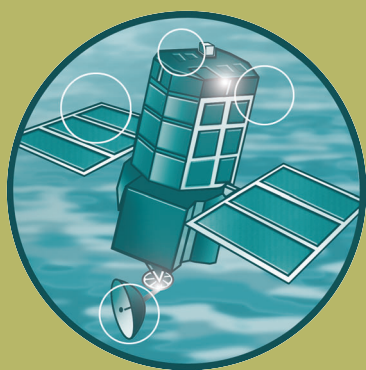


Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Development of economic appraisal methods for
flood management and coastal erosion protection

Updated PAG3 spreadsheets guidance report

R&D Project Record FD2014/PR1



The use of the revised PAG3 spreadsheets

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1 Introduction

Two of the changes in the Treasury's 'Green Book' necessitated modifications being made to the existing Defra spreadsheets:

- The change to a variation in the discount rate for different time periods.
- The extension of the time frame for analysis up to one hundred years.

The original PAG3 spreadsheets were intended to be illustrative of the way in which to approach common problems in appraisal rather than to provide a set of standard spreadsheets which could be used in all circumstances. The same is true of the revised spreadsheets: there are always likely to be special conditions that require specific modifications to match the particular circumstances.

Any standard form of spreadsheet would also have to include so many elements, many of which would not be used in a specific analysis, that the resulting spreadsheet would be so complex as to be opaque. The extension of scheme life to one hundred years already makes for very large worksheets.

In addition, project appraisal is not a mechanical process in which the appropriate numbers simply have to be 'plugged in' order to deliver the result. It requires thought and understanding; the spreadsheets provide the book-keeping, provide a means of record keeping, and here they have been reshaped in order to aid understanding and insight.

To aid in this understanding, all the cells have been colour-coded to indicate whether they are a cell in which data must be entered, whether they contain a final result, an intermediate result, and so on. The worksheet 'summary' is both the starting point and finishing point of any analysis.

In updating the spreadsheets, the opportunity has been taken to make a number of other changes which are intended to enhance usability; the Annex here lists the main changes made whilst the principal changes are discussed below.

2 Changes made in the spreadsheets

The opportunity has been taken to make it easier to use the spreadsheets to better support appraisal led design.

This treats project appraisal as an iterative process, a learning process, which leads to a decision being made as to which option should be preferred. Central to this learning process are the identification of those parameters whose values are critical to the choice between the options, and the progressive refinement of those values until a decision is

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reached as to the preferred option. At the same time, it is to be hoped that the analysis will aid in the generation of new and better options through the identification of the strengths and weaknesses of each of the initial options.

2.1 Sensitivity analysis

Therefore, sensitivity analysis should be undertaken at the beginning of the analysis; its purpose is to identify which are those critical parameters. To aid in this analysis, various graphical analyses are provided which show the proportion of benefits and costs contributed by the different streams of benefits and costs.

2.2 Robustness analysis

At the end of each iteration, a decision must be made as to whether one option should be preferred to all others: can we be confident that this option should be preferred to all others?

The benefit-cost ratio is the measure of this confidence, a benefit-cost ratio of 1.0 being the point of maximum doubt as to whether this option should be preferred to the baseline, 'do nothing', option. The question is, therefore: how much greater than one does the benefit-cost ratio have to be before we can be reasonably confident that this option should be preferred to the baseline option, given all the inevitable uncertainties surrounding the analysis?

Here, the benefit-cost ratio helps but does not provide a complete answer. A benefit-cost ratio of 3.0 means that we could have overestimated the benefits by a factor of three or underestimated the costs by a factor of three and we should still prefer this do something option to the baseline option. What it does not tell us is whether it is plausible that we have overestimated some streams of benefit or some streams of cost by the required magnitude.

The logic therefore is to take the critical parameters as identified in the sensitivity analysis and to test how far these values must be changed before our preference changes. Aids to undertaking such robustness analyses have therefore been included in the worksheets.

2.3 Error checking

Part of the process of iterative learning is to look for errors or problematic areas. It should be expected in any complex analysis some errors will initially be made and that a key component of the process is identifying and reducing or removing those errors.

There are four generic forms of possible error:

1. *Theoretical*: the theoretical understanding upon which the analysis is based may be incorrect.
2. *Formula*: the mathematical formulae used to calculate values may themselves be wrong, expressed incorrectly, or incorrectly transposed between different cells in a spreadsheet.
3. *Data*: the data may be in error.

4. *Data entry*: errors may be made in entering the data or the data may subsequently be changed in error (e.g. by tapping on a key to wake up the computer).

The frequency with which one or another form of error is found in practice is high. There are then two strategies for minimising the number of errors that occur. The first is to reduce the risk that error occurs in the first place; the second is to increase the likelihood that errors will be found and corrected when they occur.

As is usual with software, it is not warranted that there are no errors of either of the first two kinds; Excel itself has some eccentricities can introduce error. However, the spreadsheets have been tested extensively and are themselves derived from many years of practical experience.

To minimise the risk of introducing theoretical or formulaic errors, the worksheets have been locked (the password is 'flooding') in order to reduce the risk of inadvertently changing the formula in a cell or the value in a cell. It is also recommended that the originals be saved as read-only files and for each analysis a renamed copy be used. To reduce the risk of data entry errors, data has only to be entered in a single cell and then is automatically copied to other cells which use that data.

There is no mechanical way of testing whether the data itself is in error; it is necessary to consider the plausibility of the data and here experience helps. For example, if the losses estimated from a frequent event are very high, those values can, and need to, be 'ground truthed'.

In detecting errors, the use of the audit tool in Excel is recommended. Unfortunately, it is generally easier to detect a few gross errors rather than a small but widespread systemic error. It is also easiest to detect errors which are inconsistent with the dominant pattern for a parameter; for example, extreme values in a distribution, outliers in a scatter plot, or abrupt changes in gradient in a scatter plot.

Unfortunately, it is generally easier to detect a few gross errors rather than a small but widespread systemic error. It is also easiest to detect errors which are inconsistent with the dominant pattern for a parameter; for example, extreme values in a distribution, outliers in a scatter plot, or abrupt changes in gradient in a scatter plot. Typically, it is easier to pick up such errors from a picture than from staring at several hundred cells so an extensive range of graphical representations of parameter values has been included. Anything that seems surprising should be investigated until the reason for the result is determined.

2.4 Audit trail

If the first purpose of project appraisal is to help us make better choices, the second purpose is to establish an audit trail through which accountability can be shown. A key stakeholder in flood and coastal defence is the general taxpayer whose money we are spending.

Whilst the contribution of the individual taxpayer towards the costs of any single scheme is generally small, the annual amount which each taxpayer contributes in total is not trivial. Equally, the transfer of national resources to those who live or work on the flood plains is far

from negligible; in some cases, the redistribution to each individual household or property can exceed £80,000.

Hence, the taxpayer entitled to the assurance that the overall programme of works undertaken constitutes the best value for their money; that this can be demonstrated through the use of consistent methodology; and that there exists an audit trail which shows the basis upon which the decision was finally arrived at.

Any single study is likely to generate many different runs and some note pads are provided on individual worksheets in which the basis of an individual analysis should be recorded.

2.5 Deciding upon the option to be adopted

Project appraisals, although they are economic analyses, are still rooted in a financial view of the world in which an investment of money produces a return in money terms. As economic appraisals become more comprehensive in what is included, the analysis departs more and more from the conventional financial model. At the same time, as the time horizon of the analysis is increased, so too do the uncertainties become greater.

In consequence, simply mechanically applying the rule of maximising the benefit-cost ratio becomes increasingly dangerous and no simple rule can capture the full complexity of the choice. For example, the rule of choosing that option which has the maximum benefit-cost ratio is logical when all the costs are capital money costs. Applying the rule means that for a given sum of money, we get the maximum return on the capital invested.

When a significant fraction of the money costs are O & M costs, and where we want to consider a high capital cost, low running cost option to a low capital cost, high running cost option, the benefit-cost ratio is too crude a measure. This is especially true when we want to consider the implications of the different options on future operating budgets. Again, the benefit-cost ratio makes logical sense when all the benefits are reductions in resource costs, as they are with the direct benefits of flooding.

But, in the more comprehensive analyses now being undertaken, some of the benefits will be gains in unpriced consumption (e.g. recreational benefits, non-use value), and others resource gains. Add in positive and negative externalities, both in the form of changes in resource usage and consumption, and the unique meaning of the benefit-cost ratio is lost. Hence, a number of different indicators are included. If these different indicators point to different options as being that to be preferred, then thought has to be given as to which option should be preferred.

One of the two rationales for discounting is the opportunity cost of capital. Where all the costs are resource costs, the logic of seeking to maximise the return to the capital investment is self-evident. But, as noted above, in the form of comprehensive analyses now being undertaken, the costs are not limited to capital investment.

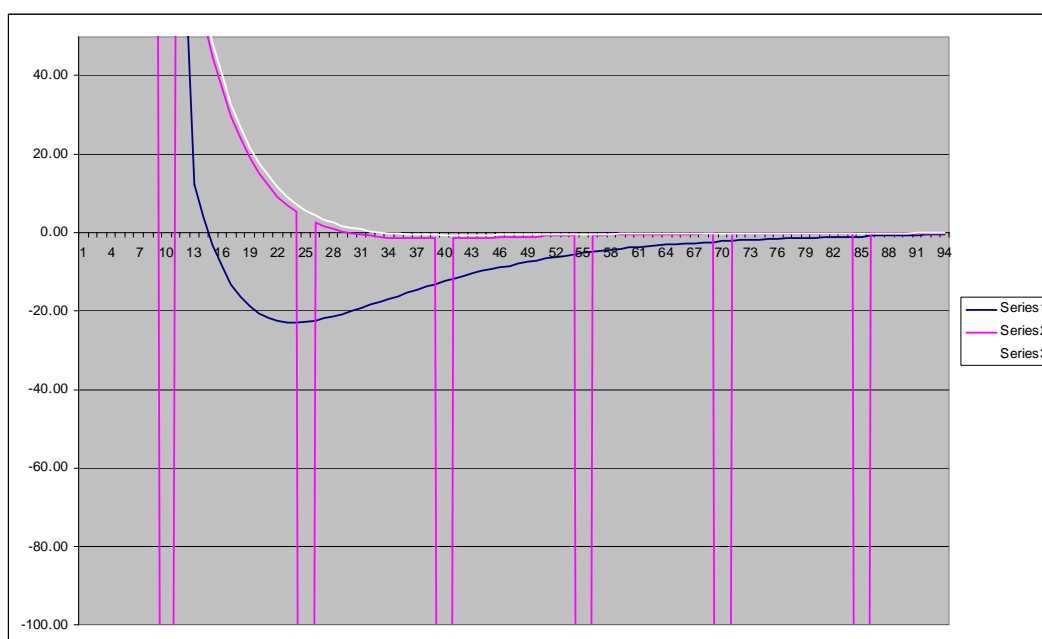
The second argument for discounting is time preference. Unfortunately, all that discounting does is to calculate the weighted area under the curve of net annual benefit over time; theoretically there exist, therefore, an infinite number of such curves, the area beneath each of which is identical for a given discount rate. Only if we care only for the area under the

curve and not at all for the shape of the curve does discounting take account of time preference. If we have any preference for the distribution of consumption over time, discounting cannot take account of this.

The spreadsheet provides plots of the net annual benefit of each option as discussed in FCD PAG3. In the example shown in **Figure 1**, under two (the benefit-cost ratio and adjusted benefit-cost ratio) of the four criteria noted above and discussed in the Annex, the first option should be preferred.

On the basis of the other two criteria (Net Present Value and adjusted capital b/c ratio), the second option should be preferred. The third option whilst having an acceptable benefit-cost ratio is inferior to the other options. However, given that the first option has a negative net annual benefit over most of its life time, one of the other options might be preferred. In choosing between those options, the need for rehabilitation of the second option at different periods over its life might be seen either as a drawback or as providing potential opportunities to retire the scheme each time rehabilitation is required.

Figure 1 Distribution of net annual benefits over time



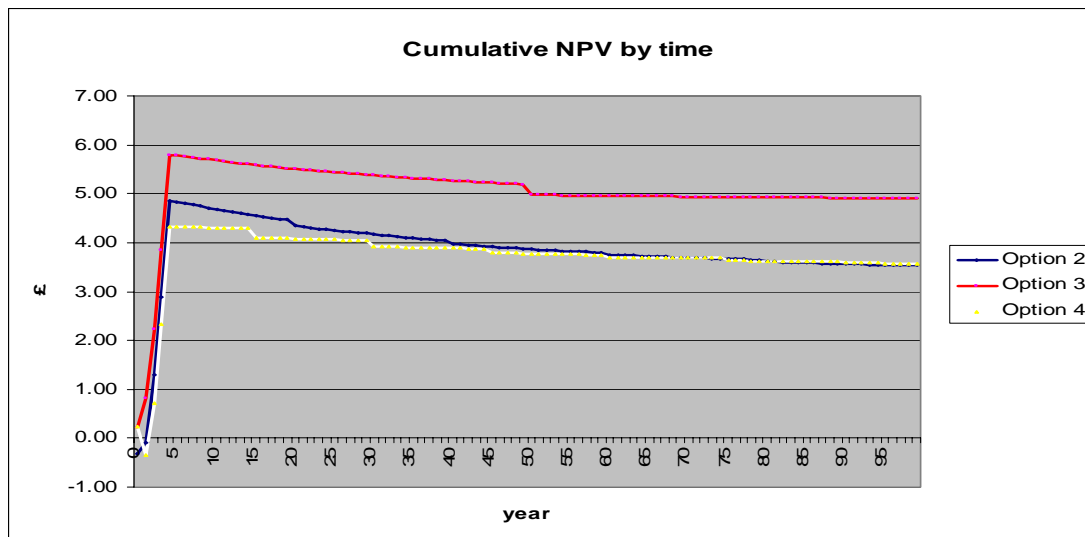
The Treasury's desire to extend the analysis to 100 years into the future greatly increases the possible alternative futures to be considered. If an option with an engineering life of 25 years is compared to one with an engineering life of 100 years, then there are 8 possible alternative futures for the former to be compared to the latter, depending upon whether the short life option is renewed at the end of its life.

At the end of each lifetime of the short-lived option, there is also an option to adopt a radically different option, including constructing the long life option. What we do now may then depend upon what we expect to do in the future; we may, for example, undertake a short life option in the expectation that we will undertake managed retreat when that short life option reaches the end of its life.

To avoid becoming lost in these multiple futures, a plot of the NPV of each option over different periods of the future is included in the revised spreadsheets (Figure 2). If the NPV of one option is above the NPV of all other options, whatever the time period of the analysis, then there is less reason to worry about what actions will be taken in the future. If the option that should be preferred now depends upon the time frame taken for the analysis then more thought has to be given to future courses of action.

In **Figure 2**, whilst for a timeframe of analysis of greater than about 60 years Option 4 should be preferred to Option 2, Option 3 is preferred to both these other options whatever the timeframe of analysis.

Figure 2 Variation of NPV of the different options for different timeframes of analysis



Annex

The major changes introduced in 2005/6 are:

- The timeframe for analysis has been extended to 100 years.
- Three difference discount rates starting at three different dates can be used (worksheet 'summary').
- A flowchart shows how each of the worksheets links together (worksheet 'flowchart').
- At a number of points, an individual cell has an Excel comment attached which describes the contents of the cell. For example, the 'summary' worksheet includes comments for the performance indicators 'adjusted benefit-cost ratio' and 'adjusted capital benefit-cost ratio'.
- The 'summary' worksheet includes space where notes about the particular run can be included.
- Cells are colour coded to show where values must be entered, values that are echoed from other worksheets, intermediate calculated values and results (see worksheet 'key').
- Data entry has been automated: the appropriate value for each parameter is only required to be entered in one worksheet, it is then echoed to other relevant worksheets.
- Taken together, the flowchart and coding make the logic of the spreadsheets easier to follow.
- A worksheet 'cost_data' for the entry of capital costs and different streams of recurrent costs both annual and cyclical has been added.
- An adjustment to the present value for costs can be made for different magnitudes of 'optimism biases.
- In addition to the usual categories of benefits (flood losses averted and erosional losses delayed), together with capital and recurrent costs, scope for the inclusion of three additional streams of benefits or costs has been introduced (worksheet 'other benefits').
- As an aid to the initial sensitivity analysis, graphics are used to show the contributions of the different streams of benefits and costs to the Present Value of the benefits and costs.
- For flooding, diagnostics are provided for the loss-probability curve which show where the inclusion of additional return periods would be likely to improve the precision of the estimate (worksheets 'sum_0', 'sum_1', 'sum_2' and 'sum_3').
- Extensive analyses are provided of the loss-probability curve for flood alleviation benefits of the upper and lower bounds on the estimate of the benefits within each interval, and the proportion of total benefits contributed both each interval and by each land use.
- 'Above design standard benefits' can be included when analysing a flood alleviation benefits.
- To support the subsequent robustness analyses, multipliers can be applied to cost elements (worksheet 'PV_costs').
- In addition to the benefit-cost ratio and Net Present Value, two additional performance indicators are provided for each option. These are the Adjusted benefit-cost ratio

(benefits – other costs)/(capital plus O & M costs) and the adjusted capital benefit-cost ratio (benefits – other costs – O & M costs)/capital costs (worksheet Summary).

- The use of a time frame of 100 years for the analysis is greater than the engineering life of some options. As a result, there is the possibility that the choice of the preferred option will depend upon the timeframe of analysis. To test whether this is the case, a plot of the NPV of each option over time frames up to 100 years is provided (worksheet 'NPV chart'). If the curves of two options cross it indicates that the choice between the options is dependent upon the time frame of analysis.
- Since discounting is an incomplete reflection of time preference the plots of the net annual benefits of the different options are provided (worksheet 'NPV chart').

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