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For contributors' addresses, see pp. 2621-2638

Capital Budgeting Techniques

Bernd Rudolph

[see also: Budgeting; Capital Budgeting; Cost of Capital; Maintenance]

I. Objectives of Capital Budgeting Techniques; II. Basic Assumptions of Capital Budgeting Techniques; III. Methods of Project Evaluation; IV. Outlook.

I. Objectives of Capital Budgeting Techniques

The quantitative methods of → *Capital Budgeting* are an aid to prepare rational investment decisions. A multiplicity of different investment appraisal methods is described in the business administration literature and applied in practice. This paper gives an overview of these methods and pays special attention to those that are characteristic of the German → *Capital Budgeting* literature.

Investment appraisal techniques can be serially classified as one of a *sequence of tasks in the capital investment area* (*Blohm/Lüder* 1983):

- stimulus of an investment proposal,
- obtaining the technical and economic data for investment computations,
- preliminary choice of investment projects,
- project appraisal,
- reconciliation of the investment proposal with overall planning,
- investment decision,
- implementation of the investment decision,
- surveillance of the investment project, and
- investment control.

From this sequence of events it can be inferred that investment appraisals are no more than an aid in the preparation of investment decisions. In actual investment decisions other considerations, which, at best, can only be partially allowed for in a quantitative project evaluation, are taken into account. For example, other or more far-reaching objectives can be pursued than those reflected in the computational procedure; or, particular interdependencies with other of the firm's decision areas, which ought in fact to be taken into account in the decision, may be omitted from the quantitative project evaluation.

The development of increasingly comprehensive models for eliminating these deficiencies is the objective of (*micro-)capital budgeting theory.* For example, this body of theory has developed decision models

- which are based on the explicit assumption that the investor pursues several objectives (*Dinkelbach* 1982) or wishes to take cognizance of the objectives of those who are external to the firm (*Picot* 1976),
- which can handle the interdependency problem, in particular, between investment and financing decisions (*Albach* 1962; *Hax* 1964), or
- which can explicitly allow for the uncertainty inherent in the data used for investment appraisal (*Albach* 1959).

In contrast to the model-building of capital budgeting theory, the development of *capital budgeting techniques* is intended more for dealing with the *practical aspects* of decision making and to a lesser extent for dealing with decision interdependencies. The intention is to confine the information requirements and the computational cost of the investment appraisals within nar-

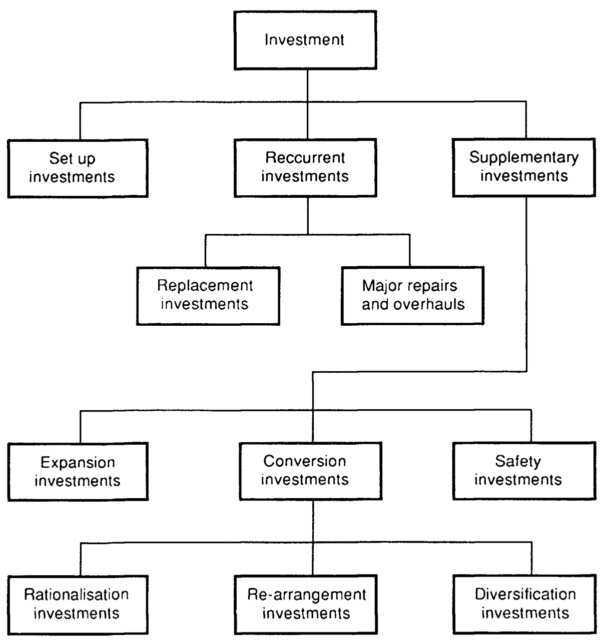

Figure 1: Classification of Investments

row limits. To make sure that the results of project evaluation can be correctly interpreted and accepted by all the departments affected within a firm, they must be clearly and usably presented and be based upon data which are self-evident in the computations themselves.

Project evaluations can be undertaken for desired investment objectives. Figure 1 (*Kern* 1976) classifies kinds of investment in accordance with intention and makes it clear that the implementation of practical investment appraisals is, at any given time, tied up with other difficulties.

II. Basic Assumptions of Capital Budgeting Techniques

1. Cash Flow Analysis

Quantitative project evaluation methods are based on an analysis of the inflows and outflows of cash that are ascribable to the investment projects. As a rule an investment's cash flow sequence begins with an *acquisition payment* which includes the project's appraisal cost, its acquisition or production cost and its installation cost. The acquisition payment is formally represented with a_0 whereby the subscript $t=0$ fixes both the payment date and the point in time to which the investment computation relates.

In the subsequent periods $t=1, 2, \ldots$. *net cash inflows* e_t are generated by the project which, for computational simplicity, are assumed to arise at the end of the period in question. At the end of the investment's *service life T* the project is disposed of and, as the case may be, a disposal value l_T should be taken into account. A cash flow sequence of the form $a_0, e_1, e_2, \ldots, e_T, l_T$ is routine, but generally not a necessary condition for the use of investment appraisal procedures. Hence, cash flow sequences commencing with an inflow, or those having negative net cash flows in individual periods, can be accounted for. In the interests of clarity, and in order to avoid complications in calculating rates of return, cash flow sequences of the form $a_0, e_1, e_2, \ldots, e_T, l_T$ are assumed hereafter.

Frequently it is not possible to ascertain what proportions of periodic net cash flows are *causally ascribable* to an individually analysed project and to other assets respectively. The possibility of systematic errors in project evaluations cannot therefore be ruled out. But, in the case of decisions on individual investment projects, the problem of ascribing cash flows is unimportant because it is a question of valuing the effects of an investment decision rather than valuing an investment project. Thus, the cash flow stream of an investment project can always at least be arrived at by taking the difference between the firm's periodic net cash flows with, and without, the implementation of that project (*Engels* 1962; *Kruschwitz* 1978).

2. Fundamentals from Financial Mathematics

By calculating interest and compound interest, a given cash flow stream $e_0, e_1, \ldots, e_t, \ldots, e_T$ can be summarised as a single amount. The point in time to which the cash flows are compounded or discounted is called the *reference date.*

If one chooses as a reference date the terminal date of the cash flow sequence, the summarising amount is described as a *terminal value*. If i is the interest rate that is used for evaluating the cash flow stream, the terminal value is computed from

$$E_T = \sum_{t=0}^{T} e_t (1+i)^{T-t}. \tag{1}$$

The expression $(1+i)^{T-t}$ is defined as a *compounding factor.*

If the point in time immediately before the first cash flow is chosen as the reference date, the summarising amount is described as a *net present value.*

$$E_0 = \sum_{t=0}^{T} e_t (1+i)^{-t}. \tag{2}$$

The expression $(1+i)^{-t}$ is described as a *reverse compounding* or *discount factor.*

The connection between the terminal value E_T of a cash flow sequence and its present value E_0 is represented by

$$E_T = (1+i)^T E_0. \tag{3}$$

If the reference date is arbitrarily chosen, the summarising amount is described as *project balance.* The project balance of a cash flow stream at point in time t^* is given by

$$E_{t^*} = \sum_{t=0}^{T} e_t (1+i)^{t^*-t} = (1+i)^{t^*} E_0. \tag{4}$$

A constant cash flow stream $e_t = \bar{c}$ for $t=1, 2, 3, \ldots,$ T, is described as an *annuity.* The present value of a cash flow stream $e_t = \bar{c}$ is

$$E_0 = \bar{c} \sum_{t=1}^{T} (1+i)^{-t} = \bar{c}\, \frac{(1+i)^T - 1}{i\,(1+i)^T}, \tag{5}$$

whereby the expression $[(1+i)^T - 1]/i\,(1+i)^T$ is described as the T year annuity factor. At times the present value of a cash flow stream is known and a computation of its annuity value is required. The required value is obtained by solving equation (5) for the annuity $\bar{c}$, that is,

$$\bar{c} = E_0\, \frac{i\,(1+i)^T}{(1+i)^T - 1} \tag{6}$$

whereby the quotient $i\,(1+i)^T/[(1+i)^T - 1]$ is described as the recovery factor.

If a constant cash flow stream $e_t = \bar{c}$ is of infinite duration *(perpetuity)*, its present value is equal to

$$E_0 = \bar{c} \sum_{t=1}^{\infty} (1+i)^{-t} = \frac{\bar{c}}{i}. \tag{7}$$

It may be the case that the interest rate for evaluating a cash flow stream does not take on the same value in all periods. If i_t is the interest rate of the t-th period, the present value of the cash flow sequence is computed from

$$E_0 = \sum_{t=0}^{T} e_t (1 + I_t)^{-t} \qquad (8)$$

where, $(1 + I_t)^t = (1 + i_1)(1 + i_2) \ldots (1 + i_t)$.

The first substantiation of the properties of discounting, and therefore the first kernel of investment computations, is attributable to *Gottfried Wilhelm Leibniz* (1682) (*Schneider, D.* 1981). In German business administration the procedures of financial mathematics were originally (and mainly) popularised by *Schneider, E.* (1951) who, to a significant extent, built on the work of *Boulding* (1935).

III. Methods of Project Evaluation

1. Decision Problems in the Investment Area

Project evaluations are prepared for a variety of business decision-making situations. In the literature of business administration, four particular decision-making situations are explored:

(1) Project evaluations for the appraisal of the merits of individual investment projects to facilitate decisions on their acceptance or rejection.
(2) Project evaluations for the choice between mutually exclusive projects that are intended to facilitate a decision on which of several investment projects should be implemented when, for non-financial reasons, the acceptance of a single project alone is possible, i.e. the cash flow stream of only one of the possible projects can be realised.
(3) Project evaluations for the determination of the optimal service life of an investment, or for determining an asset's optimal replacement date, can formally be derived by reference to the choice between mutually exclusive projects because investment computations always relate to the cash flow effects and not to investment projects.
(4) Project evaluations for decisions on the implementation of investment projects in conditions of capital rationing, or when funds can only be obtained on special terms, require *programming solutions* which can only be taken by resort to *multiple project capital budgeting* procedures. Such decisions are not the subject of this article.

Strictly speaking all business decision-making problems should be solved by resort to simultaneous planning because the funds available to firms are always limited in which case a budgetary allocation process (→ *Budgeting*) must be undertaken. On the other hand, many situations are to be found in practice in which available finance clearly does not constitute a binding constraint. In these situations the → *Cost of Capital*, i.e. the discount rate for investment computations, can be equated with the effective rate of interest on externally-raised funds and investment computation procedures can be successfully applied in dealing with decision-making situations (1), (2), and (3).

2. Project Evaluation Methods Based on Financial Mathematics

Dynamic (financial/mathematical, multiperiod, classical) methods of investment computation are represented by

- the net present value method,
- the annuity method,
- the internal rate of return method.

The net present value and annuity methods represent applications of the present value approach which presume knowledge of a predetermined discount rate. In contrast, the internal rate of return method is a self-reliant procedure which, in a comparison of alternative investments, does not always give the same signal as the net present value method.

a) The Net Present Value Method

An investment's *net present value* K_0 is defined by the sum of all discounted receipts and payments ascribable thereto as at the point in time immediately preceding the first cash flow.

$$K_0 = -a_0 + \sum_{t=1}^{T} e_t (1 + i)^{-t} + l_T (1 + i)^{-T} \qquad (9)$$

a_0 - acquisition payment as at point in time $t = 0$;
e_t - excess of receipts over payments ascribable to the project in period t;
l_T - residual value of the project at point in time T;
T - service life of the investment;
i - discount rate.

The following propositions follow directly from equation (9):

- An investment's net present value is equal to the present value of the sequence of cash flows ascribable to that investment.
- An investment's net present value is equal to the present value of its receipts minus the present value of its payments.
- An investment's net present value is the amount which, in addition to the initial payment a_0, can be repaid with interest from its subsequent net cash inflows.

If the net present value method is used in the three previously described decision-making situations, the following decision rules apply:

(1) An investment project is an economically viable alternative if the net present value K_0 of its cash flow sequence is positive.

(2) If two, or more, investment projects are mutually exclusive, the project with the highest net present value should be chosen. It can be shown that the choice between two mutually exclusive projects can be reduced to a decision on individual projects evaluated in isolation (*Hax* 1979).
(3) The inflows and outflows of cash that are ascribable to an investment project are not always invariable data from a firm's standpoint. In particular, a firm can frequently determine an investment project's service life T. A distinction is made between the
   - *technical service life* which represents the time-span during which an asset can be operated in a technical sense (the technical service life can almost be extended indefinitely by means of repairs and the replacement of components) and the
   - *economic service life* which is the time-span during which an asset can be operated economically.

The optimal life of an investment project is the time-span at which its net present value is at maximum. The maximum net present value, and therefore the optimal service life of investment projects, depends upon whether, and how, frequently an asset should be replaced (*Schneider, D.* 1980).

b) The Annuity Method

An annuity that is equivalent to a cash flow sequence $-a_0, e_1, e_2, \ldots, e_T$ is defined by a series of equal cash flows $\bar{c}$ over T periods and has a net present value which is equal to that of the original sequence.

The equivalent annuity $\bar{c}$ is given by:

$$K_0 = -a_0 + \sum_{t=1}^{T} e_t(1+i)^{-t} + l_T(1+i)^{-T} \tag{10}$$

$$\stackrel{!}{=} \sum_{t=1}^{T} \bar{c}\,(1+i)^{-t} = \bar{c}\,\frac{(1+i)^T - 1}{i\,(1+i)^T}$$

whence,

$$\bar{c} = K_0\,\frac{i\,(1+i)^T}{(1+i)^T - 1}. \tag{11}$$

Because the annuity $\bar{c}$ is, for any given service life T, a positive linear transformation of the net present value K_0, it follows,

- that an investment is economically viable if the equivalent annuity is positive, and
- that in the case of two mutually exclusive projects of equal duration the one offering the higher annuity is the more advantageous.

c) The Internal Rate of Return Method

The *internal rate of return* r of a cash flow sequence is defined as the discount rate at which the net present value of that sequence is zero and is therefore given by:

$$K_0 = -a_0 + \sum_{t=1}^{T} e_t(1+r)^{-t} = 0. \tag{12}$$

The internal rate of return indicates the *effective interest rate* of return on invested capital and therefore the average rate of return on average capital employed. If a cash flow sequence comprises a payment followed by a receipt at the following point in time, the internal rate of return denotes the degree of profitability.

In the case of a monotonically decreasing net present value function, the internal rate of return exceeds the discount rate as long as the net present value is positive. Hence, an investment is economically viable if its internal rate of return is greater than the discount rate. In the case of mutually exclusive investment projects, the project with the highest internal rate of return is not necessarily the most profitable. A ranking of investment projects by internal rate of return can therefore conflict with a ranking in accordance with the net present value method and suggest a scale of preferences which may not actually be valid.

3. Static Project Evaluation Procedures

Static (simple, single-period, accounting) investment computational procedures are exemplified by methods developed and frequently used in practice, namely,

- cost comparison statement,
- return on investment,
- pay-back period.

A significant characteristic of all static investment computational procedures is that they neglect the exact timing of the receipts and payments ascribable to an investment. Instead of cash flows they make use of average periodic costs and average periodic revenues (or periodic proceeds). Frequently the estimated costs and revenues of the first period e.g. of the first year following the installation of an asset, are taken as average values.

The static procedures are characterised by a multiplicity of variants because they are applied in practice and also subject to further practical development.

a) The Cost Comparison Statement

A cost comparison is undertaken in order to facilitate a choice between several functionally similar assets. The intention is to adopt that project which has the lowest average periodic cost *(comparison of alternatives)*.

A cost comparison is also undertaken if it is necessary to decide whether an existing asset should be continued in use, or displaced, or replaced with a new asset *(replacement problem)*. Such costs that are equal for all investment alternatives are not relevant from a decision-making standpoint and need not therefore be taken into account in a viability comparison. However, in practice, cost comparison statements include a complete cost comparison (because of the adoption of a standardised formula). In addition to the recurrent periodic operating costs (costs that are fixed or variable with respect to the level of activity), a cost comparison normally includes depreciation and interest on the capital tied up in the investment. Practical cost comparisons partly differentiate themselves by the way in which they take account of interest and capital consumption. Adopting the *"engineer's formula"* (*Rummel* 1936), costs are computed in accordance with equation (13).

$$K = K^b + \frac{a_0 - l_T}{T} + \frac{a_0 + l_T}{2}\, i \qquad (13)$$

$$= K^b + (a_0 - l_T)\left(\frac{1}{T} + \frac{i}{2}\right) + i l_T.$$

K - periodic asset cost (monthly);
K^b - periodic asset operating costs (fixed and variable labour, energy, material and maintenance costs);
a_0 - asset acquisition cost;
l_T - asset residual value at the end of its projected service life T;
T - projected service life of asset;
i - interest rate.

Equation (13) includes fixed instalment accounting depreciation $(a_0 - l_T)/T$. The average invested capital on which interest is calculated is equal to $l_T + (a_0 - l_T)/2 = (a_0 + l_T)/2$. The expression $(1/T + i/2)$ in (13) is occasionally described as a capital servicing factor. For values of $0 < i < 0{,}1$ and $T > 2$ the capital servicing factor $(1/T + i/2)$ approximates the value of the recovery or annuity factor

$i\,(1+i)^T/[(1+i)^T - 1]$ given by equation (6).

In a *comparison of alternatives of equal capability*, the asset to be preferred is that which can be operated at the lowest average periodic cost. If asset capabilities are unequal, average periodic costs do not constitute a sensible measure for choosing between them.

In the latter case a *profit comparison* should be undertaken. In certain circumstances a cost comparison is still possible. If the alternative with the higher outlays has a lower cost per unit of output, it is also the more profitable. Thus, the more viable investment project is that which results in the lowest average product unit cost. Accordingly, the solution to the *replacement problem* is that an existing asset should be substituted by a new asset when the average costs of the former exceed those of the latter.

b) The Return on Investment Method

If investment proposals not only differ with respect to periodic (or product unit) costs, but also (because of a dependence between product prices and the type of project implemented) *with respect to revenue*, a cost comparison should be extended to a profit comparison.

For any given level of capital investment, that capital project should be preferred which generates the highest average annual profit.

If projects require different levels of capital expenditure, a profitability comparison is fundamentally not tenable. In such a case a *rate of profit* statement should be prepared, i.e. average capital employed (ROI method).

$$ROI = \frac{G}{KB} \qquad (14)$$

ROI - investment project's return on investment;
G - average periodic profit;
KB - average capital employed.

An investment project is profitable if its return on investment exceeds a predetermined minimum.

c) The Pay-Back Method

The pay-back calculation (pay-off calculation, capital recovery calculation) determines the time-span required for the recovery of a project's acquisition cost from its sales revenue (net receipts). The acquisition cost recovery period is called the pay-back period:

- An investment is profitable if its pay-back period $\bar{T}$ does not exceed a predetermined maximum pay-back period $\bar{T}_{max}$.
- A project is more profitable than an alternative if the pay-back period of the former is less than that of the latter, i.e. the former recovers its acquisition cost sooner.

To determine the pay-back period $\bar{T}$, the net receipts e_t $(t = 1, 2, 3 \ldots)$ are, commencing with period 1, added together until the resultant *cumulative* sum exactly covers the acquisition payment a_0. The period $\bar{T}$ in which the last net cash inflow needed for recovery of the acquisition payment a_0 is received, defines the project's pay-back period.

$$\sum_{t=1}^{\bar{T}-1} e_t < a_0 \le \sum_{t=1}^{\bar{T}} e_t. \qquad (15)$$

When a project's net receipts are constant ($e_t = e$ for $t = 1, 2, \ldots$), the pay-back period is determined by means of a simple *averaging*. The pay-back period is then defined either as the quotient $\bar{T} = a_0/e$ or by the next highest integer. For $e_t = e$ it follows from (15) that

$$\bar{T} - 1 < \frac{a_0}{e} \le \bar{T}. \qquad (16)$$

The pay-back period measures the profitability of an investment project solely by considering the time-span during which invested capital is recovered. The project's subsequent performance is ignored and, according to the pay-back criterion, long-term projects generally appear to be less profitable than those of a short-term character.

4. Supplementary Investment Measures

a) Accounting for Taxes in Project Evaluation

Tax payments must be allowed for in investment computations if they influence the investment decision. Taxes that are independent of profits (property tax, turnover tax) are allowed for in the payments stream, i.e. they reduce the periodic net receipts (→ *Business Taxation*). The inclusion of profit-related taxes (income tax, corporation tax) has long been debated because of the view that, as a rule, they have an equal scale effect on the cash flows of investment projects and are therefore irrelevant in profitability comparisons. The present position in the → *Capital Budgeting* literature is that profit-related taxes should generally be taken into account in investment calculations but does not preclude the possibility that they may not influence decisions in individual cases.

The prescriptions for dealing with profit-related taxes in an investment computation can be summarised in two categories:

- The *net methods* treat profit-related tax as payments that reduce an investment's net receipts.
- On the other hand, the *gross methods* allow for the profit-related taxes that are ascribable to an investment by modifying the discount rate.

The *gross methods* are inexact and are only to be recommended in exceptional cases as approximation procedures. The literature therefore generally cautions against their use.

The *net methods* make use of post-tax net receipts and may be classified according to whether, and how, they allow for the tax-deductibility of depreciation and interest payments on debt capital. Three particular models can be distinguished (*Steiner* 1980):

- The *basis model* adopts the difference between net receipts and depreciation as the basis of taxable earnings and does not adjust the discount rate.
- The *standard model* utilises the same earnings basis as the basis model but reduces the discount rate by the tax rate.
- The *interest model* allows for interest payments in addition to depreciation in computing taxable earnings and, like the basis model, uses an unadjusted discount rate.

Steiner (1980) has shown that the interest model contains the basis model and the standard model as special cases. Hence, profit taxes should be allowed for in an investment computation by deducting periodic depreciation and periodic interest payments from periodic net receipts.

b) Allowing for Non-Financial Objectives in Project Evaluations

In practice it is frequently not possible solely to confine attention to the determination and evaluation of the effect of investment on profitability because other objectives are pursued which are not amenable to direct quantitative treatment in investment calculations. In such cases *utility value computations* can be prepared (*Zangemeister* 1976) to facilitate an investment project priority ranking. *Utility value analysis* is the analysis of a number of complex alternatives and is intended to order the elements of each alternative in a manner which corresponds to the preferences of the decision-maker by reference to a *multidimensional* objective function. This ranking is based on the *utility values* (total values) of the alternatives.

To simplify the weighting of the different objectives it is helpful to summarise the criteria in groups in developing a two- or multistage hierarchy of criteria. *Emmert* (1974), for example, has - on the basis of an enquiry among firms - developed the criterion catalogue shown in Figure 2 for the evaluation of the non-financial effects of investment. Other authors make the distinction between economic, technical, legal and social valuation criteria (*Olfert* 1982).

Criteria category	Criteria
End-product market criteria	Market share Degree of market saturation Product range Market strategy Advertising sensitivity
Labour and factor market criteria	Labour recruitability Raw material availability Service Delivery time
Physiological criteria	Accident security Dust, noise, etc. Stress Physical strain Servicability
Infrastructure criteria	Internal transport External transport Energy provision Prior and subsequent capacity Buisness region Removal of waste
Technical criteria	Universal applicability Capacity reverses Degree of automation Training requirements Maturity of construction Disruption to buisness on installation
Environmental criteria	Consistency with official planning Environmental damage from emissions etc. Image improvement in den-product markets Image improvement in labour market Adjustment of the environment to investment Satisfaction of socio-political requirements

Figure 2: Criteria for the Evaluation of the Non-Financial Effects of Investment

If the different criteria are not of equal importance to the decision-maker, a weighting system is a necessary precondition to the ascertainment of the constituent utilities of investment projects by reference to that array of criteria. Finally, the summation of the weighted, or unweighted, constituent utilities gives the utility values of investment projects which can then be compared.

A utility value analysis does not represent a closed decision-making computation but is an open decision-making framework that is intended to ensure the transparency of the decision and its implementability by reference to a subjectively determined weighting system and constituent utilities (*Blohm/Lüder* 1983).

IV. Outlook

Investment computational procedures have diverse qualitative features. They are characterised by an inverse relationship between their degrees of complexity and pretension on the one hand, and their level of abstraction and cost on the other (*Kern* 1976). The question of the optimal degree of complexity of the procedures that should be applied to particular investment decisions therefore suggests itself. Because this question can generally only be answered by reference to particular procedures or techniques, the choice of available investment computational procedures depends upon the investors' extremely subjective criteria. Finally it can be assumed that there is a trend toward the procedures of financial mathematics which is being reinforced by the growth in electronic data processing installations in the area of business planning (→ *ADP-Application Systems*).

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