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CAPITAL BUDGETING DECISIONS UNDER CONDITIONS OF CERTAINTY, RISK, AND UNCERTAINTY

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INTRODUCTION

The future success of a business venture depends on decisions made in the present. Among the most important are those decisions dealing with capital budgeting outlays which are expected to generate returns beyond one year. Examples include investments in fixed assets. Less obvious examples may include an increase in permanent working capital, expenditures on advertising, and research and development. The system of capital budgeting is employed to carry out the planning of these expenditures. However, capital budgeting planning deals with the future, which is usually uncertain. Since cash flows of investment proposals will be realized with varying degrees of certainty, capital budgeting methods must incorporate risk and uncertainty into the decision-making process. Management should have a clear understanding of the philosophy, techniques and criteria used in evaluating capital budgeting of projects.

The purpose of this paper is (a) to describe briefly and compare different capital budgeting techniques under conditions of certainty; (b) to describe evaluation of capital budgeting proposals under conditions of risk; and (c) to describe and compare criteria which can be used for capital budgeting under conditions of uncertainty, which are not examined in current capital budgeting literature.

CAPITAL BUDGETING UNDER CONDITIONS OF CERTAINTY

The difference between capital budgeting planning under conditions of certainty, risk and uncertainty depends on the amount of information the decision-maker has, or assumes, about the probabilities of the states of nature. In decision-making under certainty, the decision-maker knows (or assumes) which state of nature will occur and selects the alternative

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which will give the highest payoff for the state of nature. In this case, the decision-maker has complete information about the problem and there is no risk or uncertainty. For example, if one invests in U. S. Government bonds, one will have almost complete information about the future of this investment.

METHODS OF EVAULATING CAPITAL BUDGETING UNDER CERTAINTY

Capital budgeting methods can be classified into two categories. The first category includes the more sophisticated time-discounted methods such as Net Present Value (NPV), Profitability Index (PI), Internal Rate of Return (IRR), Terminal Rate of Return (TROR), Net Terminal Value (NTV), and Equivalent Annual Cost (EAC). The second category includes the shortcut rule-of-thumb methods such as paycheck period and average rate of return.

In order to use the methods listed above, the decision-maker will use one of the six formulas presented in Figure 1. These six formulas present three future value relationships and their reciprocal present value counterparts. In order to avoid the tedious task of using the formulas presented in Figure 1, printed tables are available in financial or accounting texts.

The formulas in Figure 1 use the following five factors:

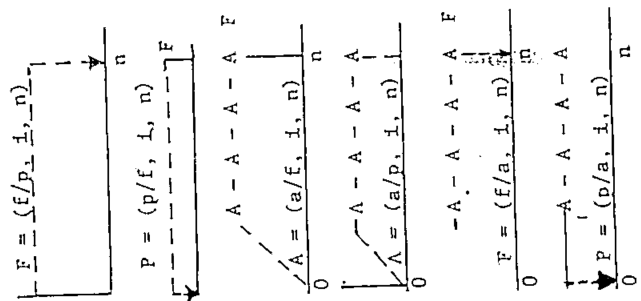
- P = present worth, a lump sum value at present time period.
- F = future worth, a lump sum value at a certain future time period.
- A = one annuity payment. Usually the interest tables are based on an annuity composed of equal payments occurring at equal time intervals with the first payment at the end of the first period. One can use annuity payments and convert them into a single present or future sum or to translate a single payment into a series of payments taking place in the past or future.
- n = number of interest periods (can be more than one interest period per year).
- i = interest rate per period. Interest rate can be compounded quarterly or monthly. For example, a 12% interest rate will be compounded four times per year at 3% if it is quarterly, and 12 times at 1% if monthly.

Each formula in Figure 1 contains four of the above listed factors. Problems facing a decision-maker usually include three of the *P*, *F*, *A*, *n*, and *i* factors with the fourth factor unknown.

It is assumed that before applying any of these methods, the decision-maker will formulate each capital budgeting project in terms of cash inflows and outflows. The cash inflows from an investment consist of the incremental profit after taxes plus incremental depreciation; the cash outflow is the actual cost of the investment. Special attention must be paid to the timing of receipts and outlays and the handling of fixed and variable costs, accounting depreciation, and working capital.

Figure 1. *Interest formulas, symbols, and descriptions*

Formula	Symbol	Function
$(1+i)^n$	(f/p, i, n)	To find the future value (F) given the present worth of a single amount (P)
$1/(1+i)^n$	(p/f, i, n)	To find the present value (P) given the future worth of a single amount (F)
$\frac{i}{(1+i)^n-1}$	(a/f, i, n)	To find the value of annuity payments (A) given the future worth of the annuity (F)
$\frac{i(1+i)^n}{(1+i)^n-1}$	(a/p, i, n)	To find the value of annuity payments (A) given the present worth of the annuity (P)
$\frac{(1+i)^n-1}{i}$	(f/a, i, n)	To find the future value (F) given the amount of annuity payments (A)
$\frac{(1+i)^n-1}{i(1+i)^n}$	(p/a, i, n)	To find the present value (P) given the amount of annuity payments (A)



Source: James L. Riggs, *Production Systems: Planning Analysis, and Control* (3rd Ed.) Wiley, 1981. p. 123.

TIME DISCOUNTED METHODS

1. *Net Present Value (NPV):* The present value of future returns, discounted at the minimum required rate of return on new investment (cost of capital), minus the cost of the investment. It is defined as follows:

$$NPV = \frac{R_1}{(1+k)^1} + \frac{R_2}{(1+k)^2} + \ldots + \frac{R_n}{(1+k)^n} - C \quad (1)$$

or

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+k)^t} - C \quad (2)$$

Here R_1, R_2, etc., represent the net cash inflows, k is the minimum required rate of return on new investments, n is the project's expected life, and C is the cost of the investment.

The decision-maker should reject any project with a negative NPV. To illustrate the NPV calculation, let us assume that an engineering firm is considering acquiring two pieces of laboratory equipment, A and B. Each requires an investment of $2000. The minimum required rate of return is 10%. The net cash flow from both equipment and the calculation of NPV is presented in Table 1A in the Appendix. Project "A" has a NPV of $160, while B's NPV is $464. On this basis, both equipment proposals should be accepted if both can be purchased, but B should be chosen if only one is to be purchased.

Advantages of this approach are: (a) it compares total cost without knowledge of income or considering the effect of taxes (these factors can be taken into account, if applicable); (b) it considers the total return which is important when the amount of capital is limited; and (c) it can take into account fluctations in cost or revenues. Disadvantages are: (a) it does not consider the rate of return and number of years for in investment to pay for itself; and (b) it assumes that funds could be reinvested at the cost of capital.

2. *Profitability Index (PI) or Benefit/Cost Ratio:* The present value of future net cash flows over the initial cash outlay or investment,

$$PI = \frac{PV \text{ of cash inflows}}{PV \text{ of investment}} = \frac{PV}{C}$$

As long as the profitability index is equal to or greater than 1.00, the investment proposal is acceptable.

In our example cited above, the profitability index for project A is $\frac{2160}{2000} = 1.08$, and for project B is $\frac{2464}{2000} = 1.23$. According to the profitability index, project B would be preferred.

For any given project, the NPV method and the profitability index give the same accept-reject signals. However, if we must choose between mutually exclusive projects, the NPV method is preferred because it expressed the expected economic contribution of the project in absolute terms. In contrast, the profitability index expresses only the relative profitability.

3. *Internal Rate of Return (IRR):* The interest rate that equates the present value of the expected future cash flows, or receipts, to the initial cost or investment. The equation for calculating the internal rate of return is:

$$IRR = \frac{R_1}{(1+r)^1} + \frac{R_2}{(1+r)^2} + \ldots + \frac{R_n}{(1+r)^n} - C = 0 \quad (4)$$

or

$$IRR = \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} - C = 0 \quad (5)$$

Here we know the value of C and the values of $R_1, R_2, \ldots R_n$, but we do not know the value of r. Notice the internal rate of return formula, Equation (4), is simply the NPV formula, Equation (2), solved for that particular value of k that causes the NPV to equal zero.

The IRR projects A and B are calculated in Table 2A in the Appendix. Project A has a 14.8% IRR, while B's IRR is 16.7%. According to the internal rate of return method, project B would again be preferred.

In general, the NPV and IRR methods lead to the same acceptance or rejection decision. However, when two investment proposals are mutually exclusive, so that we can select only one, the two methods may give contradictory results.

The difference between these two methods is due to differences in the implicit rate of reinvestment for the intermediate cash flows. The IRR method implies a reinvestment rate equal to the internal rate of return, whereas the NPV method implies a reinvestment rate equal to the required rate of return used as the discount factor. If a choice must be made, the net present value method generally is considered superior theoretically (Van Horne, 1977, p. 92).

4. *Terminal Rate of Return (TROR):* This requires the analyst to state explicitly the reinvestment rate for the cash inflows from a project. As was mentioned above, in the absence of this explicit statement, the computations of IRR implicitly assume that any cash generated during the life of the project is reinvested at the same rate as the calculated IRR. For an organization the reinvestment rate could be the organization's cost of capital, or it may be a lower rate based on investment of the idle cash in short-term securities. It may change over time, reflecting alternative reinvestment rate assumptions (Rodriquez & Carter, 1976, p. 311).

First, in order to calculate the Terminal Rate of Return, the project cash inflows (R_n, R_{n-1}, ... etc.) are compounded forward to some time horizon, (n), at the reinvestment rate, (i), as in the following equation:

$$S_n = R_{n-1}(1+i)^{n-1} + R_{n-2}(1+i)^{n-2} + R_{n-3}(1+i)^{n-3} + \ldots + R_{n-n}(1+i)^{n-n} \quad (6)$$

The second step is to find the discount rate that equates the compound value of cash inflows, (S_n), to the value of investment, (C). This discount rate, (x), is the terminal rate of return for the project as indicated in Equation (7).

$$TROR = \frac{S_n}{(1+x)^n} - C = 0 \quad (7)$$

Returning to our example, let us further assume that the firm's reinvestment rate is 5%. The TROR for project A is 9.4% and for project B is 12.1%, as it appears in Table 3A in the Appendix.

5. *Net Terminal Value (NTV):* First, it requires the calculation of the Compound Value of the cash inflows, (S_n), at the reinvestment rate, (i), as in Equation (6). Secondly, the initial investment, (C), is compounded forward at some opportunity cost or reinvestment rate as in Equation (8).

$$C_n = C_0(1+i)^n \quad (8)$$

Thirdly, the Net Terminal Value is calculated by subtracting the compound value of the investment from the compound value of the cash inflows, (S_n), as in Equation (9).

$$NTV = S_n - C_n \quad (9)$$

If the NTV is positive, the project should be accepted.

In our example, we find, from Table 3A, that the NTV for project A is $538 while project B has a $1,288 NTV.

6. *Equivalent Annual Cost (EAC):* This is a time-adjusted method to evaluate an equal annual cost over the life of an investment. This method can be used to compare investments with different economic lives by taking into account the compounding of interest.

$$EAC = CR \text{ and } R + S_i + OC \quad (10)$$

In this equation S_i represents the interest on salvage value and OC is other annual operating and maintenance costs. CR stands for capital recovery and R is the return. Together CR and R is basically an annuity amount derived from the present value investment amount. For example, CR and R on a $1,000 investment at 10 percent over five years

would be a given size annuity that could be withdrawn each year for five years to finally exhaust the sum. Of course, the total amount of withdrawals would exceed $1,000 by the amount of interest accumulated on the declining capital amount. The annual CR and R amount can be determined from the present value annuity factor (PV_a) or the capital recovery factor (CRF) by noting that the present value investment amount, I, must be the product of a PV_a factor times some appropriate annuity amount R (Monks, 1977, p. 169). Thus:

$$I = R\,(PV_a)_i^n$$

Solving for R gives

$$R_i = \frac{I}{(PV_a)_i^n} = I\left[\frac{1}{(PV_a)_i^n}\right] \quad (11)$$

where

$$\frac{1}{(PV_a)_i^n} = CRF \text{ (Capital Recovery Factor)}$$

$$R_i = I\,(CRF)$$

For example, if n = 8 years and i = 10%

$$CRF = \frac{1}{(PV_a)^8_{10\%}} = \frac{1}{5.335} = 0.187$$

The CR R applies to investment less salvage value, (1 — S), therefore, the interest on salvage value (S_i) must be included. At the end of life of the investment, the salvage value is assigned to the lender and the only cost to the borrower is the annual interest charged on the amount borrowed.

Calculation of the equivalent annual cost for two project is presented in Table 4A in the Appendix. One can see that although total investment cost for project A is lower, project B has the lower EAC per year. The equivalent annual cost is useful for organizations with fixed incomes like state and local government which rely on relatively fixed budgets for their new projects.

Advantages of the EAC are: (a) investments with different lifetimes can be compared without taking into account income or taxes on income; (b) this method is relatively exact because it takes into account compounding an equal amount each year. Disadvantages are: (a) the illusion of accuracy may be misleading since one makes assumptions about future costs, salvage value, interest rates, and equipment lifetime; and (b) total costs are not explicitly considered for calculating return on investment.

SHORTCUT RULE-OF-THUMB METHODS

1. *Payback Method:* This is based on the length of time necessary for the sum of annual cash benefits to equal the initial investment. For example, the payback period for project A is 2-1/3 years, and 4.0 years for project B. According to the payback period method, project A would be preferred. Notice that this recommendation contradicts the recommendation from all previous methods which favoured project B over A.

Although the payback period is very easy to understand and calculate, it can lead to wrong decisions. This method has three major deficiencies. First, it ignores the time value of money. Second, it fails to consider any stream of income extending beyond the payback period. Third, it has no means of adjusting for different levels of investment. It provides only a measure of the rate at which an investment is returned and, therefore, is not a useful device for selecting from among an array of projects under capital rationing. Nevertheless, the payback method continues to be in use. One recent survey indicated that 47.1% of hospitals responding used the payback method (Williams, 1974). Overall, 60% of U. S. firms used the payback method and of those, only 16% used a payback period of more than five years (Weston & Brigham, 1971, p. 132).

The payback method gives management limited insight into the risk and liquidity of a project. The shorter the payback period, the less risky the project and the greater its liquidity. The engineering firm that is cash poor may find the method to be very useful in gauging the early recovery of funds invested. There is some merit to its use in this situation, but the method does not take into account the dispersion of possible outcomes — only the magnitude and timing of the expected value of these outcomes relative to the original investment. Therefore, it cannot be considered an adequate indicator of risk.

When the payback method is used, it should be treated as a constraint to be satisfied and not as a profitability measure to be maximized. As we have already noted, some organizations still use shortcut measures of investment such as the payback period when evaluating capital expenditures. Although it can readily be shown that the use of these methods may distort investment decisions, they provide close approximations of the discounted rate of return in a number of important situations. For investment proposals with internal rates of return greater than 30% and with economic lives exceeding ten years, the payback reciprocal provides a good estimate of the internal rate of return. On the other hand, for proposals with relatively low internal rates of return of less than 8%, the payback reciprocal does not provide a good estimate of the internal rate of return. This reinforces our earlier conclusion that the payback method should not be used as a profitability measure to be maximized; rather, it should be treated as a constraint to be satisfied.

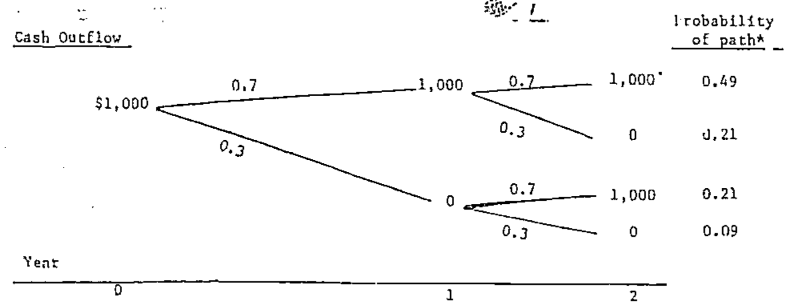
2. *Average Rate of Return:* It is defined as the ratio of average annual net income (profit after tax) to average investment. This method can approximate the true rate of return if the life of a project is long (at least twice the payback period), annual income uniform, and salvage value negligible. The advantages of this method are: (a) it is simple to use; (b) it attempts to calculate a rate of return rather than focusing on the time necessary to recapture the original investment; and (c) it considers both the amount invested and the profit the investment generates. The disadvantages are: (a) the time value of money is ignored, and (b) the project is expected to have uniform inflows — accelerated depreciation and shortened product lives require more accurate cash flow techniques (Wert & Henderson, 1979, pp. 159-160).

CAPITAL BUDGETING UNDER RISK

Under conditions of risk, the decision-maker knows or estimates the probabilities of occurrence of the various states of nature or cash flow. He selects the strategy by adding up the expected values for each strategy (payoff time probability) and determines an overall expected value for each state of nature. In this case, the decision-maker has less information than under certainty and selects the investment proposal with the highest expected values. Risk may also be evaluated by comparing the variabilities of two or more sets of data by using their respective variances or standard deviations when their means are equal, and variables are given in the same units. When these conditions are missing, one may use the coefficient of variation which is a relative measure of dispersion (ratio of the standard deviation to the mean). The standard deviation and the coefficient of variation may be used for the expected value of future cash flows. In this case, the smaller the standard deviation or the coefficient of variation of an investment among alternative investments, the better it is. For example, if Proposal A in Table IA in the Appendix has a probability of success of 0.7 and Proposal B has a probability of success of 0.6, the expected values of the NPV are $112 and $278.4, respectively. On the other hand, if the standard deviation and/or coefficient of variation for project B is considerably higher than for project A, project A may be the more attractive investment although project B has the higher expected monetary value. The same methodology can be used to evaluate projects listed under other methods presented in capital budgeting under certainty. Other useful tools for evaluating investments under risk are decision trees and simulation.

1. *Decision Tree Analysis:* The decision tree is a means of graphically illustrating the pattern of relationship among decisions involving conditional probabilities (i. e., where the probability of one alternative action is tied to the outcome of another event). Figure 2 shows a decision-tree diagram of possible outcomes for a corporation in a two-year period, with the probability of 0.7 receiving $1,000 for each of the

Figure 2. *Decision Tree of Cash-Flow Expectations*



two years, compared to the probability of 0.3 receiving no cash flow. The expected discounted cash inflows of the project costing $1,000 may be calculated assuming a discount rate of 10% as the required rate of return, as shown in Table 1.

Table 1. *Eexpected Present Value of Discounted Cash Flows*

Calculations (Present Value 10% Conditional Cash Inflows)	Discounted Cash Flows	Probability	Expected Value of Discounted Cash Flows
	(1)	(2)	(1) x (2)
0.909 ($1,000) + .826 ($1,000)	$1,735	0.49	$850.15
0.909 ($1,000) + .826 (0)	909	0.21	190.89
0.909 (0) + .826 ($1,000)	826	0.21	173.46
0.909 (0) + .826 (0)	0	0.09	0
Expected Present Value		1.00	$1,214.50

The expected net present value is $114.50 ($1,214.50—$1,100). If the firm accepts the proposal, there is a 0.04 probability of losing the entire $1,100. On the other hand, the company may gain $1,735 in discounted cash inflows, with a probability of 0.64 of achieving this result. In the other two cases, the outcome would result in losses but these would not be ruinous to the firm. *The value of the decision tree is that it sets out various choices and their probability of fulfillment and then proceeds to quantify the result.* It should be also mentioned that payoff tables and decision trees involve essentially the same computational procedures and should give identical results for the same set of data (Wert & Henderson, 1979, pp. 190—191).

2. *Computer Simulation:* Concepts presented in the decision tree analysis can be extended to computer simulation. The risk of the project depends on both its sensitivity to changes in key variables (market factors, investment cost factors, and operating and fixed cost factors) and the range of likely values of these variables, i. e., the probability distribution for each variable used in simulation.

* Probability of path equals probability of year 2.

The first step in a simulation for investment planning is to specify the probability distribution for each one of the key variables used in the simulation analysis. During the simulation process the computer will select a random value according to the probability distribution assigned by the mangement for the particular factor. Once this is done, the computer generates a set of income statements and cash flows and calculates NPV for run 1 and stores it. The computer then goes to run 2, 3 and so on. The stored NPVs for all the runs are then printed out in the form of frequency distribution, together with expected NPV and the standard deviation of this NPV. The advantage of simulation for investment planning is that it shows management the range of possible outcomes under conditions of risk if the project is accepted, not just a point estimate of NPV.

CAPTIAL BUDGETING UNDER UNCERTAINTY

Uncertainty is by far the most common condition confronting the decision-maker. Under conditions of uncertainty, the decision-maker, having no information about the probabilities of the states of nature, makes his choice based on the decision criteria he subjectively feels most reliable or comfortable with. When uncertainty exists concerning future cash flows, there is no clear-cut decision rule. The manager must rely on subjective measures to allow for the correct assessment of the investment proposal considered. Usually managers separate investment proposals into various uncertainty categories based on managerial judgement. For a group of projects one can use different criteria explained in this paper. Other methods that accomplish a similar result on an *individual project* basis include application of a risk-adjusted discount rate and use of certainty equivalent techniques.

1. *Risk-Adjusted Discount Rate (RADR):* In this method the decision-maker will adjust for varying degrees of risk implicit in an investment proposal by reducing or increasing the discount rate based on managerial judgment. It is generally agreed that riskier projects should be evaluated with a higher discount rate than the overall corporate cost of capital while a lower discount rate should be used for lower risk projects. Unfortunately, there is no good way of specifying exactly how much higher or lower these discount rates should be — given the present state-of-the-art. Risk-adjustments are necessarily judgmental and somewhat arbitrary. The general form is:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1 + k^*)^t} \qquad (12)$$

where k^* is the risk-adjusted discount rate and R_t is return for period t.

The problem is that the risk-adjusted rate penalizes projects whose cash flows are larger at the end-years of the project. This method therefore should be used only when there is an unusual increase in uncertainty close to the end-years of a project.

2. *Certainty Equivalent Techniques (CET):* In this approach, the decision-maker will adjust the cash flow of the project to reflect the degree of uncertainty involved. While the risk-adjusted discount rate adjusts the denominator, the certainty equivalent approach adjusts the cash flows themselves.

$$NPV = \sum_{t=1}^{n} \frac{C_t R_t}{(1+i)^t} \tag{13}$$

$$\text{where } C_t = \frac{\text{certain cash flow}}{\text{uncertain cash flow}}$$

and C_t is called certainty equivalent in period t.

It should be mentioned that both these methods, RADR and CET, were suggested by Stapelton (1971) and Bierman and Hass (1973). They proposed comparing expected net present value taking into account the market's risk-return trade-off and the possibility of diversifying away the uncertainty of the project's cash flow. Rubenstein (1973) suggested a comparison between the expected rate of return of a project and the default-free rate adjusted for project risk. However, according to Cooley et al. (1977), all three approaches "yield identical investment decisions and any of them can be used for investment selection or theoretical development (Cooley et al. 1977, p. 122)."

3. *Other Criteria for Capital Budgeting under Uncertainty:* In addition to the RADR and CET methods mentioned above, there are some additional criteria not mentioned by the researchers on capital budgeting under conditions of uncertainty. These criteria are mentioned in the Operations Research, Management Science, as well as Operations Management (OR/MS/OM) literature. Unfortunately, to the best of our knowledge, none of these criteria are mentioned in the capital budgeting literature although they are extensively used in the OR/MS/OM literature when dealing with decisions under conditions of uncertainty (probability not known). Let us now examine these criteria one by one.

The *Laplace Criterion* can be used for comparison of multiple projects. Under the Laplace Criterion, the decision-maker assumes that each potential state of nature should be assigned the same probability since the future states of nature are not known. This criterion is similar to the expected monetary value. The problem is treated as if it were one of risk. The decision-maker selects the alternative with the highest payoff (Miller & Starr, 1967, p. 122).

Table 2. *Payoff Matrix for Capital Budgeting under Uncertainty*

Project	Economic Condition: Boom P = 1/3	Normal P = 1/3	Recession P = 1/3	EMV
A	3,500	1,800	—1,000	1,433.33
B	2,000	1,500	950	1,483.33[3]

In Table 2, project B has the higher monetary value although it has a lower payoff during the boom and normal economic conditions.

The *Maximin Criterion* was suggested by Abraham Wald. Under the maximin criterion one assumes that the worst will happen. This is also called the pessimistic or conservative criterion. According to this criterion, the decision-maker should select the highest payoff under the worst state of nature (best of the worse) or the maximum of the minimum returns. This criterion is used by decision-makers who are extremely pessimistic, cautious, and conservative about the future payoffs of their projects and state of nature. This criterion is useful in situations when a loss would bankrupt a firm. In such an instance, management must be vey conservative. Using data from Table 2, the decision-maker would choose project B because under the worst economic conditions it would make a profit of $950 while project A would have a loss of $1,000 (Miller & Starr, 1967, p. 116).

The *Maximax Criterion* is based on an optimistic, bold and aggressive outlook for the future. The financial decision-maker in such a case should select the highest payoff under the most favourable state of nature or the maximum among the maximum payoffs (for each project). In our example in Table 2, project A has the highest payoff of $3,500 when compared to the $2,000 payoff for project B.

This criterion can be used if the payoff is either insignificant in relation to total financial resources of the firm or because management is sure of their R & D capabilities, competence of their scientists, product future, etc. Finally, management may have certain available information which indicates a very favourable state of nature in the future and therefore it is ready to make an aggressive move.

The *Hurwicz Criterion* was suggested by Hurwicz (1958) and it is a compromise between two extreme criteria, minimax and maximin. Hurwicz observed that decision-makers are rarely completely optimistic or pessimistic. They are somewhat in between these two extreme criteria. For that reason, Hurwicz suggested the use of a coefficient of optimism, α, which is a value between zero and 1 or $0.0 \leq \alpha \leq 1.0$. This coefficient of optimism, α, should be used to multiply the highest payoff for each alternative course of action. The minimum payoffs should be multipled by $1 - \alpha$ which is in fact, the coefficient of pessimism. If the coefficient of optimism is equal to 1, the Hurwicz criterion is exactly the same as the maximax criterion and when the coefficient of optimism is equal to zero, the Hurwicz criterion is exactly the same as the maximin criterion. The formula is:

$$\text{Payoff or return} = \alpha\,(\text{max. payoff}) + (1-\alpha)\,(\text{min. payoff}) \qquad (14)$$

Let us assume that the coefficient of optimism, α is 0.8 and $1-\alpha = 0.2$. The expected values for the projects A and B presented in Table 2 will be:

A $3,500 (0.8) + (—$1,000) (0.2) = $2,600*
B $2,000 (0.8) + $950 (0.2) = $1,790

The decision-maker will select project A in this case.

When the coefficient of optimism is 0.5 and the decision-maker is 50% optimistic and 50% pessimistic, the expected values of projects A and B will be $1,250 and $1,475 respectively. The decision-maker will select project B this time. Sometimes, in reality, the decision-maker cannot specifiy the coefficient of optimism, α. In such a case one may present a scale of α values from 0 to 1, as the scale presented below, and ask the decision-maker to mark an X on the line above the value of the α coefficient the decision-maker is most comfortable with.

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
α	Completely Pessimistic										Completely Optimistic

Another way to help the decision-maker specify the coefficient of optimism is to graph the values presented in Figure 3. On the right-hand side are the optimum payoffs for each project ($\alpha = 1.0$) and on the left-hand side of the graph are the minimum payoffs ($\alpha = 0.0$). By connecting the minimum and maximum points for each project we will get a point of intersection which will indicate the coefficient of optimism as 0.77. At the intersection point the decision-maker should be indifferent between the projects A and B. The more pessimistic the decision-maker is and the more his coefficient of optimism is below the 0.77 point, the more he will prefer project B. The more optimistic he is (values above 0.77), the more he will prefer project A.

Savage's Minimax Regret Criterion uses the concept of opportunity loss and regret as a decision criterion (Savage, 1951, pp. 55—67). Regret is the difference between the maximum payoff for each state of nature and the actual payoffs for each strategy. It is necessary to construct a regret matrix and select the highest regret for each strategy. The final step is to select a strategy which will minimize the maxim regret. Using the payoff matrix example presented in Table 2, Savage's criterion will give the results shown in Table 3.

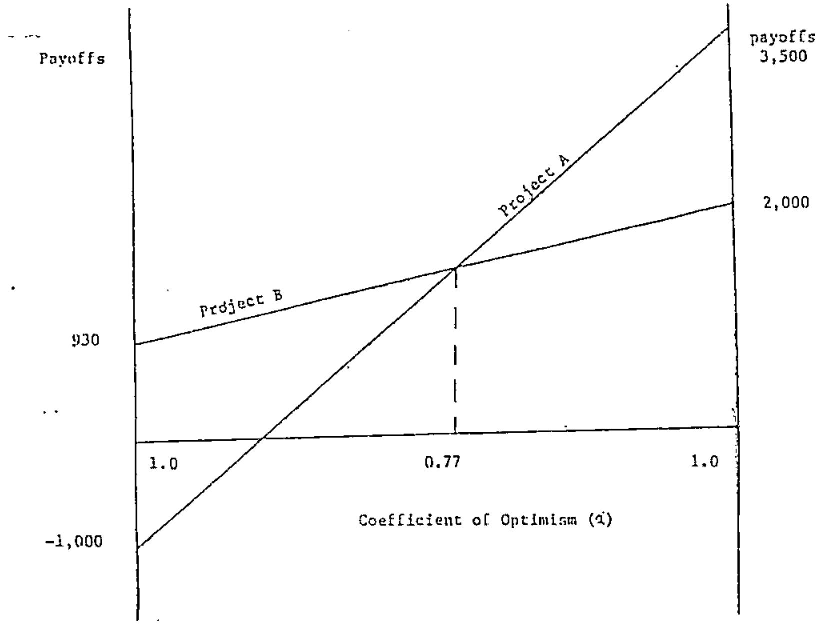


Figure 3. *The Hurwicz Criterion Graph*

The α coefficient can also be derived by solving the two equations:

$$3{,}500 - 1{,}000X = 2{,}000 + 950X$$

$$X = \frac{1{,}500}{1{,}950} = 0.77$$

Table 3. *Savage's Regret Matrix*

Project	Economic Condition: Boom	Normal	Recession	Maximum Regret
A	0	0	1,950	1,950
B	1,500	300	0	1,500*

Here one would choose project B in order to minimize the maximum regret.

There is a problem in applying this criterion. According to Lee and Moore (1975, p. 74) "... the amount of regret is presented in monetary units (dollars). Since the relative value (marginal utility) of this amount decreases as the total payoffs increase, sometimes we may select an inferior alternative when the regret criterion is adopted" as the example in Table 4 indicates.

Table 4. *A Decision Problem under Uncertainty and Regret*

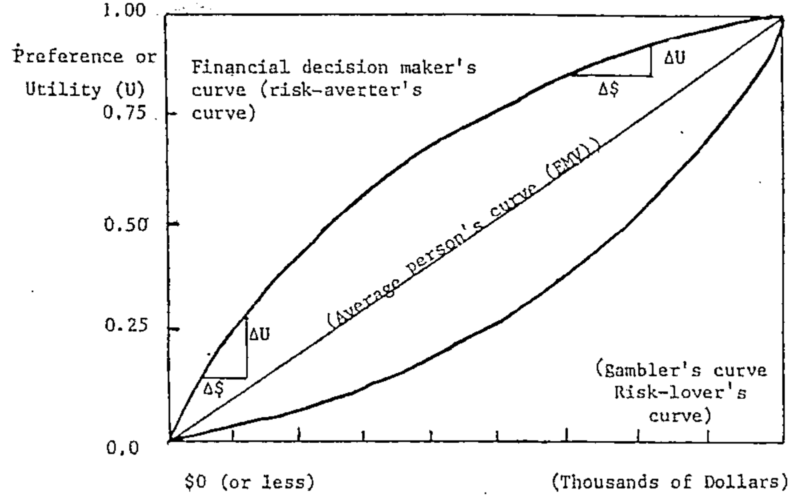
Project	State of Nature			Regret Matrix		
	N_1	N_2	N_3	N_1	N_2	N_3
C	$250,000	$123,000	—$75,000	0	0	100,000
D	150,000	123,000	25,000	100,000	0	0

The decision-maker should be indifferent between projects C and D. However, a closer analysis may indicate that under the state of nature N_3, project C will loss $75,000 and project D will bring a return of $25,000. If one takes into account utility which can be defined as an attitude toward risk, the above example may make even more sense and this is the next topic of our discussion.

A Decision about Decision Criteria. One may ask which criteria the decision-maker should apply since different criteria may suggest a choice of different strategies creating confusion. Why not use the presented decision criteria to choose a decision criterion? While we cannot suggest how to apply different decision criteria to choose a criterion, we can state that the financial decision-maker who is looking to maximize return on an investment should choose a criterion he (or top management) is most comfortable with. A criterion which will give the financial decision-maker peace of mind should be chosen. The attitudes and the state of mind of the decision-maker should not be jeopardized. One must also take into consideration the decision-maker's personality and frame of reference plus the financial position of the organization. The decision-maker could also make a comparison of the maximum and the minimum expected payoffs under different criteria, then these expected payoffs could be compared. Depending on the decision-maker's attitude toward risk (loss), he should choose the strategy which is most compatible with his personality and attitudes as well as with the organizational goals. Utility theory and attitude toward risk of both the individual (decision-maker) and the organization play a very important role in the selection of criterion.

Utility Theory may help the decision-maker determine his/her utility or attitude toward risk. A preference curve can be used to determine the expected utility for different projects. There are three basic types of utility curves as illustrated in Figure 4.

Figure 4. *Three Basic Types of Utility Curves*



Financial decision-makers are usually risk averters, especially if the projects are very large and a failure can bankrupt an organization. It is important to mention that in the case of a conservative decision-maker, the marginal utility of money is diminishing. The more money the project makes, the smaller the utility of money. On the other hand, the closer the conservative decision-maker is to bankruptcy, the large the utility of money as Figure 4 indicates. This diminishing marginal utility leads directly to risk aversion which is reflected in the capitalization rate investors apply when determining the value of the firm.

Hammond (1967) has illustrated the method to obtain a preference curve. *Utils* presented on the axis of the preference curve can be utilized in the same way payoffs are used. However, by using probabilities and payoffs one will get an average curve which is in fact the expected monetary value (EMV) curve. Whole use of utils (instead of payoffs) will indicate expected utility of a project. Expected utility, on the other hand, may lead to a different project choice than EMV. For example, if payoffs in the decision tree (Figure 2) or the Laplace matrix (Table 2) are replaced by utils, the expected utility in Figure 2 may give a different amount or the Laplace criterion may lead to a choice of a different project (Table 2).

SUMMARY AND CONCLUSIONS

This paper reviewed and compared different capital budgeting techniques used under conditions of certainty, risk and uncertainty. The advantages and disadvantages of each of the techniques were discussed in light of the assumptions and availability of data.

In the area of capital budgeting, one is forced to move away from certainty in the direction of uncertainty. This is more true for capital budgeting in technical projects. Engineers and scientists who have the technical expertise can provide better estimates and information to financial analysts/managers provided they (engineers) have a better understanding of the concepts and techniques used in capital budgeting decisions.

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APPENDIX

Table 1A. *Calculating the Net Present Value*

	Proposal A			Proposal B		
Year	Net cash flow	P. V. factor at 10%	P. V. of cash flow	Net cash flow	P. V. factor	P. V. of cash flow
1	$1000	.91	$910	$200	.91	$182
2	800	.83	664	400	.83	332
3	600	.75	450	600	.75	450
4	200	.68	136	800	.68	544
5				1000	.62	620
6				600	.56	336

	Proposal A	Proposal B
P. V. of inflows	$2160	$2464
Less: investment	2000	2000
NPV	$ 160	$ 464

Table 2A. *Calculating the Internal Rate of Return*

	10 percent			20 percent		
		Present Value			Present Value	
Year	P. V. Factor	A	B	P. V. Factor	A	B
1	.91	$910	$182	.83	$830	$166
2	.83	664	332	.69	552	276
3	.75	450	450	.58	348	348
4	.68	136	544	.48	96	384
5	.62		620	.40		400
6	.56		336	.33		198
P.V. inflows		$2160	$2464		$1826	$1772

Using linear interpolation* $IRR_A = 10\% + \frac{1600}{344} = 14.8\%$

$IRR_B = 10\% + \frac{4640}{692} = 16,7\%$

* for project A at 10% Present value is 2160
at 20% present value is 1826

Difference 10% 334

$10 \times \frac{160}{334} = 4.8$ 10% + 4.8% = 14.8%

Table 3A. *Calculation of Terminal Rate of Return and Net Terminal Value*

Compound Values

	Project A		Project B	
Year	Compound Value Factor at 5%	Compound Value	Compound Value Factor at 5%	Compound Value
1	1.158	$1158	1.276	$255
2	1.102	882	1.216	486
3	1.050	630	1.158	695
4	1.000	200	1.102	882
5			1.050	1050
6			1.000	600

	Project A	Project B
Compound value of cash inflows:	$2870	$3968
TROR	9.4%	12.1%
Compound value of investment =	2000 x 1.216 = $2432	2000 x 1.34 = $2680
NTV =	$2870 — 2432 = $ 438	$3968 — 2680 = $1288

Table 4A. *Calculation of Equivalent Annual Cost*

Project A		Project B	
Investment cost	= $45,000	Investment cost	= $54,000
Salvage value	= $ 5,000	Salvage value	= $ 4,000
Economic life	= 6 years	Economic life	= 9 years
Maintenance and operating costs	= $ 1,000/year	Maintenance and operating costs	= $1,000/year
Cost of capital	= 10%	Cost of capital	= 10%
CR&R = (1 — S) (CRF); CRF = $1/(PV_A)^6_{10\%}$ = ($45,000 — $5,000) (.2296) = $ 9,184.85		CR&R = (1 — S) (CRF); CRF = $1/(PV_A)^9_{10\%}$ = ($53,000 — $4,000) (0.1736) = $8,508.42	
S_i = ($ 5,000) (0.10) =	500.00	S_i = ($4,000) (0.10)	400.00
OR (maintenance and operation)	1,000.00	OR (maintenance and operation)	1,000.00
Total per year	$10,684.85	Total per year	$9,908.42

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ANALIZA INVESTICIONIH ODLUKA U USLOVIMA IZVESNOSTI, RIZIKA I NEIZVESNOSTI

Jugoslav S. MILUTINOVICH
George J. TITUS

Rezime

U članku se daje pregled, kao i komparacija različitih tehnika analize investicionih odluka u uslovima izvesnosti, rizika i neizvesnosti. Prednosti i nedostaci svake pojedine tehnike razmatraju se u svetlu pretpostavke i raspoloživosti podataka.

U oblasti analize investicionih odluka prinuđeni smo da se pomeramo od izvesnosti ka neizvesnosti. Ovo pogotovu važi za analizu investicionih odluka u tehničkim projektima. Ukoliko bolje poznaju koncepte i tehnike analize investicionih odluka, inženjeri i naučnici koji imaju specijalističko tehničko znanje mogu da daju bolje ocene i informacije finansijskim analitičarima odnosno preduzetnicima.

SAVETOVANJE O PROBLEMIMA EKONOMSKE STABILIZACIJE

Na Ekonomskom fakultetu u Beogradu održano je 14. decembra 1981. naučno savetovanje posvećeno ekonomskoj stabilizaciji, a u znak sećanja na krvave demonstracije protiv nenarodnog režima 1940. godine. Učesnike je pozdravio dekan Ekonomskog fakulteta prof. Vojislav Kolarić koji je istakao da će ovakve rasprave o najznačajnijim pitanjima jugoslovenske privrede i društva postati stalna praksa fakulteta. Ovaj datum ubduduće će se slaviti kao Dan Ekonomskog fakulteta u Beogradu i biće obeležavan na ovakav ili sličan način. Zatim je prof. Radmila Stojanović evocirala uspomene na demonstracije od 14. decembra 1940. god. u kojima je i sama učestvovala.

Uvodno izlaganje na ovom savetovanju podneo je potpredsednik Saveznog izvršnog veća Zvone Dragan. Obraćajući se učesnicima, on je naglasio da među jugoslovenskim ekonomistima poslednjih godina raste spremnost da se neposredno angažuju u ostvarivanju politike ekonomske stabilizacije. Ekonomska nauka ne nudi nam samo teorijski »čiste modele«, već i čitav niz konkretnih i efikasnih mera u pravcu dugoročnije politike ekonomske stabilizacije. Budući razvoj naše privrede, istakao je dalje potpredsednik Dragan, mora počivati na neinflatornim osnovama. Zbog toga je neophodna selekcija razvojnih prioriteta, prvenstveno veća orijentacija na izvoz, na proizvodnju energije, sirovina i hrane na osnovu domaćih izvora, kao i na inostrani turizam i magistralni saobraćaj. Mnogi problemi naše privrede su dugoročni i ne mogu nestati preko noći, što se mora imati u vidu u ostvarivanju stavova iz Rezolucije za 1982. godinu, smatra potpredsednik Dragan. Uzroci mnogih problema su interni a vezani su sa neusklađenošću ponude i tražnje, sa nedovoljnom produktivnošću rada i predimenzioniranom potrošnjom. Osnovni pravci promena u narednoj i sledećim godinama, prema mišljenju Dragana, bili bi sledeći:

1) ofanzivni izvoz s posebnom orijentacijom na konvertibilno tržište, selekcija uvoza i smanjivanje deficita platnog bilansa,
2) snižavanje stope inflacije, pre svega, ekonomskim merama, ali i društvenom kontrolom cena.
3) podizanje stope produktivnosti rada i stope privrednog razvoja,
4) svođenje finalne potrošnje na realni nivo uz očuvanje realnog ličnog dohotka i selekcija investicija,
5) dalja dogradnja i razvoj mehanizma ekonomske politike.

Akademik Branislav Šoškić je istakao da samoupravljanje najpotpunije dolazi do izražaja u tržišno-orijentisanoj socijalističkoj privredi. Tržišna orijentacija naše privrede je neophodna, ali i aktivna ekonomska politika protiv recesije, nezaposlenosti, inflacije, monopola, jer tržište ne može na svim po-