation of Probabilistic Information for the Evaluation of Risky Investments," Management Science (April, 1963), p. 455.

> The impressive feature of this example is that the decision between the two investments is not an easy one. This is true despite the fact that there is a difference of about $167,000 in the expected present worth and of about 6.5% in the expected rate of return. The great difference in the risk involved compels management to examine carefully

> the financial position of the firm and evaluate the seriousness of the consequences should the riskier investment fail to achieve expectations.[22]

Even Hillier's model leaves something to be desired. Like the others mentioned in this report, this model does not explain what assumptions it makes about the many uncertain variables which influence the rate of return. Selling prices, operating costs, and the useful life of facilities are only a few of the variables which are not described. It is difficult to conceive of any model which could economically incorporate all the uncertain factors. Therefore, the analyst must inevitably turn to the computer to evaluate complex investment alternatives.

Simulations

Monte Carlo simulations can be programmed to imitate the many combinations of relevant variables which might randomly occur if a certain proposal were accepted. One such model was developed at McKinsey & Company, Inc. to be a part of a complete investment analysis. Three steps are accomplished to carry out the analysis:

1. Estimate the range of values for each of the relevant, uncertain factors and the likelihood of occurrence of each value within that range.
2. Randomly select one particular value from the distribution of values for each factor. Then combine the values for all of the factors and

---

[22]Hillier, "The Derivation of Information," pp. 451-456.

and compute the rate of return (or present value) from that combination.

3. Repeat step 2 many times to determine the final likelihood of occurrence of each possible rate of return. The mean expectation then is the average of the values of all outcomes weighted by the frequency that each occurred. Variability of the final values from the average is also determined.

David Hertz illustrates the advantages of Monte Carlo simulation with an example of a medium-size industrial chemical producer which is considering an extension to its processing plant. The management of the chemical firm feels that there are nine key input factors involving some uncertainty. These relevant factors, listed in Table 2, are divided into three categories. The expected values and ranges to be used in the simulation are obviously more descriptive than the best estimates which must be used in traditional methods.

The use of single, best estimates would have led the management of the chemical firm to expect a 25.2% return. However, when the ranges were added to the means, and the data was programmed through a computer, the expected return was found to be only 14.6%. The 10.6% difference between the traditional approach and the new approach would cause management to view the profitability of plant expansion

TABLE 2

COMPARISON OF EXPECTED VALUES UNDER OLD & NEW APPROACHES*

	Conventional "best estimate" approach	New approach
MARKET ANALYSES		
1. Market size		
Expected value (in tons)	250,000	250,000
Range	--	100,000-340,000
2. Selling prices		
Expected value (in dollars/ton)	$510	$510
Range	--	$385-$575
3. Market growth rate		
Expected value	3%	3%
Range	--	0-6%
4. Eventual share of market		
Expected value	12%	12%
Range	--	3%-17%
INVESTMENT COST ANALYSES		
5. Total investment required		
Expected value (in millions)	$9.5	$9.5
Range	--	$7.0-$10.5
6. Useful life of facilities		
Expected value (in years)	10	10
Range	--	5-15
7. Residual value (at 10 years)		
Expected value (in millions	$4.5	$4.5
Range	--	$3.5-$5.0
OTHER COSTS		
8. Operating costs		
Expected value (in dollars/ton)	$435	$435
Range	--	$370-$545
9. Fixed costs		
Expected value (in thousands)	$300	$300
Range	--	$250-$375

*Source: David B. Hertz, "Risk Analysis in Capital Investments," Harvard Business Review (January-February, 1964), p. 103.

from two entirely different points of view. From this example, it is apparent that simulations can help management to more realistically evaluate capital expenditures and to avoid unwise investments.

Some people argue that using a computer is not practical for small firms or for minor projects. Actually a computer simulation can be run in very little time and at very little expense. In the example of the chemical firm, the simulation with nine input factors randomly combined in 3,600 discounted cash flow calculations took only "two minutes at a cost of $15 for computer time."[23] Therefore, even a very small firm can benefit from the speed, accuracy, and economy of computer-programmed, Monte Carlo simulations.

Probability distributions can be graphed from simulations. Graphs are especially useful in comparing investments having similar, predicted rates of return but different risks.

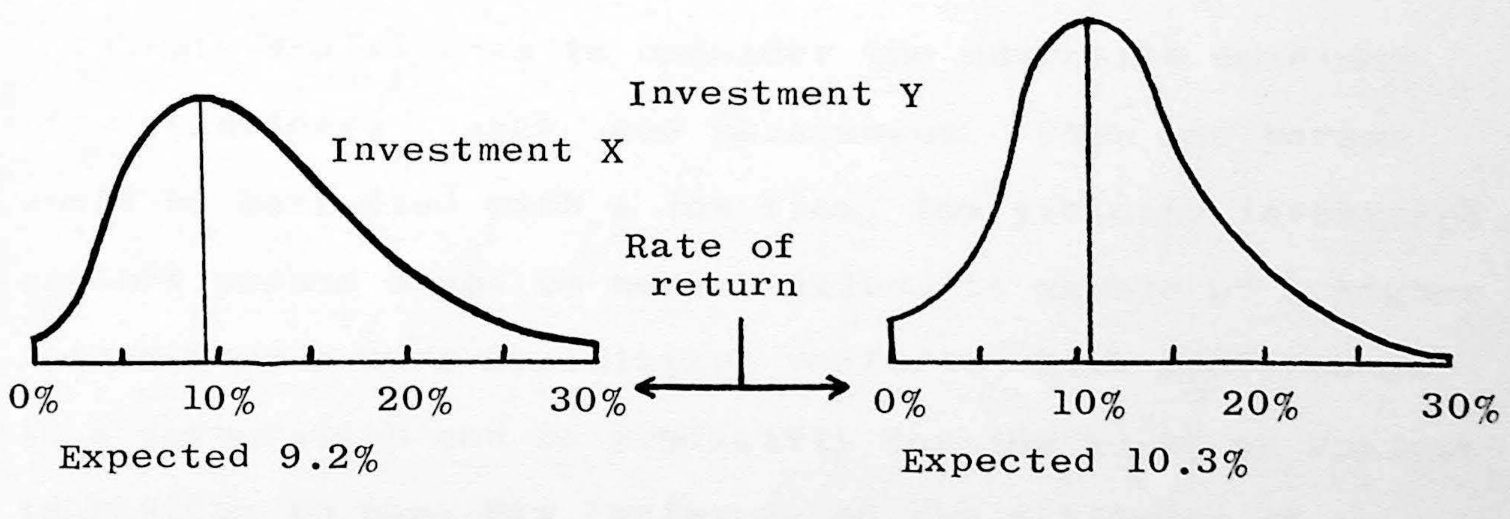

Fig. 3.--Alternative investments

Source: David B. Hertz, "Risk Analysis in Capital Investments," Harvard Business Review (January-February, 1964), p. 96.

---

[23]Hertz, "Risk Analysis in Capital Investment," pp. 99-104.

Consider, for example, two alternative investments: X and Y. Based on traditional discounted cash flow calculations, X has an expected internal rate of return of 9.2% while 10.3% is the expected rate for Y. Y appears to be the better investment until probability distributions for the two proposals are compared graphically.

From the graphed distributions shown in Figure 3, the decision maker realizes that Y is no longer clearly preferable to X. He is now aware that Y has a 10% chance of being a total loss, while X has only a 5% chance of being a total loss. It is no longer obvious that all managers, if forced to choose between the two investments, would prefer the same alternative.[24] Therefore, graphed probability distributions do help to prevent managers from jumping to wrong conclusions. As demonstrated in this example, the added information provided by probability analysis may actually complicate the decision making process.

---

[24]Hertz, "Risk Analysis in Capital Investment," pp. 99-104.

CHAPTER IV

UTILITY THEORY

Risk Preferences

Several examples have now been demonstrated which have failed to lead to any clear cut decision, Figure 2 and Figure 3 are graphs of two such examples. Unfortunately there is no guidance as to which proposal should be accepted when management is forced to choose between such alternatives. The decision must be based on individual judgment and preference. Making the decision is not easy in a sole proprietorship, and the process is extremely complex in a corporation.

While one man knows his own attitudes about risk, the corporate analyst has to consider the composite opinions of stockholders, labor, and management. When one person would be satisfied with a low risk, low yielding investment, another person might be more inclined to gamble on a higher return from a more speculative venture. Risk preferences in a corporation can be explicitly considered if an analyst is willing to base his decisions on the attitudes of one individual such as the top manager or the chairman of the board. This can be done with a utility scale which "is an individual's value scale rather than a consensus."[25]

Utility theory is a concept which explicitly states a person's attitude toward risk. This concept is based on the assumption that decisions are made "so as to maximize expected utility rather than expected value."[26] This is a reasonable assumption since few people would pay $400 for a 50-50 chance of winning either $1000 or nothing. In other words, many people feel that the status quo has a higher expected utility than the gamble's expected monetary net gain of $100.

Constructing a Utility Curve

A utility function is a numerical index which describes an individual's preferences concerning risky investments. An employee is able to make decisions for an employer once the employer's attitude is numerically stated in the form of a utility scale. A utility function can be plotted by asking an individual to choose between a series of alternatives.

The process of constructing a utility curve can best be illustrated with an example. Suppose that an investment analyst wants to plot a utility scale so that he can make decisions consistent with his employer. As a starting point,

---

[25]Irwin D. J. Bross, Design for Decision (New York: The Macmillan Company, 1953), p. 92.

[26]Harold Bierman, Jr., Charles P. Bonini, Lawrence E. Fouraker, and Robert K. Jaedicke, Quantitative Analysis for Business Decisions, (Homewood, Illinois: Richard D. Irwin, Inc., 1965), p. 192.

he lets a $0 gain be represented on a scale as 0 utiles, or utility values. The 0 value on the utility scale is arbitrary. The analyst then selects a second point on the scale to represent the employer's utility value for $1000, and decides to call this value 40 utiles. The second point on the scale could have been any arbitrary number larger than zero. With these two index points, the analyst is now ready to construct a utility scale by asking his employer's preferences on several sets of investment alternatives.

The analyst formulates a proposal using the two arbitrary index points just determined. He describes proposal A to his employer as being a 50-50 chance of gaining $1000 or nothing. Since 0 utiles represents $0, and 40 utiles represents $1000, the expected utility of proposal A is 20 utiles. (.5 of 0 utiles plus .5 of 40 utiles equals 20 utiles)

As an alternative to A, the analyst proposes B which offers some amount of money with certainty--say $500. If the employer prefers B to A, the analyst can conclude that the utility index of $500 is greater than 20 utiles.

As more alternatives are presented, the employer would eventually find some monetary value which is equally satisfying as proposal A. Assume, for example, that the employer is indifferent between a guaranteed $300 and the original gamble. Then, 20 utiles, the utility value for the gamble, can be plotted on a graph as the utility value for $300.

The analyst now has three points to describe the employer's preferences. More points can be plotted by offering monetary alternatives to various probability combinations of the three values now established. The final utility graph would look something like Figure 4.

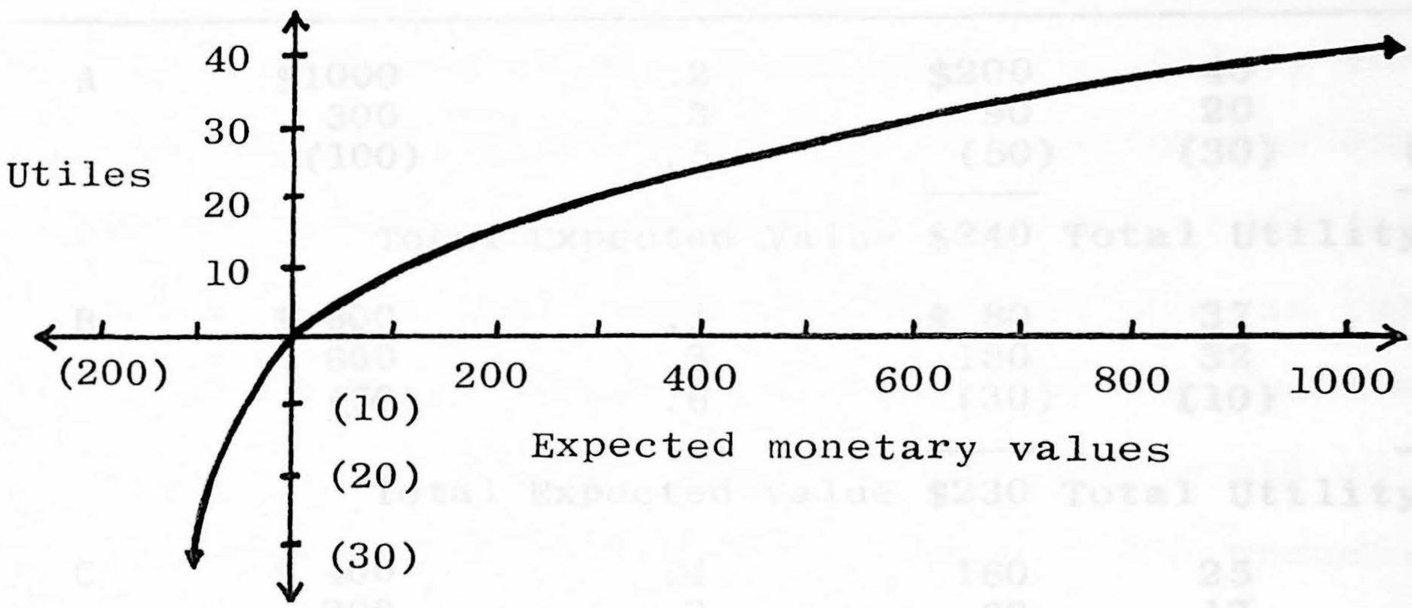

Fig. 4.--Employer's utility function

Source: Author

<u>Using Utility</u>

Utility values representing the employer's preferences can now be used by the analyst to evaluate investments. Because higher expected monetary values are represented by higher expected utility values, it is not readily apparent that the use of utility values has any advantage. The superiority of expected utility values is demonstrated in Table 3 with three alternative investments: A, B, and C. The utility values used in Table 3 are taken from the employer's utility function graphed in Figure 4.

TABLE 3

EXPECTED UTILITY VALUES*

Project	Net Present Value	Probability		Utiles	Expected Utility Value
A	$1000	.2	$200	40	8
	300	.3	90	20	6
	(100)	.5	(50)	(30)	(15)
	Total Expected Value		$240	Total Utility	(1)
B	$ 800	.1	$ 80	37	4
	600	.3	180	32	10
	(50)	.6	(30)	(10)	(6)
	Total Expected Value		$230	Total Utility	8
C	$ 400	.4	160	25	10
	200	.3	60	17	5
	0	.3	0	0	0
	Total Expected Value		$220	Total Utility	15

*Source: Author

If expected monetary values were used as a basis for capital budgeting decisions, all three projects in Table 3 would be accepted. Project A would appear to be the most desirable with an expected value of $240. Project C would be the least desirable, but it also would be acceptable since it has a positive expected net present value.

On the other hand, when the analyst converts the monetary values into utiles, he finds that project C would be most desirable to his employer. In fact, the use of utility values caused the order of preference to be completely reversed. Project A has a negative utility value indicating that the investment would be rejected by the employer.

The advantage of utility theory is now apparent, but it does have shortcomings. Constructing a utility function is time consuming both for the analyst and for the executive whose preferences are being probed. One dangerous limitation of the utility concept stems from the fact that an employer's attitudes may change from day to day. The variables which cause an investment to be uncertain may also cause an employer to change his risk preferences. "The process for the determination of Utilities as numbers needs much more development."[27] For this reason, the use of utility theory has been very limited in actual practice.

---

[27]Bross, Design for Decision, p. 94.

CHAPTER V

SUMMARY AND CONCLUSIONS

Review

Many concepts which deal with uncertainty in capital investment analyses have been discussed in this report. Although many alternative techniques to deal with risk were found to exist, the subject has failed to receive much attention in typical business textbooks. Business educators generally ignore risk in advocating the use of either the present value method or the discounted rate of return method for analyzing investments. These measures of investment worth are descriptive of reality only when certainty can be assumed. Complete certainty is never a valid assumption in business. There is little wonder why rules of thumb and subjective judgment are so frequently used in business.

Payback was found to be the most widely used explicit measure of profitability. Contributing to its popularity is the fact that payback is simple and that it avoids risk by favoring short term investments. Avoiding or ignoring risk cannot be recommended. Management needs to explicitly deal with risk to maximize the goals and objectives of its organization.

Some simple adjustments to traditional methods to allow for risk were described. Conservative forecasts, reduced estimates, present value cash flow adjustments, and inflated cut off rates were all suggested. The adjustments are all based on the idea that some incentive is needed to make risky investments acceptable. While these adjustments do reduce the chances of making a bad investment, they also reduce the chances of making a good investment.

Methods of reducing or spreading risks were also discussed. Market research, product diversification, hedging, insurance, and leasing were all suggested. While these techniques can frequently be employed, management must realize that uncertainty can never be completely eliminated.

Describing uncertain projects with probability distributions was found to be more beneficial than single value estimates used in traditional techniques. When a return can be described with a mean and standard deviation, the decision maker knows the probability that values other than the mean will actually occur.

Monte Carlo simulations were discussed. With this model, all the relevant uncertainties are first described with probability distributions. The variable inputs are then randomly combined over and over again in a computer. The result is a probability distribution representing all the possible returns which could result if the investment being evaluated were actually accepted. While simulations do not always make the investment decision easier, they do inform the analyst as to what the possible consequences of an investment may be.

Utility theory was explained as a tool which allows an analyst to make decisions consistent with his employer's risk preferences. The construction and use of a utility scale were demonstrated. The advantage of using utility values over the use of monetary values was illustrated along with the limitations of the utility concept.

Conclusions

Certain conclusions can be made from this study of uncertainty in investment analysis. Before enumerating these conclusions, one underlying assumption made throughout this study should be clarified. That assumption is that management's primary objective in analyzing investments is to maximize the monetary return. The assumption is useful for quantitative purposes, but the assumption is not valid for all organizations. The potential returns from intangibles, such as employee relations and community goodwill, cannot be ignored. Public pressure concerning ecology provides a good example of how profits must sometimes be a secondary consideration. Realizing this limitation, the following conclusions can be made.

1. Investment analyses typically used in business do

not adequately allow for uncertainty. They are appropriate only when certainty can be assumed.

2. Simple risk adjustments to forecasts or calculations fail to accurately allow for risk. They lead to the rejection of both good and bad investments, because they incorrectly assume that a higher risk venture is necessarily a less desirable venture.

3. Risks should be reduced whenever it is economically feasible to do so.

4. A probability distribution described in terms of a mean and a standard deviation is far more descriptive of uncertain factors than are single value estimates.

5. Monte Carlo simulation, incorporating present value or the discounted rate of return, is generally the best method of analyzing uncertain capital investments. It requires an explicit estimate of the variability of all the relevant factors which management feels may contribute to the uncertainty of an investment. The model can be rapidly and economically run in a computer. The result is a probability distribution which states both the expected return and the probability that other outcomes may also occur.

6. Judgment can not be eliminated from decision making. Individual preferences are sometimes required even when alternative investments are described graphically with probability distributions.

7. Utility theory has great potential as a decision making device, but its use as a common tool in business is not yet advisable.

Recommendations

Each individual and organization looks at risks differently. It is impossible to make recommendations which are satisfactory in every situation. The corner grocer might reject investing $100,000 in a risky venture expected to yield 50% because he cannot take the chance of a loss. On the other hand, General Motors might jump at such an opportunity. This example points out the need for more research in the area of utility theory. The feasibility of substituting utiles for monetary values in Monte Carlo simulations is especially worthy of further research.

Computer simulation using monetary values appears to be the best analysis method presently available to management, but it is not recommended in every case. If uncertainty is found to be a very minor factor, simple present value or internal rate of return computations may be adequate. The important thing to remember is that uncertainty should not be omitted from calculations until after the risks have been analyzed as being insignificant. If uncertainty is substantial, it must not be omitted from the decision making process. Because uncertainty cannot be avoided, uncertainty cannot be ignored in capital investment analyses.

BIBLIOGRAPHY

Books

Bierman, Harold Jr.; Bonini, Charles P.; Fouraker, Lawrence E.; and Jaedicke, Robert K. Quantitative Analysis for Business Decisions. Homewood, Illinois: Richard D. Irwin, Inc., 1965.

Bierman, Harold, Jr., and Smidt, Seymour. The Capital Budgeting Decision. New York: The Macmillan Company, 1960.

Bross, Irwin D. J. Design for Decision. New York: The Macmillan Company, 1953.

Brown, Victor H. "Rate of Return: Some Comments on its Applicability in Capital Budgeting." Contemporary Issues in Cost Accounting. Edited by Hector R. Anton and Peter A. Firmin. Boston: Houghton Mifflin Co., 1966.

Dean, Joel. Capital Budgeting. New York: Columbia University Press, 1951.

Forrester, Jay Wright. Industrial Dynamics. Cambridge: M.I.T. Press, 1963.

Haynes, William Warren. Managerial Economics, Analysis and Cases. Homewood, Illinois: The Dorsey Press, Inc. 1963.

Newman, William H., and Logan, James P. Business Policies and Central Management. Cincinnati: South-Western Publishing Co., 1965.

Periodicals

Dean, Joel. "Measuring the Productivity of Capital." Harvard Business Review, January-February, 1954, pp. 120-30.

Hertz, David B. "Risk Analysis in Capital Investment." Harvard Business Review, January-February, 1964, pp. 95-106.

Hillier, Frederick S. "The Derivation of Probabilistic Information for the Evaluation of Risky Investments." Management Science, April, 1963, 443-57.

Walker, Ross G. "The Judgment Factor in Investment Decisions." Harvard Business Review, March-April, 1961, pp. 93-99.