

CAN WE DELAY THE REPLACEMENT OF THIS PLANT?

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ABSTRACT

One of the biggest decisions facing management is the decision on when plant should be replaced. This problem is usually encountered in the heavily loaded form: ‘The replacement is due now - can we delay it?’.

In utility industries, the problem becomes more difficult in several respects, one of these being that artificial constraints may dictate what capital expenditure is permitted, or in a few cases, required to be made.

The new plant will usually be rated to be better than the old. Cash is severely limited. There are uncertainties about how both the old and the new plant will behave. It is not known how long the replacement plant will be required to operate.

Management tools are now available which allow an extensive and arguably complete calculation of this complex problem – tools which express the result in direct economic terms.

A software tool designed to address this problem is demonstrated. Within a few years, such tools will be part of the essential toolkit of the asset manager.

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CAN WE DELAY THE REPLACEMENT OF THIS PLANT?

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1. INDUSTRIAL MANAGEMENT AND THE ASSET REPLACEMENT DECISION

One of the biggest decisions facing industrial management is the replacement of major production assets. It is also a problem that is, by its nature, extremely complex. The majority of such decisions are made on the basis of some limited calculations, and large amounts of conscientious assessment. Few companies would wish to claim that they have rigorous means of assessing the optimum time at which to make such a replacement, and the reluctance to commit such expenditure, whilst absolutely valid, and a major factor in the assessment, often results in assets not being replaced until long after the optimum point.

The problem has been exacerbated in the utilities industries by a number of factors. Utilities operating under a regulator are having to work with arbitrary requirements regarding capital spend. Sometimes this is in the form of a minimum spend; more usually it is a maximum. Major assets in some industries were installed over a relatively short timespan, and large numbers of assets are now believed to be at, near, or sometimes beyond their optimum economic life, or their design life. Where safety is an issue, the decision has got to take full account of any safety implications of extending the life of an asset.

The tools available to assist the manager in this decision are few:

- A small number of companies (usually very large companies) have developed their own in-house financial modelling of this problem. Such models vary enormously in their capabilities.
- Many organisations use a form of ‘weighted parameter’ assessment. These are certainly not financial models; they are models based on the subjective assessment of the various factors considered to be influencing the decision. What they are really doing is to systemise the application of subjective assessment. They are therefore likely to achieve more consistency, and perhaps also slightly better decisions.
- A well-constructed but simple spreadsheet is often the best tool available to the decision-maker, but the problem being tackled is inherently complex, and, because of the simplifications almost always incorporated in a spreadsheet solution, there is almost always doubt regarding the degree of confidence can be accorded to the results.

2. FINANCIAL CONSIDERATIONS PART 1

The life of a new asset is probably going to be in the range from 5 to 100 years. If we were to confine ourselves to asset lives of less than 5 years, then it might be reasonable to consider cash flows without the use of discounting, but with lives in the range we are considering, **it will be essential that the evaluation should incorporate rigorous methods of Discounted Cash Flow.** The basic methods are already widely known and used by asset managers and finance departments. These methods, with varying degrees of rigour, are published in a wide range of authoritative texts, e.g. (1) (2).

There are important limitations to the two basic methods:

- To make a valid comparison of options by the use of Net Present Value (NPV) when the requirement for the asset is on-going, it is necessary that the options being evaluated span the

same period of time. However, it is extremely difficult to value the remaining life of a part-used asset.

- The use of Internal Rate of Return (IRR) can only be made where there is a full costing. In other words, if a manager's responsibility is to provide stack services to an oil refinery for the removal of flue gases, then, unless the stacks are a profit centre and the refinery is charged for each cubic metre of flue gas, it is not possible to evaluate options using IRR. If the cash flows are outgoing only, then there is no such thing as IRR. In practice, when looking at the replacement of existing assets, and particularly in a utility industry, it is seldom feasible to carry out a full costing. The service has to be provided, and it is a question of determining the most economic way in which to do it. So IRR cannot be used for such replacement decisions.

The use of discounting in the more complex situations that are generated will be referred to after a description of the shape of the problem.

All decisions are, at root, financial decisions, and the results are going to be in financial terms. Such elements as unreliability must therefore be entered both in terms of probability of failure, and the cost to the organisation of that failure. The major part of such failure cost is the 'indirect' or 'penalty' cost of the failure – the cost of the failure to production or to the user of the asset. No valid result can be achieved by regarding the cost of failure simply as the cost of the repair. Similarly, any loss of efficiency must be expressed in terms of the financial impact of that loss. Any cost of a maintenance activity may incorporate an element representing the loss of usage whilst that maintenance is undertaken as well as the direct cost of the work. The technology to handle these aspects has been available for more than 20 years. (3)(4)

3. THE SHAPE OF THE PROBLEM – UNEQUAL TIME PERIODS

We have a current asset, which is probably considered to be nearing the end (or past the end) of its design or economic life, and we have the prospect of a new asset, which, generally speaking, will not be the same as the one we are replacing. It is obvious that the predicted behaviour of the new asset will have a major effect on the optimum point at which to make the changeover. It is highly likely that the current asset will be less efficient than the new asset, and it may be known, or considered, to be less reliable than a new asset.

We are therefore clearly dependent upon both the assessment of future behaviour of the current asset, and the predicted behaviour of the new asset.

The new asset will not have an infinite life. Depending upon its predicted behaviour, and the cost of replacing it, there will be an optimum economic life, which may be calculated.

We therefore land up with the problem as shown in Figure 1. We have to compare:

- the immediate replacement of the current asset by the new asset (Figure 1a) with
- the replacement after a delay of N years (Figure 1b).

It will then be assumed that the new asset will be replaced at regular intervals set to what (on present knowledge) is calculated to be its optimum economic life.

In Figure 1, the vertical scale 'Deterioration' may for the time being be regarded as illustrative. The deterioration may represent increasing probability of failure, reduction in efficiency, or certain other forms of deterioration, or indeed a combination of these. In the analysis, it will be handled on a properly defined and quantified basis.

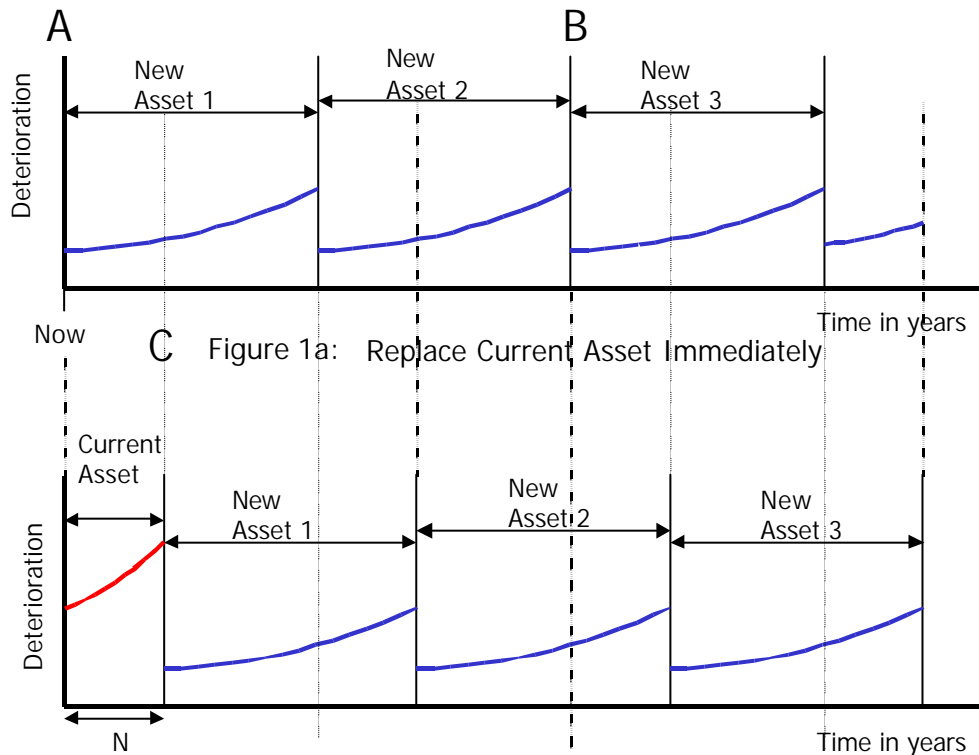


Figure 1b: Replace Current Asset in N years time

4. OBJECTIVE

Now that we have set out the shape of the problem, we can state our objective. Our requirement is to find the optimum value of N in Figure 1b, and to ascertain the cost premium of not making the replacement at the optimum point.

If the optimum point was either now, or some point in the past, then we require to know what is the cost to the organisation of not making the replacement for a further number of years.

If the optimum point is at some point in the future, then we require to know what is the cost to the organisation of not making the replacement at that optimum point.

5. FINANCIAL CONSIDERATIONS PART 2

From Figure 1, it will be seen that we shall have difficulty in comparing the options we are examining over equal periods of time. It is not valid to evaluate from A to B of Figure 1a, consisting of two complete cycles, against N years of the current asset, and two cycles minus N years of the new asset as in Figure 1b. It is therefore necessary to extend the financial methods available to provide a valid parameter by which the comparison can be made. This is explained further at Appendix 1. The methods involve no approximation, and are mathematically rigorous, being based solely upon the accepted concepts referenced in Section 2 above.

Measures

The 'parameter of merit', or 'measure of utility' will be different for the two parts of the calculation:

When evaluating the cyclic cost of the new asset, we will be using Equivalent Annual Cost (EAC) (also known as equivalent annuity series, and some other titles).

When comparing immediate replacement of the current asset with delayed replacement, or differing degrees of delay, we will be calculating a single sum of money at present value, which represents the benefit or loss resulting from the adoption of that option.

Any method that uses NPV or developments of NPV, is going to require the entry of a rate of discount. The value of this figure is a major subject which must be resolved within the user organisation. It is not addressed in this paper.

By the use of these methods, the difference between two options (or a range of options) on timing of the asset replacement can be expressed as a PRESENT VALUE LUMP SUM.

6. THE ANALYSIS

As mentioned above, we have to enter the expected deterioration of both the current and the new asset. Those who have used tools in the Cost/Risk Optimisation of maintenance activities, will be conversant with the manner in which such deterioration can be entered. As mentioned earlier, the deterioration can take on a number of forms. The most frequently encountered is an increasing probability or frequency of failure, but other forms of deterioration, such as increasing cost of maintenance of an asset with age, or loss of performance with age, may also be entered.

We also need certain other data (e.g. any lump sum expenditure involved in the changeover from the present to the new asset – Point C on Figure 1). The analysis is then carried out in two stages:

1. Evaluating the optimum economic life of the new asset, and the corresponding EAC.
2. Evaluating the financial impact to the organisation of replacing the current asset at various points.

These two stages are discussed in sections 7 and 8 respectively.

7. EVALUATING THE OPTIMUM ECONOMIC LIFE OF THE NEW ASSET AND THE EAC

Using the information about the new asset, the computer carries out a calculation of the optimum economic life of the new asset. The calculation of optimum life is well established. The mathematics were published in a number of references dating from about 1965 (5)(6). Computer programs have been available to handle this type of problem (although not always incorporating

discounted cash flow) from about 1977 (3)(4). These programs assumed a 'like-for-like' replacement.

In order to incorporate discounting, the selection of the Optimum Economic Life is done by the calculation of Equivalent Annual Cost (See Appendix 1) of the asset over a range of possible lives. The optimum economic life is the lowest point on this curve. This is shown in Figure 2.

The shape of this curve is usually fairly flat, indicating that the life to replacement is not usually very critical. Even so, it is often found that a user is operating an asset under a replacement interval which is a long way from the optimum.

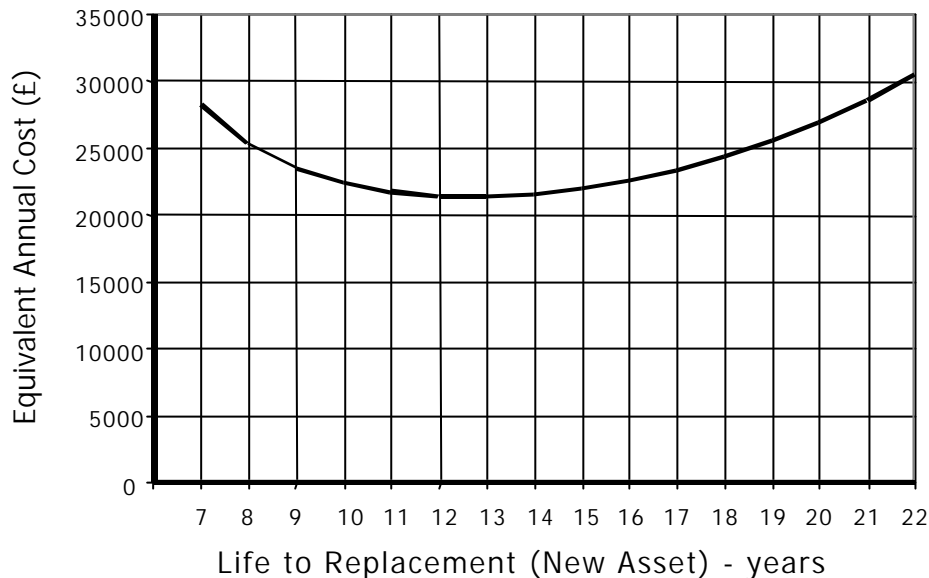


Figure 2

8. EVALUATING THE COST TO THE ORGANISATION OF REPLACING THE CURRENT ASSET AT VARIOUS POINTS

To replace the current asset at the wrong time obviously causes financial loss to the organisation. This might perhaps be described in terms of an additional cost per year, particularly if the current asset is going to continue in use for a few more years. And if we were to replace an asset a few years before the optimum point, then we might describe the loss as a cost per year until that optimum. But neither of these is very clear, and the costs and benefits do not materialise solely during that period. The knock-on effect of an early or late replacement actually never ceases, as is clear from Figure 1. The alternative is to describe the loss to the organisation resulting from an early or late replacement as a single lump-sum cost expressed in present value terms. This is sound mathematically, and is a fair description in monetary terms of the penalty for early or late replacement.

The calculation of this present value lump-sum uses:

- The results of the first part of the analysis.
- Any one-off costs associated with moving to the new asset (Point C on Figure 1).
- Information regarding the current asset, its present state and predicted further deterioration.

The results of the analysis are shown in Figure 3 for two different situations:

Figure 3a shows the situation where the optimum replacement point is still in the future.
Figure 3b shows the situation where the optimum replacement point is already passed.

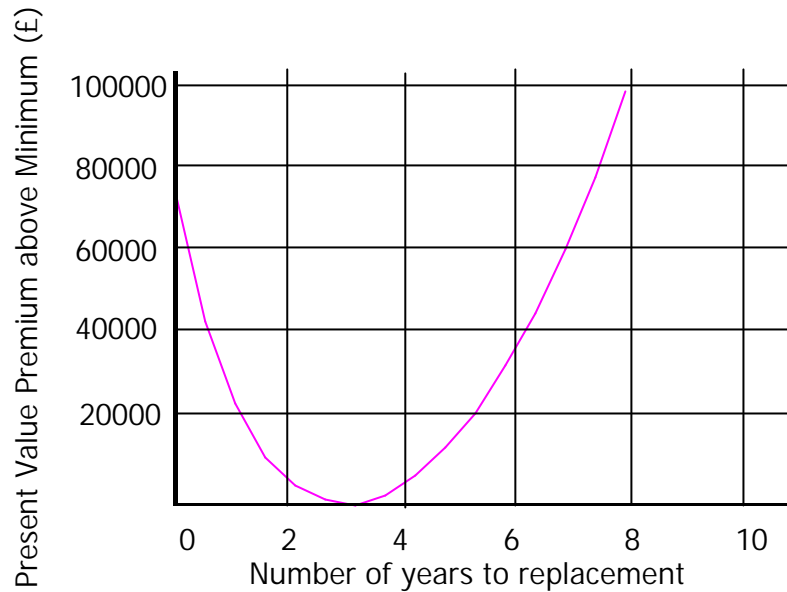


Figure 3a - Optimum Replacement

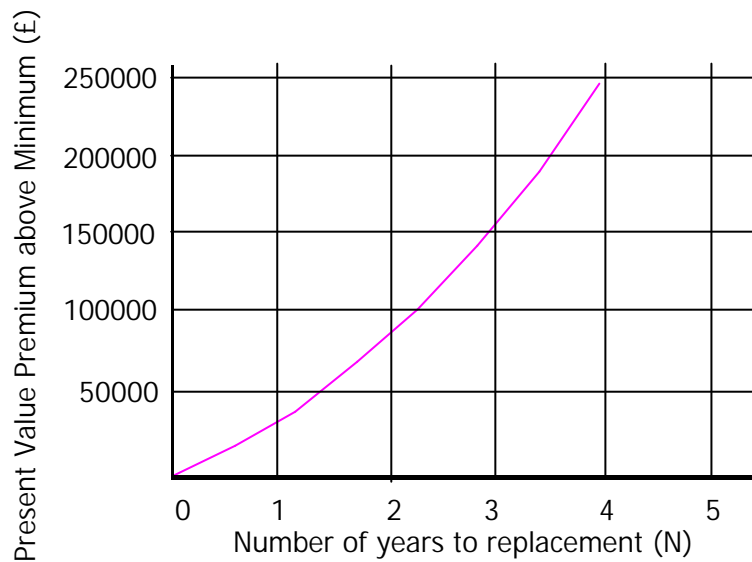


Figure 3b - Replacement Already Overdue

The computer is calculating: **“What is the cost to the organisation of delaying the replacement by N years?”**, and plotting this against different values of N. By definition, at the optimum replacement point, this will have a value of zero. The result will normally be in the form of either Figure 3a (where the optimum replacement point is still in the future) or Figure 3b (where the optimum replacement point has already been passed).

9. CASE HISTORY

9.1 The Problem

A reactor vessel was designed to have a 10-year life, and is now 14 years old. Capital funds are limited, and the cost of the new vessel is put at £4.7M. The (net marginal) value of the process is put at £1200/hour, and operation is scheduled for 8400 hours per year.

During the last year, for reasons of unreliability, only 8240 hours were achieved. The reliability of the old vessel is deteriorating, and it is predicted that about 8040 hours might be achieved in the coming year. The deterioration is likely to continue until the vessel is replaced.

The new vessel (New Asset A) should allow the full 8400 hours to be achieved. It is believed that this should continue for the first 10 years of life, and after that, reliability problems will start to limit availability. By 15 years it is estimated that 8000 hours will still be achievable.

The company require that discounting should be carried out at a rate of 8.5% per year.

The above case history has been considerably simplified. It would not be possible to handle the full problem without substantially extending the paper. The purpose here is to show that it can be done – full details of how will require a larger exercise.

9.2 Analysis

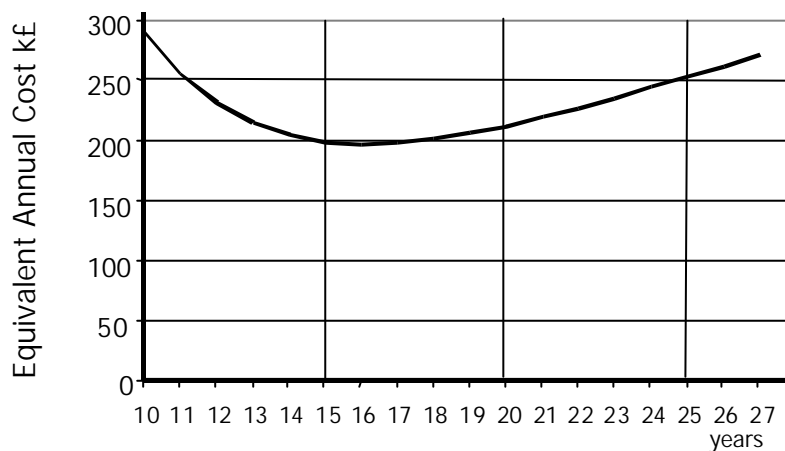


Figure 4 - Life to Replacement - New Asset A

The output of the computer calculation is shown in Figure 4. It will be seen that the optimum economic life of New Asset A is 16 years, with an Equivalent Annual Cost of about £200,000 (£197,000 in the table output, not shown). Note that this output is the Equivalent Annual Cost, and is in £/year.

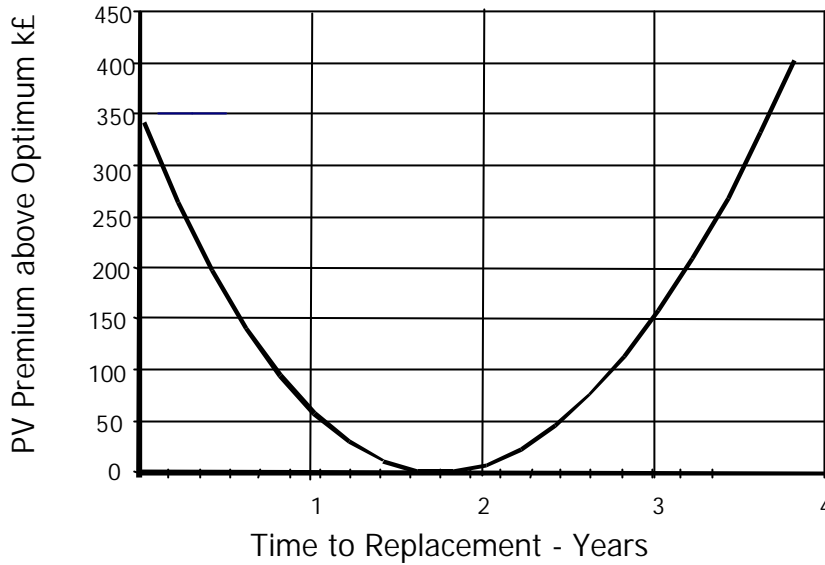


Figure 5 - Replacement of Current Asset with New Asset A

The output from the second half of the calculation is shown in Figure 5. The optimum point at which to replace the current asset with New Asset A is in two years time. The cost of replacing it either now or in four years time would be approximately £400,000. This output expresses the benefit or cost of delay in terms of a lump sum figure at present value. It is not a cost per year.

9.3 A More Efficient Asset is Available

The efficiency of the reactor is 53%. A new design of reactor (New Asset B) offers 57%. The cost of the new design would be £7.2M. Is this worthwhile, and how does it affect the point at which the changeover should be made?

9.4 Analysis

The optimum economic life of New Asset B is 19 years, with an Equivalent Annual Cost of minus £471,000. This is shown in Figure 6. The efficiency of New Asset A is taken as the datum. The negative value is relative to New Asset A, and is caused by the large improvement in efficiency over New Asset A.

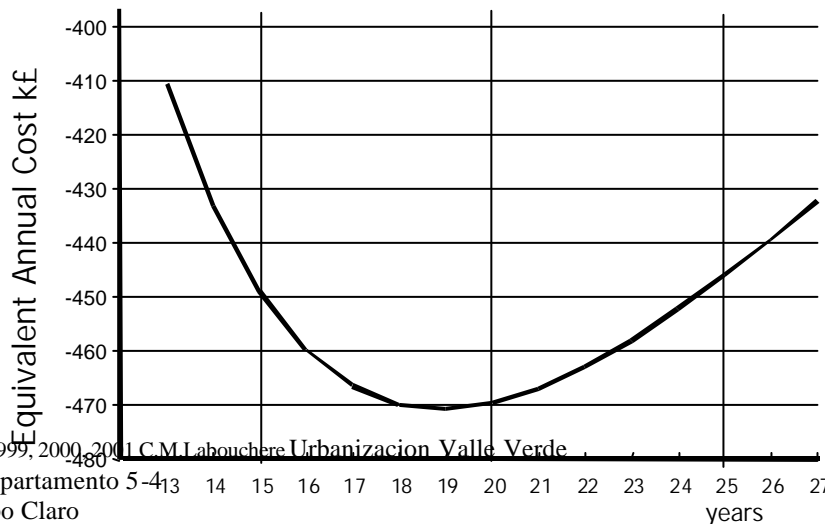


Figure 6 - Life to Replacement - New Asset B

The optimum time at which to replace the current asset with New Asset B is NOW. The cost of delaying by two years is £607,000 (lump sum at present value). This is shown in Figure 7.

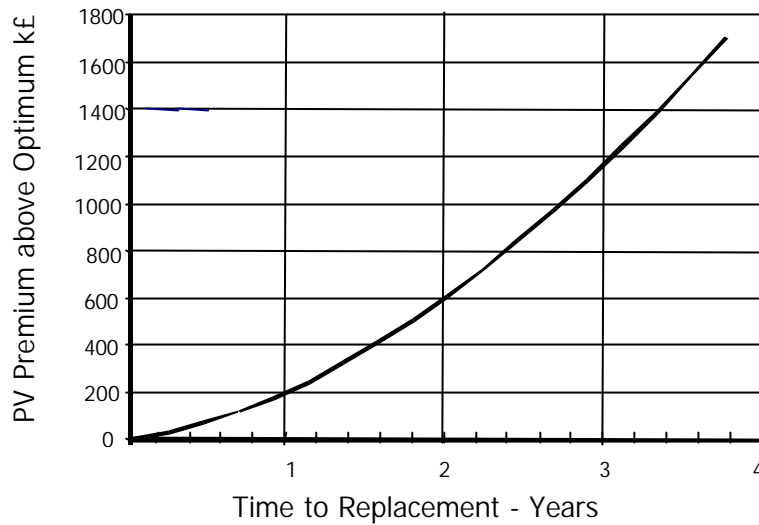


Figure 7 - Replacement with New Asset B

The PV lump sum benefit of replacing the current asset with New Asset B now, as compared with replacing it with New Asset A in two years time is £6,100,000.

To make the change to New Asset B in two years time would still have advantage in present value terms over changing to New Asset A of £5,500,000 (£6,100,000 minus £607,000).

All figures and graphs in this section have been calculated using the APT LIFESPAN program. There are no 'freehand sketches'.

10. Conclusions

10.1 Discounting is almost universally accepted in the evaluation of medium and long term future cash flows.

10.2 The application of discounting to the problem of delayed asset replacement results in mathematics that cannot be handled without an appropriate computer program.

10.3 The decisions on replacement options, even of a complex nature, can now be made with a full view of the financial impact of the expected behaviour of the different assets.

10.4 The calculations are just that – calculations. They are the application of known and totally rigorous mathematics and discounting methods to the information (or inputs) that would anyway have been the basis of the assessment.

10.5 The financial impact to the organisation of delaying a replacement is expressed in terms of a single sum of money at present value.

Chippenham
Feb 2001

Appendix:

1. Discounting techniques to compare evaluations over different time periods, and with some continuation of the current asset.

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