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Report on:

Associated Problems with Life Cycle Costing

As partial fulfillment of the ARE 512 requirements

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TABLE OF CONTENT

1. INTORDUCTION

Whether on a simple personal scale or on sophisticated professional scale decision making is a tool used by everyone. How do we chooses the car we like is it the colour, brand, price or fuel consumption efficiency? How do we choose between options such as building a factory a commercial centre or even a do-nothing option? Is the choice is based on the lease difficult, the most productive, the fastest in pay back or the least costly?
Many tools have actually evolved to help solve such dilemmas, some refer to them as problem solving techniques

1.1 SCOPE & OBJECTIVES

This paper will discuss in detail the associated problems with life cycle costing techniques. The various procedures used and their positive and negative characteristics will be presented. The paper will also point out to the discrepancies that might be encountered. The paper goes in depth with the selection of discount rates and the assessment of corresponding inconsistencies
The objective is to familiarize the reader with the life cycle costing techniques, its associated problems, and the solutions used to eliminate or reduce the effects of such problems.

1.2 LIFE CYCLE COSTING

Life Cycle Costing (LCC) is the systematic evaluation of alternative project designs and the comparison of their projected total owning, operating, and maintenance costs over the economic life of the proposed project.

Life cycle costing involves four major stages:

1. input of data
2. investment appraisal techniques
3. system application
4. output

Figure 1 illustrate the model of these four stages

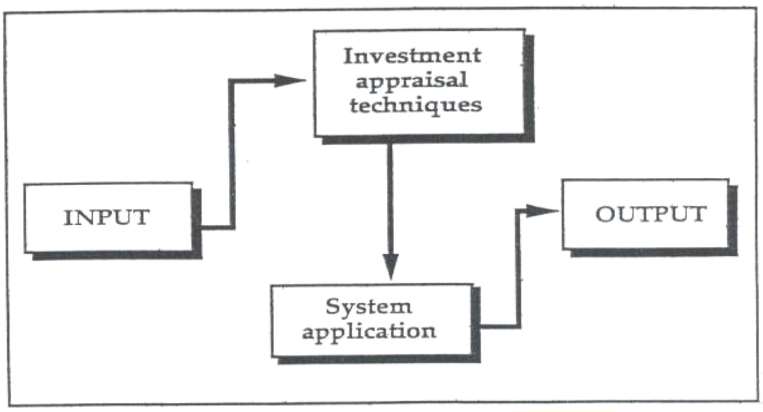


FIGURE 1: The components of life cycle costing

The first stage involves and efflux of information needed in determining the life cycle cost of an item. Data does not necessarily have to be cost data but all types of information that could help in predicting costs such as occupancy, performance, quality and physical data

Stage two is the application of investment appraisal techniques to the data collected after shaping out the information into the proper form. These techniques are usually applied to prepare cash flow diagrams. This paper will discuss the different techniques used in life cycle costing and will elaborate in their characteristics.

The system application stage includes forecasting, maintenance requirement prediction, projections, prediction of salvage values, determination of risks and uncertainties and sensitivity analysis. This paper will focus on the need for consistency life cycle costing and the associated problems.

Finally, the output stage is the shaping of the results in the proper form; tables, graphs, diagrams, ...etc.

2. APPRAISAL INVESTMENT TECHNIQUES

The appraisal techniques used in life cycle costing are numerous. The basic idea of these techniques is to evaluate different alternatives by comparing of their economical properties such as: time to pay-back, rate of return, worth at certain point in time, or cost compared to benefit.
These methods can be classifies into two different types:

1. Non-discounted methods where the time value of money disregarded
2. Discounted methods where the time value of money is considered.

2.1 NON-DISOCUNTED APPRAISAL TECHNIQUES

Even though these techniques sound unrealistic, they have proven to be appealing to many analysts . Lerner mentioned some reasons for their attractiveness

1. the relief from the need to choose an appropriate discount rate
2. the difficulty in determining cash flows with adequate certainty.
3. the interrelation of cash flows of some projects with cash flows of another

the above reasons, however, may not be appealing enough to some users to convince them to neglect the importance of the time value of money

2.2 DISCOUNTED TECHNIQUES

Their basic characteristics is taking into consideration that the value of money changes with time

2.2.1 RETURN ON INVESTMENT

It is defined as cash benefits or annual inflows that will return the original outlay plus some additional amount still unrecovered.
This return is not only the income generated by an investment, but also the savings, expense reductions, or expense avoidance that may be expected to follow the outlay

There are three types of return on investment:

1. operating return : it is the ratio of operating profits to the assets employed in earning those profits
2. cash return : it is the ratio of cash income to cash invested. The income is the net profit after tax deduction, its drawback is that, it is difficult to predict cash flows
3. equity return: it is the ratio of the net income to the common stockholders' equity.

In life cycle costing to discounting return on investment techniques may be used in the appraisal evaluation of alternatives:

a. the internal rate of return (IRR)
b. the external rate of return (ERR)

2.2.2 THE INTERNAL RATE OF RETURN (IRR)

Is defined as the interest rate that equate the future worth to zero. This method is also referred to as the discounted cash flow rate of return, internal rate of return and the true rate of return.

2.2.3 THE EXTERNAL RATE OF RETURN (ERR)

This method is not commonly used in life cycle costing even though it doesn't suffer the drawback of having the multiple root as the case with the internal rate of return.

2.3 TIME WORTH METHOD

Calculating the worth is another means for investment appraisal by the use of discounted methods these methods, however, are based on assuming a discount rate (could be the minimum attractive rate of return) and then finding the corresponding money value of the inflows and the outflows at certain points of time. The methods used are:

A) Present Worth Method

known as the net present value (NPV): this method converts all cash flows occurring through the life of an alternative to a single equivalent sum at the present (time zero) by using predetermined discount rate. This discount rate could be the minimum attractive rate of return established by the firm.

This method is most popular measure of merit available, it gives a simple an appealing interpolation of the present value of an alternative in today's price. In comparing alternative, however, special attention should be given to the life span of these alternatives. The least common multiple of their lives should be used in the analyses in order to validate the comparison. One of the drawbacks of this techniques is the choice of proper discount rate that will yield objective results when comparing alternatives. This matter will be discussed in more details later.

B) Future Worth Method

The method utilizes the same principals as the present worth method but the future worth of an investment is the one that is determined. When the alternatives are compared, the one with the largest future worth will be the most referred. Furthermore, this method suffers the same drawbacks as the present worth method.

C) Annual Worth Method

Also know as the equivalent annual cost (EUAC) method. This technique is equaling to both the present and the future methods. The greater the annual worth the more appealing investment is. The advantage of this techniques over the two other worth methods is that alternatives of different life spans can be immediately compared without the need to resort to additional tactics.

2.4 COMPARISON BETWEEN INTERNAL RATE OF RETURN AND NET PRESENT VALUE

The NPV method involves the discounting of all anticipated future negative and positive cash flows to present value at an a appropriate discount rate so as to facilitate comparison with the capital out lay

$$NPV = \sum_{t=1}^{N} \frac{I_t - P_t}{(1+r)^t}$$

Where
I_t = income in time period t
P_t = payment in time period t
N= life of project
r = discount rate
t = time period

any project with positive NPV will be considered viable investment proposition and accepted. Furthermore, two or more mutually exclusive investment projects may be evaluated by this approach with the project showing the largest positive (or the lowest negative) NPV being the preferred choice.

While the IRR utilizes the similar approach to NPV but involves the computation of the discount rate which gives a zero NPV for the project. In this case a scheme will be normally be considered viable if the IRR is greater than or equal the appropriate discount rate while when comparing investment alternatives the one with the highest IRR will usually be preferred

$$NPV = \sum_{t=1}^{N} \frac{I_t - P_t}{(1+i)^t} = 0$$

Where i = internal rate of return

The IRR method has the advantage of presenting the results in terms of percentage return on capital invested which is a form readily intelligible to most clients. And also doesn’t require the insertion of a discount rate for its computation. It does, however, suffer from a number of theoretical weaknesses which have been well documented such as; computational difficulties, the possibility of multiple solutions and problems involved with ranking mutually exclusive projects.

2.5 PROBLEMS ASSOCIATED WITH INTERNAL RATE OF RETUN (IRR)

2.5.1 COMPUTATIONAL PROBLEMS

It is not possible to solve for the IRR of a project by direct arithmetic and some form of iterative approach is required. The simplest method of bisection is very slow and tedious and a better approach is to use an iterative formula such as the Newton/Raphson method which will ensure rapid convergence to the result. Such an approach is best carried out by computer. Although 'trial and error with calculator can yield a reset of an acceptable accuracy reasonably quickly.

2.5.2 MULTIPLE SOLUTIONS (roots)

The computation of the IRR for an investment project lasting n years will effectively involved the solution of a polynomial equation of degree n-1. in most cases, this will have one real positive solution, however, under certain circumstances there may be multiple real solutions.
The following example is illustrating this phenomena.

End of Year	Cash flow	Cumulative Cash Flow
0	+3,000	+3,000
1	0	+3,000
2	-10,000	-7,000
3	+2,000	-5,000
4	+2,000	-3,000
5	+2,000	-1,000
6	+2,000	+1,000

Setting the NPV to zero, this gives an IRR of 9.4% or 51%. For discount rates less than 9.4% and greater than 51% would yield a positive NPV. The danger is, that having obtained an IRR of 51% the user might assume that the project would be viable for any discount rate up to 51%, while this scenario is incorrect.
Plotting the NPV for various discount rates gives an indication of what is happening as in figure 1 below:

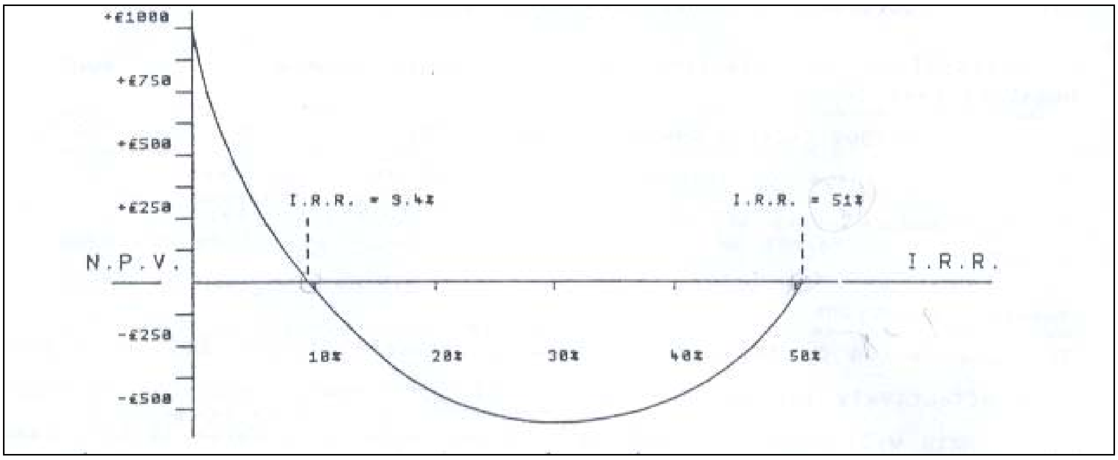


FIGURE 2: net present value against discount rate for example above

If the discount rate is taken as less than 9.4% or greater than 51% the problem produces a positive NPV, while a discount rate of between 9.4% and 51% would produce negative NPV. The viability of the project is clearly dependent upon the discount rate selection which has its effect on projects ranking. The selection of discount rate and the associated consistency problems will be discussed later.

2.5.3 RANKING OF ALTERNATIVES

Under certain circumstances the ranking of mutually exclusive projects may be sensitive to the discount rate selected. In such case it is possible that the IRR approach may yield a different results to the NPV methods.
Consider the following example:

Project	End of year cash flows				
	0	1	2	3	4
A	-1,000	+100	+350	+600	+850
B	-1,000	+1,000	+200	+200	+200

In the above example project A will have NPV of +£412 at 10% discount rate while +£361 for project B at the same discount rate, however the IRR of project B at 34.5% exceeds that of project A at 23.4% as illustrated in figure 2.

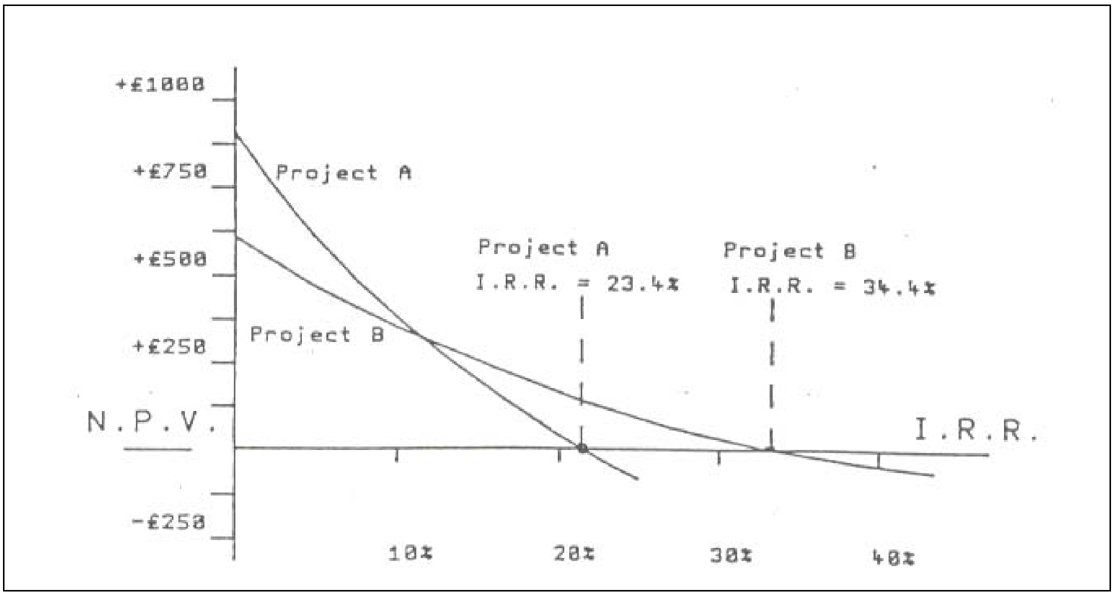


FIGURE 3: net present value against discount rate for the above example

The ranking obtained by the IRR approach might not correspond with the same answer given by the NPV approach. This doesn't conclude to the preference of an approach over the other and the conflict between the two approaches will only arise where the NPV appraisal is sensitive to the discount rate. The key to this is the selection discount rate. If the rate discount rate selected was correct then it would be reasonable to assume that the ranking produced by the NPV method is valid, if not, then no such assumption can be made.
This problem can be partially overcome by utilizing an **incremental approach** for the calculation of the IRR as detailed for the above example in the below table.

Project	End of year cash flows				
	0	1	2	3	4
A	-1,000	+100	+350	+600	+850
B	-1,000	+1,000	+200	+200	+200
A-B	0	-900	+150	+400	+650

The cash flow A-B gives an incremental rate of return of 13% which is the discount rate at which the two projects would be ranked equal by an NPV appraisal.

2.5.4 NEGATIVE CASH FLOW

The IRR method is clearly can not be applied to problems when all cash flows are negative i.e. if income is disregarded as the case the case of comparing the maintenance cost of two types of floor tiles.

3. SELECTION OF THE DISCOUNT RATE

Flanagan et al have distinguished between the following types of discount rates:

1. Discount rate : the rate that is selected to reflect the investor's time value of money.
2. Real discount rate: (Net discount rate) the effects of inflation are not included
3. Nominal discount rate: the discount rate which incorporates both the effects of the inflation and the real earning power of money.

The selection of an appropriate discount rate remains somewhat problematic. The most important of these is the real rate of interest which is the nominal interest rate less the inflation rate, this is of much importance in the case of a life cycle costing exercise as for any investment appraisal and it is not sufficient to plug in a 'standard' discount rate without regard to the circumstances.
The discount rate should account for inflation which is a significant factor in predicting future costs

$$d' = \frac{(1+d)}{(1+i)} - 1$$

Where;
d' : real discount rate
d : nominal discount rate
i : inflation rate

The selection of discount rate may involve as much educated guesswork as anything else because of the instability of the world financial system stemming from economic factors outside the control of any one government. It is dangerous results for any investment appraisal exercise without conducting a sensitivity analysis for a range of discount rate.

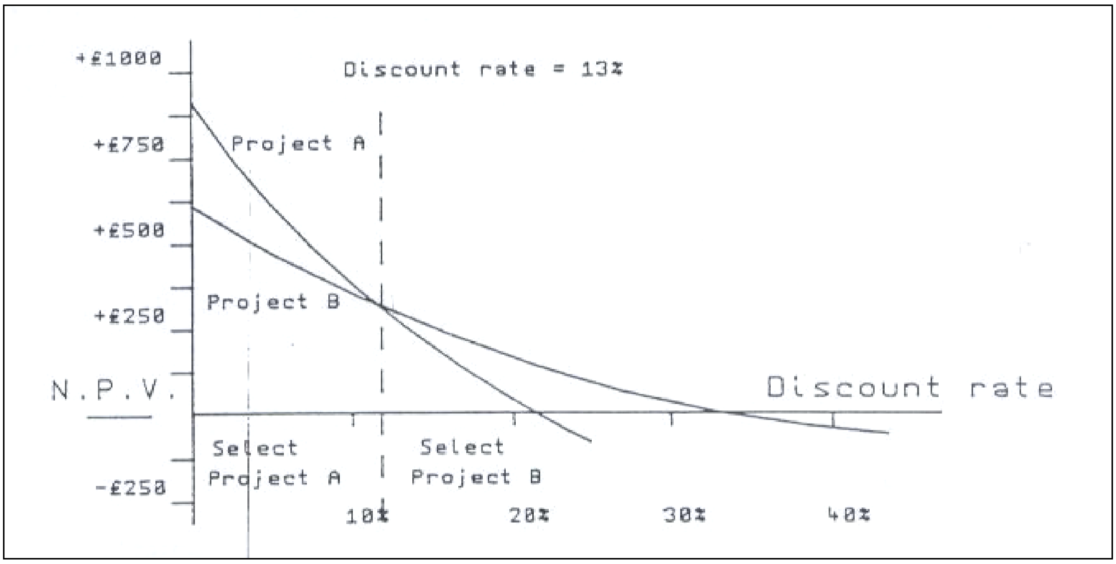


FIGURE 4: net present value against discount rate

It can be argued that the instability of real interest rate has left the traditional NPV approach somewhat inappropriate for the current economic circumstances. What is really required is an approach which incorporates an assessment of the sensitivity of the analysis to changing the discount rate.

The suggested approach involves the plotting of the NPV of the project against discount rate as illustrated in Figure 4. this will give not only the NPV for any discount rate but would also give the IRR for all alternatives. In the case of assessing the viability of a project the range of discount rates which produce a positive NPV and all leading to with negative NPV will be readily identified. Equally any multiple roots for the IRR computation will be highlighted. In the case of comparing mutually exclusive alternatives the sensitivity of the ranking to changes in the discount rate can be directly read of. Thus, alternative rankings van be given for different discount rates where appropriate along with IRR(s) for each alternative. This method would present view problems to add a module to a life cycle costing computer package provided that suitable graphic facilities were available to plot the results in the appropriate format.

4. CONSISTENCY PROBLEMS IN LIFE CYCLE COST APPRAISAL

Life cycle costing involves making projections. The main areas in which these have to be made include:

1. the capital cost of the project, including construction, land acquisition, commissioning cost
2. Financing costs
3. the cost of operating the building, such as cleaning, energy consumption, security, and insurance.
4. Maintenance, repair, and replacement costs of services and structures
5. Occupancy costs, that is the impact of the building upon the cost of the activities within it.
6. Residual values of the project, such as its resale value, salvage and disposal costs.

As the projections are about the future, they contain errors that result from uncertainty. If the projections are compiled in different ways then inconsistencies will result.
Inconsistencies could lead to projects being accepted as viable under one approach, but in being rejected if evaluated using different ones. Consequently it is necessary to set down consistent procedures to be used in life cycle costing if misallocations as a result of inconsistencies are to be avoided.
Some of the methods by which consistency can be obtained in these assumptions can themselves lead to a misallocation of resources so that it is necessary to explore the means by which consistency in these areas can be achieved. Since the projections must be made under conditions of uncertainty, it is essentially that the methods by which risk analysis should be incorporated into life cycle costing.

4.1 CONSISTENCY IN INVESTMENT APPRAISAL METHODS

Using life cycle costing involve making projections of costs and benefits at different points of time by using the discounted cash flow methods in order to place them in a time equivalent basis.
The governmental sector uses the net present vale rather than internal rate of return due to the computational problems with the latter. The net present value methods tend to be used in the context of incremental analysis so that projects are compared with the option of do nothing. The central government sets out the method of appraisal to be employed and how it is to be applied but the issue of the risk analysis methods to be employed by the government has not been resolved so that inconsistencies as a result of different assumptions being employed are still exists.
The private sector tends to make use of non-discounted cash flow methods such as payback and the rate of return, or even not to use formal methods of appraisals at all. Larger companies, with substantial capital budgets, tend to use several investment appraisal methods, of which at least one is likely to be a discounted cash flow method.

4.2 CONSISTENCY IN THE CHOICE OF DISCOUNT RATE

Discounted cash flow methods result in greater weighting been given to earlier cash flows than the later ones there is therefore a tendency to favor projects that produce earlier inflows and later outflows. The higher the discount rate employed the greater the weighting given to the earlier cash flows, so that projects which involve expenditure at an earlier dates but which produce savings in the future such as preventive maintenance and energy insulation, appears unfavorably at higher discount rate. The viability and ranking of projects are altered by the choice of discount rate so that consistency in its choice is necessary in life cycle costing.
Central government resolves this problem by the use of test discount rate to be employed in all appraisals this is set at real interest rate of 5% which can be raised up to 7% which is can be justified on the ground that the government is an almost reckless borrower so that the discount rate should reflect the loss of liquidity to the lender rather than any risk of the loan. A discount rate requires a government to achieve a return on its capital equivalent to that of private industry to ensure social preference, for example, with regard to the time of cash flows and the individual project.
In the private sector, the choice of discount rate is more problematic since it should reflect the risks of the project.

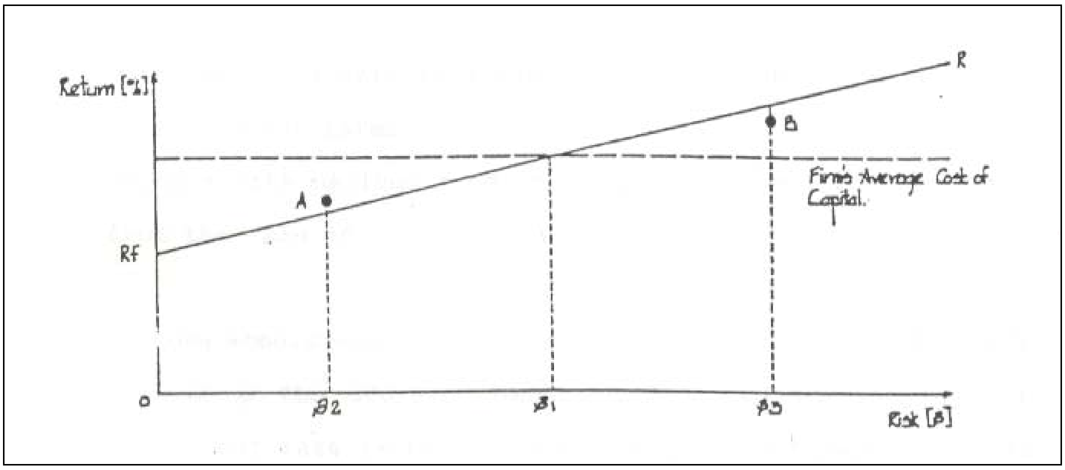


FIGURE 5: Return Vs Risk

One approach is to take the average costs of funds as the discount rate. A premium is often added to this as insurance against risks. Figure. 3 illustrate how project A which has a lower return than the risk equilibrium line would be preferred to B that has a higher rate above the equilibrium line. This will lead to the choice of the more risky option B with the insufficient risk compensated return, rather than the save alternative A with the lower return that is enough to account for the risk.
The reason for this problem is that the firm performing the appraisal has a policy that states that the preferable rate of return should be greater than the cost of capital (MARR)
There are two ways to over come such problem of risk incorporation:

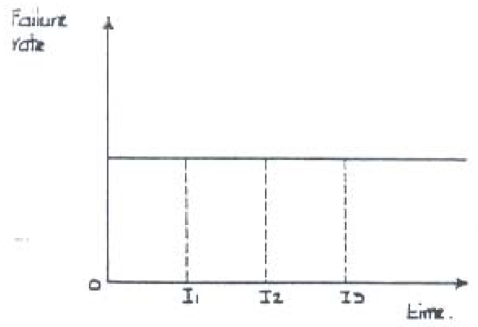
a. using beta analysis in order to come up with a risk adjusted real discount rate.

b. Using a rate derived from an “all-risk” yield that is taken from the sale of a comparable property.

Finally, one should realize that one of the most appropriate tools for overcoming these problems in identifying the proper discount rate is by performing sensitivity analysis. This will enable the analyst to have a clearer view of the sensitivity of the alternatives to this rate.

5. INCONSISTENCIES IN MAINTENANCE STANDARDS

Different assumptions about replacement intervals , maintenance and inspection polices, and response times to reports of failure can alter the viability and ranking of projects under a life cycle cost appraisal. A solution to this problem is to set maintenance standards to be achieved so that appraisals contain consistent assumptions. Typical maintenance standards deal with intervals between preventive maintenance and periodic inspections, and average and maximum times of response to particular reports of failure
There is no basic problem with setting standards of response times to reports of failure since these standards are set in terms of the performance benefits to the user of the property. Standards between preventive maintenance and inspection , or for the replacement of the components can result in deferent benefits to the user in different circumstances. Fore example, a policy of periodic inspection is liable to result in different probabilities of failure being found at each inspection according to the failure rate function.



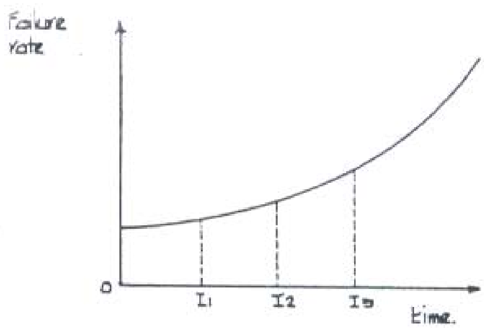


FIGURE 6A **FIGURE 6B**

In the figure 5A there is a constant failure rate so that the probability of failure between inspections is the same throughout and the probability of detecting failure at each inspection is same. In figure 5B there is an increasing failure rate, the probability of failure occurring between inspections increases over time, and with it the probability of inspection detecting failure. A standard for periodic inspections intervals therefore provide different assurance to the user of the building that failure will be detected in its early stages for different failure rates. The more rapidly the failure rate rises, the greater is the risk that failure will occur between inspections, and the less will be the benefit to the user from the avoidance of failure spreading to other parts of the system and disruption to the activities within the building from unplanned corrective maintenance. Similar problem arise with periodic maintenance.

The basic problem is that standards for periodic maintenance, inspection, and replacement are based on mean values for replacement or failure and take no account of the distribution of failures about the mean. Problems also arise with assumptions about replacement intervals for component where these are based upon the mean life. Two distributions can have the same mean life but very different deviations of failure about the mean. With the result one can have a higher risk of early failures.

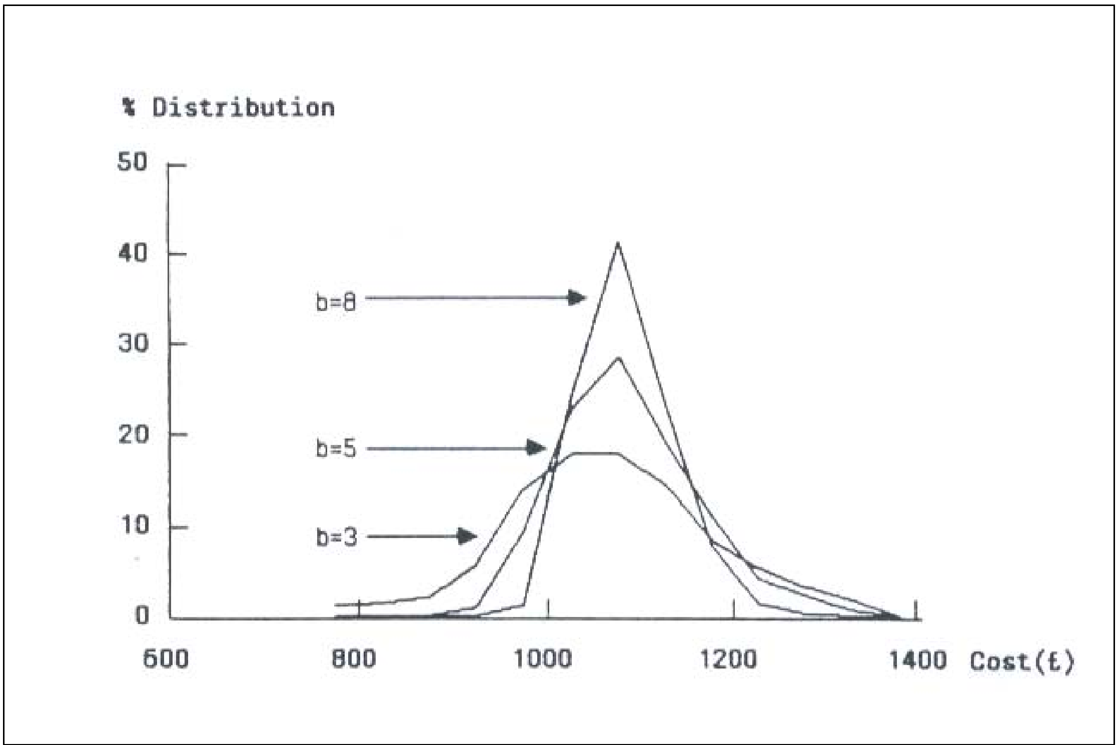


FIGURE 7: Percentage distribution Vs cost

Figure 6 shows the failure rate distributions of three functions each with a mean failure time of 7 years.

For example, suppose that two boilers are suitable for a given purpose. Boiler A has a mean life of 5 years and costs £448,83. Boiler B has a mean life of 7 years and costs £600. Using an annual equivalent approach with discount rate of 5%, there is no preference between the options since both have an annual equivalent of £103.6.
If a net present value computation had been made in which it had been assumed that there were no residual values at the end of the project's life then a different result emerges. The table below shows the results allowing for 5% and 10% discount rates

No. of years	Discount rate			
	5%		10%	
18	1291.94	1329.45	1008.01	1065.89
20	1461.10	1329.45	1074.72	1065.79
22	1461.11	1544.82	1074.72	1146,97

Boiler A appears to be best for 18, 19, 21 or 22 years but B is best for 20 years. The calculations show how easy it is to obtain the desired results by manipulating assumptions.
A Monte-Carlo approach using the failure rate function can be used to give more realistic appraisal of the life cycle cost of a project than the use of the mean life. This approach has been used in the below table to obtain the expected monetary value of life cycle costs over a 20 year life from a run of 2000 failures for the two boilers. Each of the distribution for A has a mean life of 5 years and each for B one of seven years, but three values of the Weibull parameter b have been allowed in order to show the effects of the distribution of failures on the life-time costs

b value	Discount rate			
	5%		**10%**	
3	1269.80	1303.04	1004.95	1061.16
5	1308.16	1335.39	1022.15	1078.80
8	1317.77	1335.37	1024.67	1074.34

]
Figure 7 shows that distribution of costs for boiler B with different failure rate functions and illustrates how widely the costs can vary from the mean value.

6. CONCLUSIONS

- The life cycle techniques could be discounted or non-discounted, the former ones are becoming more widely adopted due to there attractiveness.
- Most discounted methods are equivalent and would normally lead to the same results.
- The NPV method gained popularity as against IRR because of the theoretical problems with the latter approach. In fact the NPV method can suffer from the same problems in similar situations. While these problems for the NPV method were not critical in situations where the real interest rate was stable.
- The life cycle costing is concerned with the making of projections and these are capable of being manipulated by the person carrying out the appraisal to produce the desired results.
- Standards can be set in order to solve consistency problems but can themselves lead to a misallocation of resources. The paper has suggested how risk adjusted discount rate can be derived from beta analysis. It has also shown how the use of failure rate functions provide a sounder basis for maintenance standards than assumption about periodic maintenance, inspections and replacement
- The choice of the discount rate should be take seriously. Inflation and risks should be included in it since both factors are playing vital role in defining the time value of money.

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