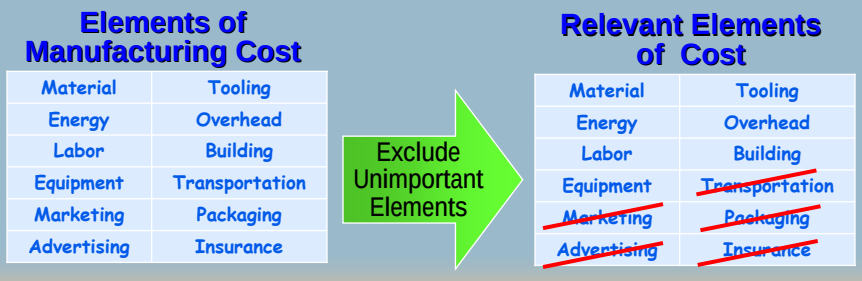
Step Two:
Identify Relevant Costs

What costs should be considered?

Creating a PBCM: Step Two

- **Identify Relevant Costs**
  - **Pertinent to Decision**
  - **Necessary for Completeness / Credibility**



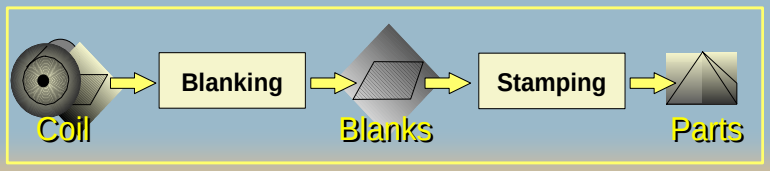
Common Relevant Cost Elements

- Variable
  - Materials (Raw Materials & Consumables)
  - Labor
  - Energy
- Fixed
  - Equipment (including Maintenance)
  - Tooling
  - Building
  - Overhead
- Begin With These, But Always Ask Whether Others Are Important
  - Tradeoff Amongst Time, Resources, and Available Knowledge

Creating A PBCM: Step Three

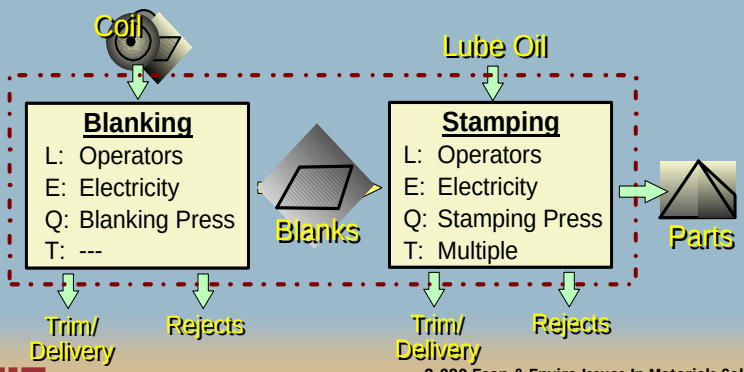
- Diagram Process Flows
  - Draw In Materials Flowing Into AND Out Of
  - Catalog For Each Process Step
    - Equipment
    - Labor
    - Energy

e.g., Sheet Metal Stamping
Forming Between Two Matched Dies



Diagramming Flows Example: Stamping

- Catalog For Each Process Step
  - *-- Labor*
  - *-- Energy*
  - *-- Equipment*
  - *-- Tools*



Cost Modeling Challenge

- **How much equipment to buy?**
- **What is the cost of producing your various products?**
  ... for your business...

?

Your Business

Modeling the Cost of Pizza Manufacture: Defining Scope

- **Cost to Whom?:**
  War & Pizza
  - **High volume (50K/y) pizza maker**
- **Cost of What?**
  - **How much does a pizza cost to make ?**
- **Cost Varying How?**
  - **... with design changes?**
  - **... with scale up to 100K/yr ?**

Diagramming Flows Example: W & P

Catalog For Each Process Step

-- Labor -- Energy -- Equipment -- Tools

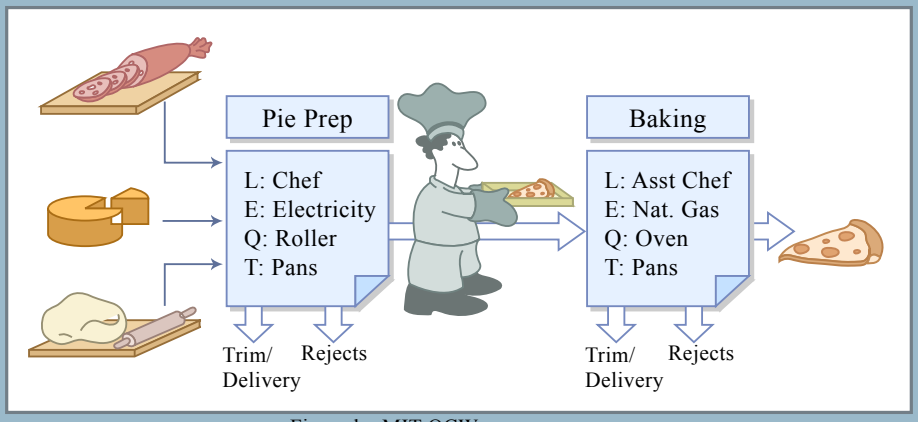


Figure by MIT OCW.

Data Collection & Model Development

- **For each resource in your diagram**
  - **How much does a unit cost?**
  - **How many units are required?**
- **Begin data collection early!!!**
  - **Start with low risk sources**
    - Probably smaller firms
  - **End with high value sources**

Step Four: Relate Costs to What is Known

- **Process Involves Four Steps**
  1) **Begin At The Current Endpoint (initially, the costs)**
  2) **Ask: How Can That Quantity Be Broken Down?**
     -- Initially, How Many Do I Need x How Much Does Each Cost
  3) **Analyze Required Information (i.e. parameters)**
     -- Are Those Parameters Acceptable Endpoints?
     -- Can I (the model) Derive Them From A Simpler Or More Relevant Set Of Information?
  4) **If No, Repeat 1 With New Endpoints**

- **Watch Out For Interdependent Parameters**
  - **e.g. Part Mass & Part Dimensions**

Step Four Example: Pepperoni Costs

- **Start at the end**
- **Think in terms of annual quantities**

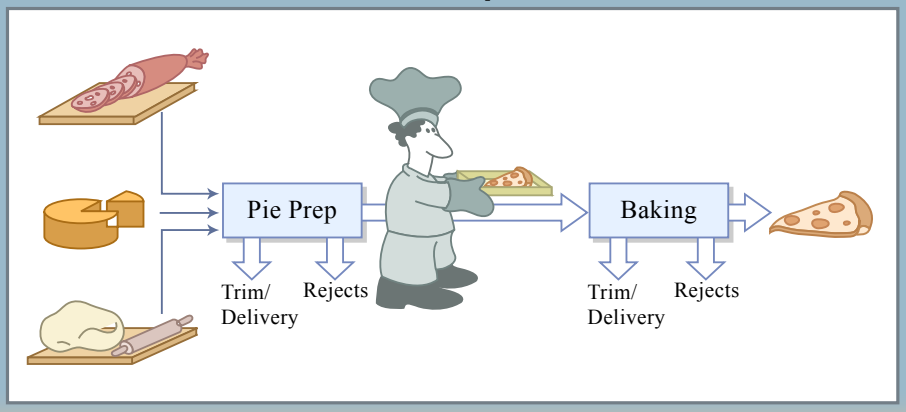


Figure by MIT OCW.

Two Important Quantities

- **Production Capacity =**
  Qty. of "Good" Parts Capable of Being Produced
  - **How much CAN a plant produce?**

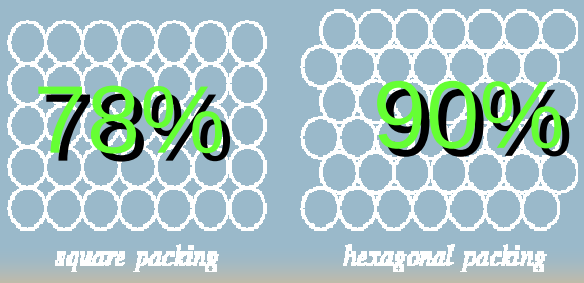
- **Production Volume =**
  Quantity of "Good" Parts Produced
  - **How much DOES a plant produce?**

Generally, Both Are Measured In Units Per Year

(e.g., parts / year, kgs / year)

Slices per Pizza

- **General area covering is difficult to solve**
  - **Solutions for small number of circumscribed circles has been solved**
- **Approximate:**



Calculating Effective Production Volume: Work Backwards from Final Step

Prepped Pizzas Produced / Year = Good Preps + Rejects

effective $PV_{Prepping}$ = $PV_{Prepping}$ + Rejects

Can model Rejects as % of total production

$$effPV_{Prep} = PV_{Prep} + R \times effPV_{Prep}$$

$$effPV_{Prep} = \frac{PV_{Prep}}{(1 - R)}$$

But what is PV_{Prep}?

Assume that PV_{Prep} = Total Pizzas Baked / Year (i.e., $effPV_{Baking}$)

$$effPV_{i} = \frac{effPV_{i+1}}{(1 - R)}$$

For last step, substitute PV for $effPV_{i+1}$

Next Question ...

What is the cost of equipment?

How much equipment to buy?

A Little Intro - http://www.remcousa.com/flash.html

A Little Intro - http://www.remcousa.com/flash.html

Key Structuring Constraint -- Time

- Hours of daily operation an operational constant
- To get more than a day's production, you need more resources
- Inverting that calculus can be used to scale/size an operation
- Defines capital requirements

Determining Equipment Requirements: Compare Time Needed With Time Available

- Time Needed
  - To Make Product + To Load/Unload
  - Total Number of Pies (effective PV)
  - Cycle Loading (Analogous To Multiple Cavities)
- Time Available
  - Shifts, Days
  - Less Breaks, Downtime, Maintenance
- Ratio: Line Utilization/Requirements

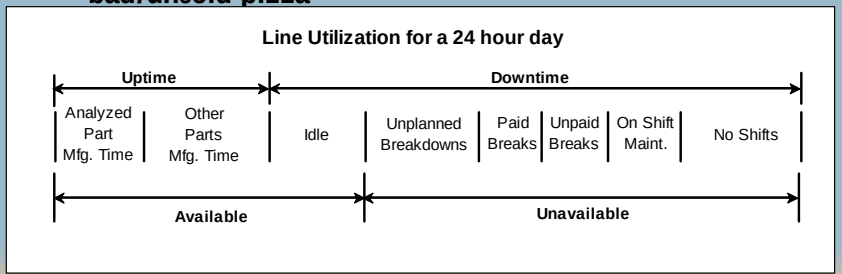
Determining Equipment Requirements: Compare Time Needed With Time Available

- **Minimum equipment requirement:**

$$\frac{\text{Annual Required Production Time}}{\text{Annual Available Operating Time}}$$

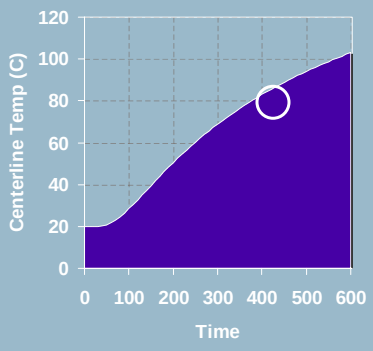
Cycle Time as Basis, but Other Issues are Critical

- **Total processing time**
  - **Processing**
  - **Load/Unload Time**
  - **Time spent making bad/unsold pizza**
- **Other times**
  - **Downtime Due To Scheduled Breaks**
  - **Unscheduled Downtime**

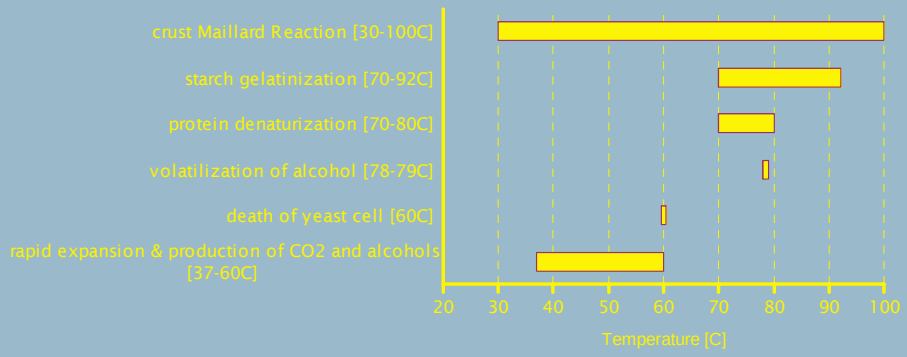


Considering Process Time for W&P

- **Assumptions:**
  - **Initial temp: 20˚C**
  - **Oven temp: 225˚C**
  - **α: 7.5E-9**
  - **Thickness: 10 mm**
- **How long will it take to cook?**
- **What's the centerline temperature reach target? … 80 ˚C**



Considering Process Time for W&P Breadmaking: Temperatures



Ref: Oregon State; Nutrition & Food Management (NFM236)
http://oregonstate.edu/instruct/nfm236/bread/index.cfm

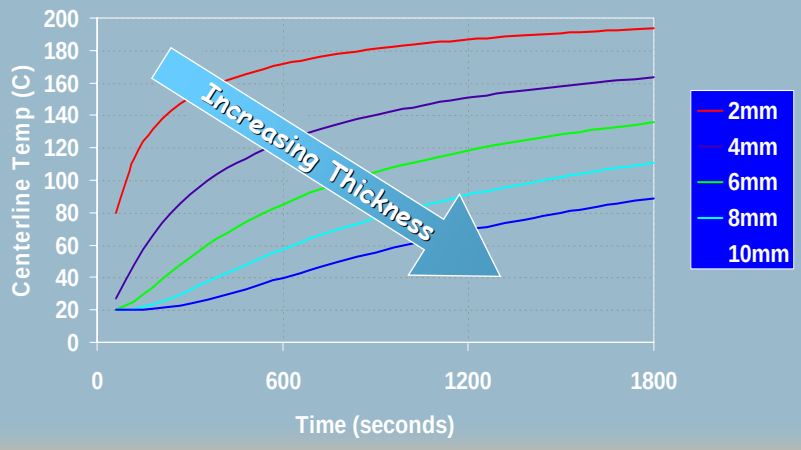
Heat Transfer, Non-Steady State

- Let's rely on some experts
  - Tufts' Gourmet Engineering class, EN43
  - Assume constant surface temperature:

$$\frac{T(x,t) - T_{surface}}{Ti - T_{surface}} = \text{erf}\left\{\frac{x}{2\sqrt{\alpha t}}\right\}$$

A relation between time, temperature and position

Time, Temperature and Thickness



Distribution of Capital Costs Over Time

- Simplicity Is Best At Outset
  - Complex capital accounting relies on extra knowledge, usually case specific
- Simple amortization -- opportunity cost of capital
  - Distributed over goods sold, not made

Dedicated Capital Or Not?

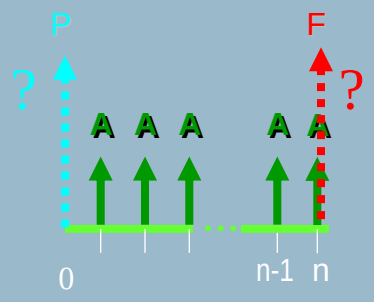
- Dedicated: Can only be used to make a single good
- Non-dedicated: Can be used to make other goods
  - Note: Just because it can be used doesn't necessarily mean it will be used!

Relating a Uniform Series of Payments to P or F

- **Uniform series of payments – often called an *Annuity***
- **By convention:**
  - **P at time 0**
  - **A at end of period**
  - **F at end of period**

Therefore:

- **1st A, 1 period after P**
- **Last A, coincident with F**



Formulas for N Periods
Finite Series of Equal Payments

a) Future Value (F)

$$= \sum_{i}^{N} A(1+r)^{i}$$

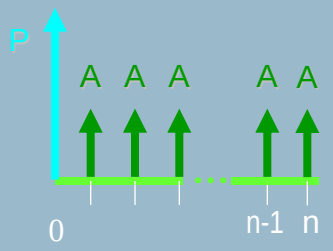
$$= A\,\frac{[(1+r)^{N} - 1]}{r}$$

b) Payment (A)

$$= P \times r\,\frac{[(1+r)^{N}]}{[(1+r)^{N}-1]}$$

$$= P\,(crf)$$

crf = Capital Recovery Factor



Consequences of Capital Utilization