# Problem 02

## What is the Right Price?

E213 – Engineering Cost Decisions

SCHOOL OF ENGINEERING

# Module Coverage: Topic Tree

## E213 – Engineering Cost Decisions

- Cost Allocation and Estimation
  - Activity Based Costing method
  - Cost Estimation techniques
- Concept of Equivalence
  - Single payment
  - Uniform series and uniform gradient
- Project Evaluation
  - Single Project Evaluation
    - MARR & EW Method
    - IRR& ERR
  - Multiple Projects Comparison
    - Project life = study period
      - Payback method
    - Project life ! = study period
      - Repeatability/Co-terminated Assumption
    - Public Project Evaluation
      - B/C Ratio Approach
- Depreciation and Tax
  - depreciation
  - Tax
- Replacement Analysis
- Sensitivity Analysis

# Estimating Techniques (Models)

- Estimating techniques (models), together with detailed cost and revenue data, are used to develop individual cash flow estimates and net cash flow for each alternative.
- It is impossible to produce exact data about the future.
- The estimations are expected to be inexact, but it should be adequate to suit the need at reasonable cost
- Cost and revenue estimates can be classified according to the details, accuracy, and their intended use as follows:
  - ➢ Order of magnitude estimates
    - ✓ used mainly in planning and initial evaluation stage
  - ➢ Semi-detailed or budget estimates
    - ✓ used in the preliminary or conceptual design stage
  - ➢ Definitive (detailed) estimates
    - ✓ used in the detailed engineering / construction stage

# Estimating Techniques (Models)

- The common estimating models:
  - Indexes
  - Unit
  - Factor
  - Power Sizing
  - Parametric: Learning Curve
- These estimating models are useful for:
  - Order-of-magnitude estimates, semi-detailed or budget estimates
  - Initial selection of feasible alternatives for further analysis
  - Conceptual / preliminary design phase of a project
- The level of detail will depend upon the accuracy of the model's data

# Estimating Model: Indexes

- Index is a dimensionless number that indicates how a cost or price has changed with time, referencing to a base year.
- Provides a convenient means of developing cost and price estimates from historical data

$$C_n = C_k \left( \frac{I_n}{I_k} \right)$$

Where $I_k$ = index for some base year $k$
$I_n$ = index for some current year $n$
$C_n$ = estimated cost or price of item in year $n$
$C_k$ = cost or price of item in year $k$

<u>Example</u>:

Your parents complained about the price of food lately. Given that the price they paid for a plate of noodle in year 1990 was \$1.50 when the Consumer Price Index (Food) had a value of 43.9, in year 2000, the index had a value of 87.8. What was the approximate cost of the same plate of noodle in year 2000?

$C_{2000}$ = \$1.50 (87.8 / 43.9)
= \$3

# Estimating Model: Unit Technique

- This technique involves using a “per unit factor” that can be estimated effectively.
- Examples: fuel cost per km, annual savings per 500 operating hours or revenue per customer served
- Such factors, when multiplied by the appropriate unit, will give a total estimate of cost savings or revenue
- Useful for preliminary estimating purposes
- Cautious that such average values can be misleading

Example:

Given that a semi-detached house is approximately 350 square meters, estimate the cost using a factor of $5,500 per square meter.

*$5,500 x 350 = $1,925,000*

# Estimating Model: Factor Technique

- Factor Technique is an extension of the Unit Technique.
- Sums the product of several quantities or components and adds these to any components estimates directly.

$$C = \sum_{d} C_d + \sum_{m} f_m U_m$$

Where

- $C$ = cost being estimated
- $C_d$ = cost of the selected component d that is estimated directly
- $f_m$ = cost per unit of component m
- $U_m$ = number of units of component m

Example:

Estimate the cost of a house consisting of **120 square meters, two porches and a garage**. Using a factor of **$4,000 per square meter**, **$4,000 per porch** and **$6,000 per garage** for the two directly estimated components.

The total estimate cost will be:

($4,000 x 120) + ($4,000 x 2) + $6,000 = $494,000

# Estimating Model: Power Sizing Technique

- The power-sizing technique is frequently used for **estimating capital investment for industrial plants and equipment.**
- It is also known as exponential model
- It assumes that cost varies as some power of change in capacity or size

$$\frac{C_A}{C_B} = \left(\frac{S_A}{S_B}\right)^X ,$$

$$C_A = C_B \left(\frac{S_A}{S_B}\right)^X ,$$

where

$$\left.\begin{aligned} C_A &= \text{cost for plant A} \\ C_B &= \text{cost for plant B} \end{aligned}\right\} \quad \text{(both in \$ as of the point in time for which the estimate is desired)}$$

$$\left.\begin{aligned} S_A &= \text{size of plant A} \\ S_B &= \text{size of plant B} \end{aligned}\right\} \quad \text{(both in same physical units)}$$

$X$ = *cost-capacity factor* to reflect economies of scale.*

# Estimating Model: Power Sizing Technique

**Example**

Peter wanted to make a preliminary estimate of the cost to build a 600-MW solar power plant. It is known that a 200-MW plant cost \$100 million. The power-sizing factor is 0.79.

Estimated cost of a 600-MW plant

$= \$100 \text{ million} \times (600/200)^{0.79}$

$= \$238 \text{ million}$

# Parametric Cost Estimating

- Parametric cost estimating is the use of historical cost data and statistical techniques to predict future costs

- A *Cost Estimating Relationship* (CER) relates the cost or price of an item to a number of independent variables or cost drivers

- Used in early design stages to estimate cost, especially where little data is available

- Statistical techniques may be used to develop CERs. For example, simple linear regression and multiple linear regression

# Parametric - Learning Curve Model

- A learning curve models the increased worker efficiency and improved organizational performance with ***repetitive*** production of a good or service
- Learning curve is also known as experience curve or a manufacturing progress function
- Most common learning curves assume a ***constant percentage reduction*** in, say, labour hours, as the number of units produced is ***doubled***.

In general $Z_u = K\,s^a$ and $u = 2^a$ for $a = 0,1,2,3,\ldots$

where $u$ = the output unit number
$Z_u$ = the quantity of input resources need to produce $u^{th}$ unit of output.
$K$ = the quantity of input resources needed to produce the first output unit.
$s$ = the learning curve slope parameter expressed as a decimal.

Taking logs of the both equations,

$$\log Z_u = \log K + a \log s \qquad \text{and} \qquad a = \log u / \log 2$$

Hence

$$\begin{aligned} \log Z_u &= \log K + (\log u / \log 2)\ \log s \\ &= \log K + \log u\ (\log s / \log 2) \\ &= \log K + n \log u \qquad \text{where } n = \log s / \log 2 \\ &= \log K u^n \end{aligned}$$

$$\Rightarrow \qquad Z_u = K u^n$$

# Cost Estimation in the Design Process

- The price of a product may be determined by two approaches:
  - ➢ Bottom-up (cost-based) approach

    Also known as design-to-price

    ***Selling price = Total unit product cost + Profit Margin***
  - ➢ Top-down (target costing) approach

    ***Selling price*** determined by:

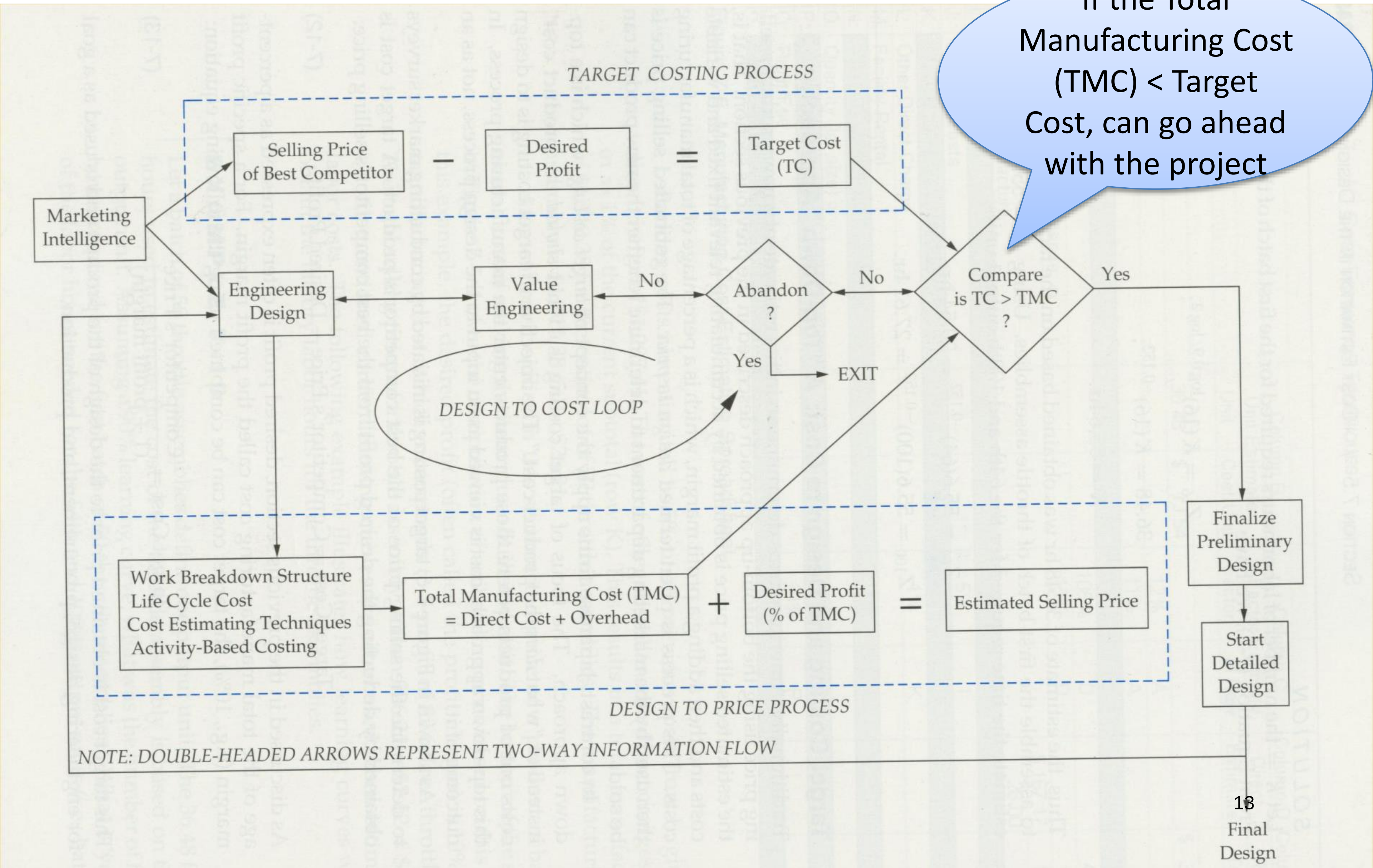
    ✓ Market research

    ✓ Competitor's price

    Target cost of product = ***Price / (1 + m)***

    Where *m* = profit margin expressed as a fraction

# The Concept of Target Costing and its Relationship to Design




If the Total Manufacturing Cost (TMC) < Target Cost, can go ahead with the project

# Problem 02

## - Suggested Solution

# Learning Curve (Assembly Time)

- Estimate Total Direct Labour Hours:
  **Total direct labor time**
  **= Testing Time + Assembly time**

- A 94% learning curve for assembly time

  - K = 3.8 hour; s = 0.94
  - n = log 0.94 / log 2 = - 0.0893
  - Time to assemble all 100 units

$$= (3.8) \sum_{u=1}^{100} u^{-0.0893} \; *$$

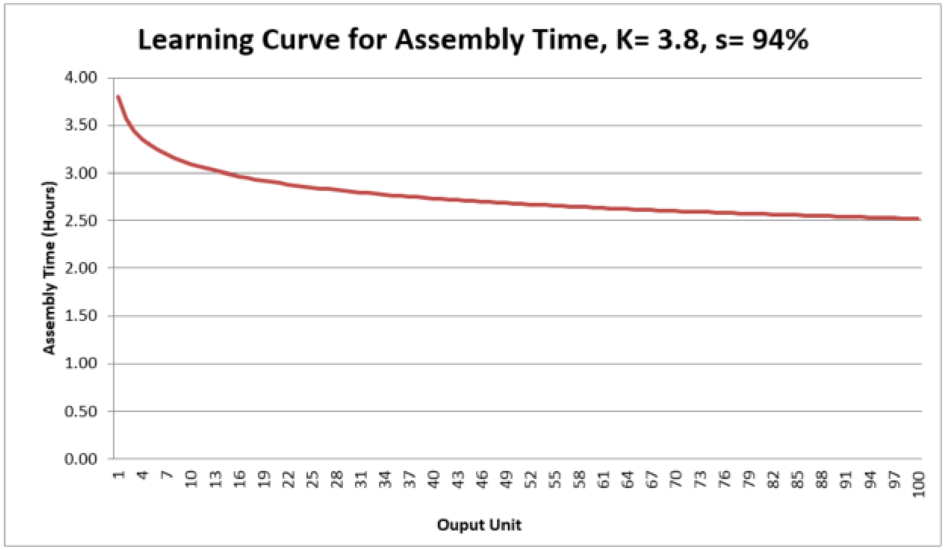
$$= (3.8)\,(1^{-0.0893} + 2^{-0.0893} + \ldots + 100^{-0.0893})$$

**= 275.62 hours**

* Note:
"∑" = summation symbol

- Testing time
  = 1.5 x 100
  = **150 hours**

- Total direct labour hours
  = 275.62 + 150
  = **425.62 hours**




| Learning Curve % | | 0.94 |
|---|---|---|
| n | | -0.089267338 |
| Unit | Assembly Time (Hours) ($Ku^n$) | |
| 1 | 3.80 | |
| 2 | 3.57 | |
| 3 | 3.45 | |
| 4 | 3.36 | |
| ... | ... | |
| 98 | 2.52 | |
| 99 | 2.52 | |
| 100 | 2.52 | |
| Total | 275.62 | |

# Cost Estimation

Using Excel worksheet, the total unit product cost = $1007.57 per unit

| Direct Materials | Unit Cost ($) |
|---|---|
| Chasis and structures | 85 |
| Motors and movement mechanisms | 100 |
| Printhead and heated bed assemblies | 250 |
| Mother Board and Sensors | 100 |
| **Total Direct Material Cost** | 535 |

| Direct Labour | Time Taken per Units (Hours) |
|---|---|
| **Testing Time** | 1.5 |
| **Assembly Time** | 2.76 |
| **Total Direct Labour Time** | 4.26 |
| **Total Direct Labour Cost** | 44.69 |

| | |
|---|---|
| **Overhead Cost ($)** | $140 |
| **Cost Per unit** | 719.69 |
| **Profit (40%)** | 287.88 |
| **Selling Price** | **$1,007.57** |

Sum of total direct material, direct labor and overhead cost.

Selling price to achieve 40% profit.

= $719.69*40%

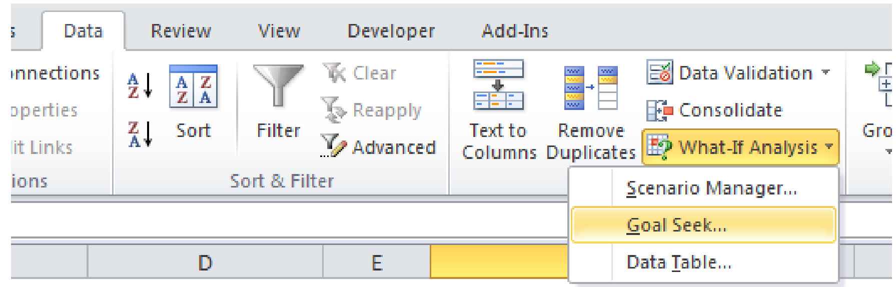
Greater than $950

# Target Costing

- The target selling price of 1 unit of 3D printer: $950
- With a profit margin of 40%, the target cost will be:
  - Target cost = $950/1.40 = $678.57 <  $719.69
- One of the solutions is to reduce the cost of the major cost driver:
  - Printhead and heated bed assemblies

The following slides show that the target price of $950 can be reached if the cost for Printhead and heated bed assemblies can be reduced to $208.88 (use MS Excel Tools → Goal Seek).

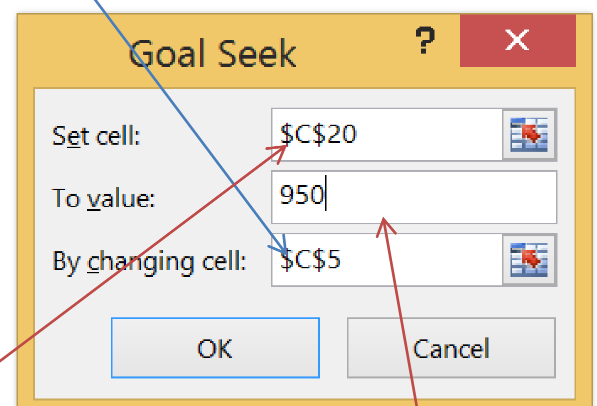
# Target Costing (Using Goal Seek)




| Direct Materials | Unit Cost ($) |
|---|---|
| Chasis and structures | 85 |
| Motors and movement mechanisms | 100 |
| Printhead and heated bed assemblies | 250 |
| Mother Board and Sensors | 100 |
| **Total Direct Material Cost** | 535 |

| | |
|---|---|
| **Total Number of Camera (Unit)** | **100** |
| **Labour Cost/Hour ($)** | **$10.5** |
| **Testing Time (Hour/Unit)** | **1.5** |
| **Overhead Cost** | **$14,000** |
| **Profit Margin** | **40%** |

| **Direct Labour** | **Time Taken per Units (Hours)** |
|---|---|
| **Testing Time** | 1.5 |
| **Assembly Time** | 2.76 |
| **Total Direct Labour Time** | 4.26 |
| **Total Direct Labour Cost** | 44.69 |
| **Overhead Cost ($)** | $140 |
| **Cost Per unit** | 719.69 |
| **Profit (40%)** | 287.88 |
| **Selling Price** | **$1,007.57** |




Target value

# Target Costing (Reduce Cost of Direct Materials)

| Direct Materials | Unit Cost ($) |
|---|---|
| Chasis and structures | 85 |
| Motors and movement mechanisms | 100 |
| Printhead and heated bed assemblies | 208.8815363 |
| Mother Board and Sensors | 100 |
| **Total Direct Material Cost** | 493.8815363 |

| Direct Labour | Time Taken per Units (Hours) |
|---|---|
| **Testing Time** | 1.5 |
| **Assembly Time** | 2.76 |
| **Total Direct Labour Time** | 4.26 |
| **Total Direct Labour Cost** | 44.69 |

| | |
|---|---|
| **Overhead Cost ($)** | $140 |

| | |
|---|---|
| **Cost Per unit** | 678.57 |

| | |
|---|---|
| **Profit (40%)** | 271.43 |
| **Selling Price** | **$950.00** |

By reducing the cost of Printhead and heated bed assemblies to $208.88, the target price of 1 unit of 3D printer can meet $950.

# Learning Objectives

- Apply common cost estimation models (indexes, unit technique, factor technique and power sizing) for cost estimation.
- Describe the characteristics of parametric cost estimating.
- Develop parametric cost estimating relationships using power-sizing technique or the learning curve.
- Apply the learning curve model.
- Employ the two approaches (bottom-up and top-down) of cost estimation in the Design Process.
- Construct a cost estimation model using Microsoft Excel spreadsheet.

# E213 Engineering Cost Decisions (Topic Flow)

Today's learning

- Application of ABC costing method in cost management
- Application of different cost estimating techniques
- Comparison of alternatives using the concept of equivalence
- Alternatives evaluation using single, uniform series and uniform gradient cash flows
- Project evaluation using MARR and Equivalent Worth method
- Project evaluation based on Internal Rate of Return and External Rate of Return
- Evaluate alternatives of equal life spans using payback method
- Evaluate alternatives with different life spans
- Evaluate public projects through incremental B/C analysis
- Depreciation estimation and consideration in economic analysis
- Tax consideration in economic analysis
- Replacement analysis application
- Risk and uncertainties handling in economic analysis