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I. Introduction

Business organizations are continually faced with the problem of allocating scarce resources - time or money - to alternative uses. Investments are commitments of resources, made in the hope of realizing benefits that are expected to occur over a reasonably long period of time in the future. The future success of the company depends on the investment decisions made today. The decision maker faces a number of potentially serious problems: a large number of available alternatives, interrelationships among projects, manpower and capital constraints, uncertainties because of unreliable or incomplete data. The purpose of capital budgeting is to provide a decision framework which considers the problems associated with the investment decision and yet is a help to business management in analyzing and deciding on investment proposals.

With reference to Bierman and Smidt (3, p. 4), "Capital budgeting is a many-sided activity that includes searching for new and more profitable investment proposals, investigating engineering and marketing considerations to predict the consequences of accepting the investment, and making economic analyses to determine the profit potential of each investment proposal".

This article starts with a discussion of the major shortcomings of classical capital budgeting methods, i.e. considering investment projects

only on an individual basis, and, therefore, failure to consider
the statistical interrelationships among the set of proposals and
the existing asset base of the firm. In a second paragraph, it is
shown how the application of modern portfolio theory to the asset
expansion problem has provided a solution to this basic problem of
failing to explicitly consider the true risk premium attached to
any investment. This is done by means of a survey of the results from
major research in the area of financial portfolio theory related to the
capital budgeting problem. Finally, the author discusses the problem
which arise in practical application of the portfolio approach to capital
project appraisal. Answers to those problems are formulated on the
basis of recent research in portfolio theory.

II. Weaknesses of the Classical Capital Budgeting Techniques

Usually, any decision-making process can be seen as a set
of consecutive phases (e.g. Ansoff (1), Simon (47)), such as problem
identification, formulation of alternatives, evaluation of alternatives.
This analytical process is followed by selection, implementation and
information feed-back. Investment theory has primarily been concerned
with the evaluation of the contribution by alternative investment projects
and the selection from a set of investment proposals. Numerous capital
budgeting techniques and decision criteria have been proposed in an
attempt to provide a decision framework for the decision maker. The most
widely used methods are also the more simplistic capital budgeting decision
techniques that have been suggested such as pay-back, internal rate of

return, and net present value. Research by Westwick and Shohet (59)

showed that the internal rate of return was by far the method preferred

by most companies out of a sample of 81 British firms, followed by the

NPV and pay-back. However, only 10 out of 81 companies used a single

method in evaluating investment proposals. Comments by participants suggested

that discounted cash flow (IRR, NPV) tend to be used for major investments

and pay-back for small investments or as a screening device for larger

projects. Although the net present value was not ranked first, it is

often, but not universally, cited as the superior capital budgeting

decision rule.

The theoretical solution to the capital budgeting problem,

underlying these standard evaluation methods, is to select those projects

for investment for which the expected return is greater than the cost

of capital to the firm. Or in case of the NPV rule, when the so-called

marginal cost of capital is known, all projects, whose NPV is positive

when discounted at that rate, should be accepted. According to the

traditional capital budgeting theory a project is described as the net

present value of all cash flows associated with a proposed investment. In

fact there is much more about it. To quote Bower (5, p. 12), "In fact,

the theory is false on theoretical grounds because it ignores the

essential effects of uncertainty". Both Bower (5, p. 399) and Donaldson (13)

have made clear that the purpose of capital procedures is not a go-no-go

decision on a project; but instead a review of the potential impact of

accepting a new project on the existing total asset base (market value)

of the firm.

The keystone of the standard approach to the investment problem is the proposition that the value of a project is equivalent to the discounted value of its anticipated yield. Thus in selecting an investment proposal, the investor should seek to maximize the discounted value of the project's yield over the projected life time. However, capital budgeting decisions have to be made in a world of uncertainty. In order to account for risks some writers (e.g. Chen (10), Fama (15), Shapiro (44), Van Horne (53), Weston and Brigham (58)) use risk-adjusted discount rates. They require that the rate at which expected returns are discounted must vary with the risk involved in a particular investment. By having multiple discount rates (hurdle rates) the firm applies a risk adjustment in any discounted cash flow evaluation of projects which had varying degrees of risk. In the Fremgen (18) survey, 54% of the 170 respondents indicated their firms used higher discount rates when evaluating riskier projects. Robichek and Myers (40) point out that using a uniformly higher discount rate to reflect additional risk involves penalizing future cash flows relatively more heavily than present ones. They propose a certainty - equivalent method where risk-adjusted cash flows are discounted at the risk-free rate. This method requires generating certainty equivalent cash flows, for which no satisfactory method has yet been developed. Others require that a risk allowance be subtracted from each project's expected return, i.e. the higher the risk, the greater the risk allowance. Cash flow adjustments are often preferred on the pragmatic grounds that there is available more and better information on the effect of

risks (e.g. inflation, exchange rate changes) on future cash flows than on the required discount rate.

A first major weakness of the standard capital budgeting techniques is, as suggested by Bierman and Hass (2), that "there has been no theoretically acceptable method proposed for a businessman to apply in determining the amount by which the time value of money should be adjusted for risk or the size of the dollar risk premium that should be deducted from the net present value of an investment that has been computed using a default free discount rate as the time value of money". It is probably a more useful approach to apply sensitivity analysis to different sets of operating cash flows instead of adjusting the discount rate.

There is another rather obvious inadequacy which attaches to the standard approach. It implies that, in order to attain the optimal allocation of funds, the firm should place all of its funds in those investments having the highest discounted value of expected returns. This theory attaches no merit to diversification no matter how the expected returns are formed nor at what rate the expected returns are discounted. As Markowitz (32) points out, the "discounted expected return maxim" is probably a heritage of classical economy theory which assumes (a) a perfect capital market, i.e. unrestricted opportunity to lend and borrow at the same risk-free rate and no transaction costs, and (b) certainty with respect to all decision variables. This second common shortcoming of considering projects only on an individual basis is the result of a failure to consider the statistical interrelationships among the set of investment proposals and the existing asset base of the firm.

The risk of an individual investment lies not only in the degree
of uncertainty of that investment's cash flows but also in the extent to
which these flows vary with the cash flows from the other assets held
by the firm.

III Portfolio Approach to Capital Budgeting.

Portfolio theory developed by Markowitz (31, 32), Sharpe (45, 46),
Lintner (26), Mossin (33, 34), Robichek and Myers (39, 41), and
Tobin (51), provides an answer to the basic shortcomings of the classical
economic approach to the capital budgeting problem. According to
portfolio theory, all investment projects should be evaluated with respect
to their expected return and risk, with a general desire to maximize
the market value of the company. The theory assumes that expected return
is desirable and that risk (i.e. variance of return) is undesirable.
That is, the investor wishes to get the greatest return for the level
of risk he is willing to assume. The basic tenet of modern portfolio theory
is that the risk of a portfolio of capital assets depends not only on
the variance of the returns of individual capital assets in the portfolio.
The risk of a portfolio of capital budgeting projects can be reduced
by diversifying the investment projects held in the portfolio in such a
way so as to include projects that are not perfectly positively correlated
with other projects in the portfolio. Modern portfolio also provides
the decision-maker with an explicit measure of the risk incorporated by
a particular investment proposal, i.e. the covariance of the project's
expected return with those of all other projects of the firm.

According to modern financial theory, the principal objective of management in capital investment is to increase the value of the firm. The value of the firm is based on the market price of its stocks traded in competitive . and efficient capital markets[*]. It follows that if the stock market is efficient, equity prices will fully reflect the favourable effect of profitable capital investments in fixed assets. Therefore, in order to predict the effect of a proposed capital investment on the value of the firm, management must discount the project's expected cash flows at the market's equivalent required rate of return. Correspondingly, those projects should be accepted which will lead to an increase in value of the company. i.e. by investing in projects with higher returns than those offered by investment in the capital market in securities of the same risk.

However, before discussing the development of the portfolio approach to capital budgeting, one must remind that there are significant differences between the capital budgeting and the standard portfolio problems. As mentioned by Cord (12) the main difference is that in the budgeting problem the variable can only take the values of one or zero, i.e. funds are invested in a particular project or they are not. Because of the integer nature of the problem, the capital budgeting problem does not permit either a quadratic objective function. However, in practice it might be possible in some cases to vary the size of investment projects or to execute only a part of an investment project. The standard portfolio problem also assumes that all investors are expected utility maximisers and have a quadratic utility function of wealth.

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[*]A market is defined as efficient when transaction prices fully reflect all relevant information. For a survey of research findings concerning the efficieny of capital markets see Firth (17).

In the typical security portfolio case, the total amount invested
is considered fixed, only the fraction of the different securities
in the portfolio changes. Let,

x_i = fraction of total investment in security i,

i = 1, ...,N

$\sigma_{i,j}$ = covariance between security i and j, i ≠ j

for i = j, $\sigma_{ii} = \sigma^2_i$ = variance security i.

σ^2_p = portfolio variance.

then, the variance of the security portfolio is given by:

$$\sigma^2_p = \sum_{i=1}^{N} \sum_{j=1}^{N} x_i \, x_j \, \sigma_{ij} \qquad \forall \ i,j$$

In the project portfolio case, the typical decision criterion is:

$$\sigma^2_p = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} \qquad \forall \ i,j$$

Adding a project to the portfolio does not change the mean earnings
generated from the projects already in the portfolio, for the investment
budget is increased. There are no x_i's which are redefined with each
addition or deletion from the portfolio. This is in contrast to the
security portfolio, where a fixed amount of money is invested. In other
words, the optimum mixture (x_i's) in the security portfolio can be
selected independent of the size of the budget. In the project portfolio,
this selection is not possible. This means that the separation theorem[*]
holds for security portfolios, but does not hold for project portfolios.

[*]the seperation theorem, suggested by Tobin (51), says that the proportionate
composition of a stock portfolio is independent of the relative amount of the
ratio of the gross investment in stocks to the total net investment.

Another major difference with the standard security portfolio problem is that outlays for capital investments can stretch over more than one budget period. There is a definite difference of time horizon. Finally, changes in the composition of a security portfolio usually incur relatively small transaction costs compared to adding or deleting a project to the fixed assets investment portfolio of a company.

The Lorie and Savage (28) problem may serve as a point of departure for the discussion, since their article was the initiation to the current thinking on portfolio choice of capital investments. They proposed a method of choosing a group of investments subject to a fixed capital constraint. It is a two-period problem, in which given the net present value of a set of independent investment alternatives, and given the required outlays for the projects in each of two time periods, the model finds the subset of projects which maximizes the total net present value of the accepted ones while simultaneously satisfying a constraint on the outlays in each of the two periods.

Weingartner (55, 56) generalized this problem to an arbitrary number of time periods and stated as an integer programming problem.

Let: c_{ij} = cash investment in year i in project j

$i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, N$

C_i = total cash budget constraint in year i

b_j = net present value of project j (discounting is done by the cost of capital)

x_j = fraction of project j accepted, x_j = 0 or 1.

The Weingartner model is then:

$$\max \quad \sum_{j=1}^{N} b_j \cdot x_j$$

whereby:

$$\sum_{j=1}^{N} c_{ij} x_j \leq C_i \qquad \text{for } i = 1,2,\ldots\ldots\ldots, n$$

$$x_j = 0$$

or $\quad x_j = 1 \quad$ for $j = 1,2,\ldots\ldots N$

$$C_i, c_{ij} \geq 0$$

A more recent major advance in the field of capital budgeting has been the application of the well-known Sharpe (45)- Lintner (27)- Mossin (33) Capital Asset Pricing Model (CAPM) to provide capital expenditure decision rules for risky projects. According to CAPM the required return on a project j is given by

$E(R_j) = R_f + (E(R_m) - R_f)\beta_j$, where R_f is the risk-free interest rate, $E(R_m)$ the expected rate of return of the market portfolio (i.e. a broadly based market index), and β_j is the volatility of project j.

β_j is given by: $\beta_j = \dfrac{\text{Cov } (R_j, R_m)}{\sigma^2_{R_m}}$, where

Cov (R_j, R_m) represents the covariance of project j with the market and $\sigma^2_{R_m}$ represents the variance of the market return.

Rubenstein (18), Stapleton (48), Weston (57) and others have

shown that a project should be accepted only if:

$E(R_j) > R_f + (E(R_m) - R_f)\beta_j$. The expected return on the new project

must exceed the rate of return on a risk-free security (i.e. treasury

bill) plus the market risk premium weighted by β_j, the measure of

the individual project's systematic risk. The investment criterion,

usually referred to as the market price of risk, MPR, criterion,

$$E(R_j) > R_f + \lambda \, Cov \, (R_j, R_m) \text{ with } \lambda = \frac{E(R_m) - R_f}{\sigma^2_{R_m}}$$

this general relationship is illustrated in the figure below:
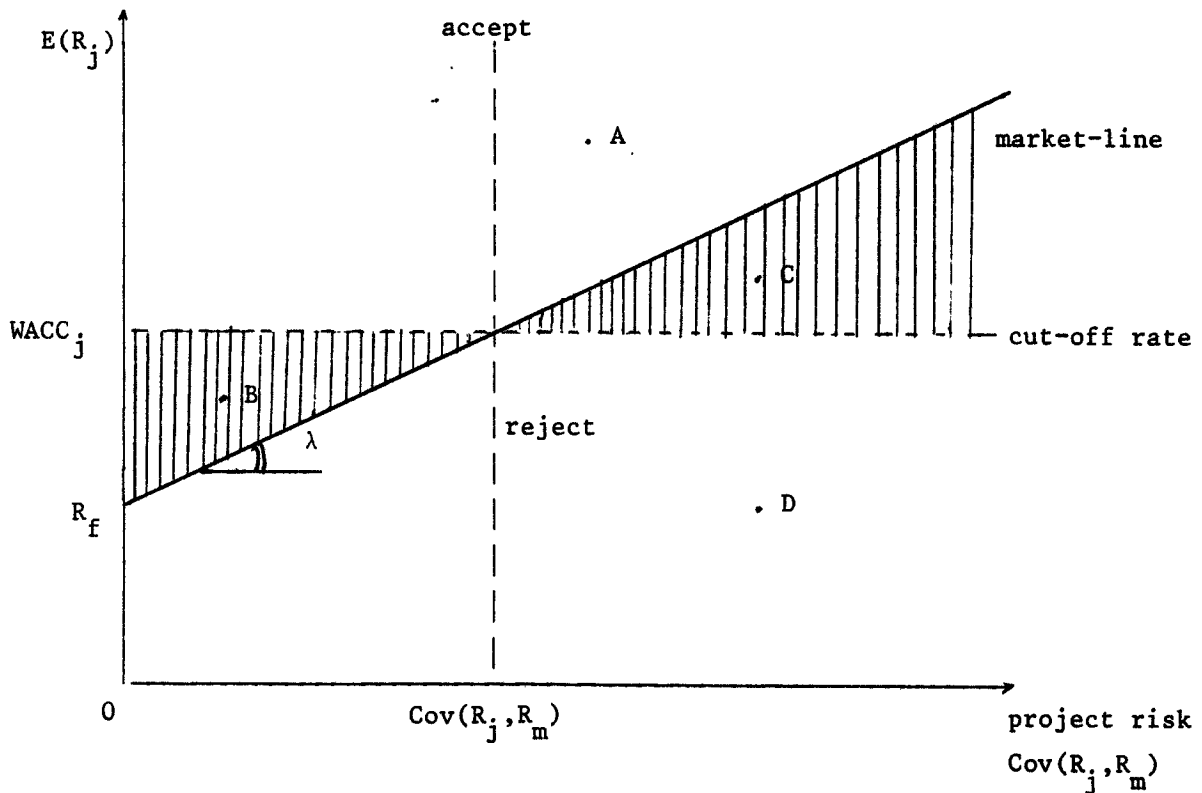
Graphically, the decision criterion implies a firm should accept
a project only if the project's return-risk order pair plots
above the market line, such as projects A and B, and reject all
those that plot below the market line, such as C and D. Acceptance
of projects such as A and B with returns in excess of the levels
required by the return-risk market equilibrium relation will lead
to an upward revision of the firm's share price. To see this, when
such favorable projects are added to the firm's operations, the firm
can be viewed in temporary disequilibrium with the firm's expected
return on its common stock higher than required by the market line. To
restore · equilibrium, induced by the excess returns, individual
investors will start bidding up the share price of the firm.
The constant slope of the market line, λ, may be interpreted as the
risk-adjusted cost of capital appropriate to all firms and all projects.
Rubenstein (42) asserts that all firms in the economy may use λ,
i.e. $\dfrac{E(R_m) - R_f}{\sigma^2_{R_m}}$, as a hurdle rate for all projects.
This contrasts with the traditional "weighted average cost of capital"
(WACC) criterion which must be computed separately for each firm.
Following the WACC-criterion a project should be accepted only if
$E(R_j) > WACC_j$, that is, graphically, only if it falls above the horizontal dotted
line in the Figure above, i.e. such projects as A and C. Therefore,
for projects that fall in the shaded areas, such as B and C, the WACC
and MPR criteria lead to contradictory decisions. The WACC criterion
is invalid because it fails to consider the risk of projects.

For example, projects with $E(R_j) > WACC_j$ but with very high risk, such as C, will be improperly accepted. Rubenstein (42) gives two reasons for the invalidity of a general application of the traditional WACC-criterion in evaluating investment proposals. First, he says that the WACC criterion will only lead to the correct cut-off rate if projects fall in the same risk class of the firm, i.e. only if the projects plot on a vertical dotted line in the Figure above. His second explanation for the failure of the WACC criterion is the fact that it is not a marginal criterion. The appropriate marginal cost of capital for project j is equal to the appropriate discount rate for the project, i.e. $R_f + \lambda \, Cov \, (R_j, R_m)$.

At present a large number of researches have suggested a portfolio approach to capital budgeting. To name only a few, we refer to Broyles and Franks (7), Cohen and Elton (11), Fabozzi (14), Van Horne (54), Levy and Sarnat (24), Mao and Helliwell (30), Näslund (36), Quirin (37) and Wiper and Longbottom (61).
The multiperiod case of using CAPM for capital budgeting was developed by Bogue and Roll (4), and independently by Hamada (20). Simulation models for capital budgeting using the CAPM were formulated by Carter (8), Salazar and Sen (43) and Sundem (50).

III. Questions and Answers

Although there have been numerous theoretical applications of modern portfolio theory to the selection of optimal combinations of real assets, the portfolio approach has not known a widespread use

in actual business practice up to this day. A number of researchers have even questioned both the need and the validity of applying a portfolio approach to the capital budgeting problem. The argument is that if investors can highly diversify their portfolio to obtain the return-risk relationship they desire, then no additional benefits results if the company considers the statistical interrelationships among its current and prospective projects. Haley and Schall (19) suggest that since a company's stockholders hold highly diversified portfolios accross all assets, the company deciding on a project need not concern itself with diversification. The company only has to compare the initial outlay the project requires and the nature the project has. This value is taken to be the same, regardless of which company accepts the projects (see Brigham (6), Bierman and Hass (2). Myers (35) used a time-state-preference model to show that equilibrium in the security markets requires that corporate investment proposals be independent, that is, the value of an individual project is unaffected by any properties of other projects with which the project might be combined. Hoskins (22), Lewellen and Long (25), Rubinstein (42), Tuttle and Litzenberger (52) use the index model approach to argue that, when stockholders diversify properly, the appropriate measure of the risk of a capital budgeting proposal is the nondiversifiable component of the total risk of the proposal, i.e. its β-coefficient. Therefore, statistical interrelationships among projects are irrelevant and portfolio models are unnecessary in capital budgeting.

On the other hand, Fama (16), Jensen and Long (23), Stiglitz (49)
and Whitmore (60), note, as did Lintner (26) and Mossin (33), that
contrary to the common interpretation, the value of a specific project is
independent on the company undertaking it, even if no economic dependencies
are assumed to exist between the projects. It is argued that a particular
choice of a risky investment project by one company, although it
enhances that companny's value, can cause a detrimental effect by
increasing aggregate risk through the interaction with returns of other
securities in investors' portfolios. In our view, the shareholder should
not be concerned if the firm itself is not well diversified, since he
can diversify his holdings at least as easily and as cheaply as can
the firm. Since most shareholders own diversified portfolios, management
need not diversify for the sake of its shareholders but to reduce the
company risk to its management and workers. The major contribution of
modern portfolio theory to the capital budgeting problem is to assist
management in analysing and evaluating the risk associated with
individual investments within the context of a set of other investments.

Probably, the single most difficult problem in applying the
portfolio approach is the formulation of the investor's probability beliefs
concerning the cash flows is not new to the investor, it only requires
that the investor's beliefs and predictions are made explicit. In classical
capital budgeting theory, various ways were suggested in which one can
take risk into account. Näslund (36) lists the following techniques:
increasing the interest rate for more risky projects, substracting

a certain amount from the mean future inflows associated with the
project, shortening the time horizon for more risky projects, or some
other form of sensitivity analysis. It is often unclear, however,
how these methods are exactly related to the amount of risk involved
(for a discussion see Hillier (21)).

If in making probability assessments the errors are systematically
biased, then they are not likely to be of overwhelming importance to
stockholders, for they can diversify away many of these misassessments
in their personal portfolios. However, Bogue and Roll (4) claim that
the use of an improper capital budgeting techniques, such as risk
adjusted discount rates without portfolio consideration, will result
in aggregate errors which stockholders will not be able to eliminate.

The problem of project risk assessment is somewhat more
complex in planning a new product activity, since no historical
data are available from which to obtain the input required in the portfolio
model. Several ways of dealing with the subjective evaluation of portfolio
variance have been formulated in the modern capital budgeting literature.
Carter (8, p. 78) proposes to let the firm's managers specify the correlation
between investment projects on the basis of certain criteria (e.g. net
present value). For a given situation, these correlations can generate
the covariance matrix. He also mentions that if the existing firm is huge
in relation to any proposed project, the loss in accuracy is minimal when
the correlation between new projects are ignored.

In this case, one should rather only estimate the correlation between each new project with the existing firm's asset base or some market index. The practical problem remains if the managers are willing to make these correlation forecasts and of what quality they will be.

Another solution, suggested by Carter (8), is to ignore the variance approach altogether and to ask managers to accept gambles or judgments which reveal their certainty-equivalent[*] preferences for future cash flows of projects or portfolios. To obtain a distribution of cash flows which may be expected in each year of the project, ask the manager what payment he would accept with certainty in place of that uncertain cash flow in that year, and discount the certainty-equivalent value at a risk-free rate.

Markowitz (32) originally suggested the use of the semi-variance[**] as a measure of risk, instead of the now standard use of the covariance between the project's return and the market. Mao (29) conclued on the basis of a field study of 8 firms that the negative covariance, i.e. the variance of outcomes below the mean, was a far better measure of risk.

Another weakness of the portfolio approach is the usual assumption of a single-period optimization. It is a partical question that many firms do not face capital budgeting decisions in a portfolio

[*] Certainty-equivalents have been discussed in the business literature by Raiffa (38) and others.

[**] The semi-variance, $SV_j = E[R_j - R^0]^2$, is the expected value of the squared deviations of the possible returns with respect to an arbitrary chosen reference point, R^0.

context (see Chamberlain (9)). In current practice, a project is suggested, investigated, and approved or rejected individually. The main reason being that investment projects are spread over time and so are the investment decisions. The CAPM approach does not deny this fact, but only suggests that every project should be evaluated on the basis of its impact on the firm's portfolio of existing projects, i.e. the impact on the market value of the firm.

Finally, there remains the question of multiple goals of the firm. According to CAPM, all investors evaluate portfolios by only two parameters, expectation and variance of investment return. In a firm, many other objectives may play an essential role in making decisions on investments in physical assets. Firms operate in imperfect markets* as well on the product as on the production factors side. The on-going concern should place the return-risk analysis of individual project in a broader context of continuity of the firm.

V. Conclusion

Classical capital budgeting methods evaluate investment proposals on an individual basis, failing to recognize the statistical relationships among the set of proposals and the existing investments of the firm. In practice, this shortcoming could partially be waived by adjusting the operational cash flows of the project for the impact they have on the other current and future projects of the firm. Classical methods also fail to explicitly measure the risk incurred by accepting

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*A market is defined as perfect when there are no transaction costs, no taxes, free and complete information, and infinite divisibility of capital assets (projects).

a particular project, i.e. the impact of accepting a new project on the market value of the firm.

The portfolio approach (CAPM) provides an answer to the shortcomings of the classical economic approach to the capital budgeting problem. However, there remain a number of difficulties in practical application of the portfolio approach, such as the assessment of the probability distribution of the projects' cash flows, the single-period optimization in CAPM, and the question of multiple goals of the firm. After all, the final choice in all business decisions is, of course, intuitive. It must be, otherwise,it is not a decision, just a conclusion.

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