Engineering Economics: Discounted Cash Flow (DCF)

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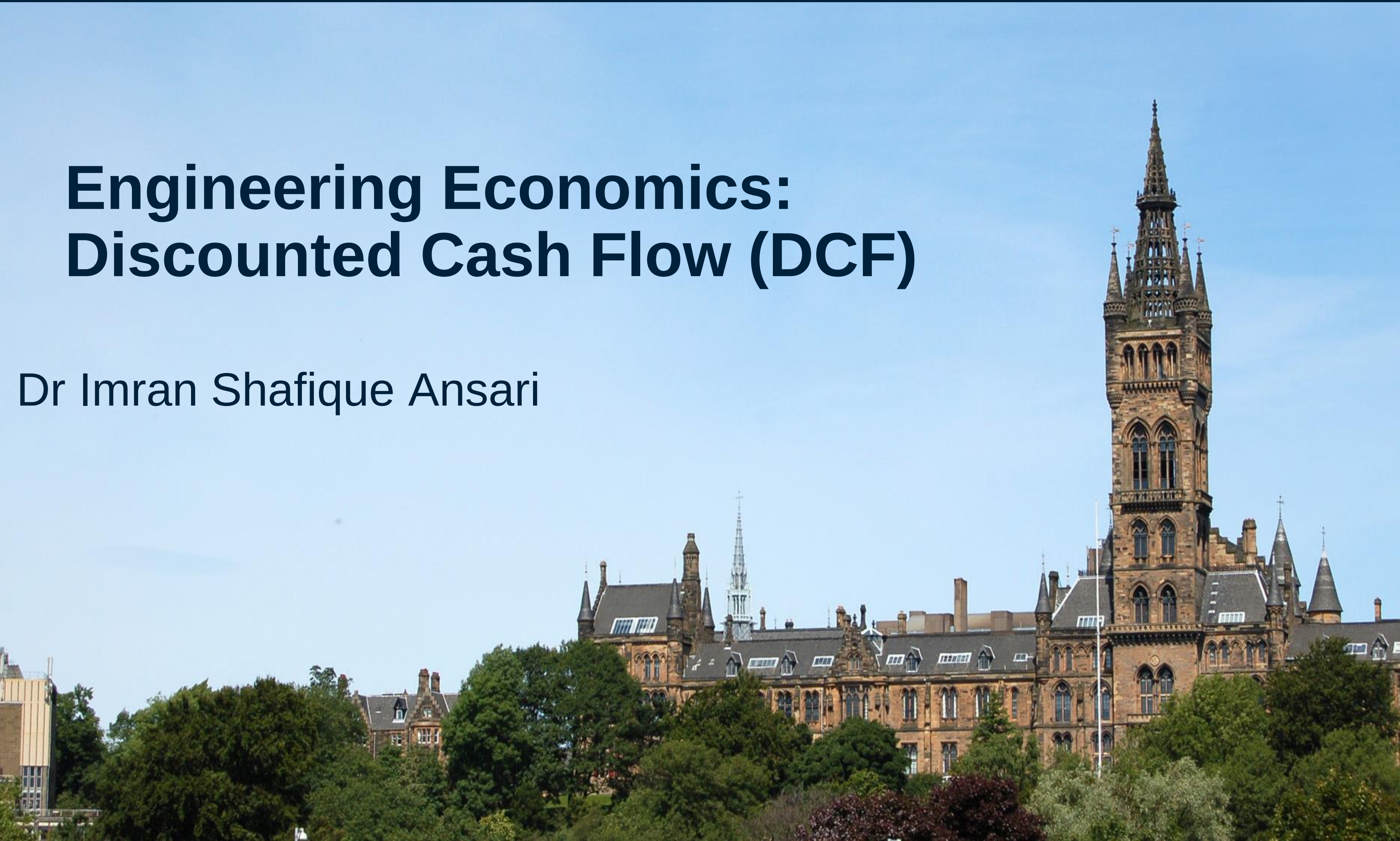

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"I'm an engineer – get me out of here!"

Why bother with project finances?

Engineering show-stopper …

- Nothing kills a smart technological idea more rapidly than poor project financial predictions
- “Poor” does not only mean unfavourable – it can also include destructive misrepresentation of a project that should in fact be favourable
- Tedious as it might seem, then, for us to ply our engineering trade unhindered, we need to face up to the need to concern ourselves with the financial case for proceeding (or not) with a given project
- All engineers should be able to do this sort of analysis, at least to a basic level

Price and Cost

- These two terms are used interchangeably in everyday life
- In project finance, however, a useful distinction can be usefully drawn between them:
  - The **cost** is the amount of money required to produce something (be this a physical entity or a service)
  - The **price** is the amount of money you are able to recover in exchange for that same thing
- Thus, in round terms:

Price = Cost + Profit

*(Albeit 'profit' needs to be used with care, e.g. is it **pre-tax** profit that is indicated?)*

If you remember <u>NOTHING</u> else from this course; 'REMEMBER THIS!!'

The Time value of Money…

- Economists, generally accept that £1 (or $ or RMB) today **<u>is more valuable</u>** to me than the promise of £1 (or $ or RMB) in a month /year /decade's time
- In part, this proposition can be explained by the macro-economic phenomena of inflation (i.e. the gradual increase in the cost of goods) and currency depreciation
- However social psychology research has demonstrated that, even in economies with stable, low-inflation economies, people still tend to instinctively accord more value what they have now as opposed to what they might reasonably expect to have at some future date
- This attitude is the founding principle of '**discounting**'

Discounting

- If we accept that £100 today is worth more than £100 will really be worth in ten years' time, then **we have accepted** the fundamental idea of "discounting"
- Discounting may be defined as the process of determining the present value of a payment or a stream of payments that is to be received in the future
- Discounting is the **reciprocal** of compound interest:
  - e.g. let's say I invest £100 today in a savings account with a 5% annual return. In one year, the amount in the bank will be £105. If I leave it in the bank and the same interest rate applies for the following nine years, after ten years the amount in the account will be £163.89.
  - In discounting terms, this means that the **present value** of £163.89 that **we might** possess ten years in the future is currently £100

Discounted Cash Flow Analysis

Using the concept of discounting, a series of bills that will have to be paid in future, over the life of a project, can be reduced to their equivalent present values by means of **discounted cash flow analysis**

Let's say we have a project that requires a bill of £100 to paid immediately, a bill of £105 to be paid in one years' time, and a bill of £163.89 to be paid in ten years' time. We have already seen that, in a world with a 5% inflation rate, these three quantities all have a present value of £100.

Hence if we add these together, the **present value (PV)** of the entire project is simply **-**£300. (Contrast this with the simple sum of the three figures, which would be **-**£368.89)

Opportunity cost

- If a project is proposed that yields a higher PV (i.e. a higher yield on investment) than could be achieved by investing in some alternative project (or just putting the money in a bank savings account) then that project is most likely to be favoured by investors
- In financial jargon, the '**opportunity cost**' of an investment is the value of the next best option – the greater the margin of your project above the 'opportunity cost' then the greater the ease with which it will attract investors
- While it is possible to find people willing to settle for less than the opportunity cost on altruistic grounds (such as saving the environment), there are usually limits to the benevolence of even the most starry-eyed investor

Discounting rate

- Discounted cash flow analysis is carried out using assumed interest rates (which may be allowed to vary for future years, albeit this **complicates** the calculations considerably)

China = ~2.7% p.a. (May 2018)

- These interest rates are rarely the same as the base lending rate (BLR) established by, for instance, a national central bank, because:
    - Most investors want to see a better return than they could get from a savings account that only offered the BLR – otherwise, why put in the extra effort and run the additional risk?

Some Test Examples

1. **If you <u>deposit</u> 1000RMB in the Bank of China with a guaranteed interest rate of 2.5% p.a, how much would you have after 1 year, 10 years?** [1025.0 RMB, 1280.1RMB]

2. **If you were to <u>borrow</u> 250 000 RMB from the Bank of China at a rate of 3.0% pa to pay for your studies, how much would you have to repay when you graduate?** [281 377 RMB]

3. **If you are designing a new product that will take you 3 years to design and build. How much <u>should you quote</u> to your customer (for delivery in 3 years time) if you want to cover your expenses <u>and</u> make 100 000 RMB (today equivalent) profit? Your expenses are 1 000 000 RMB per year and will all increase by inflation of 5% ?**
[(1 000 000*{$(1.05)^1 + (1.05)^2 + (1.05)^3$} + $(1.05)^3$ * 100 000= 3 425 860 RMB]

Project lifetime

- Before we can do a DCF analysis, we need to decide **how far into the future** the analysis of capex, opex and revenues will be taken

- This might be the period of time you think you will be able to sell a product for:-
  - Mobile phone: 9 -12 months
  - Television: 2 years
  - Car: 5 years
  - Power station: 50 years

Present Value – simple case

- Building on our earlier discussion, we can define a simple formula to calculate the present value of a single cost incurred at some point in the future. The thinking goes as follows:
  - If a discount rate of 5% applies, then the value of £100 in 1 year's time is, as we have seen

i.e. a £100 cost today is equivalent to a £105 cost in 1 years time

$$£100 \times (1 + 0.05) = £105$$

In two years' time it would be:

$$£100 \times (1 + 0.05) \times (1 + 0.05) = £110.25$$

We can generalise this for *n* years' time as:

$$£100 \times (1 + 0.05)^n$$

Turning this analysis around, to calculate the present value (V_p) of a single payment (V_n) at ***n* years** in the future, assuming an **interest rate of *r***, we simply calculate:

$$V_p = \frac{V_n}{(1 + r)^n}$$

i.e. 'the equivalent today cost' of a future cost in 'n' years time.

Present Value calculation

- The previous equation only gives the present value of a **<u>single sum</u>** of money spent at some point *n* years in the future.
- In most engineering projects, life is rather more complicated, and we are faced with multiple costs, which vary from year to year. In this case we obtain the Present Value (PV) by summing the individual present values thus:

$$\boldsymbol{NV} = \frac{V}{(1+r)^1} + \frac{V}{(1+r)^2} + \frac{V}{(1+r)^3} + \ldots + \frac{V}{(1+r)^n}$$

- which we can simplify to:

$$\boldsymbol{NV} = \sum_{i=1}^{n} \frac{V_i}{(1+r)^i}$$

NPV of the project as a whole

- So far we have considered only PV of **costs** (PV_c), but similarly we can calculate a PV of **benefits** (PV_b) such as revenues
- To get the **Net PV** of the project as a whole, we **subtract** PV_c from PV_b i.e. $\mathbf{NPV = PV_b - PV_c}$
- There are alternative methods of considering projects; we can calculate the **Benefit / Cost Ratio** (**B/C**)

  ($B/C = NPV_b / NPV_c$)

  - Values of $B/C > 1$ indicate a project worth considering, and the more it exceeds 1 the better
  - If $B/C < 1$, the project is uneconomic

Internal Rate of Return (IRR)

- Another method of comparing projects is calculating the Internal Rate of Return (IRR) for a project.

- Instead of calculating the Net Present Value of a project for a given (assumed) interest rate, they calculate the %age interest needed to apply to exactly make NPV = 0

- The Internal Rate of Return (IRR, expressed as a percentage) is the discounting rate at which the overall project NPV (i.e. $NPV_b - NPV_c$) equals zero, i.e. it is the value of ***r*** which ensures that the following equation exactly balances:

$$V = \sum_{i=1}^{n} \frac{V}{(1+r)^i} = 0$$

Diagrams for Engineering Economics

Cash Flow Diagrams

Equivalent Issues

Engineering Decision

Cash Flow- expenses and receipts

Engineering projects generally have economic consequences that occur over an extended period of time

For example, if an expensive piece of machinery is installed in a plant were brought on credit, the simple process of paying for it may take several years

Each project is described as cash receipts or expenses at different points in time

Typical Cash flows for Engineering projects

The expenses and receipts due to engineering projects usually fall into one of the following categories:

1. Initial Expense to build or to buy and install **cost**
2. Operations and maintenance (O&M): annual expense, such as electricity, labor, and minor repairs **cost**
3. Salvage value: receipt at project termination for sale or transfer of the equipment (can be a salvage cost) **cost**
4. Overhaul: major capital expenditure that occurs during the asset's life **cost**

Balanced against:-

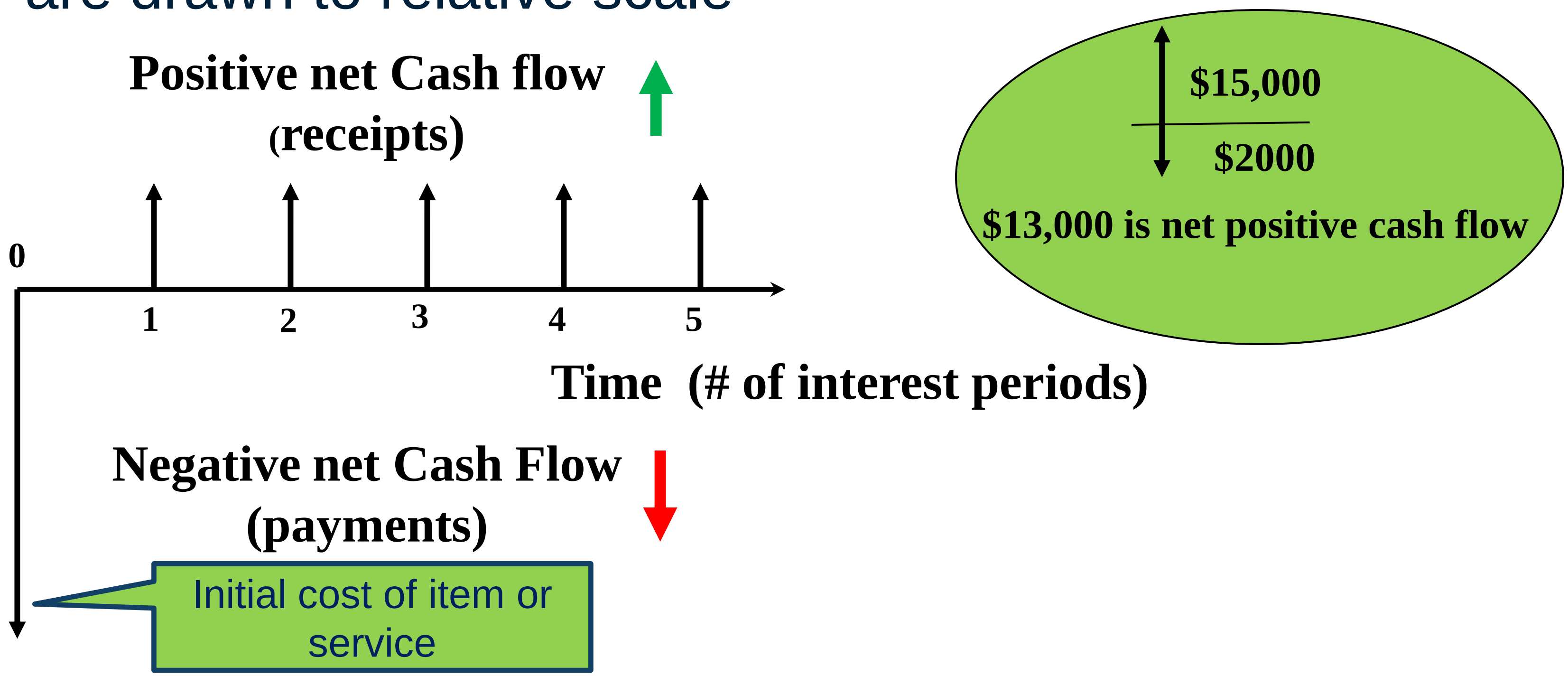
Revenues: annual receipts from the sale of products or services **income**

Cash Flow Diagrams

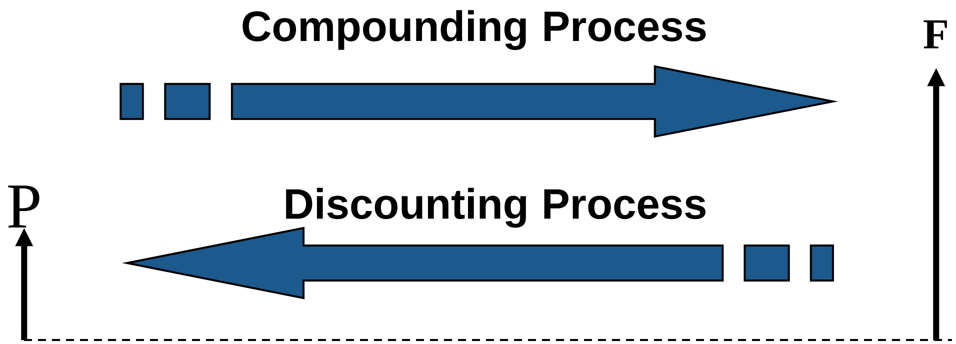
- The costs and benefits of engineering projects over time are summarised on a cash flow diagram.
- Cash flow diagram illustrates the size, sign, and timing of individual cash flows, and forms the basis for engineering economic analysis
- A Tool! To show expenses and receipts

Cash Flow Diagrams

A cash flow diagram is created by first drawing a segmented time-based horizontal line, divided into appropriate time unit. Each time when there is a cash flow, a vertical arrow is added – pointing down for costs and up for revenues or benefits. The cost flows are drawn to relative scale



Single Cash Flow (Simple Case)



$$F = P(1+r)^n$$

$$P = \frac{F}{(1+r)^n}$$

P=Present equivalent value

F= Future equivalent value

r = Annual interest rate

n = number of years

An Example of Cash Flow Diagram

Boney (right) borrowed $1,000 from a bank at 8% interest.

Two end-of-year payments will be made;

1. At the end of the first year, he will repay half of the $1000 principal plus the interest that is due.

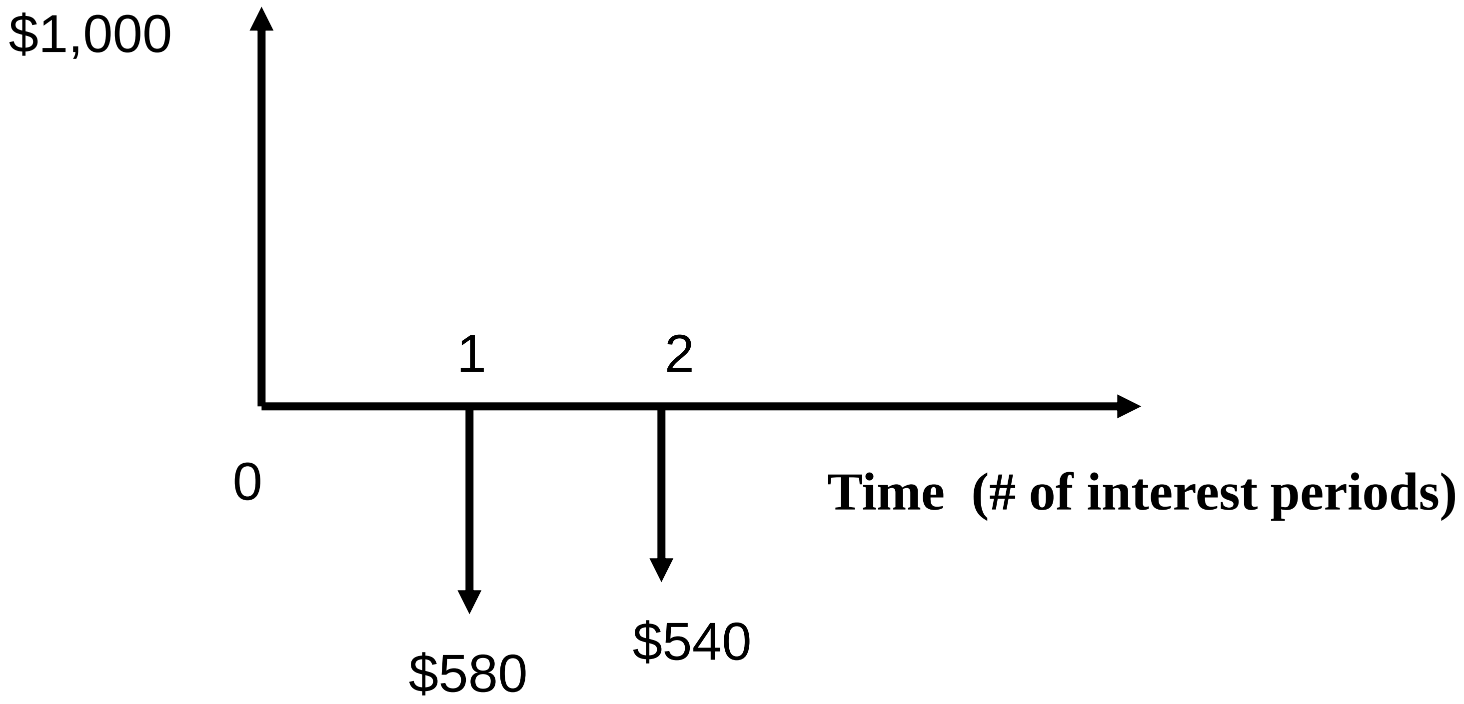
2. At the end of the second year, he will repay the remaining half plus the interest for the second year.

An Example of Cash Flow Diagram

Cash flow for this problem is:

End of year	Cash flow (as seen by 'Boney')	Cash flow (as seen by the Bank)
0	+$1000	-$1000
1	-$580 (-$500 - $80)	+580
2	-$540 (-$500 - $40)	+540
	-$120	+$120

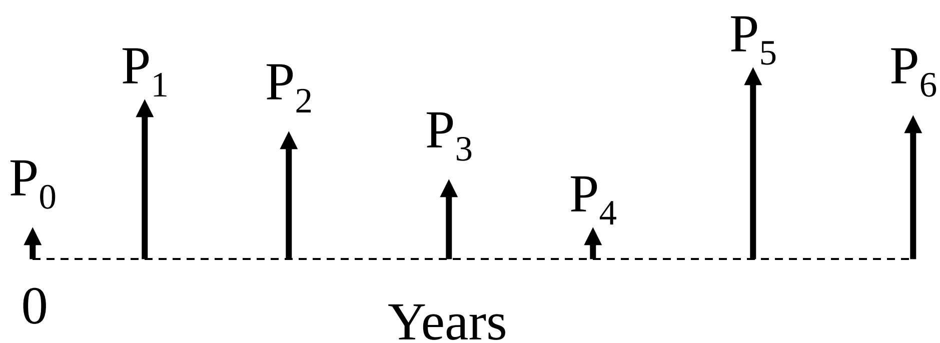
Cash Flow Diagram (as seen by Boney)



Uneven Payment Series

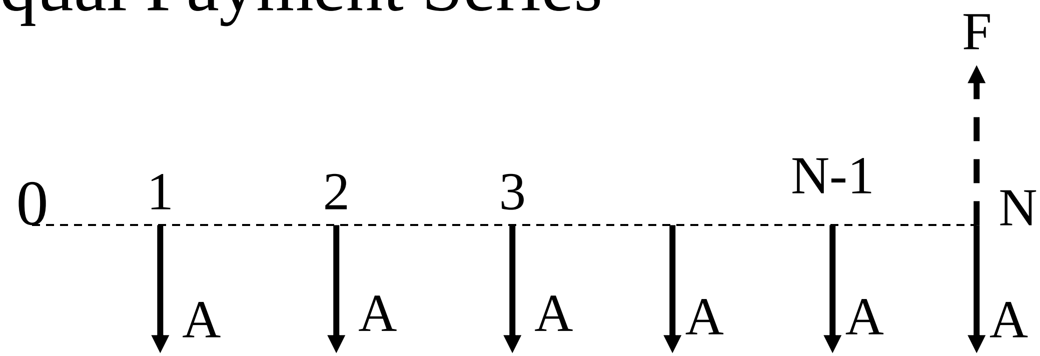
Find the **present worth** of any uneven stream of payments by calculating the present value of each individual payment and summing the results

Future worth can then be calculated by using the interest formula



$$P = \frac{F}{(1+i)^N}$$

Equal Payment Series



$$F = A(1+i)^{N-1} + A(1+i)^{N-2} + ...A(1+i) + A$$

$$F = A + A(1+i) + A(1+i)^2 + ... + A(1+i)^{N-1}$$

$$(1+i)F = A(1+i) + A(1+i)^2 + ... + A(1+i)^N$$

Subtracting two above equations from each other yields:

$$F(1+i) - F = -A + A(1+i)^N$$

$$\boxed{F = A\left[\frac{(1+i)^N - 1}{i}\right]}$$

Economic Equivalence

Which one would you prefer?

- $20,000 today
- $50,000 ten years from now
- $ 8,000 each year for the next ten years

We need to compare their economic worth!

Economic equivalence exists between cash flows if they have the same economic effect.

Convert cash flows into an equivalent cash flow at any point in time

We cannot make a decision on the information above:- we do not know the interest rate!!

Venezuela Inflation = 13,799% pa !!!

Summary

- **If you are evaluating or comparing the financial benefit of different products or opportunities**

- **Use a common time basis**

Equivalent cash flows **are equivalent** at **any common point in time**

Use the present time = **present worth**

Use some future point in time = **future worth**

- **Equivalence depends on interest rate**

Final Problem

You are the IC development manager for Apple iphones. Your CEO has just seen the following article in the business papers….

THE DAILY NEWS

www.dailynews.com THE WORLDS FAVORITE NEWSPAPER - since 1879 -

TSMC starts to build Fab 18

5nm volume production in early 2020

TSMC's Fab 18: Milestones

	Phase 1	Phase 2	Phase 3
Construction Start	Early 2018	Q3 2018	Q3 2019
Equipment Move-In	Early 2019	?	?
High-Volume Manufacturing Start	Early 2020	2020	2021

Dear Duncan,
Do you recommend a redesign of the main processor chip for the new fab to save money?
Please let me have your view by tonight.
regards,
Tim Cook xx ☺

What would you do?

a) Panic & run away !!
b) Call a 1000 person meeting
c) Get a cup of good coffee and a quiet place to think

What information do you know?

If—
If you can keep your head when all about you
Are losing theirs and blaming it on you,
If you can trust yourself when all (wo)men doubt you…;
Rudyard Kipling

Brief Comparison of TSMC's Fab 15 and Fab 18

	Fab 15	Fab 18
Initially Expected Investment**	NT$300 billion ~$9.375 billion	NT$500 billion ~$17.08 billion

	Ax
Microarchitecture	
	ARMv8 (ARM)
…cture	Monsoon, Mistral
	Monsoon, Mistral
Process	10 nm
Transistors	4,300,000,000
Technology	CMOS
Die	89.23 mm²
Word Size	64 bit
Cores	6
Threads	6
Max CPUs	1 (Uniprocessor)

- Payback Period = 24 months (from McKinsey on Semiconductors)
- 'When all 3 phases of the manufacturing facility are completed, its wafer start capacity will exceed 1M wafer starts per year (300mm)'
- Existing A11 chip running on 10FF process, die size = 89.23mm^2
- It will take you 2 years to do the redesign

Advertised PPA Improvements of TSMC's CLN7FF Nodes

Data announced by TSMC during conference calls, press briefings and in press releases

	7FF vs 16FF+	7FF vs 10FF	7FF EUV vs 7FF	5FF EUV vs 7FF EUV
Power	60%	<40%	10%	lower
Performance	30%	?	lower	higher
Area Reduction	70%	>37%	~10%	tangible
HVM Start	~Q2 2018	-	~H2 2019	H1 2020

Calculations

We need to make a couple of [reasonable] assumption:-

a. The variable costs (chemicals, labour etc) is the same in 10nm fab as the new 7nm fabs. (i.e. VC in Fab 15~= VC Fab 18). You are presently running in fab 15(10nm). Fab capacity ~ 1Mwafers/yr in both (TSMC published data)

b. Device yield (%age Good Die Per Wafer (GDPW) is about the same (90%)

c. The **'relevant costs'** are dominated by CapEx in the fabs

We can now calculate the relative costs of moving fabs:-

On 10nm, 300mm wafer we get 70 650mm^2/ 89.23mm^2 = 792 gross die
Apply 90% yield per wafer gives 712 good die (per 12 inch wafer)

If Fab 15 Capex = $9.375Bn and payback is 2 years (i.e. 2M wafers) then the Capex contribution per wafer is $4 687 **(equivalent to about $6.58 per good die)**

Similarly calculating for 7nm EUV process, we get an area improvement of 37% x 10% ~= 43% area saving (i.e. die size reduces from 89.23mm^2 to 50.59mm^2 so good die = 1257
If Fab 18 CapEx = $17.08Bn (payback over 2 years == 2M wafers) = $8 540 / wafer equivalent to Capex Contribution to wafer cost = **($6.79 per good die)**

Conclusion: Based on the Capex Argument, it is **<u>not</u>** sensible to move fabs **BUT** as we have assumed variable costs are approximately the same, the **76% increase in good die would say 'yes' to moving.**

Thank you

谢谢