# Product, process and schedule design II.

- Chapter 2 of the textbook
- Plan of the lecture:
  - Process design
  - Schedule design

# Product, process and schedule design

| | Steps | Documentation |
|---|---|---|
| **Product design** | •Product determination | |
| | •Detailed design | •Exploded assembly drawing<br>•Exploded assembly photograph<br>•Component part drawing |
| **Process design** | •Process identification | •Parts list<br>•Bill of materials |
| | •Process selection | •Route sheet |
| | •Process sequencing | •Assembly chart<br>•Operation process chart<br>•Precedence diagram |
| **Schedule design** | •Quantity of the product | |
| | •Equipment requirements | |
| | •Operator requirements | |

# Process Design

- Determination of *how* the product is to be produced
  - Who should do the processing? (Which part of the products should be made?)
  - How the part will be produced?
  - Which equipment will be used? (for the parts which will be made in-house)
  - How long will it take to perform the operation?

- Production methods are the most fundamental factor affecting the physical layout

# Process Design

- Within the process design process, we need to consider following issues
  1. *Process identification*
     - Make-or-buy analysis
     - Parts identification
  2. *Process selection*
     - How the product will be made (operations, equipment, raw material, etc.)
  3. *Process sequencing*
     - How components are put together

# Process Design – 1. Process identification

*Make-or-buy decisions*

- The scope of the facility depends on the level of vertical integration
- How are the make-or-buy decisions made?
  - Can the item be purchased?
  - Should we go for subcontracting?
    - Supplier
    - Contractor
  - Can we make the item?
  - Is it cheaper for us to make than to buy?
  - Is the capital available so that we can make it?
- Managerial decisions requiring input from finance, industrial engineering, marketing, process engineering, purchasing, human resources, etc.

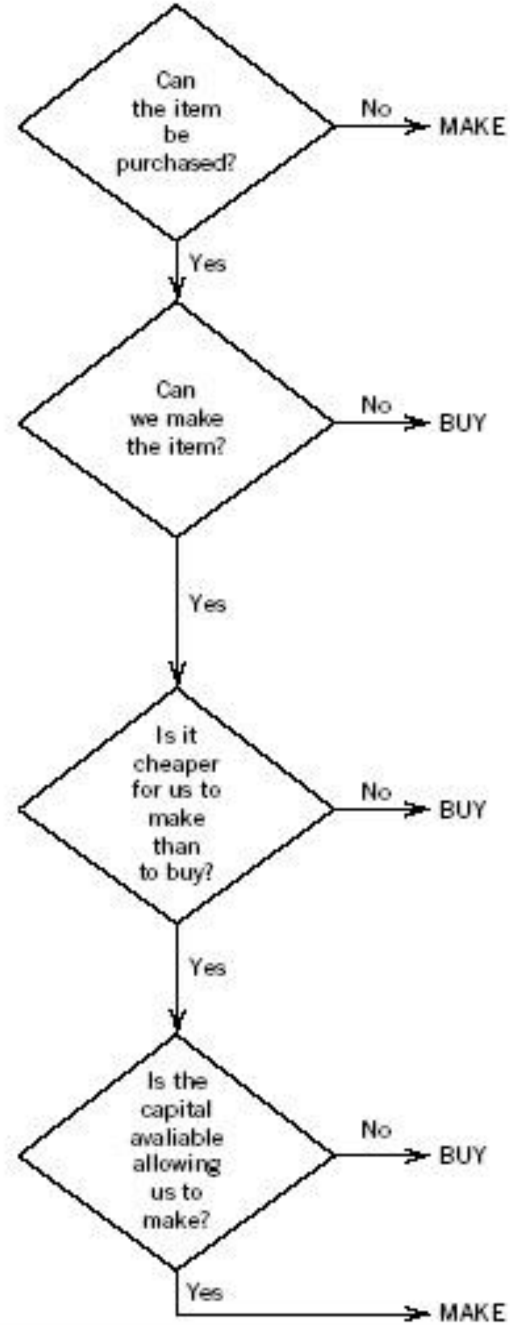
Secondary Questions — Primary Questions — Decisions

1. Is the item available?
2. Will our union allow us to purchase the item?
3. Is the quality satisfactory?
4. Are the available sources reliable?

1. Is the manufacturing of this item consistent with our firm's objectives?
2. Do we possess the technical expertise?
3. Is the labor and manufacturing capacity available?
4. Is the manufacturing of this item required to utilize existing labor and production capacities?

1. What are the alternative methods of manufacturing this item?
2. What quantities of this item will be demanded in the future?
3. What are the fixed, variable, and investment costs of the alternative methods and of purchasing the item?
4. What are the product liability issues which impact the purchase or manufacture of this item?

1. What are the other opportunities for the utilization of our capital?
2. What are the future investment implications if this item is manufactured?
3. What are the costs of receiving external financing?

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# Process Design – 1. Process identification

- The input to the facility planner is a listing of the items to be made/purchased.
  - *Parts list* – component parts of a product:
    - part numbers
    - part name
    - number of parts per product
    - drawing references
  - *Bill of materials* - structured parts list:
    - contains hierarchy referring to the level of product assembly

**PARTS LIST**

Company T. W., Inc. Prepared by J. A.
Product Air Flow Regulator Date

| Part No. | Part Name | Drwg. No. | Quant./ Unit | Material | Size | Make or Buy |
|---|---|---|---|---|---|---|
| 1050 | Pipe plug | 4006 | 1 | Steel | .50" × 1.00" | Buy |
| 2200 | Body | 1003 | 1 | Aluminum | 2.75" × 2.50" × 1.50" | Make |
| 3250 | Seat ring | 1005 | 1 | Stainless steel | 2.97" × .87" | Make |
| 3251 | O-ring | — | 1 | Rubber | .75" dia. | Buy |
| 3252 | Plunger | 1007 | 1 | Brass | .812" × .715" | Make |
| 3253 | Spring | — | 1 | Steel | 1.40" × .225" | Buy |
| 3254 | Plunger housing | 1009 | 1 | Aluminum | 1.60" × .225" | Make |
| 3255 | O-ring | — | 1 | Rubber | .925" dia. | Buy |
| 4150 | Plunger retainer | 1011 | 1 | Aluminum | .42" × 1.20" | Make |
| 4250 | Lock nut | 4007 | 1 | Aluminum | .21" × 1.00" | Buy |

Figure 2.7 Parts list for an air flow regulator.

**BILL OF MATERIALS**

Company T. W., Inc. Prepared by J. A.

Product Air Flow Regulator Date

| Level | Part No. | Part Name | Drwg. No. | Quant./ Unit | Make or Buy | Comments |
|---|---|---|---|---|---|---|
| 0 | 0021 | Air flow regulator | 0999 | 1 | Make | |
| 1 | 1050 | Pipe plug | 4006 | 1 | Buy | |
| 1 | 6023 | Main assembly | — | 1 | Make | |
| 2 | 4250 | Lock nut | 4007 | 1 | Buy | |
| 2 | 6022 | Body assembly | — | 1 | Make | |
| 3 | 2200 | Body | 1003 | 1 | Make | |
| 3 | 6021 | Plunger assembly | — | 1 | Make | |
| 4 | 3250 | Seat ring | 1005 | 1 | Make | |
| 4 | 3251 | O-ring | — | 1 | Buy | |
| 4 | 3252 | Plunger | 1007 | 1 | Make | |
| 4 | 3253 | Spring | — | 1 | Buy | |
| 4 | 3254 | Plunger housing | 1009 | 1 | Make | |
| 4 | 3255 | O-ring | — | 1 | Buy | |
| 4 | 4150 | Plunger retainer | 1011 | 1 | Make | |

**Figure 2.8** Bill of materials for an air flow regulator.

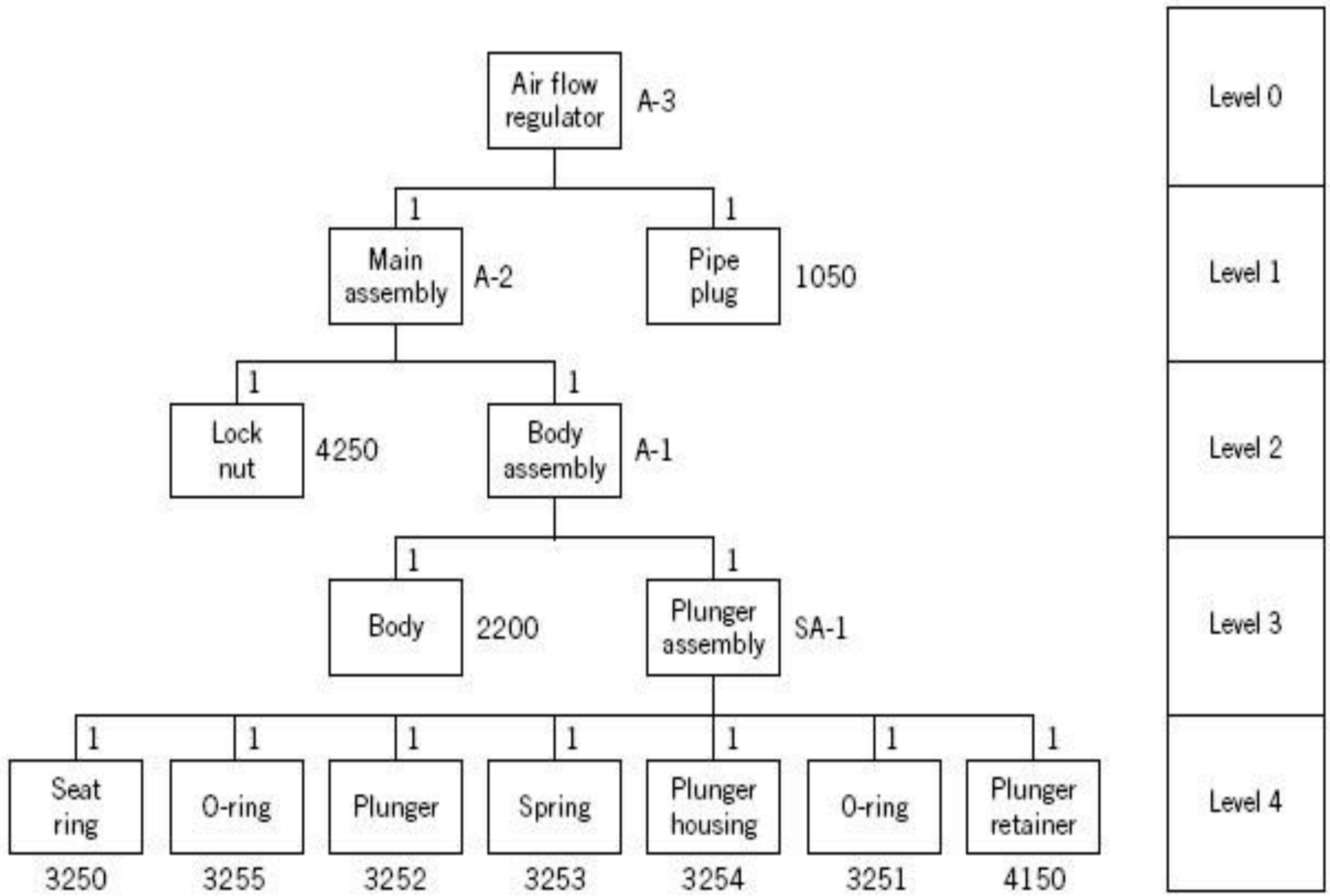



Figure 2.9 Bill of materials for an air flow regulator.

# Process Design – 2. Process Selection

- How the products will be made
- 6-step procedure:

1. Define elementary operations
2. Identify alternative processes for each operation
3. Analyze alternative processes
4. Standardize processes
5. Evaluate alternative processes
6. Select processes

# Process Design – 2. Process Selection

- *Route sheet* - output of process selection, it identifies processes, equipment and raw materials

| Data | Production Example |
|---|---|
| Component name and number | Plunger housing – **3254** |
| Operation description and number | Shape, drill, and cut off – **0104** |
| Equipment requirements | Automatic screw machine and appropriate tooling |
| Unit times (Per component) | Set-up time: 5 hrs.<br>Operating time: 0.0057 hrs |
| Raw material requirement | 1 in. diameter X 12 ft aluminum bar per 80 components |

# Process Design – 2. Process Selection

**ROUTE SHEET**

| | | | | | |
|---|---|---|---|---|---|
| Company | A.R.C., Inc. | Part Name | Plunger Housing | Prepared by | J. A. |
| Produce | Air Flow Regulator | Part No. | 3254 | Date | |

| Oper. No. | Operation Description | Machine Type | Tooling | Dept. | Set-up Time (hr.) | Operation Time (hr.) | Materials or Parts Description |
|---|---|---|---|---|---|---|---|
| 0104 | Shape, drill, cut off | Automatic screw machine | .50 in. dia. coller, feed fingers, cir. form tool, .45 in. dia. center drill, .129 in. twist drill, finish spiral drill, cut off blade | | 5 | .0057 | Aluminum 1.0 in. dia. × 12 ft. |
| 0204 | Machine slot and thread | Chucker | .045 in. slot saw, turret slot attach. 3/8–32 thread chaser | | 2.25 | .0067 | |
| 0304 | Drill 8 holes | Auto. dr. unit (chucker) | .078 in. dia. twist drill | | 1.25 | .0038 | |
| 0404 | Deburr and blow out | Drill press | Deburring tool with pilot | | .5 | .0031 | |
| SA1 | Enclose subassembly | Dennison hyd. press | None | | .25 | .0100 | |

**Figure 2.11** Route sheet for one component of the air flow regulator.

# Process Design – 3. Process Sequencing

- The method of assembling the product
- *Assembly chart* – shows how the components are combined
- *Operation process chart* – gives an overview of the flow within the facility
  - A combination of route sheets and assembly charts
- *Precedence diagram* – establishes precedence relationships

# Assembly Chart

This part was identified in route sheet already

Assemblies

Inspection

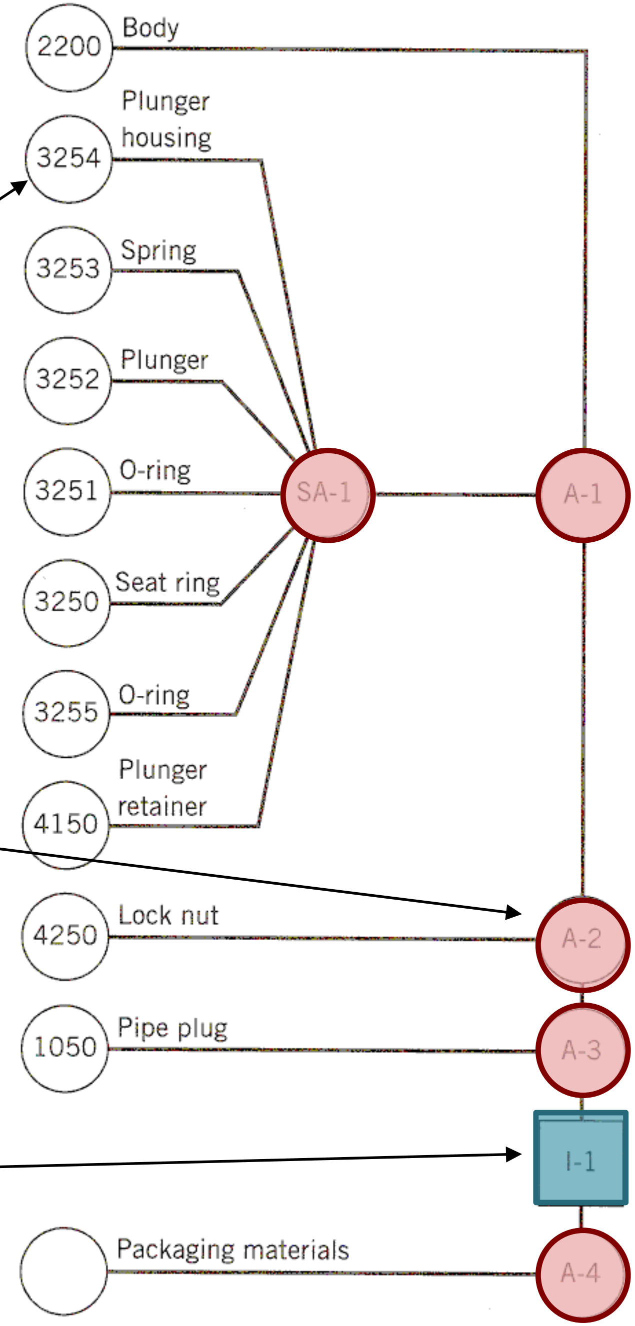



Figure 2.12 Assembly chart for an air flow regulator.

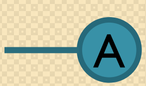
Assembly operation

Inspection

# Operation process chart

- *Route sheet* provides information on production methods
- *Assembly chart* determines how components are put together
- *Operation process chart* is a combination of route sheet and assembly chart


Manufactured component




Purchased component

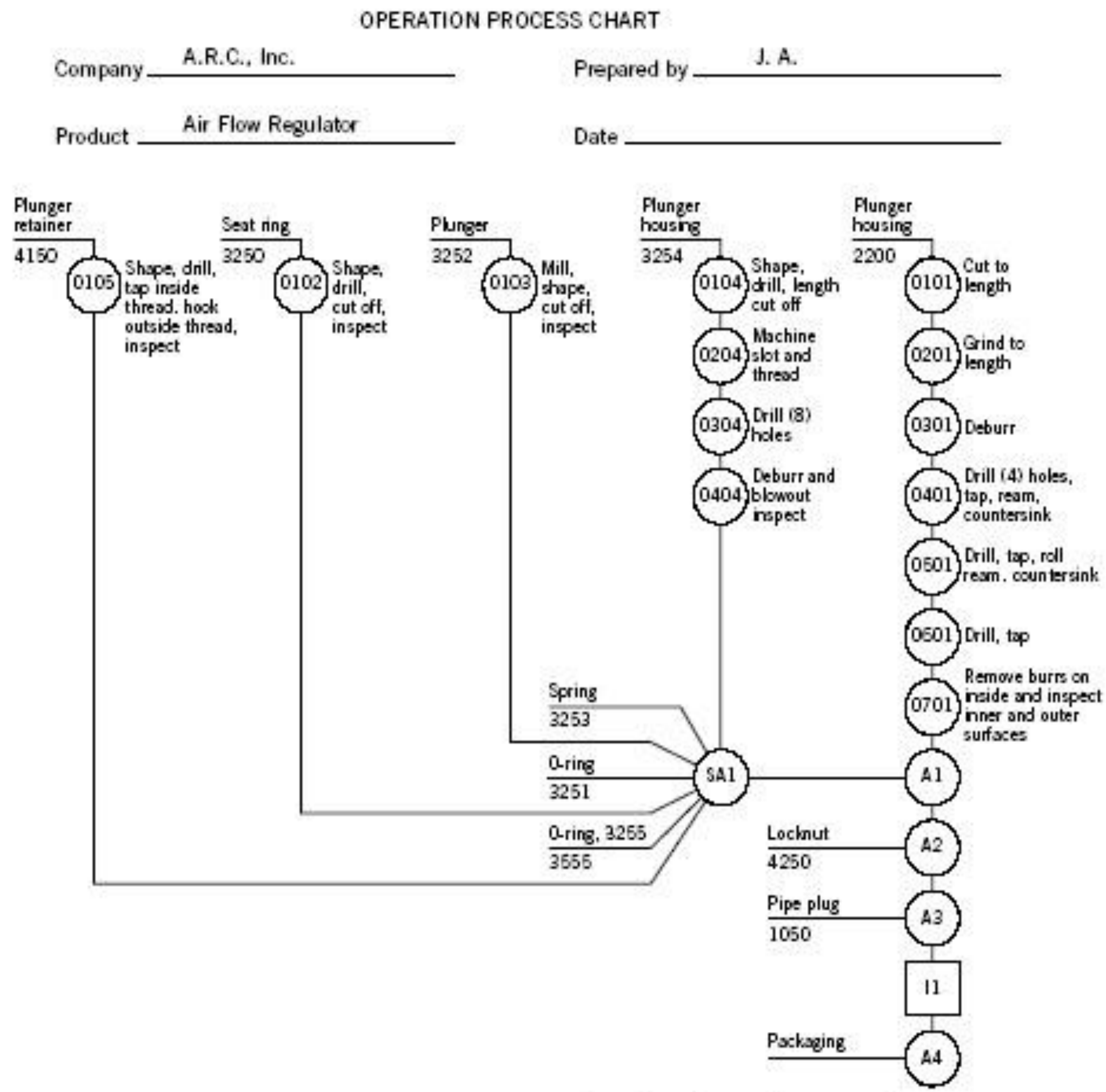



Figure 2.13 Operation process chart for the air flow regulator.

# Process Design – 3. Process Sequencing

## Precedence Diagram

In the operation process charts, it is not clear if two machining operations have any dependency

Observe the part #3254:

- Operations 0204 and 0304 can be done <u>at the same time</u>

- Yet, the operation 0104 should be completed <u>before both</u> 0204 and 0304

We cannot observe this information in operation process charts

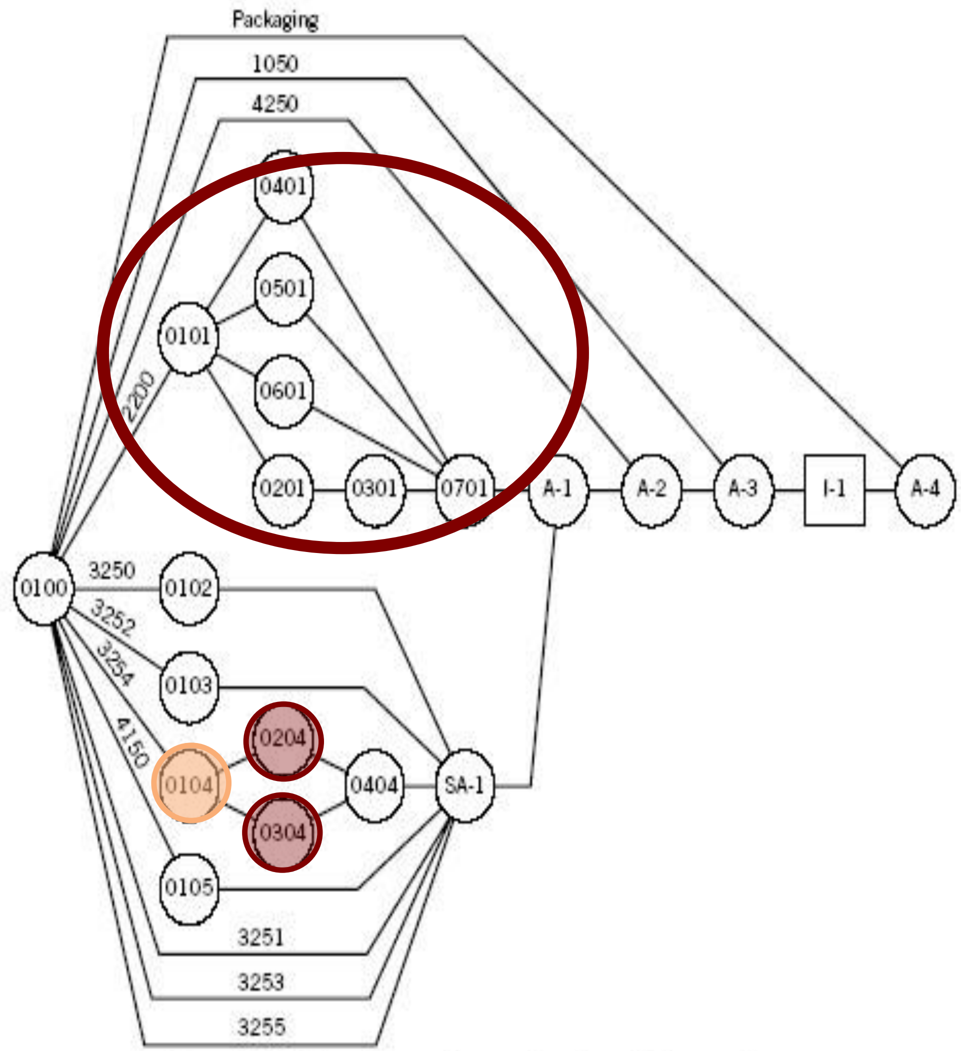
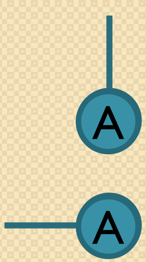


Figure 2.14 Precedence diagram for the air flow regulator.

# Operation process chart

- *Route sheet* provides information on production methods
- *Assembly chart* determines how components are put together
- *Operation process chart* is a combination of route sheet and assembly chart



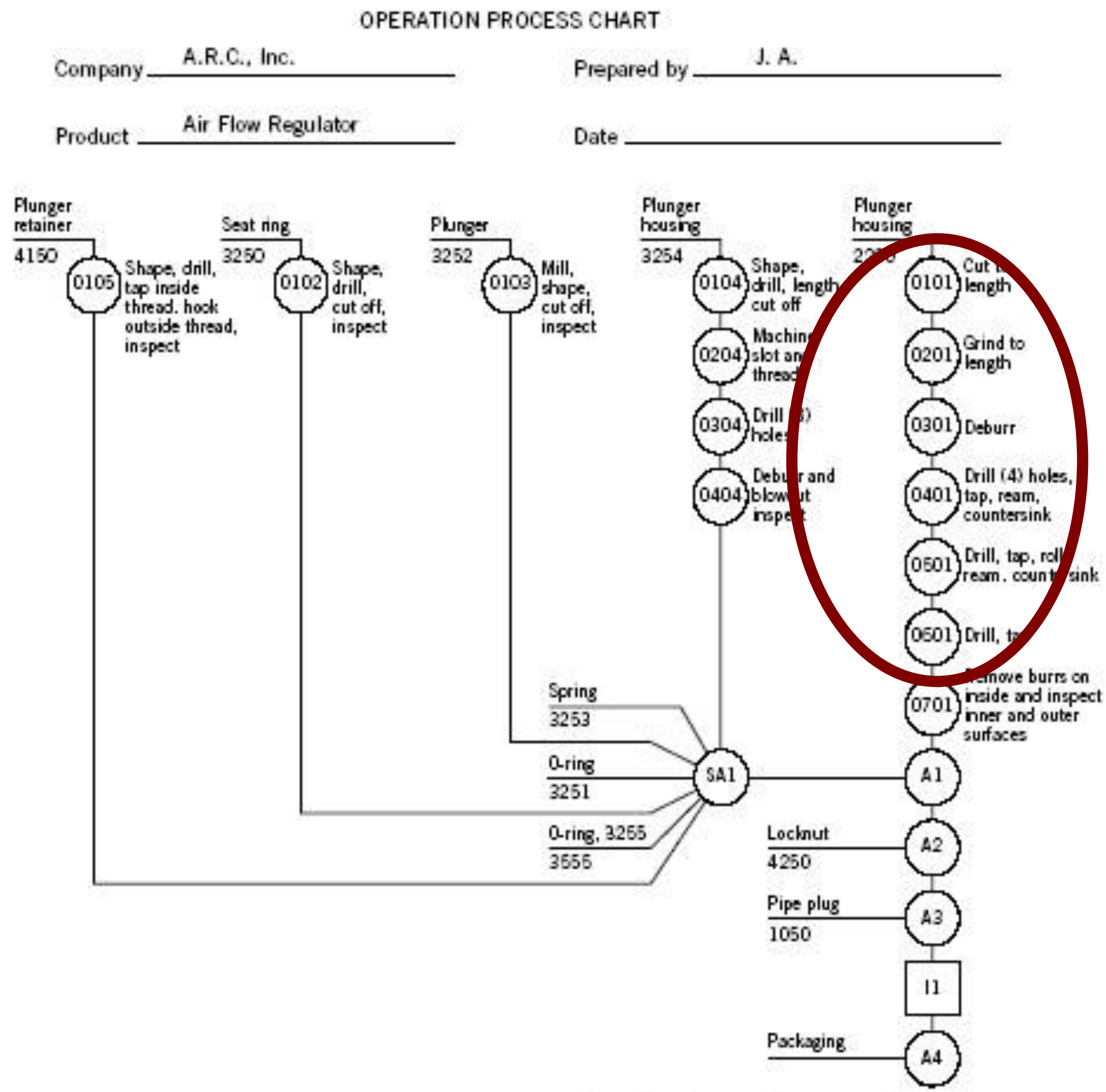




Figure 2.13 Operation process chart for the air flow regulator.

# Schedule design

- Schedule design provides answers to questions involving:
  - Production quantity - *lot size decisions*
  - When to produce - *production scheduling*
  - How long to produce

- Schedule design decisions impact machine selection, number of machines, number of shifts, number of employees, space requirements, storage equipment, material handling equipment, personnel requirements, storage policies, unit load design, building size, etc.

# Schedule design

- We design facilities for major parts and operations
- What do we need to know to start designing our facilities
  - Number of products demanded by the market
  - Number of products to be produced
  - Number of machines required
  - Number of employees required
  - Sequence of operations
  - Relationships between departments

# Schedule design - Marketing information

- Objective – market estimate
- Data from marketing:
  - Production volumes
  - Trends
  - Future demands
- Min information provided by marketing:

Table

| Product or Service | First Year Volume | Second Year Volume | Fifth Year Volume | Tenth Year Volume |
|---|---|---|---|---|
| A | 5000 | 5000 | 8000 | 10,000 |
| B | 8000 | 7500 | 3000 | 0 |
| C | 3500 | 3500 | 3500 | 4,000 |
| D | 0 | 2000 | 3000 | 8,000 |

- Ideal information provided by marketing:

Table 2.3 *Market Analysis Indicating the Stochastic Nature of Future Requirements for Facilities Planning*

| | | First Year | | Second Year | | Fifth Year | | Tenth Year | |
|---|---|---|---|---|---|---|---|---|---|
| Product or Service | Demand State | Probability | Volume | Probability | Volume | Probability | Volume | Probability | Volume |
| A | Pessimistic | .3 | 3000 | .2 | 3500 | .1 | 5500 | .1 | 7,000 |
| | Most likely | .5 | 5000 | .6 | 5500 | .8 | 8000 | .9 | 10,000 |
| | Optimistic | .2 | 6000 | .2 | 6500 | .1 | 9500 | | |
| B | Pessimistic | .1 | 7000 | | | | | | |
| | Most likely | .6 | 8000 | .7 | 7000 | .9 | 3000 | 1.0 | 0 |
| | Optimistic | .3 | 8500 | .3 | 8000 | .1 | 3500 | | |
| C | Pessimistic | .2 | 2000 | .2 | 2000 | .2 | 2000 | .2 | 2,000 |
| | Most likely | .7 | 4000 | .7 | 4000 | .7 | 4000 | .6 | 4,000 |
| | Optimistic | .1 | 4500 | .1 | 4500 | .1 | 4500 | .2 | 5,000 |
| D | Pessimistic | | | .1 | 1500 | .1 | 2500 | .2 | 7,000 |
| | Most likely | 1.0 | 0 | .9 | 2000 | .8 | 3000 | .6 | 8,000 |
| | Optimistic | | | | | .1 | 3500 | .2 | 9,000 |
| Confidence level or degree of certainty | | 90% | | 85% | | 70% | | 59% | |

# Volume-variety chart – Pareto law

- 85% of the production volume is attributed to 15% of the product mix
- Therefore when facilities are designed, top 15% of the items that are produced should be considered the most

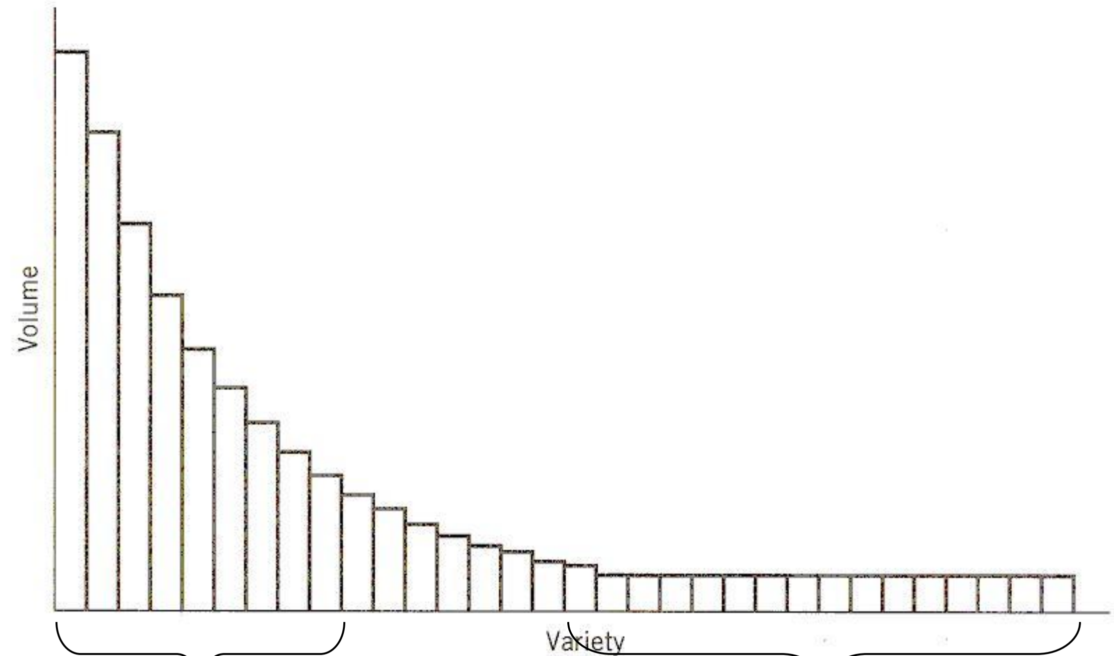



Figure 2.15 Volume-variety chart for a facility where Pareto's law is applicable.

More general items produced everyday:

*Mass production area*

Items that are produced maybe by special orders etc.:

*Job shop area*

# Volume-variety chart – Pareto law does not apply

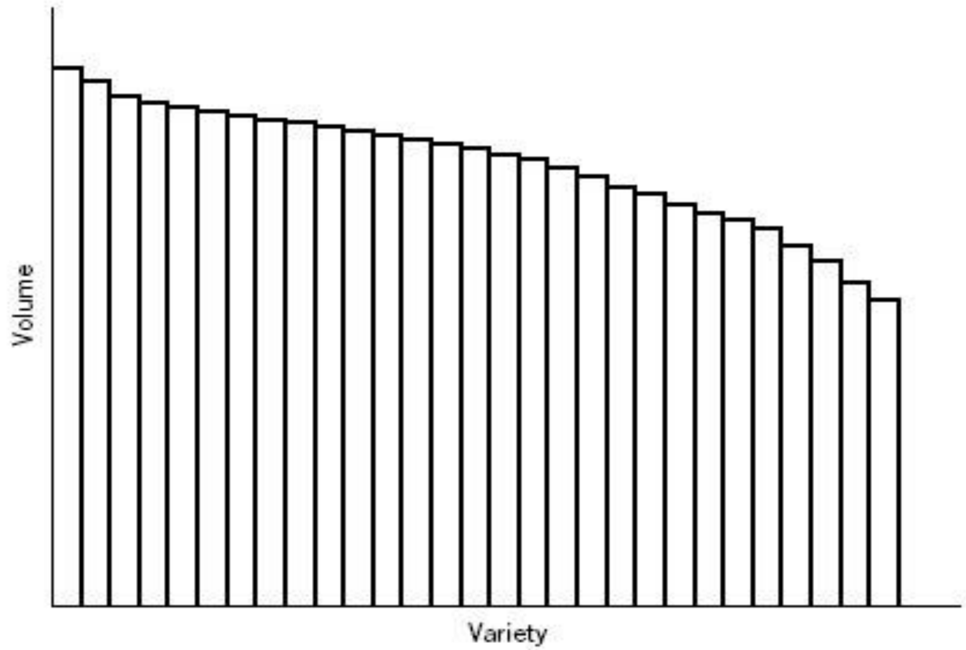



Figure 2.16 Volume-variety chart for a facility where Pareto's law is not applicable.

- If no products dominate the production flow, a general job shop facility is suggested

# Schedule design – Process requirements

- Specification of process requirements has three phases:
  - Determination of the quantity to be manufactured for each component
  - Identification of each equipment required by each operation
  - Overall equipment requirements

# Process requirements – Quantity determination

- *Scrap Estimates*
  - Determination of the quantity to be manufactured for each component
    - For ***high volume*** production
    - The estimation of scrap

- *Reject Allowance Problem*
  - Determination the number of additional units to allow when the number of items to produce are very few and rejects randomly occur
    - For ***low volume*** production
    - The cost of scrap is very high

# Reject allowance problem

- *x*: Number of good units
- *p(x)*: Probability of producing exactly *x* good units
- *Q*: Quantity of production
- *C(Q, x)*: Cost of producing *Q* units, with *x* good units
- *R(Q, x)*: Revenue from producing *Q* units, with *x* good units
- *P(Q, x)*: Profit from producing *Q* units, with *x* good units *P(Q, x)* = *R(Q, x)* - *C(Q, x)*
- *E[P(Q)]*: ***Expected profit*** when *Q* units are produced

$$E\left[P(Q)\right] = \sum_{x=0}^{Q} P(Q, x)\, p(x)$$

$$E\left[P(Q)\right] = \sum_{x=0}^{Q} \left\{R(Q, x) - C(Q, x)\right\} p(x)$$

How do we actually decide Q?

The goal is having exactly **x** units of good items. *No more, no less!*

# Reject allowance problem

$$E[P(Q)] = \sum_{x=0}^{Q} \{R(Q,x) - C(Q,x)\} p(x)$$

- To maximize expected profit, *Q* can be determined by enumerating over various values of *Q*
- For most cost and revenue formulations the equation is a concave function
- ***X*** and **Q** are discrete variables, therefore ***p(X)*** is a discrete probability function
- If ***b*** is the number of defects then probability of each number of defects may be different: P(***b***=1), P(***b***=2) etc.

# Reject Allowance Problem - Problem 1

- 4 castings needed, **no less no more**
- Price=$30,000
- Cost=$15,000
- The probability of casting being good is 90%

➤ How many castings to produce?

➤ Probability of losing money?

- Revenue $$R(Q,x)=\begin{cases} \$0 & x<4 \\ \$30000*4=\$120000 & 4<=x<=Q \end{cases}$$
- Cost $$C(Q,x)=\$15000*Q$$
- Profit $$P(Q,x)=\begin{cases} -15000*Q & x<4 \\ \$120000-15000*Q & 4<=x<=Q \end{cases}$$
- Expected Profit:

$$E[P(Q)]=\sum_{x=0}^{3}(-15000Q)p(x)+\sum_{x=4}^{Q}(120{,}000-15{,}000Q)p(x$$

# Probabilities

- For each Q, the probability associated with each x is different!

- The historical probabilities may be available
- You may need to calculate the values of probability mass function:

$$p(x) = \binom{N}{x} p^{x} (1-p)^{(N-x)}$$

  - Example: Probability of producing only 2 good items when an order size is 10 and when the probability of producing a good item is p = 95%

$$P(2) = \binom{10}{2} 0.95^{2} * (1-0.95)^{(10-2)}$$

# Reject Allowance Problem - Problem 1

## Probability mass function: (p=90%)

| Casting Production | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Good Castings | Probabilities | | | | |
| 0 | 0.0001 | 0.00001 | 0.000001 | 0.0000001 | 0.00000001 |
| 1 | 0.0036 | 0.00045 | 0.000054 | 0.0000063 | 7.2E-07 |
| 2 | 0.0486 | 0.0081 | 0.001215 | 0.0001701 | 0.00002268 |
| 3 | 0.2916 | 0.0729 | 0.01458 | 0.0025515 | 0.00040824 |
| 4 | 0.6561 | 0.32805 | 0.098415 | 0.0229635 | 0.0045927 |
| 5 | 0 | 0.59049 | 0.354294 | 0.1240029 | 0.03306744 |
| 6 | 0 | 0 | 0.531441 | 0.3720087 | 0.14880348 |
| 7 | 0 | 0 | 0 | 0.4782969 | 0.38263752 |
| 8 | 0 | 0 | 0 | 0 | 0.43046721 |
| Total Probability | 1 | 1 | 1 | 1 | 1 |

$$p(x) = \binom{N}{x} p^x (1-p)^{(N-x)}$$

# Reject Allowance Problem - Problem 1

Calculation of net income for combinations of x and Q

$$P(Q,x) = \begin{cases} -15000*Q & x < 4 \\ \$120000 - 15000*Q & 4 <= x <= Q \end{cases}$$

| # Good Castings | Number of Castings Scheduled | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| 0 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 1 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 2 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 3 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 4 | $60,000 | $45,000 | $30,000 | $15,000 |
| 5 | $0 | $45,000 | $30,000 | $15,000 |
| 6 | $0 | $0 | $30,000 | $15,000 |
| 7 | $0 | $0 | $0 | $15,000 |

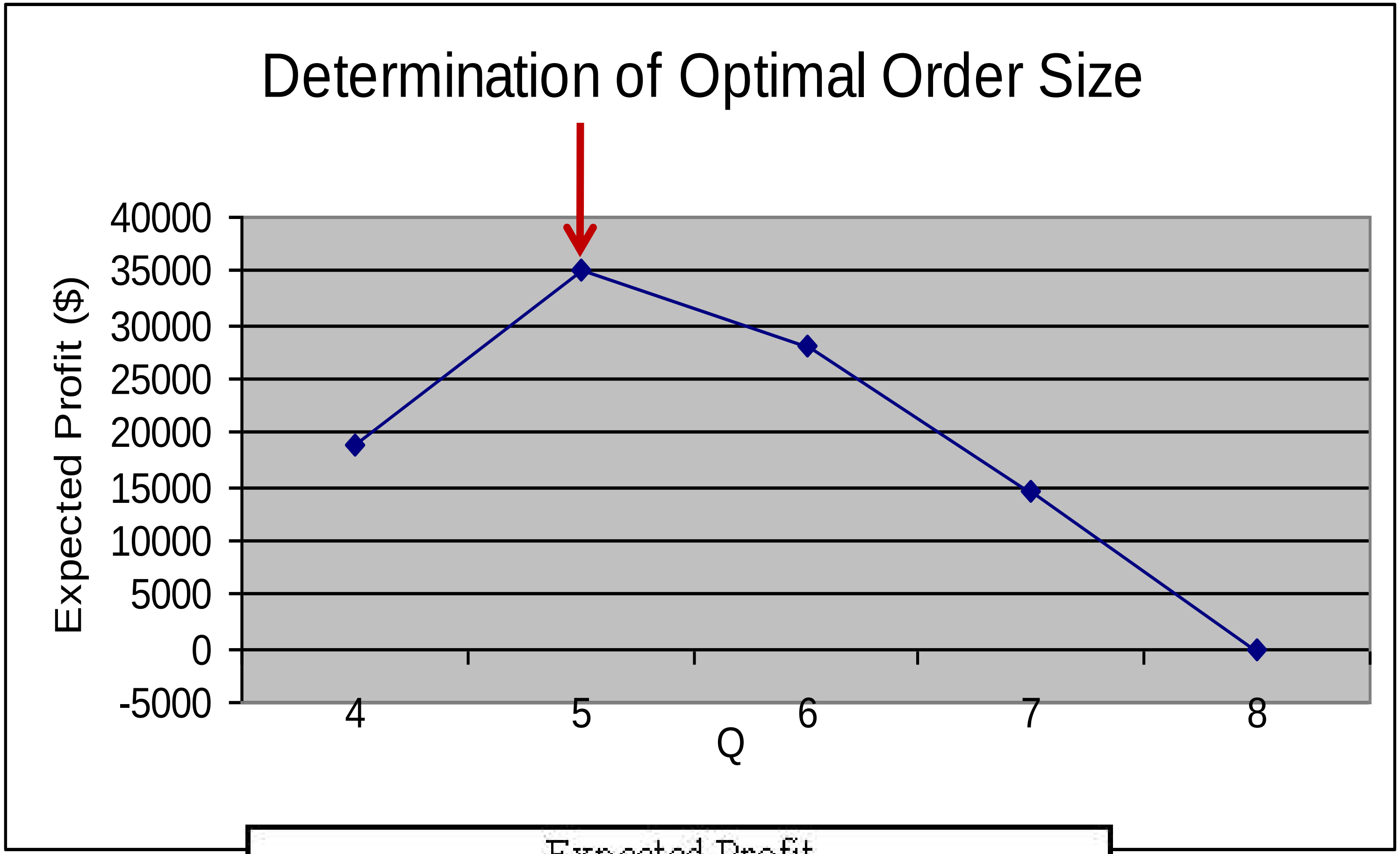
# Reject Allowance Problem - Problem 1

Calculation of expected profits for Q = 4,5,6,7 and 8

$$E[P(Q)] = \sum_{x=0}^{Q} P(Q,x)\,p(x)$$

| Good Castings | P(X) | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|
| | 0 | -6 | -0.75 | -0.09 | -0.0105 | -0.0012 |
| | 1 | -216 | -33.75 | -4.86 | -0.6615 | -0.0864 |
| | 2 | -2916 | -607.5 | -109.35 | -17.8605 | -2.7216 |
| | 3 | -17496 | -5467.5 | -1312.2 | -267.9075 | -48.9888 |
| | 4 | 39366 | 14762.25 | 2952.45 | 344.4525 | 0 |
| | 5 | 0 | 26572.05 | 10628.82 | 1860.0435 | 0 |
| | 6 | 0 | 0 | 15943.23 | 5580.1305 | 0 |
| | 7 | 0 | 0 | 0 | 7174.4535 | 0 |
| | 8 | 0 | 0 | 0 | 0 | 0 |
| E[p] == | | 18732 | 35224.8 | 28098 | 14672.64 | -51.798 |

# Reject Allowance Problem - Problem 1




| Expected Profit<br>Number of Castings Scheduled | | | |
|---|---|---|---|
| 4 | 5 | 6 | 7 |
| $18,732 | **$35,225** | $28,098 | $14,673 |

# Reject Allowance Problem - Problem 1

- Probability of losing money (if Q=5)?
- The probability of losing money on the transaction is the probability of the net income being negative when *Q* equals 5.

# Reject Allowance Problem - Problem 1

Calculation of net income for combinations of x and Q

| # Good Castings | Number of Castings Scheduled | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| 0 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 1 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 2 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 3 | -$60,000 | -$75,000 | -$90,000 | -$105,000 |
| 4 | $60,000 | $45,000 | $30,000 | $15,000 |
| 5 | $0 | $45,000 | $30,000 | $15,000 |
| 6 | $0 | $0 | $30,000 | $15,000 |
| 7 | $0 | $0 | $0 | $15,000 |

A negative net cash flow occurs if less than 4 good castings are produced.

# Reject Allowance Problem - Problem 1

- The probability of losing money on the transaction is the probability of the net income being negative when *Q* equals 5.
- A negative net cash flow occurs if less than 4 good castings are produced.

| Cating Production | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Good Castings | Probabilities | | | | |
| 0 | 0.0001 | 0.00001 | 0.000001 | 0.0000001 | 0.00000001 |
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| 8 | 0 | 0 | 0 | 0 | 0.43046721 |
| Total Probability | 1 | 1 | 1 | 1 | 1 |

- The probability of producing less than 4 good castings equals:

$0.00001 + 0.00045 + 0.0081 + 0.0729 = 0.0816$

# Problem 2:

- 20 castings are needed (*no more, no less*)
- C = $1100/unit
- Price = $2500
- Recycling Value = $200
- Q=? If maximizing expected profit

$$R(Q,x)=\begin{cases} \$200Q & x<20 \\ \$2500*20+(Q-20)*200 & x>=20 \end{cases}$$

$$C(Q,x)=\$1100*Q$$

$$P(Q,x)=\begin{cases} (200-1100)*Q & x<20 \\ [\$2500*20+(Q-20)*200]-1100*Q & x>=20 \end{cases}$$

$$E[P(Q)]=\sum_{x=0}^{19}-900Q*p(x)+\sum_{x=20}^{Q}(50{,}000+200Q-4000-1100Q)p(x)$$

$$=\sum_{x=0}^{19}-900Q*p(x)+\sum_{x=20}^{Q}(46{,}000-900Q)p(x)$$

# Reject allowance problem – Problem 2

$$E[P(Q)] = \sum_{x=0}^{19} -900Q * p(x) + \sum_{x=20}^{Q} (46{,}000 - 900Q) p(x)$$

$$E[P(Q)] = -900Q + 46{,}000 \sum_{x=20}^{Q} p(x)$$

- First determine the Expected profit for a chosen Q
- Perform the same procedure for a new Q value
- When the profit starts decreasing you have found your solution

- For each Q, the probability associated with each x is different!

Historical probability distributions for the number of good products out of $Q$

| # Good Castings ($x$) | Number of Castings Produced ($Q$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 12 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 16 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 19 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 | 0.00 |
| 20 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 |
| 21 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 |
| 22 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 | 0.05 |
| 23 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 | 0.05 |
| 24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 | 0.05 |
| 25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 | 0.05 |
| 26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 | 0.10 |
| 27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 | 0.10 |
| 28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 | 0.15 |
| 29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.20 |
| 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |

## ***P(Q,x):*** Calculation of net income for combinations of x and Q

$$P(Q,x) = \begin{cases} -900 * Q & x < 20 \\ 46000 - (900 * Q) & x >= 20 \end{cases}$$

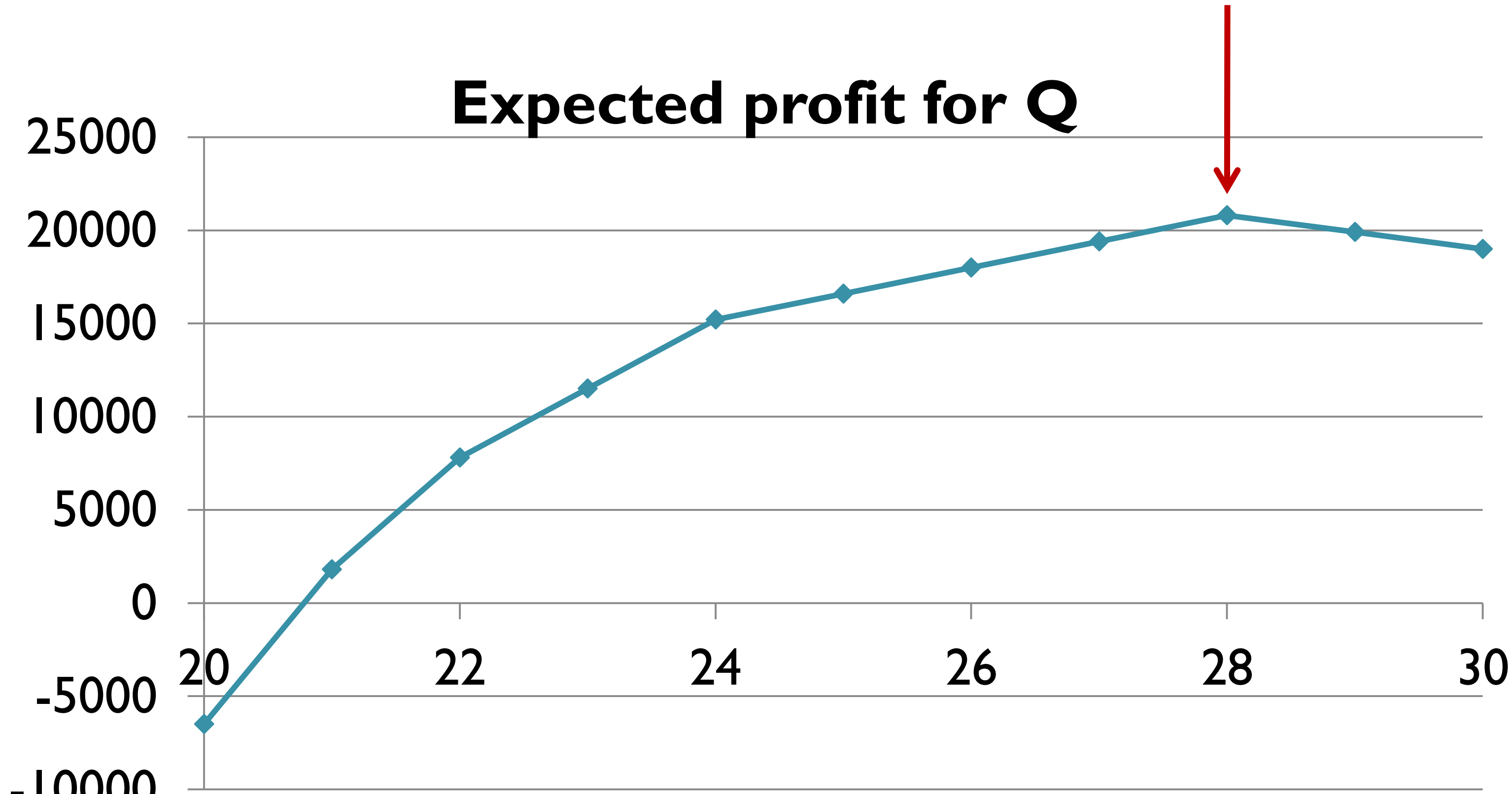
Table 2.7 *Profit from Producing Q Castings, with Exactly x Being Good*

| # of Good Castings | Number of Castings Produced (Q) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 12 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 13 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 14 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 15 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 16 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 17 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 18 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 19 | –18,000 | –18,900 | –19,800 | –20,700 | –21,600 | –22,500 | –23,400 | –24,300 | –25,200 | –26,100 | –27,000 |
| 20 | 28,000 | 27,100 | 26,200 | 25,300 | 24,400 | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 21 | | 27,100 | 26,200 | 25,300 | 24,400 | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 22 | | | 26,200 | 25,300 | 24,400 | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 23 | | | | 25,300 | 24,400 | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 24 | | | | | 24,400 | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 25 | | | | | | 23,500 | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 26 | | | | | | | 22,600 | 21,700 | 20,800 | 19,900 | 19,000 |
| 27 | | | | | | | | 21,700 | 20,800 | 19,900 | 19,000 |
| 28 | | | | | | | | | 20,800 | 19,900 | 19,000 |
| 29 | | | | | | | | | | 19,900 | 19,000 |
| 30 | | | | | | | | | | | 19,000 |

# Reject allowance problem – Problem 2

Table 2.8 *Expected Profit from Producing Q Castings*

| Number of Castings Produced (Q) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| –6,500 | 1,800 | 7,800 | 11,500 | 15,200 | 16,600 | 18,000 | 19,400 | 20,800 | 19,900 | 19,000 |



# Next lecture

- High volume production: Scrap estimates
- Equipment fractions
- Machine assignment problem
- Facility planning