What are we up to?

- Two sides of the coin
  - Engineering systems design
  - Management of risk and opportunity
- Take-aways:
  - Knowing how to value flexibility and know how to incorporate it into the design of technology systems
  - Appreciating the differences between real options and traditional financial options
  - Understanding organisational barriers to implementation
- Formal objectives
  - Understanding the options paradigm
  - Experience in valuing risky projects

Today’s agenda

- Theme: go/no go decisions for technology projects
- Making an economic case for a project
  - Break even analysis
  - Rate of return
  - Net present value
- A critique of traditional NPV
  - How does NPV cope with uncertainty?
  - How does NPV cope with flexibility?
- It’s not so simple…
Project valuation

- **Project valuation:** Making an economic case for a technology project
  - Convince the board that the company can do nothing better with the investment capital than investing it in the project
  - Compare project payoffs with alternative investment opportunities within the company and in the market place
  - Take existing portfolio of projects and long-term strategic considerations into account (alignment of project with existing strengths and strategic positioning of the company)
  - **Design optimisation:** adding design features to technology projects to make them economically more attractive

CFO’s point of view

- Finance department: A project consists of an initial investment followed by a stream of future cash flows
  - Invest in the project only if there is no “better” alternative investment opportunity
  - Two major problems:
    - Uncertainty: Cash flows of the project depend on external uncertainties
    - Flexibility: Cash flows depend on our (and our competitors’) management decisions during the life time of the project
  - How can we compare streams of uncertain payoffs which depend on future decisions (which in turn depend on uncertain events)?
  - Let’s first look at how projects are evaluated in practice...

Traditional tools for project valuation

- Break-even analysis
- Accounting rates of return
- Net present value

See Traditional Project Appraisal.xls
Break-even analysis

- Input:
  - Initial investment
  - Projected cash flows over a number of periods
- Break-even point:
  - Number of periods necessary for the sum of discounted cash flows to exceed the initial investment
- Making a case for the project:
  - Compare break-even point with company benchmark

Accounting rates of return

- Input:
  - Projected book value of investment over the life time of the project
  - Projected profits of the project over its lifetime
- Accounting rate of return:
  - average profit / average book value
- Making a case for the project:
  - Compare the ratio with company benchmark

Net present value

- Most popular valuation criterion
- Inputs:
  - Initial investment
  - Projected cash flows over the life time of the project
  - Discount rate
- NPV = Present value of cash flows minus initial investment
- Making a case for the project:
  - NPV > 0
- Let’s have a closer look at NPV
NPV: underlying alternative investment opportunities

- The NPV criterion is equivalent to comparing the project with a single alternative investment opportunity:
  - Suppose you can invest an arbitrary amount in a portfolio of investment opportunities with a guaranteed return of r% p.a.
  - How much do you need to invest now to be able to withdraw the project cash flows when they occur?
  - If the life time of the project is T periods with cash flows \( x_t \) for \( t = 1, \ldots, T \), then

\[
\begin{align*}
  y &= \sum_{t=1}^{T} \frac{x_t}{(1+r)^t} \quad \text{(discounting)} \\
  y &= \int_{0}^{T} x_t e^{-rt} \, dt \quad \text{(continuous discounting)}
\end{align*}
\]

- \( y \) is called the present value (PV) of the cash flow stream
- Economic case: Invest in the project if \( NPV > 0 \)

First problem with NPV: Which discount rate?

- Discount rate should reflect “opportunity cost of capital”
- Opportunities: Portfolios of alternative investments
  - Returns of portfolios
    - Are random
  - Depend on risk
  - Which portfolio?
    - Need for “optimal” portfolio
    - But: riskier portfolios are likely to have larger returns
- Portfolio management:
  - Return depends on management (“re-balancing”) of portfolio
- Theoretical questions addressed by Capital Asset Pricing Model (CAPM) under certain assumptions
  - see e.g. Bréleau and Myers, Principles of Corporate Finance or Luenberger, Investment Science

Risk premium

- Approach: Discount rate = risk free rate + risk premium
- Should the risk premium be constant over time?
  - Assumes risk to be “constant” over time
- Technology projects:
  - Most risks get resolved very quickly (technological risk, demand for new product, regulatory uncertainty, etc.)
Practical approaches to discount rates

- Managerial praxis I: “Use company-internal ‘hurdle’ rate”
- Technology projects have often long time horizons
  - Sensitive dependence on discount rate
  - £1 at 10% over a period of 20 years is worth >£7
  - £1 at 5% over a period of 20 years is worth <£3
- Managerial praxis II: Find portfolio with the same risk profile as the new project and maximal expected return and use this maximal expected return as benchmark discount rate
  - Technology projects: “Which project portfolios have similar risk profile?”
  - Plan of averages
- Lesson 1: It is not clear which discount rate should be chosen in practice?

Second problem with NPV: The forecast is always wrong

- Let’s have a look at a spreadsheet example (open NPV.xls worksheet Project Plan)
- Cash flow calculated on the basis of forecasted demand
  - Demand in period t is uncertain and depends on endogenous (price) and exogenous (economy, fashion, competitors) variables
  - Unknown demands in periods 1,…,t-1 may help us to predict demand in period t more accurately (statistical dependence)
- Lesson 2: “NPV is a function of uncertain quantities and therefore itself uncertain”

Let’s formalize this...

- Mathematically: NPV depends on uncertain quantities $X_1$,…,$X_n$ (random variables):
  $$NPV = NPV(X_1, …, X_n)$$
- A function of a random variable is itself a random variable
  - A single number (even the mean) is very limited information about a random variable
  - Can make a better economic case from knowledge of the NPV distribution
- If we can’t get the distribution then we want at least some of its characteristics:
  - expected NPV
  - variance of NPV
  - 95% confidence interval for NPV
The “flaw of averages”

- In practice, decisions are often made on the basis of expected NPV alone.
- Assumes that variability (i.e., risk) is captured in discount rate.
- Naive approach: Let’s work with expected demands.
  - Let’s assume marketing department has given us a price of £1000 and expected demands for that price.
- Is the NPV then the “expected NPV”?
  - Let’s look at an example (NPV.xls).
- Lesson 3: The “flaw of the averages”: Plugging expected values into uncertain cells in a spreadsheet does not give expected values of the formula cells.
- Mathematically: 
  \[ E(f(X)) \neq f(EX) \]

The flaw of averages and discount rates

- Recall practical advice: “Take as discount rate the average return of the best portfolio with the same risk level as the new project.”
- However: NPV depends non-linearly on the discount rate (flaw of the averages).
  - Way out: simulate, using historic period returns instead of averages.
  - Jensen’s Inequality: the NPV calculation on the basis of average rate of return is lower than the expected NPV based on historic returns.
- See Flaw of the averages for discount rates.xls.
- But: Returns of new project and benchmark portfolio are correlated.
- What’s right?
Third problem with NPV: No managerial activity

- NPV assumes that the cash flows of the project are fixed
- Even if cash flows are random and simulation is used to evaluate expected NPV, there is no managerial flexibility in the model
- Typically, management acts depending on unfolding uncertainties
- Typical actions
  - Postpone projects
  - Grow project
  - Increase marketing efforts
  - Abandon project
- Let’s look at an example (see NPV.xls, worksheet expansion option)

Summary

- “Company should invest in a project if there are no better investment alternatives”
- NPV-criterion has severe drawbacks:
  - NPV criterion is based on FIXED cash flow projections and does not take managerial flexibility into account (this undervalues the project)
  - Uncertainty is often not taken into account properly in practice (flaw of averages)
  - What should the discount rate be?

Back to the basics

To make an economic case for a new project we need to argue that adding the new project to the existing project portfolio (and therefore abandoning or down-sizing other projects) increases the “desirability” of the stream of future cash flows
The courtroom paradigm

- Innocence hypothesis: The project does not add value to the portfolio
- Jury: The decision maker
- Prosecutor (Engineer): "I want the project in the portfolio"
  - Constructs a case that the project adds value to the company’s portfolio
  - In particular: needs to argue how the portfolio re-balancing should be done (i.e. where the money should come from)
- Defence lawyer (CFO): "I don’t want the project in the portfolio"
  - Need to reply to the prosecutors case by constructing alternatives investment portfolios that do not include the new project and arguing that these are more beneficial to the company than investing in the project
- Question: Why don’t we use as innocence hypothesis that the project adds value to the portfolio?

Using a computer...

- Prosecutor: Build a stochastic (scenario-based) computer model of the project, including decision points and decision rules (plans of action for all possible scenarios)
- Defence lawyer: Build a stochastic model of a sensible alternative investment strategy (using projects or assets from within the company or in the market place), including possible decision points and decision rules
- Jury: Decide whether there is a case for the project on the basis of the (random) difference between the cash flow streams of the project and the alternative investment strategy
  - Can use simulation to estimate the distribution of the difference between the cash flow streams of the two investments for given decision rules
  - Jury also will take strategic issues into account

Simulation Results
What’s the problem with this approach?

- Meaning of “optimal” decision rule is not clear
  - What is optimal for cash flow in period 1 may be bad for cash flow in other periods
  - What is optimal in one scenario may be bad in another
- Approach allows us to compare investments with regard to risk but not with regard to flexibility
  - Alternative investment is often more flexible – e.g., investments in stock portfolio vs. investing in a new aircraft project
- Model is complex
  - But there may be no simple solutions to a complex problem
  - If we could only do something that was similar to the above but simpler...
- Research: Suggest rules of thumb to practitioners which are conceptually sound but have simple intuitive interpretation
  - Academics adds to practitioners confidence that they are doing the right thing by following their intuition

Conclusion

- NPV criterion has serious pitfalls
- The courtroom is a sensible model for project appraisal
- Complexity of cases for or against a project is a serious hurdle to acceptance in practice
  - But then again: there may not be a simple solution to this complex problem
- More questions than answers...

Appendix: Returns of portfolios

- A portfolio is an investment of £ $w_i$ in investment opportunity $i = 1, \ldots, n$
- The return of the portfolio
  \[ r(w) = r(w_1, \ldots, w_n) = w_{i_1} + \ldots + w_{i_n} \]
  is approximately normal if $n$ is large (central limit theorem)
- The expected return is
  \[ E(r(w)) = E(w_{i_1} + \ldots + w_{i_n}) = w_i E(r_i) + \ldots + w_n E(r_n) \]
- The variance of returns is
  \[ \sigma^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} \]

\[ \text{Invariance of limit} \]

\[ \text{Invariance under substitution} \]