$$$$$$$$$$$$$$ $ENGINEERING$ $ECONOMICS $ $$$$$$$$$$$$$$

ME 481 Senior Design I

Fall 2020

Presented by

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based on presentation developed by Dr. Zhuoyuan Song

Introduction to Engineering Economics

- As global competition increases, engineers are increasingly asked to analyze and monitor their processes and products, not only to ascertain their level of quality but their cost-effectiveness as well.
  - It is imperative to know the scientific and engineering principles of design work and decision-making in a world where technology is constantly evolving.

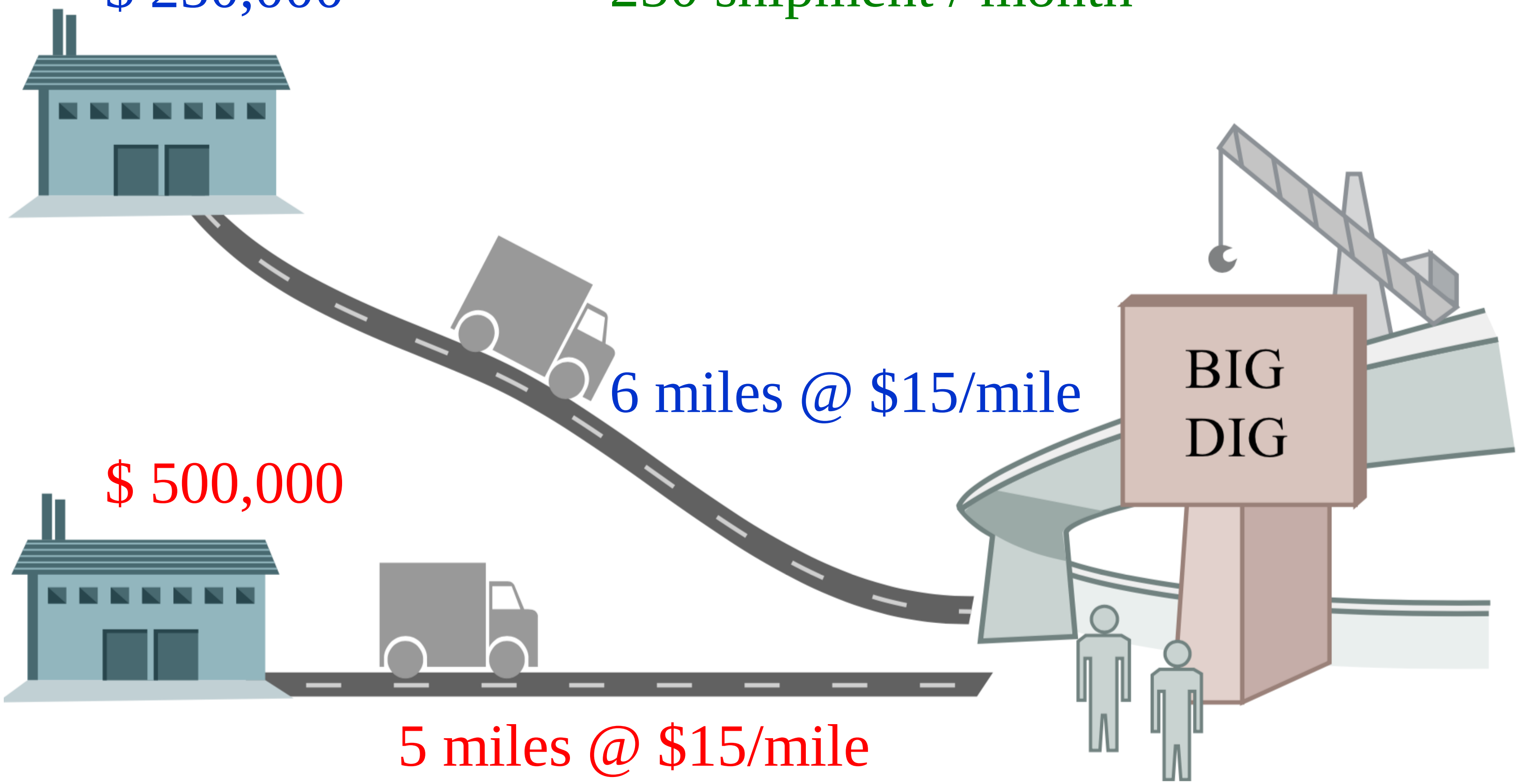
- *Engineering Economics – Analysis for Evaluation of Alternatives*, Ira H. Kleinfeld, John Wiley & Sons, 1992

Where to Build: Far or Near?

$ 250,000

250 shipment / month

Site A:



6 miles @ $15/mile

$ 500,000

Site B:

5 miles @ $15/mile

By MIT OCW

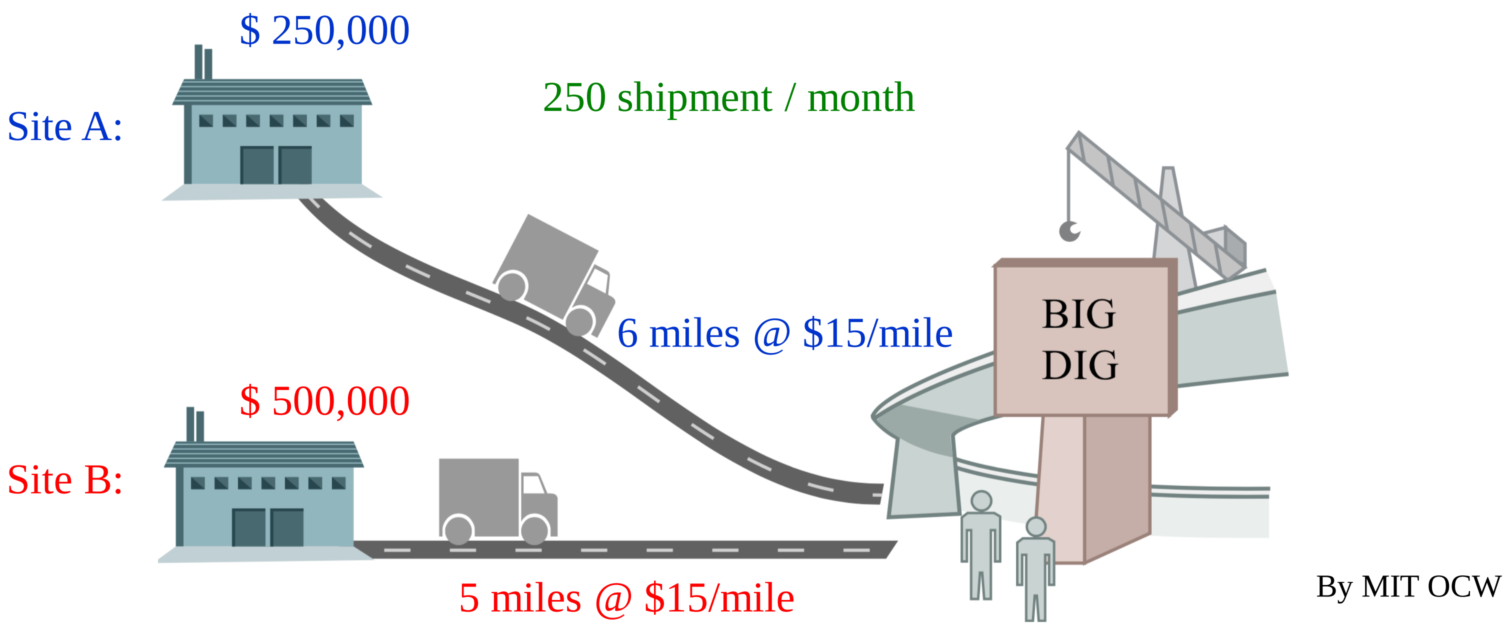
Where to Build: Far or Near?

Cost	Site A	Site B	
Cost to build @ site	$250,000	$500,000	
Monthly Costs			
Average Hauling Distance	6	5	miles
Hauling Expense	$15	$15	/mile
Shipments	250	250	/month
Total Monthly Cost	$22,500	$18,750	

Monthly Savings	$3,750

By MIT OCW

Where to Build: Far or Near?



- **Simple payback:**
  - Site B is preferred after less than 6 years
  - ($500,000 − $250,000) / $3,750/month ≈ 67months

- **Considering reasonable business assumptions (15% discount rate)**
  - ???

Where to Build: Far or Near?

- **Considering reasonable business assumptions (15% discount rate)**
  - $250,000 in cash with Site A, however…
  - $3,750 * 12 = 45,000 additional monthly cost
    - Year 1: FV = $250,000 * 1.15 - $45,000 = $242,500
    - Year 2: FV = $242,500 * 1.15 - $45,000 = $233,875
    - Year 3: FV = $233,875 * 1.15 - $45,000 = $223,956
    - Year 4: FV = $223,956 * 1.15 - $45,000 = $212,550
    - Year 5: FV = $212,550 * 1.15 - $45,000 = $199,433
    - Year 6: FV = $199,433 * 1.15 - $45,000 = $184,348
    - Year 7: FV = $184,348 * 1.15 - $45,000 = $167,000
    - Year 8: FV = $167,000 * 1.15 - $45,000 = $147,050
    - Year 9: FV = $147,050 * 1.15 - $45,000 = $124,108
    - Year 10: FV = $124,108 * 1.15 - $45,000 = $ 97,724
    - Year 11: FV = $ 97,724 * 1.15 - $45,000 = $ 67,383
    - Year 12: FV = $ 67,383 * 1.15 - $45,000 = $ 32,490
    - Year 13: FV = $ 32,490 * 1.15 - $45,000 = $ - 7,637
  - Site B is preferred after > 12 years!

Engineers & Economics

- **Engineers** seek solutions to problems, and the economic viability of each potential solution is normally considered along with the technical aspects.

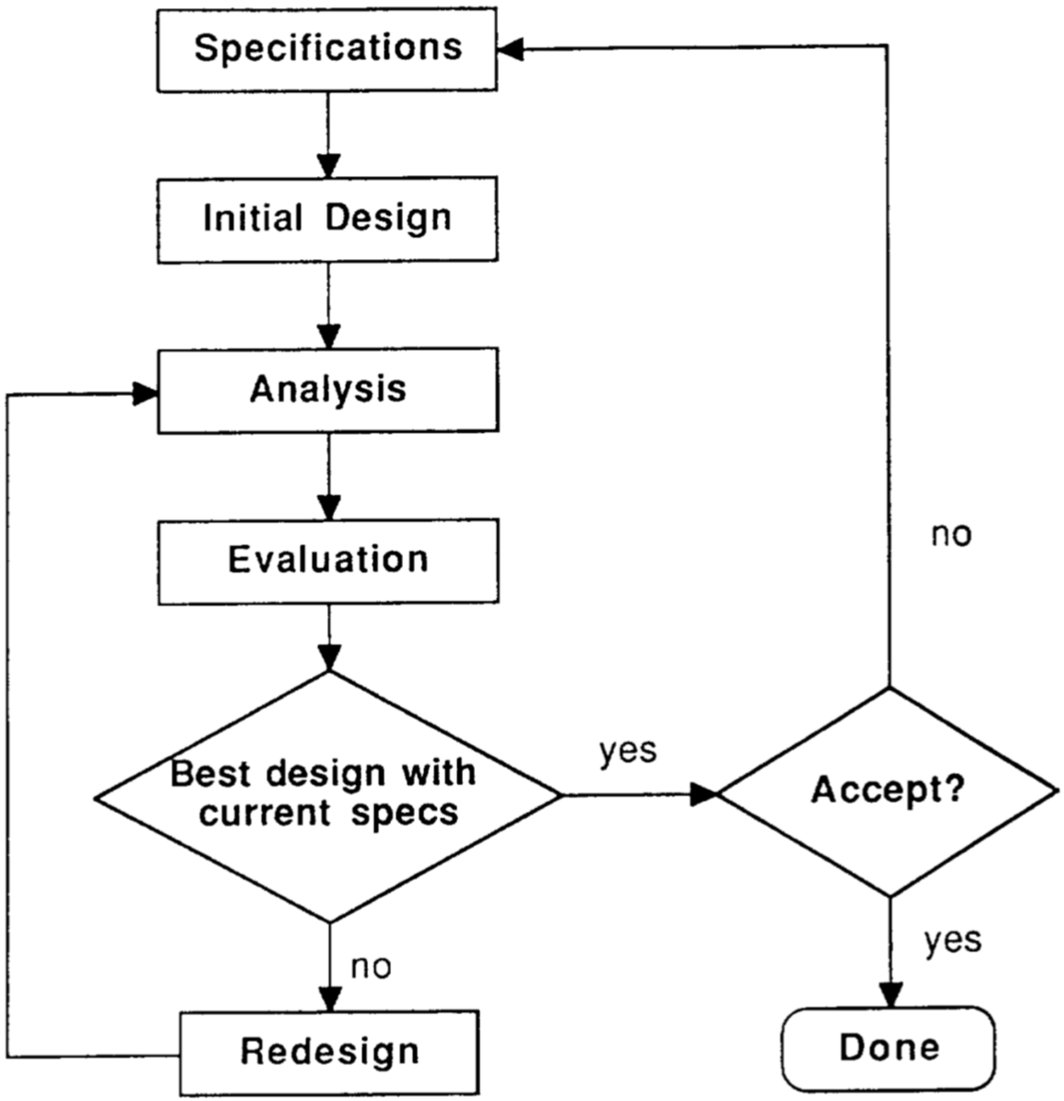
- "**Economics** is the study of how people and society choose to employ scarce resources that could have alternative uses in order to produce various commodities and to distribute them for consumption, now or in the future, ..."
  -- Paul Samuelson and William Nordhaus, *Economics*, 1985.

- **Engineering economics** is the application of economic principles to engineering problems.

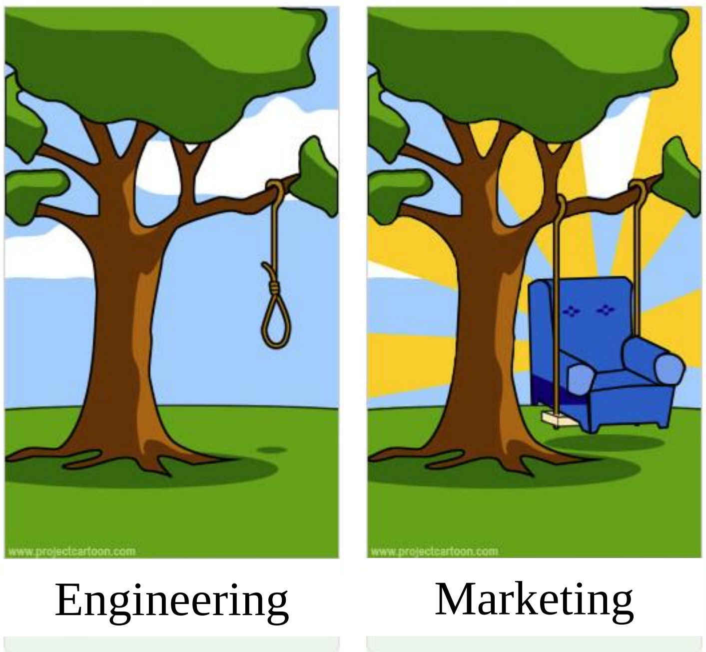
- Systematic evaluation of the economic merits of proposed solutions to engineering problems.

- If factors can be valued in $$$, they should be included in the economic analysis

Why Engineering Economics?



D.L. Thurston and A. Locascio, *The Engineering Economist*, 1994



Hewlett-Packard's ill-fated TouchPad.

What Do We Need to Know?

- Time value of money
- Estimation of cash flows
- Quantitative measurements of profitability

Time Value of Money

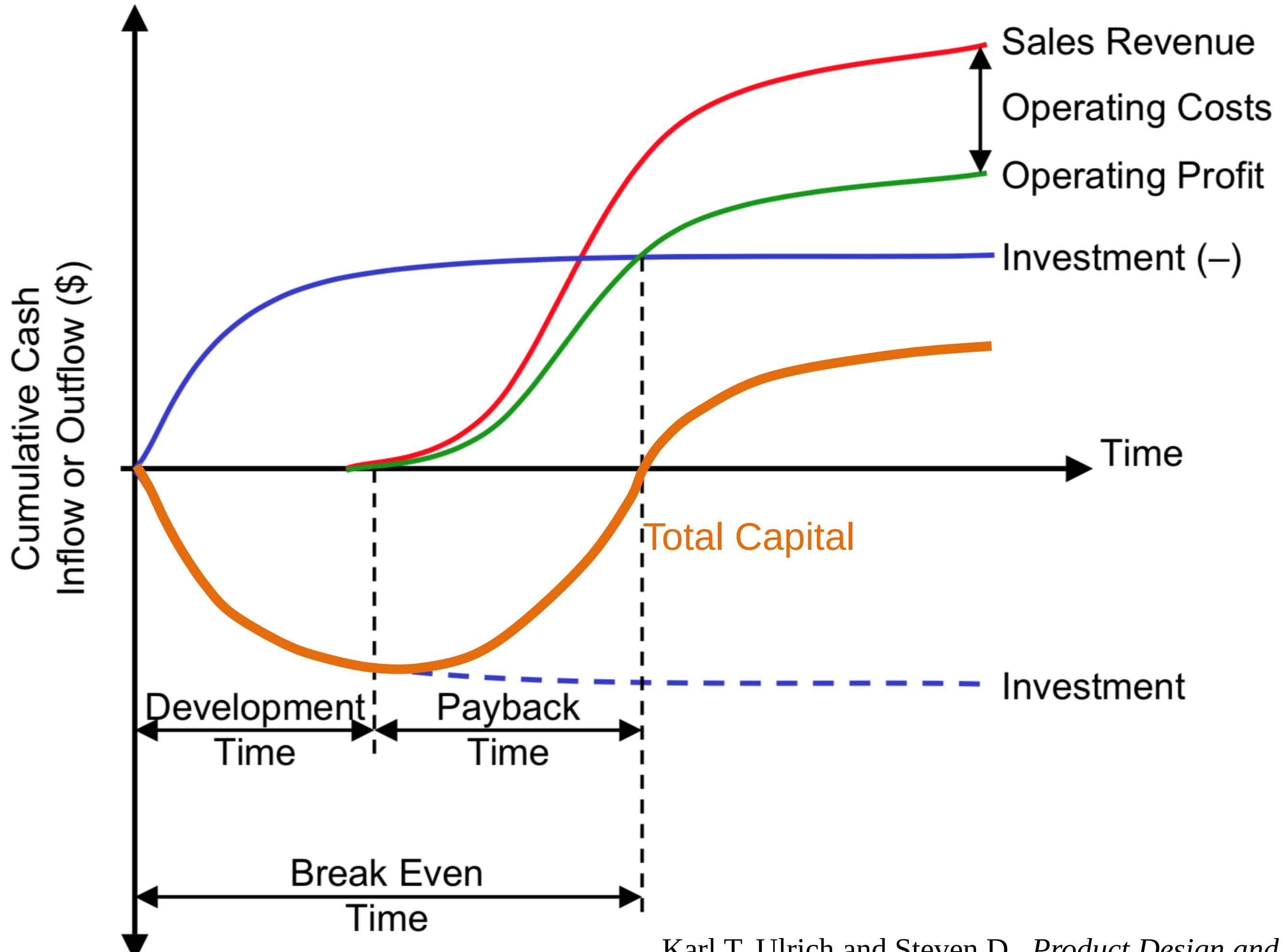
- Time value of money (TVM) is central to most engineering economic analyses. It's the fundamentals underlying all financial activities!

- TVM: money that is available at the present time is worth more than the same amount in the future, given that the dollar today has the capacity to earn interest.

- In simpler terms:
  - A dollar was worth more yesterday than today;
  - A dollar today is worth more than a dollar tomorrow.

Cash Flow

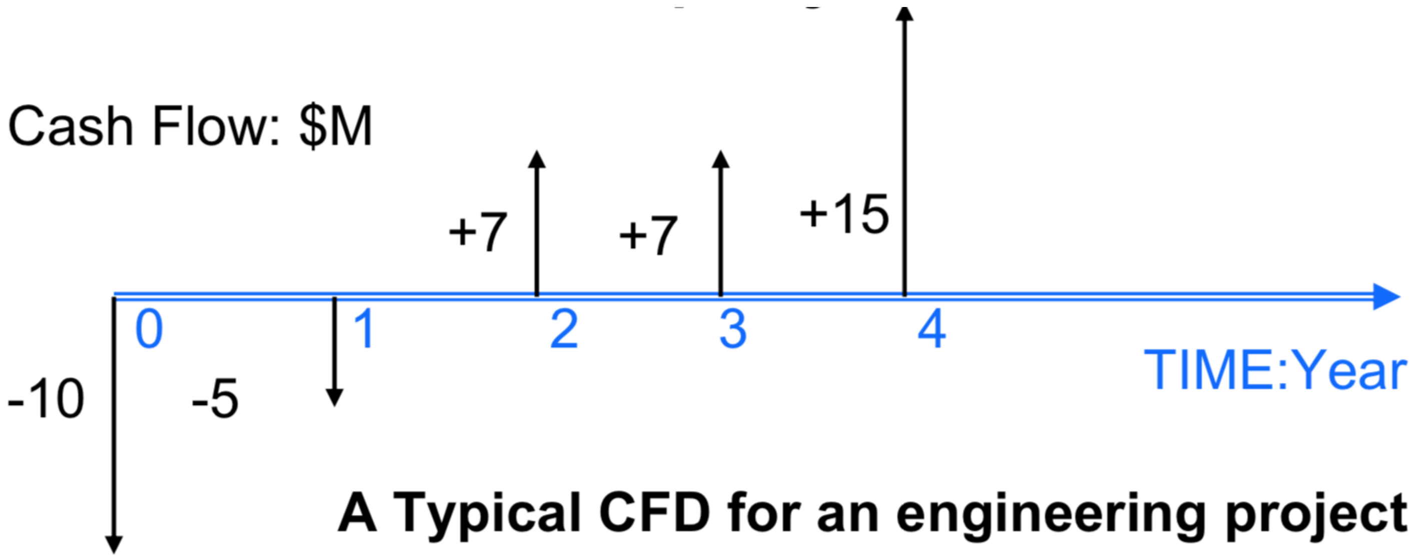
- **Cash flow** is the net amount of **cash** and **cash**-equivalents being transferred into and out of a project.



Karl T. Ulrich and Steven D., *Product Design and Development*, 2000.

Cash Flow Diagram (CFD)

- **Cash flow diagram** is adopted to show the cash flows for a project over time



A Typical CFD for an engineering project

- How to project cash flows?
  - Cost estimation (the task of engineers!)
  - Product pricing and sales projection (Mutual efforts of S&M dept., consulting, engineers, and project managers)

Type of Costs

Two types of costs associated with an engineering projects:

- One-time costs: first costs and salvage costs
- Annual costs (or benefits): occur every year or several years of the project

First costs or initial costs are the costs necessary to a project:

- Costs of new equipment
- Costs of shipping and installation
- Costs of renovations needed to install equipment
- Cost of engineering
- Cost of permits, licenses, etc.

Annual costs or periodic operational and maintenance costs of a project:

- Cost of utilities
- Cost of maintenance
- Cost of marketing and advertisement
- Cost of servicing and customer support
- Cost of recycling, etc.

First Costs also known as ***Non-Recurring Expenditures (NRE)***
Annual Costs also known as ***Recurring Expenditures (RE)***

Concept of Equivalence

Example: Opportunity to Invest

- Invest $15,000
- $18,000 return after 4 years

Alternative 1:

$15,000 now

$18,000 future

Alternative 2:

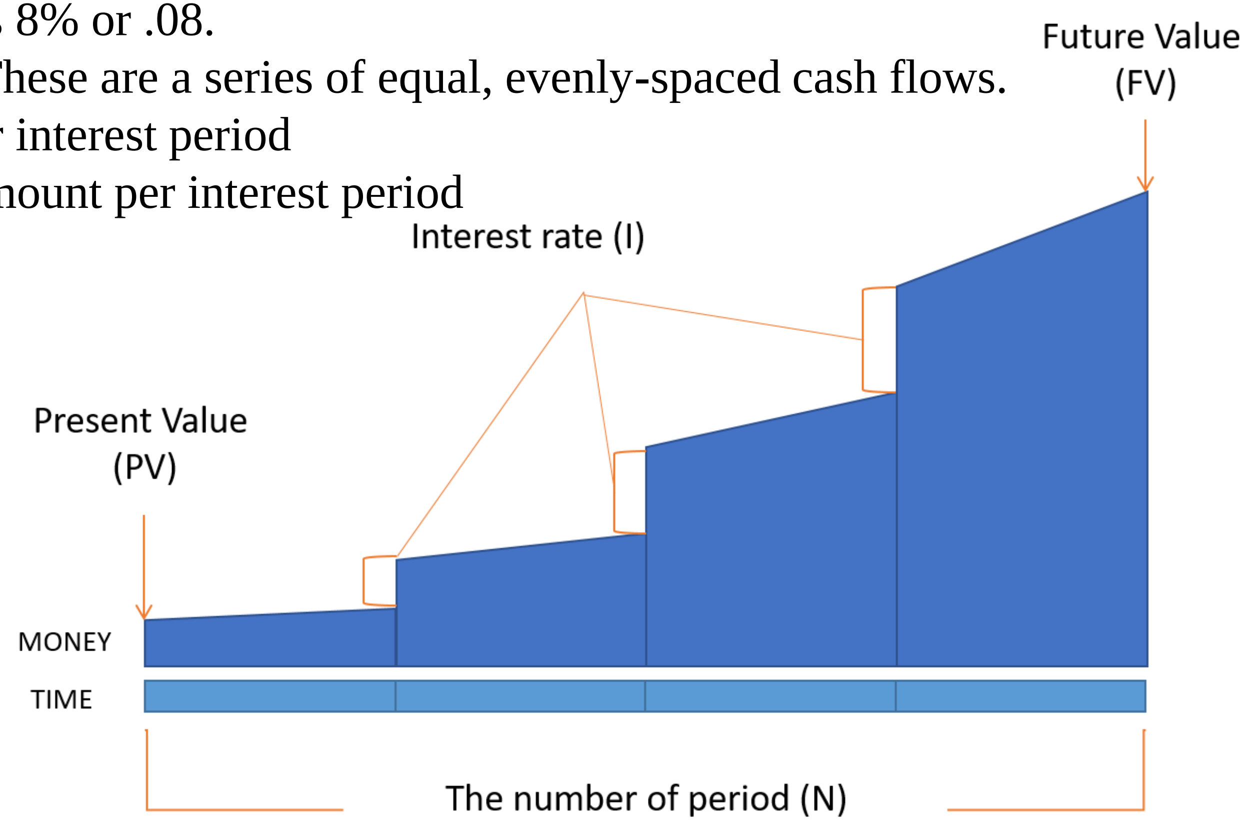
$15,000 now

5% compound annual return on money market

Year	Principal	Interest	Cumulated Cash Flow
1	$15,000	$750	$15,750
2	$15,750	$787.50	$16,537.50
3	$16,537.50	$826.88	$17,364.38
4	$17,364.38	$868.22	$18,234

Characterize Time Value

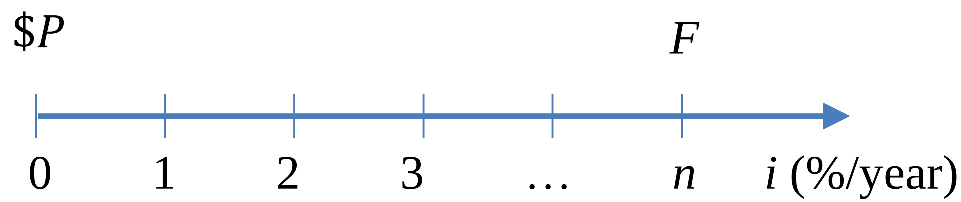
- **Present value (PV)** - money in hand at the present time, initial investment for future.
- **Future value (FV) -** ending amount at a point in time in the future. It should be worth more than the present value, provided it is earning interest and growing over time.
- **The number of periods (N) -** timeline for investment (or debts). It is usually measured in years, but it could be any scale of time such as quarterly, monthly, or even daily.
- **Interest rate (I) -** growth rate of your money over the lifetime of the investment. It is stated in a percentage value, such as 8% or .08.
- **Payment amount (PMT) -** These are a series of equal, evenly-spaced cash flows.
  - A – Uniform amount per interest period
  - G – Uniform gradient amount per interest period



Penn State Financial Literacy Series

Characterize Time Value

- Principal \$ P
- Interest i (% / year)
- n year
- What is the future value F?



$$F = P\,(1+i)^n$$

Factor notation:

$$F = P\,(F/P, i, n)$$

Interest factors

Year	Amount
0	P
1	$P(1+i)$
2	$P(1+i)^2$
3	$P(1+i)^3$
n	$P(1+i)^n$

Single Payment Formulas

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	to F given P	$(F/P, i\%, n)$	$(1+i)^n$
Single Payment Present Worth	to P given F	$(P/F, i\%, n)$	$(1+i)^{-n}$
Uniform Series Sinking Fund	to A given F	$(A/F, i\%, n)$	$\frac{i}{(1+i)^n-1}$
Capital Recovery	to A given P	$(A/P, i\%, n)$	$\frac{i(1+i)^n}{(1+i)^n-1}$
Uniform Series Compound Amount	to F given A	$(F/A, i\%, n)$	$\frac{(1+i)^n-1}{i}$
Uniform Series Present Worth	to P given A	$(P/A, i\%, n)$	$\frac{(1+i)^n-1}{i(1+i)^n}$
Uniform Gradient Present Worth	to P given G	$(P/G, i\%, n)$	$\frac{(1+i)^n-1}{i^2(1+i)^n}-\frac{n}{i(1+i)^n}$
Uniform Gradient † Future Worth	to F given G	$(F/G, i\%, n)$	$\frac{(1+i)^n-1}{i^2}-\frac{n}{i}$
Uniform Gradient Uniform Series	to A given G	$(A/G, i\%, n)$	$\frac{1}{i}-\frac{n}{(1+i)^n-1}$

Moves a single payment to N periods later in time

Moves a single payment to N periods earlier in time

Takes a single payment and spreads it into a uniform series over N later periods.

Takes an arithmetic gradient series and moves it to a single payment two periods earlier than the first nonzero payment of the series.

†.......... $F/G = (F/A - n)/i = (F/A) \times (A/G)$

A - Uniform amount per interest period

G - Uniform gradient amount per interest period

NCEES Handbook

Factor Table

Factor Table - $i = 12.00\%$

n	*P/F*	*P/A*	*P/G*	*F/P*	*F/A*	*A/P*	*A/F*	*A/G*
1	0.8929	0.8929	0.0000	1.1200	1.0000	1.1200	1.0000	0.0000
2	0.7972	1.6901	0.7972	1.2544	2.1200	0.5917	0.4717	0.4717
3	0.7118	2.4018	2.2208	1.4049	3.3744	0.4163	0.2963	0.9246
4	0.6355	3.0373	4.1273	1.5735	4.7793	0.3292	0.2092	1.3589
5	**0.5674**	**3.6048**	**6.3970**	**1.7623**	**6.3528**	**0.2774**	**0.1574**	**1.7746**
6	0.5066	4.1114	8.9302	1.9738	8.1152	0.2432	0.1232	2.1720
7	0.4523	4.5638	11.6443	2.2107	10.0890	0.2191	0.0991	2.5515
8	0.4039	4.9676	14.4714	2.4760	12.2997	0.2013	0.0813	2.9131
9	0.3606	5.3282	17.3563	2.7731	14.7757	0.1877	0.0677	3.2574
10	**0.3220**	**5.6502**	**20.2541**	**3.1058**	**17.5487**	**0.1770**	**0.0570**	**3.5847**
11	0.2875	5.9377	23.1288	3.4785	20.6546	0.1684	0.0484	3.8953
12	0.2567	6.1944	25.9523	3.8960	24.1331	0.1614	0.0414	4.1897
13	0.2292	6.4235	28.7024	4.3635	28.0291	0.1557	0.0357	4.4683
14	0.2046	6.6282	31.3624	4.8871	32.3926	0.1509	0.0309	4.7317
15	**0.1827**	**6.8109**	**33.9202**	**5.4736**	**37.2797**	**0.1468**	**0.0268**	**4.9803**
16	0.1631	6.9740	36.3670	6.1304	42.7533	0.1434	0.0234	5.2147
17	0.1456	7.1196	38.6973	6.8660	48.8837	0.1405	0.0205	5.4353
18	0.1300	7.2497	40.9080	7.6900	55.7497	0.1379	0.0179	5.6427
19	0.1161	7.3658	42.9979	8.6128	63.4397	0.1358	0.0158	5.8375
20	**0.1037**	**7.4694**	**44.9676**	**9.6463**	**72.0524**	**0.1339**	**0.0139**	**6.0202**
21	0.0926	7.5620	46.8188	10.8038	81.6987	0.1322	0.0122	6.1913
22	0.0826	7.6446	48.5543	12.1003	92.5026	0.1308	0.0108	6.3514
23	0.0738	7.7184	50.1776	13.5523	104.6029	0.1296	0.0096	6.5010
24	0.0659	7.7843	51.6929	15.1786	118.1552	0.1285	0.0085	6.6406
25	**0.0588**	**7.8431**	**53.1046**	**17.0001**	**133.3339**	**0.1275**	**0.0075**	**6.7708**
30	0.0334	8.0552	58.7821	29.9599	241.3327	0.1241	0.0041	7.2974
40	0.0107	8.2438	65.1159	93.0510	767.0914	0.1213	0.0013	7.8988
50	0.0035	8.3045	67.7624	289.0022	2,400.0182	0.1204	0.0004	8.1597
60	0.0011	8.3240	68.8100	897.5969	7,471.6411	0.1201	0.0001	8.2664
100		**8.3332**	**69.4336**	**83,522.2657**	**696,010.5477**	**0.1200**		**8.3321**

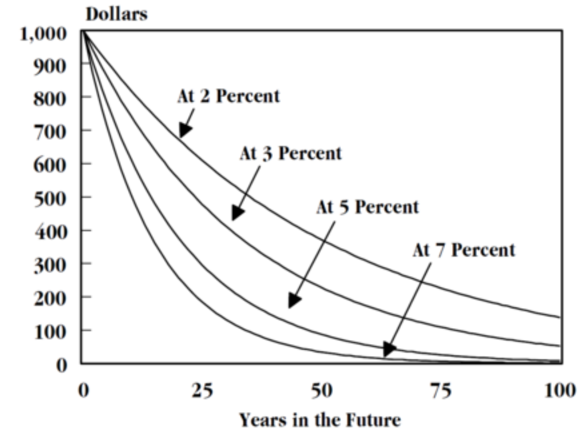
Interest Rates

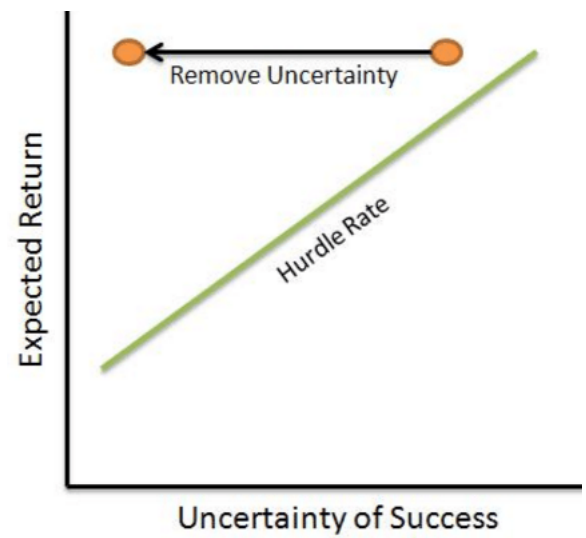
- **Compound interest rate:** interest is calculated on the initial principal and also includes all of the accumulated interest of previous periods of a principal.

- **Discount rate:** used in discounted cash flow analysis to determine the present value of future cash flows.
  - For example, to determine the present value of $1,000 a year from now, you need to discount it by a particular interest rate. Assuming a discount rate of 10%, the present value would be $909.09 = 1000/(1+0.1).

- **Hurdle rate:** the minimum rate of return on a project or investment required by a manager or investor.
  - The hurdle rate denotes appropriate compensation for the level of risk present; riskier projects generally have higher hurdle rates than those that are less risky.

- **Must meet the company's investment criteria.**
  - Opportunity cost of the capital





capitalbudgetingtechniques.com

Product Economics Example

- **Stanley Hammer**
- Designed in 1995 by Product Genesis for Stanley Tools
- Contractor Grade™
- Graphite composite shaft core with over-molded jacket
- Soft rubber grip

FORM+FUNCTION
By John Pierson

Getting a Handle On Hammer Markets

HAMMER MAKERS are trying to get a better grip on their market.

Plumb Tool's invention of the fiberglass handle in 1954 and Estwing's solid steel hammer in 1926 were revolutionary. Now Stanley Tools, a subsidiary of The Stanley Works, is offering an evolutionary grip.

Designed with Product Genesis, Cambridge, Mass., Stanley's new Contractor Grade hammers have grips of softer, light-grey vinyl. Concentric, wavy grooves are meant to provide better traction and a place for sweat to run off. The traditional elliptical handle has given way to a rounder shape — thinner toward the end, thicker in the middle. The grip's end is more flared to keep the hammer from flying out of the hand.

All hammers represent a compromise between strength and comfort. Estwing's solid steel model almost never breaks but creates a lot of vibration. So the company covers its steel handle with a blue nylon/vinyl grip that absorbs the shock.

In the early 1980s, Hart Tool of Huntington Beach, Calif., mated a curved hickory hatchet handle to a steel hammer head to produce its California Special, which has a strong following among West Coast house framers. "Wood absorbs shock better but is the weakest," says John Reid, a Hart principal.

Not all pros like the new Stanley grip. "My hand is big, but the new Stanley overfills it and threatens to break my grip," says Bill Greene, an East Bridgewater, Mass., carpenter and cabinet maker.

But Dennis Pitts, an installer for Midland Seamless Gutters, Warwick, R.I., prefers his new Stanley hammer over his old Stanley. "It doesn't slip," he says.

Left, Stanley's new hammer with its softer grip. Right, an older model.

• Development cost and timing	$120k, 9 months
• Testing cost and timing	$100k, 1 year
• Tooling investment and timing	$200k, 6 months
• Ramp-up cost and timing	$50k, 3 months
• Marketing and support cost and timing	$250k + $80k/year for 2 years
• Sales volume and lifetime	200k units/year, 5 years (actually not flat)
• Unit production cost	$4/unit + $2/unit overhead
• Unit revenue	$12/unit wholesale
• Discount rate	10%/year

630k, 30 month

Quantification of Profitability

- **Profitability: the central target of most projects!**
- **Net Present Value (NPV)**

$$NPV = \sum_{periods} \frac{period\ cash\ flow}{(1 + discount\ rate)^{period}} \qquad NPV = \sum_{n=1}^{N} \frac{C_n}{(1+i)^n}$$

Step 1: Examines the total value of all cash flows at time 0.

Step 2: "i" as the rate of return that could be achieved otherwise, or cost of capital.

Step 3: If NPV > 0, the project is acceptable.

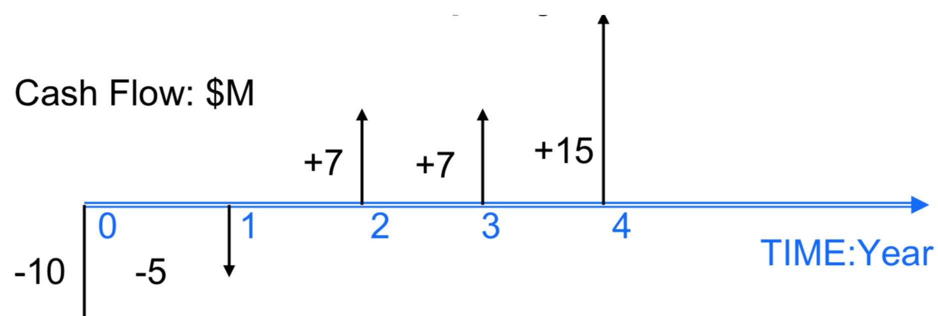
For our sample Cash Flow Diagram

- The expected rate of return (cost of capital): 10%
- The present value of C(0): PV[C(0)] = -$10M
- The present value of C(3): PV[C(3)] = 7/(1+10%)^3 = $5.26M
- The net present value of the project: SUM{PV[C(i)]} = $6.74M > 0
- Project accepted!

- **Return on Investment**

$$RoI = \frac{Annual\ Average\ Profit}{Total\ Investment}$$

RoI = (7+7+15-10-5)/4/(10+5) = ~24%



A Typical CFD for an engineering project

Summary

- Time value of money
  - Why does money have time value?
  - How to calculate?
- Cash flow and equivalence
- Interest factors
- Quantification of Profitability

By R. Khalil

- Take-aways:
  - \$1 today ≠ \$1 tomorrow
  - If factors can be valued in \$\$\$, they should be included in the economic analysis