NET PRESENT VALUE AND RISK MODELLING FOR PROJECTS

MARTIN HOPKINSON

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Net Present Value and Risk Modelling for Projects

'The book is well-reasoned and well-written. It provides a lot of insight in an accessible form. I particularly like Martin's attention to the parallel and integrated consideration of: (1) uncertainties of time and cost in construction, with (2) uncertainties in operations (operating costs, efficiency and market prices). The unifying theme of Net Present Value, reflecting the time value of money, is a way to incorporate these into useful strategic decision-making about the management of projects.'

David T. Hulett, FAACE, President at Hulett & Associates, LLC

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Contents

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List of Figures

List of Tables

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Preface

In the early stages of a project's life cycle an organisation has to consider questions such as:

- Have we made the right choices when planning this project?
- Should the project be preferred to other projects?
- Should the project be stopped or approved to proceed to the next phase?

Given the importance of these questions, most organisations use a project governance process to ensure that they are addressed at the right time and the right decisions are made as consequence. Net Present Value (NPV) modelling and NPV risk modelling are techniques that can help support the decisions involved.

A project may be worth doing provided that its costs are more than justified by its benefits. This principle lies at the heart of any project business case. If we can forecast the financial value of a project's benefits, we can compare it to the project's cost to test how attractive the business case is. NPV modelling is a way of performing this test. Its approach to discounting cash whereby future cash can be compared to today's value is considered to make it a robust method for making financially-based project selection and approval decisions.

NPV risk modelling is an extension to the NPV method that can provide an improved way of representing the implications of project-specific risk. Although its use is less widespread, it can add value to project forecasting and management processes. NPV modelling is based on deterministic calculations i.e. it uses single value estimates and calculates a single value output. NPV risk models are more sophisticated in that that they allow inputs to fluctuate in ways that represent the effects of risks on both costs and benefits. Their outputs represent the implications of risk by showing how project NPV could vary as a consequence.

In this book, I have chosen to focus on deterministic NPV models before moving on to NPV risk modelling. This is because it makes the methods easier to explain and because anyone developing an NPV risk model should be familiar with NPV modelling principles. However, it is also true that anyone developing an NPV model should be familiar with methods for modelling the effects of risk. There is also often a good case to be made for relatively simple NPV risk models to be used from the earliest stages of a project; the periods during which the best opportunities for managing the implications of risk are often to be found. Thus, a preferred approach might be to develop and use NPV risk models prior to the development of a deterministic NPV model with the level of detail that is typically used to support the key project go/no decision.

There are a number of people who I would like to thank for their help. Chris Chapman and David Vose and David Hulett have kindly provided me with feedback on parts of the risk-related material, whilst Dave Missen and Clive Mountford reviewed the accountancy aspects of the NPV modelling chapters. Any mistakes are mine only. I would also like to thank staff at Pallisade and Vose Software for their support in respect of my use of the risk simulation tools @RISK for Excel and ModelRisk respectively. Dave Barton might be surprised to find me thanking him for his brief look at an earlier draft. However, the look on his face persuaded me to take a different approach to the opening sections! Finally, I would like to thank Jane, Emily and Peter Hopkinson for their frank reviews of earlier drafts!

Martin Hopkinson

Chapter 1

Background to Project Net Present Value and Risk Modelling

This chapter provides a background to Net Present Value (NPV) modelling methods. It starts by explaining how to perform present value calculations and why they provide a robust basis for project financial appraisal. It also identifies why NPV methods are particularly useful during the earliest stages of a project; the time during which the fundamentally important decisions tend to be made. However, the limitations of NPV methods should also be understood. They are best suited to projects whose merits can be judged in financial terms and, as with any modelling methodology, there are limits to the accuracy of their results. The chapter ends by identifying the implications of these limitations

Present Value Calculations – The Basis for Net Present Value Modelling

Let's consider the following two opportunities:

1. Opportunity 1 – invest £10m today: investment matures at £13m two years later.

2. Opportunity 2 – implement project at a cost of £10m spread over one year: realise benefit from the project of £12m spread over the following year.

Assuming there is an equivalent level of risk attached to each of these opportunities, which is the better of the two? Since both involve the same two-year time period, the intuitive answer is that Opportunity 1 is the better because it has a net value of £3m, whereas Opportunity 2 returns only £2m. However, this intuitive reasoning is incorrect because it does not take into account the fact that cash two years in the future is worth less than the same amount of cash today. To make a sound financial judgement we need to know how to discount the value of cash over time.

Tying up cash costs money. If an organisation borrows cash, it has to fund interest on the loan. If, instead, it raises money by selling equity, its shareholders will expect a return on their investment. Similarly if it has cash that it does not use, there is an equivalent opportunity cost. For example, the cash could be lent and money earned as interest on the loan or it could be used to fund other business opportunities. Given that tying up cash costs money, cash today is worth more than the same amount of cash in the future.

Today's value of an amount of cash is its present value. If we know the cost of tying up cash or delaying its receipt, we can calculate the present value of cash at different points in the future. The rate of cost can be expressed as a discount rate. For example, if the discount rate (D) is 10%, the annual cost of tying up £100 cash is £10. On this basis, we would need £100(1 + D) = £100(1 + 0.1) = £110 one year in the future to compensate for having £100 today. This is equivalent to calculating that the present value of £110 one year in the future would be £110/(1 + D) = £100. Thus, if an amount of value of cash in one year in the future is written as A_1 and its present value written as P_1, then $P_1 = A_1 / (1 + D)$. In general, since the associated costs accumulate at a compound rate, for a point in time that is n years in the future the present value P_n of an actual amount of cash A_n is calculated by the formula:

$$P_n = A_n / (1 + D)^n$$

The present value of future cash is thus driven by two factors: the discount rate and how far into the future the cash is being valued. Table 1.1 shows examples of the calculation of present values of £1 using two different discount rates at various numbers of years into the future. Figure 1.1 includes the points in Table 1.1 and shows the exponential curves produced by the two discount rates.

Table 1.1 Illustration of the effect of different discount rates

	Time differential forwards from today						
	0	+1 year	+2 years	+5 years	+10 years	+20 years	+30 years
Present Value of £1 for D=4%	£1	£0.9615	£0.9246	£0.8219	£0.6756	£0.4564	£0.3083
Present Value of £1 for D=10%	£1	£0.9091	£0.8264	£0.6209	£0.3855	£0.1486	£0.0573

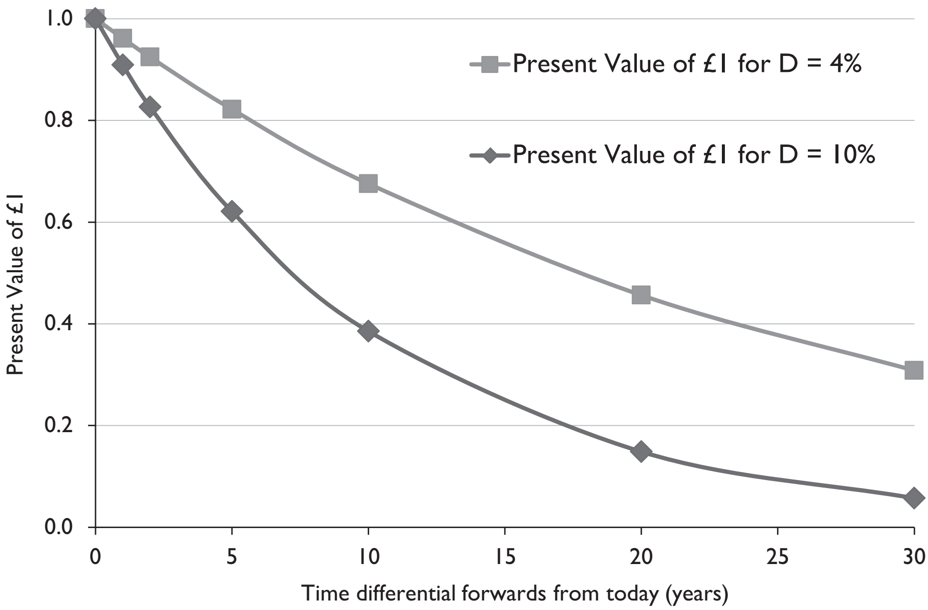

Figure 1.1 Illustration of the effect of different discount rates

The factor by which an amount of cash in the future should be discounted to calculate its present value is called the discount factor. If we assume that the correct discount rate for our two earlier opportunities is 10%, Table 1.1 shows that the discount factor for cash two years from now is 0.8264. We can use this factor to calculate the present value of Opportunity 1, which matures after two years, as follows:

- Present value of cash investment = Cost × discount factor for time now = £10m × 1 = £10m.
- Present value of cash on maturity = Cash on maturity × discount factor at two years = £13m × 0.8264 = £10.743m.

By subtracting the present value of the cash on investment from the present value of the cash on maturity we can calculate the net value of the opportunity in present value terms. This is called the Net Present Value (NPV). Thus:

- Opportunity 1 NPV = £10.743m – £10m = £0.743m.

We can now use the same principles to calculate the NPV for Opportunity 2. However, since this opportunity is a project, its costs and benefits are spread over periods of time. This requires an adjustment to the way in which discount factors are calculated. Since costs are spread over the first year it would be inappropriate to use discount factors such as those in Table 1.1 which correspond to year start and end dates. A better approach is to use the discount factor that corresponds to the mid-point of the year, since this more closely represents the average point in time over which costs would be incurred. The same approach can be used to calculate the discount factor for the value of the project's benefits, which are spread over the second year.

The present value discount factor for the mid-point of the first year (d_1) can be calculated by the formula:

$$d_1 = 1 / \sqrt{(1 + D)}$$

Subsequent mid-year discount rates can be calculated by successive divisions by (1 + D). Thus, when using an Excel spreadsheet, mid-year discount rates can be calculated in as illustrated in Figure 1.2.

	A	B	C	D	E	F
1	Discount Rate	10%	Year 1	Year 2	Year 3	Year 4
2	Mid-year discount factor		0.9535	0.8668	0.7880	0.7164
	Formulae for Row 2 cells		=1/SQRT(1+B1)	=C2/(1+$B1)	=D2/(1+$B1)	=E2/(1+$B1)

Figure 1.2 Calculation of mid-year present value discount factors in Excel[1]

We can now use the discount factors in Figure 1.2 to calculate the NPV for Opportunity 2 as follows:

- Present value of project cost = Cost × discount factor for mid-point of Year 1 = £10m × 0.9535 = £9.535m.

1 Although Excel includes its own NPV function, I would recommend the calculation of present value discount factors in a manner similar to that shown in Figure 1.2 as being the better alternative. One advantage is that the modeller can view the effect of discounting directly in the spreadsheet, whereas the Excel function provides a black box calculation. For example, a modeller may not realise that the Excel NPV formula discounts all values during a year on the basis on the year end discount factor. Microsoft's design and naming of the relevant formulae can also be confusing (Benninga, 2014).

- Present value of project benefits = Cash value of benefits × discount factor for mid-point of Year 2 = £12m × 0.8668 = £10,402m.

- Opportunity 2 NPV = £10.402m – £9.535m = £0.867m.

Since the Opportunity 1 NPV is only £0.743m, from a financial perspective, Opportunity 2 is the better of the two. This is the reverse of the conclusion that would have been reached with the intuitive use of undiscounted values. The reversal is due to the fact that whilst the investment opportunity's cost and benefit are separated by two years, the average points in time for the project cost and benefits are separated by only one year. Discounting therefore has a greater effect on the former calculation. An important lesson to emerge from this is that cash flow timings have a significant impact on NPV models.

However, Opportunity 1 was not inevitably inferior to Opportunity 2. Had a smaller discount rate been used the result could have been reversed. Both opportunities would also have had a higher NPV. As Figure 1.1 illustrates, selection of the discount rate can make a significant difference to present value calculations. Discount rate selection is discussed in more detail in Chapter 3.

Cash Flows vs Profit

NPV calculations are based on cash flows and discounting the value of cash flows over time. Cash flows are usually calculated over equal periods (typically years) of the project life, with benefits being modelled as positive contributions to the flow of cash whilst costs make a negative contribution. At first sight, a project manager might be forgiven for regarding net cash flow as being the equivalent of profit. However an accountant will readily explain that profit during a period takes into account other factors such as write-downs on the value of assets and decisions concerning the phasing of revenue; factors that do not involve the transfer of cash. As a result, it would be unusual for profit during each year of a project to match its cash flow, although the differences must balance over the long term.

Project managers tend to be familiar with forecasting cost and benefits in a manner suited to the cash flow approach. In many cases, the phasing of profit may be irrelevant to the decisions being supported by NPV modelling. However, if preparing a detailed NPV model, taxation-related cash flows may need to be accounted for, in which case the phasing of profit would be relevant. The worked example of an NPV model in Chapter 4 illustrates some of the issues involved.