Life Cycle Costing for Building Services

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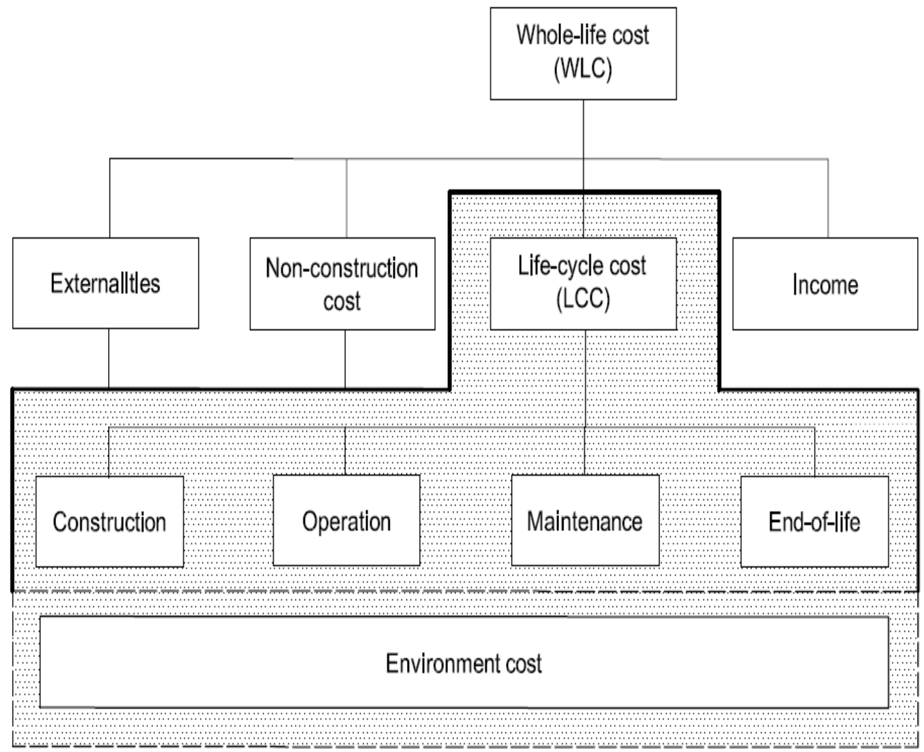
Why Life Cycle Costing?

- Increased emphasis on sustainability and energy efficiency
- Investing in systems that save energy generally must be justified or at least quantified in a financial manifestation

LCC or WLC?

- Life Cycle Costing versus Whole Life Costing
- These two terms are not mutually exclusive nor are they necessarily synonyms
- The terms are often used interchangeably however
- In the UK, WLC is most common but it is used in a context in line with the LCC definition



BS ISO 15686-5 definition from Figure 2

For the Record

- Life Cycle Assessment (LCA) – “the method of measuring and evaluating the environmental impacts associated with a product, system or activity, by describing and assessing the energy and materials used and released to the environment over the life cycle”
- Therefore LCA is not considered further in this presentation

Life Cycle Cost Types for Building Services

- Capital Costs
- Operational & Maintenance Costs
- End-of-life Costs and Residual Value

Initial, Construction or Capital Costs

- For building services the capital cost for LCC should include both the equipment procurement cost and the installation cost (installed cost figure)
- Early stage work can use rules of thumb (e.g. £5,000/kWp for PV installed cost), but detailed design stages should use actual quotes from contractors/suppliers
- Widely considered the most certain cost items of the life cycle as these costs occur in the present or near-present

Operational & Maintenance Costs

- Energy Costs
- Maintenance Costs
  - Preventative
  - Corrective
  - Deferred
  - Cleaning
- These costs are relatively uncertain by nature
- Energy costs are considered more volatile than Maintenance costs which tend to track inflation

End-of-Life Costs and Residual Values

- Residual values of building services (e.g. an old boiler) are mainly valued for scrap when replacement time arrives
- Removing old services equipment requires labour and thus a disposal cost
- Environmental concerns with old equipment such as asbestos containing materials, can add to disposal costs at end-of-life
- Disposal costs are also typically included in the capital cost of undertaking equipment replacement or refurbishment, thus for most building services projects disposal costs are assumed to counteract any salvage costs leading one to ignore both in a comparative analysis. This is not always the case, but is a sound assumption for most small and medium building size applications

Client Should Agree Scope & Objectives of LCC

- There are different ways of using and conducting LCC
  - Client has fixed budget and they want to spend all of it on positive NPV projects ranked in order of financial benefit
  - Simple comparative analysis between two projects where only one gets chosen based on financial merit
  - Client may simply want to see that a higher capital cost is worth the added investment in order to produce energy cost savings

Service Life of Plant & Equipment

- Choosing a realistic service life period for equipment is very important to ensure accurate valuation
- When comparing plant options with different service lives, this variable becomes even more important and mid-study plant replacement costs should be considered
- A good source for service life expectancies is CIBSE Guide M – Maintenance Engineering & Management Appendix 13.A1

Time Value of Money

- The value of money fluctuates with time
- Central banks like the Bank of England and the US Federal Reserve Bank tend to encourage moderate inflation in the 2-3% range YOY.
- Recommend an inflation rate assumption of 3% YOY

How Does LCC Account for Inflation?

- Inflation is typically embedded in operational and maintenance cost figures and the discount rate
- Maintenance costs tend to track general inflation
- Energy cost fluctuations are more volatile than general inflation
- LCC is typically presented in real cost figures to avoid over-complication (this method is also required for public sector projects)

Selecting a Discount Rate

- Represents the opportunity cost of capital over time
  - Similar investments could be discounted at the firms hurdle rate (or weighted average cost of capital, WACC)
  - Could be the yield on an interest bearing account or sinking fund
  - Yield on government bonds (so called risk free rate of return)
  - Average returns from previous similar projects
- Real versus Nominal discount rate
  - Nominal rate includes inflation
  - Real rate excludes inflation (e.g. The nominal discount rate for an investment is 7%, general inflation is assumed at 3%, thus the real discount rate is 4%)

Selecting a Discount Rate

- Opportunity cost ultimately depends on the condition of the client's firm at any given time and the macro economic environment, for instance what rates the central banks are offering (e.g. LIBOR & Fed funds rate)
- The economic environment in most of the world in the last decade has been one of "cheap" money meaning interest rates have been low, this encourages borrowing and discourages saving

Selecting a Discount Rate

- A firm’s “hurdle rate” is typically their WACC
  - If a company’s financial structure is 60% equity/40% debt, the expected return on equity by investors is 8% and the corporate bonds were issued at 5%, then the WACC is 6.8% (0.08*0.6 + 0.05*0.4), thus a company’s operational projects should meet or exceed this return figure in order to meet stakeholder obligations (this figure is a nominal interest rate and thus still includes inflation)
- A firm’s hurdle rate can also be different for different asset classes
  - For instance plant replacement could be considered essential for operations with funding out of general operating budgets or sinking funds, thus the opportunity cost could be lower than the firm’s WACC (for instance a bank or bond interest rate)

Selecting a Discount Rate

- There is no consensus on discount rate selection, it is a matter of personal preference and client methodology
- There is a standard figure for public sector projects in the UK however which is also a good default figure for the private sector. This figure is provided by HM Treasury Greenbook and is 3.5% for projects 0-30 years in duration (typically adequate for building services)
- The rate of 3.5% is a *real* discount rate and thus does not include inflation (or has inflation already removed)

HM TREASURY

Selecting a Discount Rate

- The US Government also requires a particular discount rate to be used for public building projects, this rate changes annually
- The *real* discount rate for 2010 is 3.0%
- This rate is dictated by 10 CFR 436 which states that the rate is derived from a 12 month moving average for all US Treasury bonds over 10 years in duration with a ceiling of 10% and a floor of 3% (current moving average for the last 3 years is actually only 0.9% as a result of Fed ZIRP)
- Annual inflation rates are determined by the President’s Council of Economic Advisors

Energy Prices

- Energy prices are more volatile than general inflation and, on average, escalate at a higher rate
- Energy prices depend on many complex factors
  - Political stability in fossil fuel producing countries and distribution networks (e.g. pipelines and ship tankers)
  - Rate of discovery of new raw sources, extraction, refinement and distribution
  - Demand from various industries and countries
  - The possibility of “peak oil”; the depletion of fossil fuel resources
  - Monetary influences (e.g. “quantitative easing” and currency devaluation)

Energy Prices

- For public projects in the US, the Department of Energy – Energy Information Administration (DOE-EIA) recommends energy escalation rates for projects based on region in the US on an annual basis for LCC
- Escalation rates are provided for:
  - Electricity
  - Oil
  - LPG
  - Natural Gas
  - Coal

Energy Prices

- Energy price trends in the UK are now handled by the Department for Energy and Climate Change (DECC)
- Once again, energy price escalation rates for LCC are a matter of personal or client preference
- While historical price trends are important, many difficult to predict factors go into estimating future energy prices which is essentially what is being attempted with LCC
- Energy market watchers can spend their entire careers analysing and predicting future energy prices
- Building industry professionals should therefore go with average views and trends
- For building services applications I recommend an energy price escalation figure of 3% annually (this is an escalation rate over-and-above general inflation)

DEPARTMENT OF ENERGY & CLIMATE CHANGE

Tracking Fossil Fuel Market Prices

- Crude Oil (futures markets)
  - US – West Texas Intermediate: Cushing, Oklahoma (New York Mercantile Exchange or NYMEX)
  - UK/Europe – Brent Index: North Sea (Intercontinental Exchange or ICE)
- Natural Gas
  - US – Henry Hub: Intersection of 13 gas pipelines in Erath, Louisiana (NYMEX)
  - UK – National Balancing Point (NBP): Virtual trading location, unlike Henry Hub (ICE)

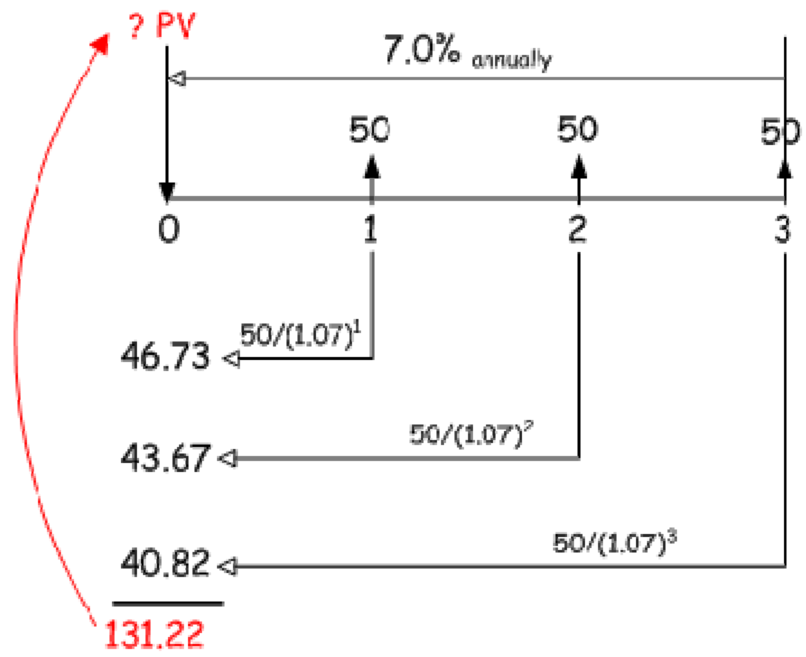
Water Prices

- Water prices in the UK are set by industry regulator Ofwat
- Water price changes are somewhere between general inflation and energy costs in volatility
- Average *real* year-over-year increases in water costs (in the UK generally) over the last two decades come to about 2%

O F W A T

Conducting LCC Analysis

- With so many figures floating around at different points in time it can help to produce a Cash Flow Diagram to visualise the problem



Discounting Cash Flows

- Discounting a single cash flow to present value

$$PV = \frac{C_N}{(1+i)^N} \qquad PV = \frac{£1{,}000}{(1+0.035)^{10}} = £708.92$$

PV = Present value
C_N = Cash flow at year N
N = Year of cash flow
i = Interest rate (discount rate)

Example:
C_{10} = £1,000
i = 3.5%
N = 10 years

- Single Present Value (SPV) Factor

$$PV = C_N \times \left[\frac{1}{(1+i)^N}\right] = C_N \times SPV$$

Discounting Cash Flows

- Annually Recurring Costs (Annuity)
- Uniform Present Value Factor (UPV)

$$PV = A \times \left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] = A \times UPV$$

PV = Present value
A = Annual recurring cash flow
N = Number of years
i = Interest rate (discount rate)

Example:
A = £1,000
i = 3.5%
N = 10 years

$$PV = £1{,}000 \times \left[\frac{(1+0.035)^{10} - 1}{0.035(1+0.035)^{10}}\right] = £1{,}000 \times 8.3166 = £8{,}316.61$$

Discounting Cash Flows

- Annually Recurring Cost with Escalation Rate (e.g. Energy Usage)
- Modified Uniform Present Value Factor (UPV*)

$$PV = A \times \left(\frac{1+e}{i-e}\right) \times \left[1 - \left(\frac{1+e}{1+i}\right)^N\right] = A \times UPV^*$$

PV = Present value
A = Annual recurring cash flow
N = Year of cash flow
i = Interest rate (discount rate)
e = Escalation rate

Example:
A = £1,000
i = 3.5%
N = 10 years
e = 3%

$$PV = £1{,}000 \times \left(\frac{1+0.03}{0.035-0.03}\right) \times \left[1 - \left(\frac{1+0.03}{1+0.035}\right)^{10}\right] = £1{,}000 \times 9.7381$$

$$= £9{,}738.11$$

Analysing LCC Results

- Form of results
  - Net present value (NPV)
  - Internal rate of return (IRR)
  - Simple pay back period (PBP)
  - Discounted PBP
  - Net Savings (NS)
  - Saving to investment ratio (SIR)
  - Adjusted internal rate of return (AIRR)

- The form of results is typically dictated by the client, certain types have advantages & disadvantages

Net Present Value

- The sum of the present values of the individual cash flows in a given project (discounted cash flows)
- Projects with a positive NPV create value (are profitable)
- NPV is scalable

$$NPV = \sum_{N=0} \frac{C_N}{(1+i)^N}$$

NPV = Net present value
C_N = Cash flow at year N
N = Year of cash flow
i = Interest rate (discount rate)

Example:
C_0 = £1,000 (cost)
$C_1 = C_2$ = £500 (savings)
i = 3.5%

$$NPV = \frac{-£1{,}000}{(1+0.035)^0} + \frac{£500}{(1+0.035)^1} + \frac{£500}{(1+0.035)^2}$$
$$= -£1{,}000 + 483.09 + 466.76 = -£50.15$$

Internal Rate of Return

- IRR defines the discount rate that produces a NPV of zero (or the rate at which the costs equal the benefits of the investment)
- The resulting IRR of an investment should then be compared to the company's *hurdle rate* or WACC
- If the IRR > WACC, then the project adds value
- If the IRR < WACC, then the project decreases value
- IRR should be used with caution because it is possible for an capital project to have more than one rate of return that results in a NPV = 0, this can occur in building services projects when plant replacements result in negative cash flows in future years
- IRR must be calculated by iteration, therefore computers are best suited for IRR calculations

$$NPV = \sum_{N=0} \frac{C_N}{(1+i)^N} = 0$$

NPV = Net present value
C_N = Cash flow at year N
N = Year of cash flow
i = Interest rate (IRR)

Simple Payback Period

- Used for "simple" LCC, essentially ignoring discount, inflation and escalation rates (not approved for public sector projects)

PBP = Simple payback period
C_N = Annual cash flow at year N (constant)
C_0 = Initial investment

Example:
C_0 = £100,000 (cost)
C_N = £18,000 (savings)

$$PBP = \frac{C_0}{C_N} = \frac{£100{,}000}{£18{,}000} = 5.56\ years$$

Discounted Payback Period

- A bit trickier to calculate than simple PBP
- One must sum the cumulative annual cash flows until the initial cost is exceeded, within that year that exceeds the initial cost the fraction of that year must be interpolated

Net Savings

- NS is a comparative assessment tool
- One compares the value of an alternative investment in relation to a base case
- It is scalable like NPV and indeed is simply a comparative variation on NPV

$$NS_{A-BC} = \sum_{N=0} \frac{A_N}{(1+i)^N} - \sum_{N=0} \frac{BC_N}{(1+i)^N}$$

$NS_{A\text{-}BC}$ = Net Savings of Alternative A over Base Case
A_N = Alt A cash flow at year N
C_N = Base case cash flow at year N
N = Year of cash flow
i = Interest rate (discount rate)

Example:
NPV_A = £134,000
NPV_{BC} = £76,000

$$NS_{A-BC} = £134{,}000 - £76{,}000 = £58{,}000$$

Savings to Investment Ratio

- Essentially the same as a Benefit to Cost Ratio except SIR is typically used when savings occur from reductions in operating costs
- SIR is also a relative method for comparison of investment alternatives versus a base case
- Note: the same base case, discount rate and study period must be used for all alternatives to have an apples-to-apples comparison
- An alternative is cost effective if the SIR > 1.0, this is equivalent to a NS > 0
- It is possible to get an alternative (A) with a higher SIR than alternative (B), yet B's NPV is lower than A's
- SIR should be used for evaluating single or multiple (ranking) project alternatives against a base case; therefore do not use SIR for evaluating mutually exclusive project alternatives

Savings to Investment Ratio

$$SIR_{A-BC} = \frac{\sum_{N-0} A_N/(1+i)^N}{\sum_{N=0} BC_N/(1+i)^N}$$

$SIR_{A\text{-}BC}$ = Savings to Investment Ratio between Alt A & Base Case
A_N = Alt A cash flow at year N
BC_N = Base case cash flow at year N
i = Interest rate (discount rate)

Example:
NPV_A = NPV of Alt A = £150,000
NPV_{BC} = NPV of BC = £100,000

$$SIR_{A-BC} = \frac{NPV_A}{NPV_{BC}} = \frac{£150{,}000}{£100{,}000} = 1.5$$

Adjusted Internal Rate of Return

- AIRR is a relative cost measure and therefore must be used in comparison with a base case
- Like IRR, AIRR is compared to a company's *hurdle rate* for viability
- It is possible to get an alternative (A) with a higher AIRR than alternative (B), yet B's NPV is lower than A's
- AIRR should be used for evaluating single or multiple (ranking) project alternatives against a base case; therefore do not use AIRR for evaluating mutually exclusive project alternatives
- AIRR, in comparison to IRR, assumes that any savings generated by an alternative over a base line can be reinvested at the discount rate for the remainder of the study period
- The formula for AIRR includes the SIR value

Adjusted Internal Rate of Return

$$AIRR = (1 + i) * (SIR)^{\frac{1}{N}} - 1$$

AIRR = Adjusted Internal Rate of Return
SIR = Savings to Investment Ratio
N = Number of years
i = Interest rate (discount rate)

Example:
SIR = 5
i = 3.5%
N = 20 years

$$AIRR = (1 + 0.035) * (5)^{\frac{1}{20}} - 1 = 12.17\%$$

Risk and Uncertainty in LCC

- Predicting the future is inherently uncertain, therefore assumed values for inputs into LCC models should be carefully considered
- Uncertainty Analysis Types
  - Deterministic
    - Sensitivity Analysis
  - Probabilistic
    - Decision Trees
    - Probability Distribution
    - Cumulative Distribution Functions
    - Monte Carlo Simulation

Risk Attitude

- Let’s say I would flip a coin with someone to see if they would win £1,000...
- Before I flip the coin, how much money would I have to offer in assured cash in order for you to forgo the coin toss?
- The answer is a reflection of your risk attitude

Sensitivity Analysis

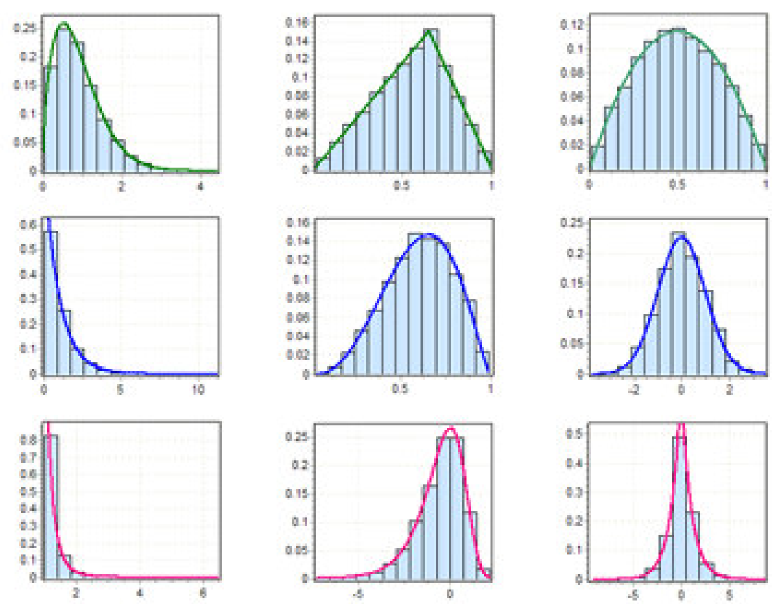
- The method consists of changing input variables by predicted magnitudes and recording the changes in model outputs
- When only one variable changes at a time, the output changes linearly
- So only two points are generally needed on either side of the expected value (usually in % terms for comparison with other variables)
- If multiple input variables are analysed, one can determine which input variables affect the outcome to a larger degree (the variable with the larger slope, unless plotted horizontally)
- Knowing the sensitivity of the model to various inputs can better inform decision makers and help determine if more accurate input information is needed
- Graphical representations such as Spider Charts and Tornado Charts help demonstrate the sensitivity of input variables

Decision Trees

- A decision tree is a decision support tool maps decisions and their consequences and associated probabilities
- Organisation:
  - Decision Nodes – represented by a square
  - Chance Nodes – represented by a circle
  - End Nodes – represented by triangles
- Decision trees are risk neutral unless utility functions are used

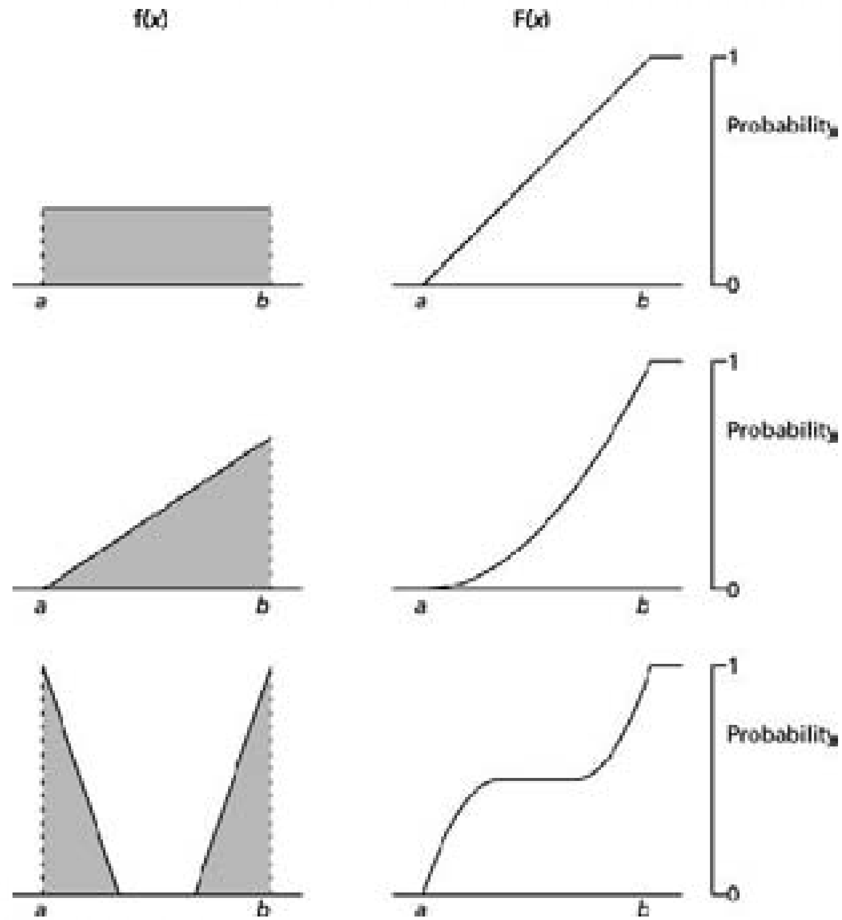
Probability Distribution

- Input variables and output results can have a wide variety of probability distributions within the same investment analysis



Cumulative Distribution Functions

- Probability distributions can also be plot another way



Monte Carlo Simulation

- Detailed simulation of a quantitative model is now generally referred to ask Monte Carlo Simulation or Monte Carlo Methods
- History lesson: The name “Monte Carlo” comes from one of the first scientists to use the method, Stanislaw Ulam, who was working on the Manhatten Project in the 1930s-40s. They needed a code name for the method due to the secretive nature of the project so he appropriately named it after the casino that his uncle frequented
- The computational method relies on repeated sampling from a number of input variables in order to inform the probabilities of various outcomes
- Monte Carlo Simulation is most useful in models where input variables involve many uncertainties and probability distributions

Monte Carlo Simulation

- Software Packages for Monte Carlo
  - @Risk (Palisade Corporation)
  - Crystal Ball (Oracle)
  - Risk Analyzer Excel Add-in
  - Monte Carlito Excel Add-in

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