MECH431

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General economics concepts

> **Economics:** is study of the use of scarce resources that have alternative uses

- We don't have enough resources to give everyone what they want (time, budget, facilities, data, labor, people with expertise...)
- Managing scarce resource requires making choices and often value judgements
- Making a choice involves "not" doing another choice - trade-offs

> **Opportunity cost:** the cost of forgoing the next best thing

- Economics quantifies resource management
- Econometrics is statistics used to analyze economic data

Decision framework and current cost models

Problems come in levels of difficulty

- Simple: not much effort required; small amount of variables; obvious solutions exist
- **Intermediate**: economics problem; needs structured thought;
- Complex: involves a mixture of economic, political, social, and ethical elements; (annual budget of a corporation; building a pipeline; choosing a partner...)

Intermediate questions focus on costs, revenues and benefits that occur at different times

- Which projects are worthwhile?
- How should projects be designed?

Not all problems require engineering economics analysis. Problems that do should

- be important enough to justify serious thought
- have economics issues as a significant component of the analysis leading to a decision
- require organization
- the problem requires decision variables and their consequences be well understood
- there are non-financial factors involved (first nations rights, safety, ethics...)

Decision-making process

1. Recognize the problem
2. Define the goal
   - Wide scope: "make the business more profitable"
   - Narrow scope: "Determine the most economical machine to buy"
3. Assemble relevant data
4. Identify feasible alternatives
5. Select the criterion to determine the best alternative
6. Construct a model
7. Predict the outcomes or consequences for each alternative
8. Choose the best alternative
9. Audit the results

> **Current cost models:** simple arithmetic models that compare anticipated costs and benefits over a short period of time. (Such as costs and revenue per unit of product produced and sold.)

In current cost models we only consider the costs, but we neglect

- Currency inflation
- Cost of time, cheaper option may take a longer time
- Depreciation of instruments
- Quality of product
- Functionality of product
- Ethics
- Environmental impacts
- Differentiate between business and pleasure activities (going to Hawaii for training - is this appropriate?)
- Safety - what is safe enough, what is too safe?
- Issue that arise from globalization - different countries have different ethical expectations

Costs and cost estimating

> **Costs:** the economic value of the resources used in the production of goods and services. (Such as land, labour, capital, utilities, . . .)

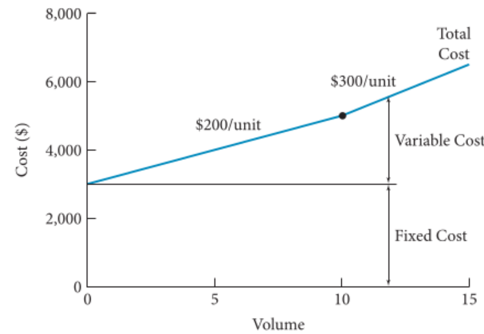
There can also be **social costs**. These are also called externalities. An **externality** is a cost (or benefit) to a third party caused by a producer that is not financially incurred or received by that producer.

There are various types of costs:

- **Fixed costs:** costs that remain constant
  The rent for a storage unit stays the same regardless how much of that unit you utilize.
- **Variable costs:** opposite of fixed costs. They depend on the level of output, or activity
  The amount of raw material a manufacturer need to purchase varies with the number of items produced.
- **Total cost** is sum of the fixed and variable cost.
- **Marginal cost:** variable cost per unit
- **Average cost:** total cost per unit

On a units-produced versus total cost plot,

- the fixed cost is a constant offset to the curve
- the variable cost manifests itself in the **changing** slope of the curve as more/less units are produced
- the variable cost at unit n is cost curve evaluated at n minus the fixed cost
- the marginal cost for the n^{th} unit is reflected in the slope of the curve at n

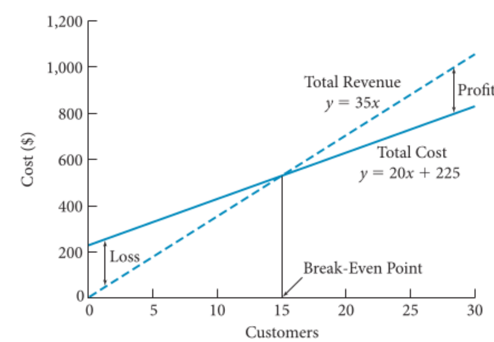


The same terms and definitions apply when we consider **revenues**. We

- **Break even:** when the total revenue is equal to the total costs
- **Profit:** when the total revenue exceeds the total costs
- **Loss:** when the total costs exceed the total revenue

On a units-produced versus costs plot, the

- **Break even point** is at the intersection between the revenue and costs curve
- the profit/loss (at n^{th} unit sold) is the difference between the revenue and cost curve at n



Since the cost curve at $n = 0$ has a non-zero offset, we say that our production has fixed costs. In the plot shown, we do not have fixed revenue.

Sunk cost: money spent in the past that cannot be recovered.

- disregarded in engineering economic analysis

Example: money paid to buy a car two years ago. The money you spent shouldn't affect you decision when you decide to buy a new car.

Opportunity cost: cost associated with a resource being used for an alternative task; cost of forgoing the next-best thing.

Overhead cost: "indirect costs of running a company that cannot be tied to any particular task that the company executes."

Looking at costs on a timescale,

- **Recurring costs:** costs that occurs at regular intervals

  An Paying rent for your storage unit.

- **Non-recurring cost:** unique costs that occur at irregular intervals

  Costs due accidents, unexpected illness, capital expenditure (buying new equipment)

  To prevent large non-recurring costs, we may choose to buy insurance. This leads to a recurring cost of the insurance premium.

When comparing different options, the **incremental cost** is the cost difference between two alternatives.

When considering how costs are actually "paid out"

- **Cash costs:** require money to move from one party to another
- **Book costs:** are recorded ("accounting costs"), but are not transactions, and do not involve cash flow from one party to another

  Book costs are often accounting exercises. They do not directly involve cash flow, so they are not accounted for in an analysis. But they can generate cash costs/revenue. How you report your spending can lead to different tax percentages.

The **life cycle** is all the time from conception to the retirement of a product/process.

- **Life cycle cost:** total of all the costs incurred over the life cycle of the process/product
- **Life cycle costing:** designing products, goods, and services recognizing their associated costs over their life cycles.
- The later a design change is made, the higher the cost.
- Early design decisions "lock in" costs that will be incurred later - 70% to 90% of all costs are set during the design phases

Cost models

We can classify cost estimating into three levels:

1. **Rough estimates:** back of the envelope calculations, accuracy can vary widely
2. **Budget/Semi-detailed estimates:** based on historical data
3. **Detailed estimates:** estimates made from detailed designs using quantitative models and vendor quotes; Highly accurate

Estimation accuracy are affected by

- **Resource constraints:** whether there is enough time and labor to retrieve all the information we need for a precise estimate
- **Experience:** Whether the estimator is experienced
- **One-of-a-kind estimates:** whether similar projects has been done in the past that can be used as a reference for the current estimate; (the cost of sending astronauts to the moon for the first time)

Cost estimating models

1. **Per-unit model:** uses a cost per unit factor
2. **Segmenting model:** divided a problem into item, estimate each, and add together
3. **Cost indexes:** cost indexes are dimensionless values that record the historical change in costs. The ratio of cost indexes are of primary interest. They are not absolute measures

$$\frac{\text{Cost at } T = a}{\text{Cost at } T = b} = \frac{\text{Index value at } T = A}{\text{Index value at } T = b}$$

4. **Power sizing model:** used to estimate the costs of industrial plants or equipment. We account for the economies of scale using a **power sizing exponent**, x, which determines how much to scale up or down costs of an product at two different capacities

$$\frac{\text{Cost at capacity A}}{\text{Cost at capacity B}} = \left(\frac{A}{B}\right)^x$$

5. **Learning curve:** accounts for cost improvements. The time required to produce the N^{th} unit is related to the time required to produce the first unit, and a **learning curve exponent**

$$T(N) = N^b T(1)$$

Learning curves are often referred to by its **percentage learning slope**. A curve with $b = -0.074$ is a "95%" learning curve since $2^b = 0.95$.

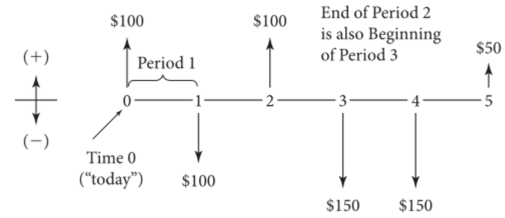
We can calculate b by

$$b = \frac{\log(\text{learning curve expressed as a decimal})}{\log 2}$$

Cashflow diagrams

A cash flow diagram is a chart of class flows over a period of time. It consists of

- discrete time points $(0, 1, 2, 3, \ldots)$
- arrows to indicate cash flow
- the arrow points up (positive) if it represents revenue
- the arrow points down (negative) if it represents expenses
- the length of the arrow is proportional the amount of cash involved
- Instead of arrows, we can use bars instead



The categories of cash flow:

- **First cost:** cost that occurs at time 0
- **Operations and maintence:** ongoing/recurring expenses
- **Salvage value:** receipt at project termination
- **Revenues:** annual receipts (annual sales/ reduced costs)
- **Overhaul:** major capital expenditure occuring during life of asset

Simple cashflow analysis techniques

Do not provide a comprehensive view of a project. They help set minimum financial viability requirements before doing more detail analysis.

> **Payback period:** the payback period is the time required for the profits to equal the cost, neglecting any interest rates and any economic consequences beyond the payback period.

Two options may have the same payback period, but one option might provide further benefits, but this is not reflected in the payback period.

Two options may have the same payback period, but one option might provide a consistent return, while the returns of the other option may be back weighted. (They have different benefits vs time curves.) The payback period does not reflect this.

The pay back period does no account for the **time value of money**.

> **Cost benefit ratio (CBR):** the ratio of total costs divided by total benefits. If CBR ≥ 1, then the project may be worthwhile. Otherwise, further consideration is required.

Time value of money

Engineering projects often take up over multiple years.

> **Time value of money:** the idea that the value of cash today will be worth more than in the future because of the present day's earning potentials.

- The stronger the preference for current consumption, the more important time is in investing
- When time becomes important, we also need to consider **interest**, inflation, depreciation, other costs

> **Interest:** two interpretations of interest:
> 1. rate at which we consider how the value of money changes over time (related to the time value of money, and uncertainty and risk)
> 2. an amount paid by a borrower to get access to money; an amount received by a lender to lose access to a sum of money

Another interpretation is based on **uncertainty and risk**. The later we receive the benefits, the less certain we can be about what the money will be worth, and what it can be used for.

Money is a has value, and so they can be leased or rented.

- **Interest payments:** is the "rent" that a party pays to whenever they borrow a sum of money; this also reflects the risk of the lender losing the money entirely
- **Interest rate:** is the rate of return received by a lender for lending money; they quantity how a lender/borrower values money over time

To a lender,

- A high interest rate loan means that the lender values the same amount of money higher today, than they do in the future
- A low interest rate loan means that we value money today similarly than we do in the future
- A zero interest rate means that the lender values money at exactly the same between today and the future
- A negative interest rate means that the lender values the money more in the future than they do today (extremely rare in an engineering scenario)

> **Inflation:** refers to the trend that the amount of goods and services we can purchase with the same amount of money decreases over time.

> **Depreciation:** most assets tend to lose value over time.

We rather have money today since

- Having money today means that we can collect rent on it (Money is a commodity)
- Less risk
- money tend to lose value over time assets depreciate over time
- Having money today means that we can invest it today

Simple and compound interest

Consider the following definitions

- **P:** present value. This is the value at the initial time of an analysis
- **F:** future value. This is the value of as asset in the future relative to time of PV
- **i:** interest rate per period
- $\mathbf{I_n}$**:** interest paid in the single period n
- **n:** index for the period

For discrete cast flows, we can compute

> **Simple interest:** interest that is applied once to the "principal amount" and paid at the end of the term (on the **maturity date**). Given the principal value P, interest rate per period i, and n periods,
>
> $$I = Pin$$

The total amount that a lender who lends out P for n periods receives is the future value F.

$$F = I + P$$

Simple interest is easy to compute, but rarely seen in real life.

> **Compound interest:** interest that is computed on the outstanding amount after every compounding period. The outstanding amount includes the unpaid principal and unpaid interest that has been accumulated.
>
> $$I_n = P(1+i)^n - P$$

At the end of the first period:

$$I_1 = Pi$$

and the future value at the end of the first period is

$$F_1 = I_1 + P = P(1+i)$$

At the end of the second period,

$$I_2 = i(P(1+i))$$

and the future value at the end of the second period is

$$\begin{aligned} F_2 &= F_1 + I_2 \\ &= P(1+i) + Pi(1+i) \\ &= P(1+i)^2 \end{aligned}$$

The total amount we need to pay after n compounding periods is

$$F_n = P(1+i)^n$$

Finally,

$$I_n = F_n - P$$

We cand define the **single payment compound amount factor**:

$$\text{SPCAF} = (1+i)^n$$

which is constant for any combinations of i, n.

The inverse of the SPCAF is the **single payment present worth factor**:

$$\text{SPPWF} = \text{SPCAF}^{-1}$$

- Values of SPCAF are often tabulated in compound interest tables
- We compute F from P by multiplying P by the SPCAF
- An interest rate that is used to convert F to P is a **discounting rate**
- An interest rate used to convert a P to F is a **compounding rate**

Nominal and effective interest rates

Other than per year, interest rates can be specifed "semi-annually", or "quarterly", et cetera.

- **Nominal interest rate (r):** is an interest rate computed by directly scaling an interest rate such that it becomes a "per year" interest rate, with no consideration of compounding.

Example: a bank bond pays 1% every quarter. The nominal rate is $1\% \times 4$ which gives 4% per year.

- **Effective interest rate ($\mathbf{i_a}$):** takes compounding into consideration - a bond that pays 1% quaterly will end up paying you more than 4% annually. For m compounding periods,

  $$i_a = \left(1 + \frac{r}{m}\right)^m - 1$$

  r/m is the interest rate per compounding period.

Example: investing 1000 dollars at 6% per year, compounded semi-annually. (The 6% is nominal interest rate.)

The future value of our investment after one year is

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

where i is the interest rate per compounding period, and n is the number of periods.

In this case, we have 6% per year, but its compounded semi-annually. So i is $6\%/2 = 3\%$. A year consists of two compounding periods, so $n = 2$. Then the future value is

$$F = 1000(1+0.03)^2 = 1060.90$$

Recall that the interest amount is

$$I = F - P = 60.90$$

So the effective annual interest rate is $I/P = 6.09\%$.

Cashflow equivalence

A sum of money at one time period may have the same "value" as a more/less sum of money at another period in time, with respect to an interest rate.

We can use `Excel` functions, `FV`, `PV` to help us.

- If we want the future value on an investment, then we should put the present value as negative
- If we want the present value of a future amount (that is a revenue), then the value returned by `PV` is negative, since we have to invest this present amount to receive a future amount