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Boost Quality of Engineering Project Solutions Throgh Economic Analysis And Comparing alternatives

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Abstract: In this paper the principles and applications of money-time relationships are given. Economic profitability of engineering projects, using more methodes is analised. On the bases those methodes, comparing mutually exclusive alternatives of projects was done, because of optimization of decision. The emphasized theoretical states in this paper are applicated.

Keywords: Money-time, profitability, alternative, compari

1. INTRODUCTION

Realization of the engineering project, except technical correctness, is based on economic justification. Engineering economy is occupied with this problem through systematic analysis of interest and time money relation. The difference between projects requires different analyses of capital and money investments; therefore there isn't unique method for evaluating economic justification of project solution. On the other hand, it is pointed on project liquidity by the payback period method.

2. MONEY – TIME RELATIONSHIPS AND EQIVALENCE

The majority of engineering economy studies involve commitment of capital for extended periods of time, so the effect of time must be considered. Therefore, money has a time value.

2.1 The Concept of Equivalence

Alternatives should be compared as far as possible when they produce similar results, serve the same purpose, or accomplish the same function. This is not always possible in some types of economc studies. Our attention is directed at answering the question: How can alternatives for providing the same service or accomplishing the same function can be compared when interest is involved over extended periods of time?

Thus, we should consider the comparison of alternative options, or proposals, by reducing them to an equivalent basis that is dependent on (1) the interest rate, (2) the amounts of money involved, (3) the timing of the monetary receipts and/or expenses, and (4) the manner in which the interest, or profit, on invested capital is paid and the initial capital recovered.

2.2 Interest Formulas Relating Present and Future Equivalent Values of Single Cash Flows

Fig. 1 shows a cash flow diagram involving a present single sum, P, and a future single sum, F, separated by N periods with interest at i% per period.

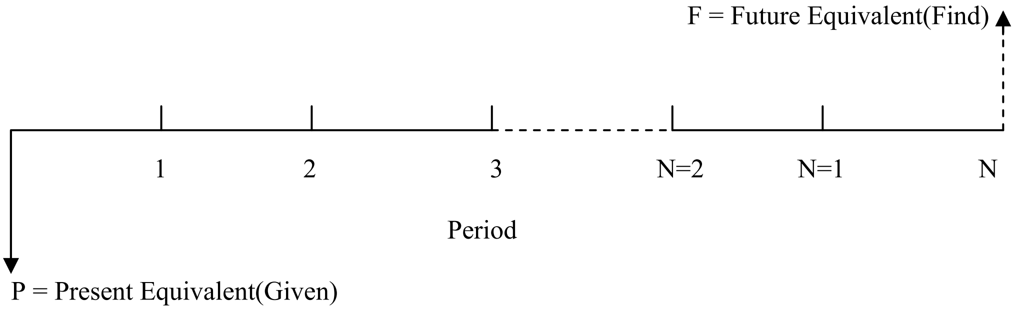


Fig. 1 General Cash Flow Dijagram Relating Presents Equivalent and Future Equivalent of Single Payments

Finding F When Given P

If an amount of P € is invested at a point in time and i% is the interest rate per period, the amount will grow to a future amount by the end of N periods

$$F = P(1 + i)^N \qquad (2.1)$$

The quantity $(1 + i)^N$ in Equation (2.1) is commonly called the single payment compound amount factor. We use the functional symbol (F/P, i%, N) for $(1 + i)^N$. Hence Equation (2.1) can be expresed as

$$F = P(F/P, i\%, N) \qquad (2.2)$$

Finding P When Given F

Solving Equation 2.1 for P gives the relationship

$$P = F(1 + i)^{-N} \qquad (2.3)$$

The quantity $(1 + i)^{-N}$ is called the single payment present worth factor.We shall use the functional symbol (P/F, i%, N) for this factor.Hence

$$P = F(P/F, i\% \ N) \qquad (2.4)$$

2.3 Interest Formulas Relating a Uniform Series(Annuity) to its Present and Future Equivalent Values

Fig. 2 shows a general cash flow diagram involving a series of uniform (equal) receipts, each of amount A, occurring at the end of each period for N periods with interest at i% per period. Such a uniform series is often called an *annuity*. It should be noted that the formulas and tables to be presented are derived such that A occurs at the end of each period, and thus:

1. P (present equivalent value) occurs one interest period before the first A (uniform amount).
2. F (future equivalent value) occurs at the same time as the last A, and N periods after P.
3. A (annual equivalent value) occurs at the end of periods 1 through N, inclusive.

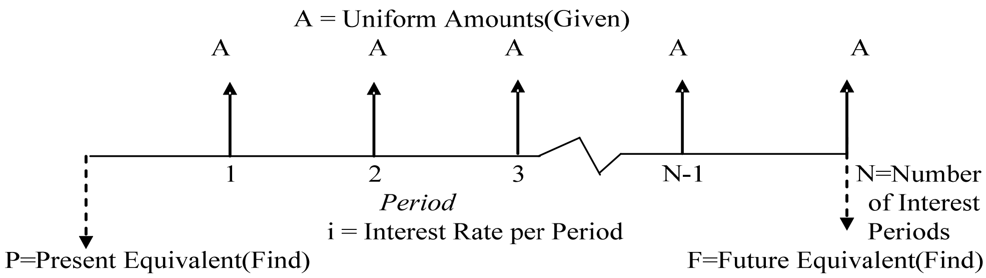


Fig. 2 General Cash Flow Diagram Relating Uniform Series (Ordinary Annuity) to Its Present Equivalent and Future Equivalent Values

Finding F When Given A

If a cash flow in the amount of A occurs at the end of each period and i% is the interest rate per period, the future equivalent value F, at the end of the N-th period is obtained by summing the future equivalents of each of the cash flows. Thus,

$$F = A\{[(1 + i)^N - 1]/i\} \qquad (2.5)$$

The quantity $\{[(1+i)^N-1]/i\}$ is called the uniform series compound amount factor.We shall use the functional symbol (F/A, i%,N) for this factor. Hence Equation 2.5 can be expressed as

$$F = A(F/A, i\%, N) \qquad (2.6)$$

Finding P When Given A

From Equation 2.1, $F=P(1+i)^N$, substituting for F in Equation 2.5 we have the relation for finding the present equivalent value of a uniform series of end-of-period cash flows of amount A for N periods:

$$P=A\{[(1+i)^N - 1]/[i(1+i)^N]\} \qquad (2.7)$$

The quantity in brackets is called the *uniform series present worth factor.* We shall use the functional symbol (P/A, i%, N) for this factor. Hence

$$P= A(P/A, i\%, N) \qquad (2.8)$$

Finding A When Given F

Taking Equation 2.5 and solving for A, one finds that

$$A = F\{i/[(1+i)^N - 1]\} \qquad (2.9)$$

Thus, Equation 2.9 is the relation for finding the amount A, of a uniform series of cash flows occurring at the end of N interest periods that would be equiavalent to its future equivalent value occurring at the end of the last period. The quantity in brackets is called the sinking fund factor. We shall use the functional symbol (A/F, i%, N) for this factor. Hence

$$A = F(A/F, i\%, N) \qquad (2.10)$$

Finding A When Given P

Taking Equation 2.7 and solvig for A,

$$A = P\{[i(1+i)^N]/[(1+i)^N - 1]\} \qquad (2.11)$$

Thus, Equation 2.11 is the relation for finding the amount A, of uniform series of cash flows ossurring at the end of each of N interest periods that would be equivalent to, or could be traded for, the present equivalent P, occurring at the beginning of the first period. The quantity in brackets is called the capital recovery factor. We shall use the functional symbol (A/P, i%, N) for this factor. Hence

$$A = P(A/P, i\%, N) \qquad (2.12)$$

3. METHODS FOR EVALUATING THE ECONOMIC PROFITABILITY OF A SINGLE PROPOSED PROBLEM SOLUTION

Because patterns of capital investment, revenue (or savings) cash flows, and disbursement cash flows can be quite different in various projects, there is no single method for performing engineering economic analyses that is ideal for all cases. Consequently, severel methods are commonly used.

In this work we concentrate on the corect use of five methods for evaluating the economic profitability of a single proposed problem solution (i.e., alternative). The five methods are: *Present Worth (PW), Annual Worth (AW), Future Worth (FW), Internal Rate of Return (IRR), and External Rate of Return (ERR)*. The first three methods convert cash flows resulting from a proposed solution into their equivalent worth at some point (or points) in time by using an interest rate known as *the Minimum Atttractive Rate of Return (MARR).* The IRR and ERR methods prroduce annual rates of profit, or returns, resulting from an investment, and are then compared against the MARR.

A sixth method, the payback period is a measure of the speed with which an investment is recovered by the cash inflows it produces. This measure, in its most common form, ignores time value of money principles. For this reason, the payback method is often used to supplement information prodused by the five primary methods.

3.1 The Present Woth Method

The Present Worth (PW) method is (2.11) based on the concept of equivalent worth of all cash flows relative to some base or beginning point in time called the present. That is, all cash inflows and outflows are discounted to the present point in time at an interest rate that is generally the MARR. The PW of an investment alternative is a measure of how much money an induvidual or a firm could afford to pay for the investment in excess of its cost.

To find the PW as a function of i% (per interest period) of a series of cash inflows and outflows, it is necessary to discount future amounts to the present by using the interest rate over the appropriate study period (years, for example) in the following manner:

$$PW(i\%)= F_0(1+i)^0 + F_1(1+i)^{-1} + F_2(1+i)^{-2} + \cdots + F_k(1+i)^{-k} + \cdots + F_N(1+i)^{-N} = \sum_{k=0}^{N} F_k(1+i)^{-k} \qquad (3.1)$$

where

i = effective interest rate, or MARR, per compouding period

k= index for each compounding period ($0 \le k \le N$)

F_k= future cash flow at the end of period k

N = number of compounding periods in the planning horizon (i.e.,study period)

The relationship given in Equation 3.1 is based on the assumption of a constant interest rate troughout the life of a particular project. If the interest rate is assumed to change, the PW must be computed in two or more steps.

The higher the interest rate and the further into the future a cash flow occurs, the lower its PW is. As long as the PW (i.e., present equivalent of cash inflows minus cash outflows) is greater than or equal zero, the project is economically justified, it is not acceptable.

3.2 The Future Worth Method

Because a primary objective of all time value of money methods is to maximize the future wealth of the owners of a firm, the economic information provided by the Future Worth (FW) method is very useful in capital investment decision situations. The future worth is based on the equivalent worth of all cash inflows and outflows at the end of the planing horizon (study period) at an interest rate that is generally the MARR. Also, the FW of a project is equivalent to its PW; that is, FW = PW(F/P, i%, N). If $FW \ge 0$ for a project, it would be economically justified.

Equation 3.2 summarizes the general calculations necessary to determine a project's future worth:

$$FW(i\%) = F_0(1+i)^N + F_1(1+i)^{N-1} + \cdots + F_N(1+i)^0 = \sum_{k=0}^{N} F_k(1+i)^{N-k} \qquad (3.2)$$

3.3 The Annual Worth Method

The Annual Worth (AW) of a project is an equal annual amounts, for a stated study period, that is equivalent to the cash inflows and outflows at an interest rate that is generally the MARR. Hence, the AW of a project is annual equivalent revenus or savings ($\underline{R}$) minus annual equivalent expenses ($\underline{E}$), less its annual equivalent Capital Recovery (CR) amount, which is defined in Equation 3.4. An annual equivalent value of $\underline{R}$, $\underline{E}$, and CR is computed for the stady period, N, which is usually in years. In equation form the AW, which is a function of i%, is

$$AW(i\%) = \underline{R} - \underline{E} - CR(i\%) \qquad (3.3)$$

Also, we need to notice that the AW of a project is equivalent to its PW and FW. That is, AW = PW(A/P, i%, N), and AW = FW(A/F, i%, N). Hence, it can be easily computed for a project from these other equivalent values.

As long as the AW is greater than or equal to zero, the project is economically attractive; otherwise, it is not. An AW of zero means that the annual return exactly equal to the MARR has been earned.

The Capital Recovery (CR) amount for a project is the equivalent uniform annual cost of the capital invested. It is an annual amount that covers the following two items: a) loss in value of the asset and b) interest on invested capital (i.e., at the MARR).

There are several convenient formulas by which the CR amount (cost) may be calculeted.

Probably the easiest formula to understand involves finding the annual equivalent of the initial capital investment and then subtracting the annual equivalent of the salvage value.

Thus

$$CR(i\%) = I(A/P, i\%, N) – S(A/F, i\%, N) \qquad (3.4)$$

Where

I = initial investment for the project

S = salvage (market) value at the end of the study period
N = project study period

3.4 The Internel Rate of Return Method

IRR method is the most widely used rate of return method for performing engineering economic analyses. It is sometimes called by severel other names, such as *investor's method, discounted cash flow method, and profitability index.* This method solves for the interest rate that equates the equivalent worth of an alternative's cash inflows (receipts or savings) to the equivalent worth of cash outflows (expenditures, including investment costs). Equivalent worth may be computed with any of three methods discussed earlier. The resultant interest rate is termed the *Internal Rate of Return (IRR).*

For a single alternative, the IRR is not positive unless (1) both receipts and expenses are present in the cash flow pattern and (2) the sum of receipts exceeds the sum of all cash outflows. Be sure to check both of these conditions in order to avoid the unnecessary work involved with finding that the IRR is negative.
By using a PW formulation, the IRR is the i`% at which

$$\sum_{k=0}^{N} R_k(P/F, i`\%, k) = \sum_{k=0}^{N} E_k(P/F, i`\%, k) \quad (3.5)$$

where R_k = net revenues or savings for the k-th year
E_k = net expenditures including any investment costs for the k-th year
N = project life (or studi period)

i` is often used in place of (i) to mean the interest rate that is to be determined.
Once i` has been calculated, it is compared with the MARR to assess wheter the alternative in question is acceptable. If i`≥ MARR, *the alternative is acceptable; otherwise, it is not.*
A popular variation of Equation 3.5 for computing the IRR for alternative is to determine the i` at which its net PW is zero.

$$PW = \sum_{k=0}^{N} R_k(P/F, i`\%, k) - \sum_{k=0}^{N} E_k(P/F, i`\%, k) = 0 \quad (3.6)$$

A graph of PW versus the interest rate typically has the general convex form shown in Fig. 3. The point at which PW=0 in Fig. 3 defines i`%, which is the project's IRR. The value of i`% can also be determined as the interest rate at which FW=0 or AW=0.
For example, by setting net FW equal to zero, Equation 3.7 would result:

$$FW = \sum R_k(F/P, i`\%, N-k) - \sum E_k(F/P, i`\%, N-k) = 0 \quad (3.7)$$

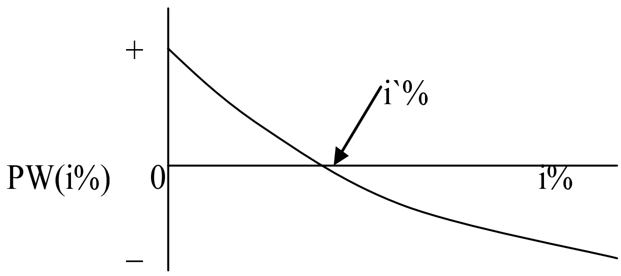


Fig. 3 Plot of PW Versus Interest Rate

3.5 The Externel Rate of Return (modified internal rate of return)

This method directly takes into account the interest rate (ε) external to a project. If this external reinvestment, which is usually the firm's MARR, happens to equal the project's IRR, then the ERR method produces results identical to those of the IRR method.

In general, three steps are used in the calculating procedure. First, all net cash outflows are dicounted to time 0 (the present) at ε% per compounding period. Second, all net cash inflows are compounded to period N at ε%. Third, the external rate of return, which is the interest rate that establishes equivalence between the two quantities, is determined. The absolute value of the present equivalent worth of the net cash outflows at ε% (first step) is used in this last step. In equation form, the ERR is the i`% at which

$$\sum E_k(P/F,\varepsilon\%,k)(F/P,i`\%,N)= \sum R_k(F/P, \varepsilon\%, N\text{-}k) \quad (3.8)$$

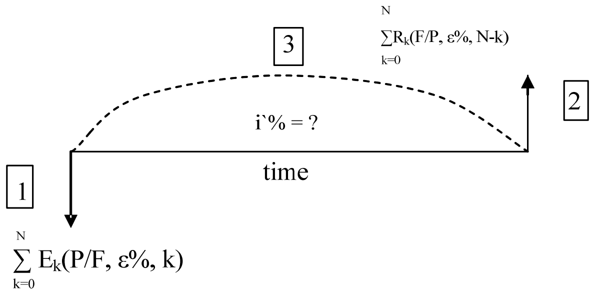
Where R_k = excess of receipts over expenses in period k

E_k = excess of expenditures over recipts in period k

N = project life or number of periods for the study

ε = external reinvestment rate per period

Graphically, we have the following (the numbers relate to the three steps):



A project is acceptable when i'% of the ERR method is greater than or equal to the firm's MARR.

The external rate of retum method has two basik advantages over the IRR metod:

1. It can usually be solved for directly rather than by trial and error.
2. It is not subject to the possibility of multiple rates of return.

3.6 The Payback (Payout) Period Method

All methods presented thus far reflect the profitability of a proposed alternative for a study period of N. The payback method, which is often called the simple payout method, mainly indicates a project's liquidity rather than its profitability. Historically, the payback method has been used as a measure of a project's riskiness, since liquidity deals with how fast an investment can be recovered. Quite simply, the payback method calculates the number of years required for cash inflows to just equal cash outflows. Hence, the simple payback period is the smallest value of θ (θ ≤ N) for which this relationship is satisfied under our normal end-of-year cash flow convention.

For a project where all capital investment occurs at time zero, we have:

$$\sum_{k=1}^{\theta}(R_k - E_k) - I \geq 0 \quad (3.9)$$

The simple payback period, θ, ignores the time value of money and all cash flows that occur after θ. As can be seen from Equation 3.9, the payback period does not indicate anything about project desirability except the speed with which the investment will be recovered. The payback period can produce misleading results, and it is recommened as supplemental information only in conjunction with one or more of the five methods previously discussed.

Sometimes the discounted payback period, θ' (θ' ≤ N), is calculated so that the time value of money is considered:

$$\sum_{k=1}^{\theta'}(R_k - E_k)(P/F, i\%, k) \geq 0 \quad (3.10)$$

where

i% - minimum attractive rate of return

I – capital investment usually made at the present time (k=0)

θ'- the smallest value that satisfies Equation 3.10

Using the payback period to make investment decisions should generally be avoided except as a measure of how quickly invested capital will be recovered, which is an indicator of project risk. The simple payback and discounted payback period methods tell us how long it takes cash inflows from a project to accumulate to equal (or exceed) the project's cash outflows. The longer it takes to recover invested monies, the greater is the perceived riskiness of a project.

4. BASIC CONCEPTS FOR COMPARING ALTERNATIVES

Most engineering projects can be accomplished by more than one feasible design alternative. When the selection of one of these alternatives excludes the choise of any of others, the alternatives are called *mutually exclusive.* Typically, the alternatives being considered require the investment of different amounts of capital, and their annual revenues and costs may vary. Because different levels of investment normally produce varying economic outcomes, we must perform an analysis to determine which one of the mutually exclusive alternatives is preferred and, consequently, how much capital should be invested.

Five of the basic methods discussed in Chapter 3 for analyzing cash flows are used in the analyses in this Chapter (PW, AW, FW, IRR and ERR). These methods provide a basic for economic comparison of alternatives for an engineering project. When correctly applied, these methods result in the correct selection of a preferred alternative from a set of mutually exclusive alternatives.

The problem of deciding which mutually exclusive alternative should be selected is made easier if we adopt this rule based on principle: *The alternative that requires the minimum investment of capital and produces satisfactory functional results will be chosen unless the incremental capital associated with an alternative having a larger investment can be justified with respect to its incremental benefits.*

Under this rule, we consider the acceptable alternative that requires the least investment of capital to be the *bases alternative*.

4.1 Investment and Cost Projects and Alternatives

Investment alternatives are those with initial capital inestment(s) that produce positive cash flows from increased revenue, savings through reduced costs, or both.

Cost alternatives are those with all negative cash flows except for a possible positive cash flow element from disposal of assets at the end of the project's useful life.

4.2 Ensuring a Comparable Basis

There are two rules for facilitating the corect analysis and comparison of mutually exclusive alternatives when the time value of money is not a factor (present economy studies). These rules are here extended to account for the time value of money.

Rule 1: When revenues and other economic benefits are present and vary among the alternatives, choose the alternative that maximizes overall profitability. That is, select the alternative that has the greatest positive equivalent worth at i = MARR and satisfies all project requirements.

Rule 2: When revenues and other economic benfits are not present or are constant among the alternatives, consider only the costs and select the alternative that minimizes total cost. That is, select the alternative that has the least negative equivalent worth at i=MARR and satisfies all project requirements.

5. EQIVALENT WORTH METHOD

The equivalent worth methods convert all relevant cash flows into equivalent present, annual or future amounts. When these methods are used, consistency of alternative selection results from this equivalency relationship. Also, the economic ranking of mutually exclusive alternatives will be the same using the three methods. Consider the general case of two alternatives, A and B. If

$PW(i\%)_A < PW(i\%)_B$

then

$PW(i\%)_A(A/P, i\%, N) < PW(i\%)_B(A/P, i\%, N)$

and

$AW(i\%)_A < AW(i\%)_B$

Similarly,

$PW(i\%)_A(F/P, i\%, N) < PW(i\%)_B(F/P, i\%, N)$

and

$FW(i\%)_A < FW(i\%)_B$

The most straightforward technique for comparing mutually exclusive alternatives when all useful lives are equal to the study period, is to determine the equivalent worth of each alternative based on total investment at i=MARR. Then, for investment alternatives, the one with the greatest positive equivalent worth is selected. And, in the case of cost alternatives, the one with the least negative equivalent worth is selected.

Example

Three mutually exclusive alternatives for implementing new modernize lining electrolytic cell in Elecrtolysis KAP are being considered. Each alternative meets the same servis (support) requirements, but differences in capital investment amounts and benefits (cost savings) exist among them. The study period is 7 years and the usefull life is also 7 years. Market values of all alternatives are assumed to be zero at the end of their useful lives. Is the firm's MARR is 10% per year, which alternative should be selected in view of the following estimates?

	Alternative A	Alternative B	Alternative C
Capital investment	- 194994€	-459918€	-329745€
Annual cost savings	34500	83500	66750

Solution of example by PW method

$PW(10\%)_A$ = - 194994 + 34500(P/A, 10%, 10) = 16993.67€
$PW(10\%)_B$ = - 459918 + 83500(P/A, 10%, 10) = 53153.60€
$PW(10\%)_C$ = - 329745 + 66750(P/A, 10%, 10) = 80405.05€

Solution of example by AW method

$AW(10\%)_A$ = - 194994(A/P,10%,10) + 34500 = 2764.73€
$AW(10\%)_B$ = - 459918(A/P,10%,10) + 83500 = 8648.50 €
$AW(10\%)_C$ = - 329745(A/P,10%,10) + 66750 = 13084.00€

Solution of example by FW method

$FW(10\%)_A$ = - 194994(F/P,10%,10) + 34500(F/A,10%,10) = 44077.25€
$FW(10\%)_B$ = - 459918(F/P,10%,10) + 83500(F/A,10%,10) = 137866.86€
$FW(10\%)_C$ = - 329745(F/P,10%,10) + 66750(F/A,10%,10) = 208549.99€

For all three methods (PW, AW, FW) in this example, notice that C>B>A because of the equivalency relationship among the methods.Also, notice that Rule 1 (4.2) applies in this example since the economic benefits (cost savings) vary among the alternatives.

6. CONCLUSION

Engineering economy involves the systematic evaluation of the economic merits of proposed salutions to engineering problems. Using time value of money concept is first step of analisis of engineering projects. For evaulating the ecomomic profitability of proposed solution, methods based on time value of many concept is possible sucesfully used. We learned that choosing the alternative with the largest equivalent worth (or least negative in the case of cost alternatives) using the MARR would produce this desired result. It is demonstrated the application of the profitability analysis methods to select the preferred alternative.

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