Queen Mary University of London

EBU5608 Product Development and Management

Topic 11 – Design for Manufacturing

Agenda

- Design for manufacturing
- Understanding manufacturing costs
- Design for assembly

Queen Mary University of London

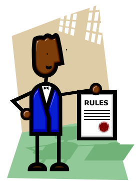
Design for X Topics

- Design for Manufacturing
- Design for Production
- Design for Assembly
- Design for Recycling/Disposal
- Design for Life Cycle
- Design for Environment

Queen Mary
University of London

Design for Manufacturing (DFM)

- DFM is a **design strategy** that requires
  - the expertise of **multiple** team members
  - the use of basic design **rules**, **guidelines**, and **cost** models

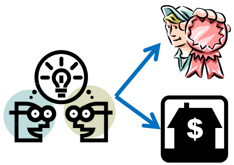


Design for Manufacturing (DFM)

- DFM often **results** in
  - significant **cost** reduction
  - improvement in product **quality**
  - the development of cross-functional **expertise** within the organisation


Focus on manufacturability

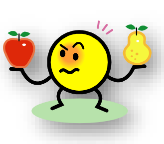
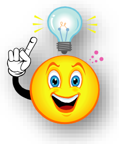
- Focussing on how a product can be manufactured helps the design team to find **solutions** to these design **issues**:
  - Detailed **design** decisions can have substantial impact on product **quality** and **cost**
  - Development teams face **multiple**, and often **conflicting**, **goals**



Queen Mary
University of London

Focus on manufacturability (cont.)

- It is important to have **metrics** with which to compare **alternative** designs
- Dramatic **improvements** often require substantial creative efforts **early** in the process
- A **well-defined** method helps the decision-making process


Queen Mary
University of London

Manufacturing cost

- Manufacturing cost has a major effect on the **economic success** of a product
- An organisation wants to ensure it obtains the **highest profit** margin possible and therefore tries to identify the **lowest manufacturing** cost
- Economically successful design is about ensuring high product **quality** while minimising manufacturing **cost**

Price

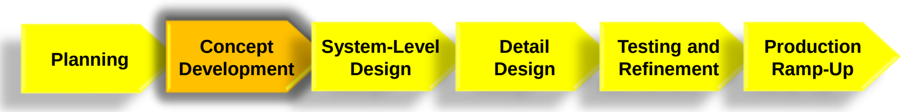
Cost

Design for Manufacturing (DFM)

- Design for manufacturing (DFM) is one way of achieving this goal
- **Effective** DFM practice leads to low manufacturing costs without sacrificing product quality
- DFM is only effective if the **cross-functional team** is effective

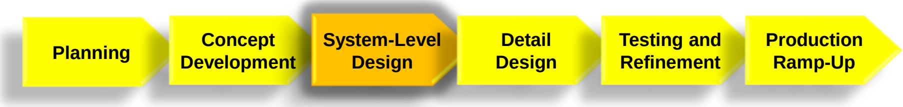
Design for Manufacturing (DFM) and the phases

- DFM begins during **Phase 1 - Concept Development** - when the products’ **functions** and **specifications** are being determined
- When **choosing** a product concept, **cost** is almost always one of the criteria on which the decision is made



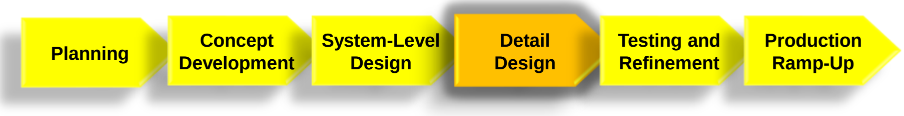
Design for Manufacturing (DFM) and the phases (cont.)

- During **Phase 2 – System-level design** - the team makes decisions about how to break up the product into **individual components**
- These decisions are largely based on the expected **cost** and **manufacturing complexity** implications



Design for Manufacturing (DFM) and the phases (cont.)

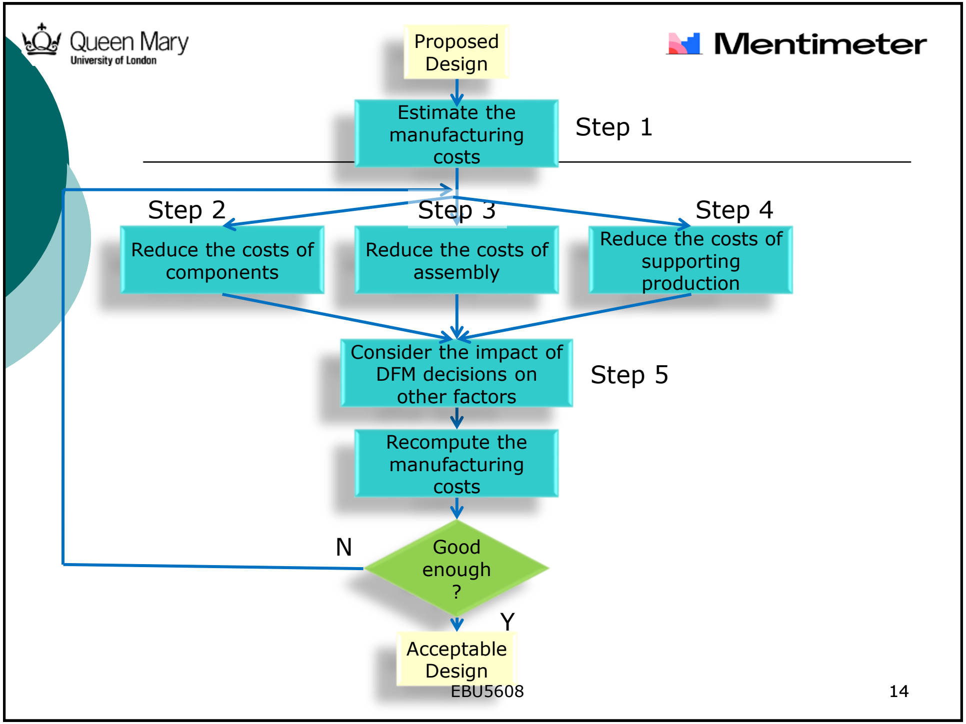
- **Accurate** cost estimates become available during **Phase 3 – Detail Design**
- At this point, many more decisions are driven by consideration of **how** the product will be **manufactured**



Queen Mary
University of London

Design for Manufacturing (DFM) - the 5-step process

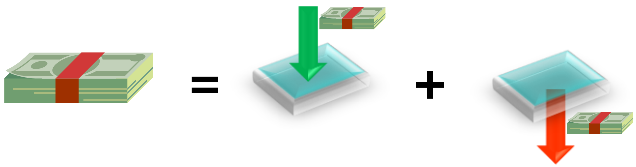
- Ulrich and Eppinger propose a DFM method with **five steps**
  - plus interactions
- This is shown on the next slide


Queen Mary
University of London
Mentimeter
Proposed Design
Estimate the manufacturing costs
Step 1
Step 2
Step 3
Step 4
Reduce the costs of components
Reduce the costs of assembly
Reduce the costs of supporting production
Consider the impact of DFM decisions on other factors
Step 5
Recompute the manufacturing costs
Good enough ?
N
Y
Acceptable Design
EBU5608
14

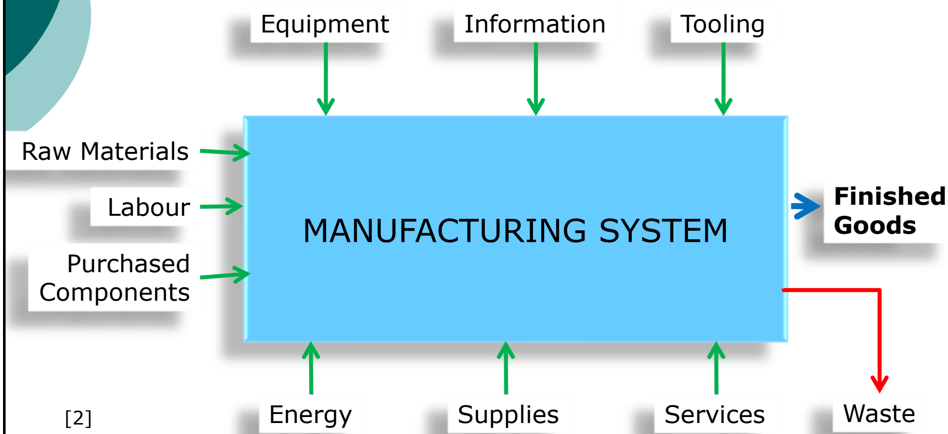
14

Step 1 - Estimate the manufacturing costs

- The manufacturing cost is the **sum** of
  - all of the expenditures for the **inputs** of the system
  - plus the expenditures for **disposal of the wastes** produced by the system



Step 1 - Estimate the manufacturing costs



[2]

Queen Mary
University of London

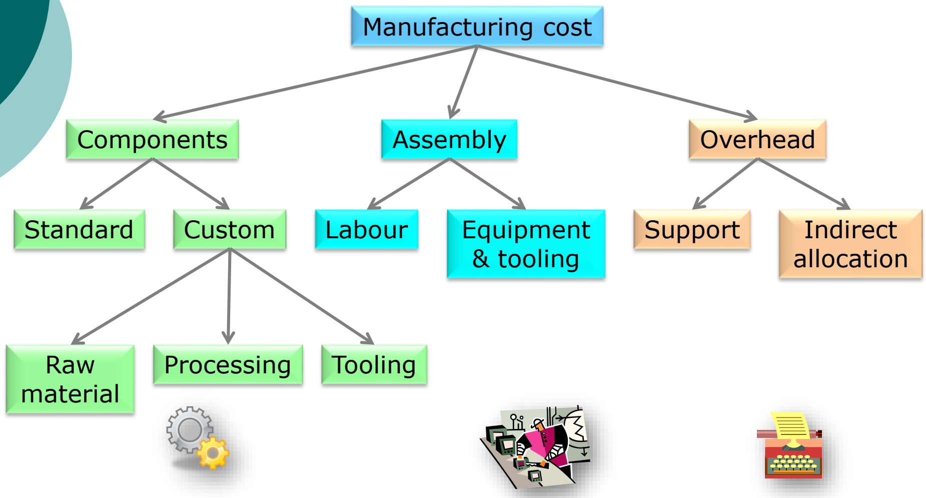
Unit manufacturing cost

- The '**unit manufacturing cost**' is
  - the **total manufacturing costs** for a time period (usually a quarter or a year)
  - **divided** by
  - the **number of units** of the product manufactured during that period
- In other words – 'how much it costs to make each unit'!

Manufacturing cost categories

- There are three categories of costs which make up manufacturing costs:
  - Component costs
  - Assembly costs
  - Overhead costs
  - These are shown in more detail on the next slide

Understanding manufacturing costs



Understanding manufacturing costs – component costs

- **Component costs**, include
  - **standard parts** from suppliers
    - e.g. motors, switches, electronic chips etc.
  - **custom components** from suppliers
    - made according to the manufacturer’s design from raw materials, such as sheet steel

Understanding manufacturing costs – assembly costs

- **Assembly costs (labour, equipment & tooling)**
  - Goods are generally **assembled** from parts
  - This process of assembly incurs **labour** and **equipment/tooling** costs

Queen Mary
University of London

Understanding manufacturing costs – overhead costs

- **Overhead costs**
  - Overhead is the category used to cover all of the other costs
  - There are two types of overhead cost
    1. Support costs
    2. Indirect allocations

Understanding manufacturing costs – overhead costs (contd)

1. **Support costs**
   - These are the costs associated with materials handling, quality assurance, purchasing, shipping, receiving, etc
   - These are the support systems associated with **manufacture of the product**
     - these costs greatly depend on the **product design**

Understanding manufacturing costs – overhead costs (contd)

2. **Indirect allocations**
   - The costs of manufacturing that **cannot** be directly linked to a particular product but which must be paid for to be in business
     - e.g. the salary of a security guard or the cost of building maintenance
   - Indirect costs are **not** specifically linked to the **design** of the product
     - they are therefore are **not** relevant to **DFM** (although they do contribute to the cost of the product)

Queen Mary
University of London

Estimating costs

Queen Mary
University of London

Estimating the costs of standard components

- This can be done in one of two ways:
  - **Comparing** each part to a substantially **similar** part the firm is already producing or purchasing in comparable volume
  - Asking for **price quotes** from vendors or suppliers

$
$$
$$$

Estimating the costs of standard components (cont.)

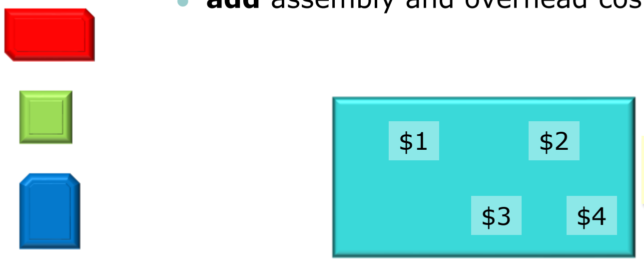
- The cost per unit will generally **reduce** if a **greater number** of units is purchased from a supplier
  - This should be considered when designing the product
- **Standardised** components can lead to
  - the requirement for a **larger number** of units from the supplier
  - and therefore a **reduction** in overall **cost**

Estimating the costs of custom parts

- When the custom component is a **single** part, we estimate its cost by adding up the costs of
  - raw materials
  - processing
  - tooling

Estimating the costs of custom parts

- Where the custom component is actually an **assembly** of **several parts**, then we consider it a "product"
- To arrive at the cost of this "product" we
  - estimate the cost of **each** subcomponent, and then
  - **add** assembly and overhead costs



Product cost = $1+$2+$3+$4=$10

Fixed Costs vs. Variable Costs

- **Fixed Costs** – incurred in a predetermined amount, regardless of number of units produced (i.e. setting up the factory work area or cost of an injection mold)
- **Variable Costs** – incurred in direct proportion to the number of units produced (i.e. cost of raw materials)

Queen Mary
University of London

Estimating the cost of assembly

- Manual assembly costs can be **estimated** by
  - summing the estimated **time** of each assembly operation and
  - multiplying by a **labour** rate
- An **example** can be seen in the next slide

Example of the calculation for cost of assembly

- This is the assembly of an **inlet system** which is part of a car engine
- The system is **made** up of
  - a valve – a metal casting that can block the inlet
  - O-rings – to seal gaps
  - a spring – to release the valve
  - a cover – for the whole assembly
- **Assembly** time includes
  - **Handling** time – e.g. picking up the components
  - **Insertion** time – e.g. joining the components together

[4]

Queen Mary
University of London

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)

Queen Mary University of London

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00

1.50+1.50

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00
O-rings	2	2.25	4.00	12.50

2x(2.25+4.00)

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00
O-rings	2	2.25	4.00	12.50
Spring	1	2.25	6.00	8.25

2.25+6.00

Queen Mary University of London

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00
O-rings	2	2.25	4.00	12.50
Spring	1	2.25	6.00	8.25
Cover	1	1.95	6.00	7.95

1.95+6.00

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00
O-rings	2	2.25	4.00	12.50
Spring	1	2.25	6.00	8.25
Cover	1	1.95	6.00	7.95
Total time (seconds)				**31.70**

Sum of all above

Example of the calculation for cost of assembly

Component	Quantity	Handling Time (sec)	Insertion Time (sec)	Total Time (sec)
Valve	1	1.50	1.50	3.00
O-rings	2	2.25	4.00	12.50
Spring	1	2.25	6.00	8.25
Cover	1	1.95	6.00	7.95
Total time (seconds)				**31.70**
Assembly Cost at $45/hour				**$0.40**

45x(31.70/3600)

Queen Mary
University of London

Estimating the overhead costs

- This is a **difficult** aspect of cost estimation
- The aim is to **share** the **total** overhead costs of the company across **all** of the products made by that company
- Most firms assign overhead charges by using **overhead rates**

Queen Mary
University of London

Estimating the overhead costs (cont.)

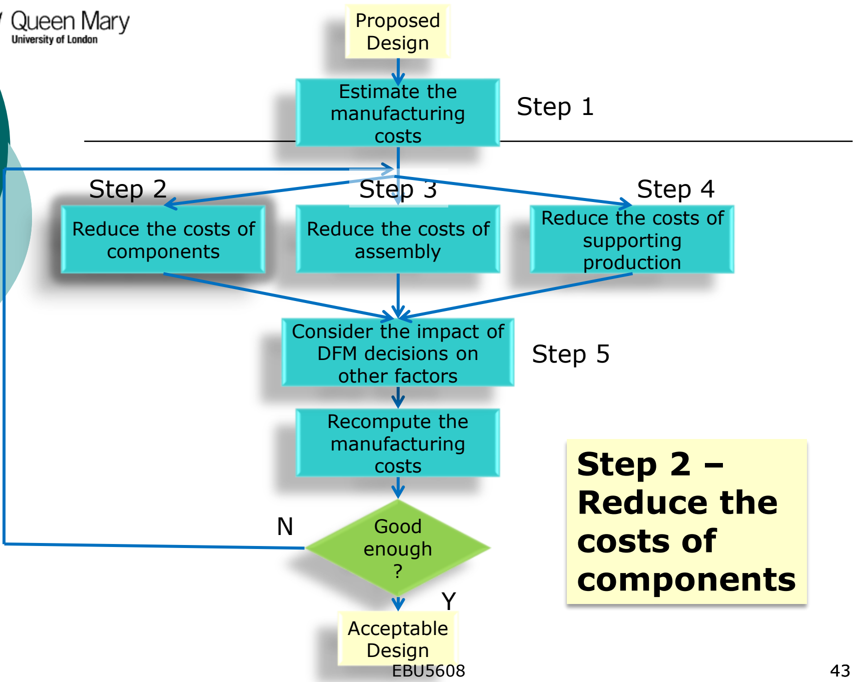
- Overhead rates are typically applied to one or two **cost drivers**
  - Cost drivers are parameters of the product which are **directly measurable**
- **Common** cost drivers are
  - the cost of any purchased **materials**
  - the cost of assembly **labour**
  - the number of hours of **equipment time** the product consumes
- Overhead charges are added in **proportion** to the value of the drivers

Queen Mary University of London

Estimating the overhead costs - an example

- The overhead rate for purchased **materials** for a product is **10%** (of the purchased cost)
- The overhead rate for assembly **labour** for the product is **80%** of the labour costs
- A product containing $100 of purchased components and $10 of assembly labour

Item	Value	Overhead rate	Overhead cost
Component costs	$100	10%	$10
Labour costs	$10	80%	$8
Total overhead costs			**$18**



Step 2 – Reduce the costs of components

Step 2 – Reduce the costs of components

- For most **highly engineered** products, the cost of purchased **components** will be the most **significant** element of the manufacturing cost
- The aim is to **minimise** these costs as part of the **design process**
- There are **4 key aspects** to consider:
  1. Understand the process constraints and cost drivers
  2. Redesign components to eliminate processing steps
  3. Choose the appropriate economic scale for the part process
  4. Standardise components and processes

1. Understand the process constraints and cost drivers

- Design decisions can **drive up** costs if they are **complicated** to achieve in production
- Designers should be aware of the **process constraints** and **cost drivers** early in the development process
- For example - a designer may specify a very **complex shape** for a case (because it looks nice) without understanding how difficult and expensive it is to **make**

2. Redesign components to eliminate processing steps

- A reduction in the number of **steps** in the production of a product will reduce **costs**
- Designers should be encouraged to design products with components that can be **manufactured** in the **minimum** number of steps
- For example, does each component need to be painted – will it be seen by the customer in the end product? Not painting it will remove a step

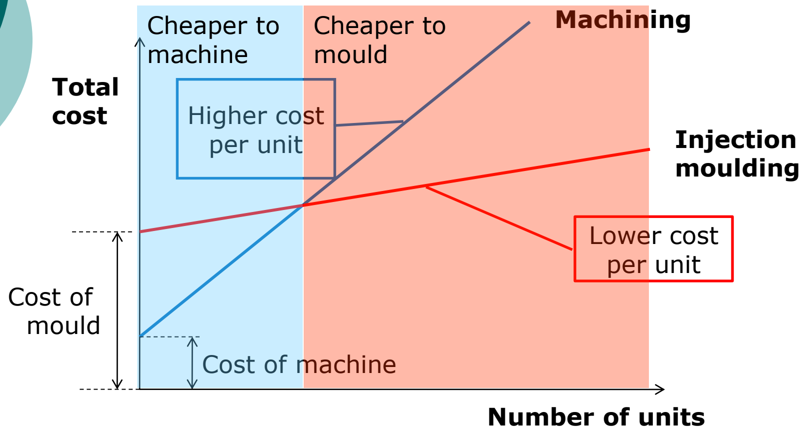
Mentimeter

Queen Mary University of London

3. Choose the appropriate economic scale for the part process

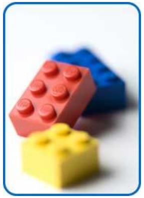
- Economies of scale can be achieved in production
- But – the **right process** must be chosen for the **quantities** involved
- Some processes are best suited to **small scale** production
- Other processes are best suited to **large scale** production

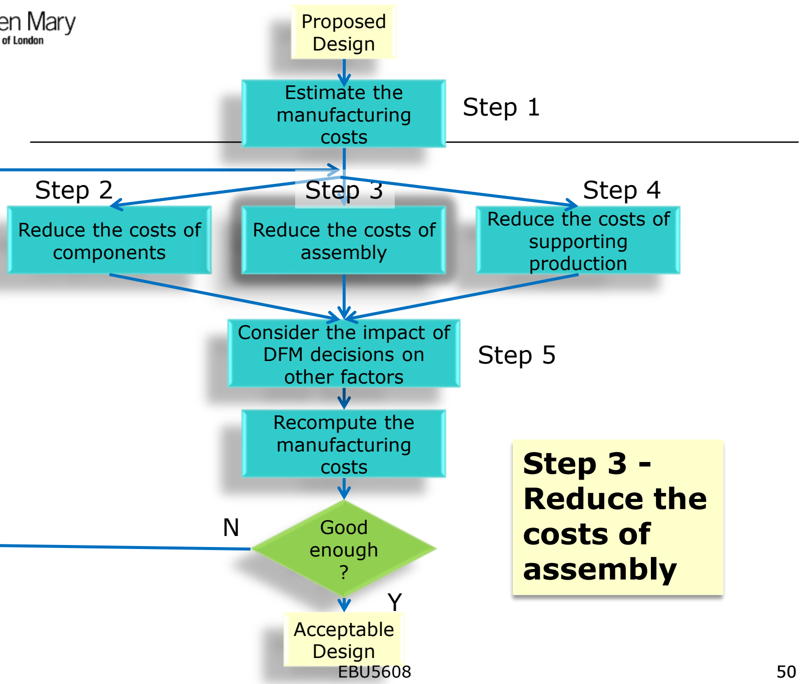
3. Choose the appropriate economic scale for the part process



4. Standardise components and processes

- Continual identification of **standardisation** is key to the reduction of production costs
- Standardised components lead to
  - the achievement of **economies of scale**
  - a lower cost per unit from **suppliers**
- They also allow an organisation to have a **range of products** available to the customer with minimal additional cost





Step 3 - Reduce the costs of assembly

Queen Mary
University of London

Step 3 –
Reduce the costs of assembly

- 'Design for Assembly' (DFA) places an emphasis on identifying ways in which **assembly costs** can be reduced
- The key ideas of DFA are to:
  - Minimize parts **count**
  - Maximize the ease of **handling** parts
  - Maximize the ease of **inserting** parts
- The **benefits** of DFA are:
  - Lower **labour** costs
  - Other **indirect** benefits

Queen Mary University of London

Design for Assembly rules

Example set of DFA guidelines from a computer manufacturer

1. Minimize parts count
2. Encourage modular assembly
3. Eliminate adjustments
4. Eliminate cables
5. Use self-fastening parts
6. Use self-locating parts
7. Eliminate reorientation
8. Facilitate parts handling
9. Specify standard parts

Queen Mary
University of London

Design for Assembly

- Key ideas of DFA:
  - Minimise parts count
  - Maximise the ease of handling parts
  - Maximise the ease of inserting parts
- Benefits of DFA
  - Lower labor costs
  - Other indirect benefits
- Popular software developed by Boothroyd and Dewhurst.
  - http://www.dfma.com

Queen Mary
University of London

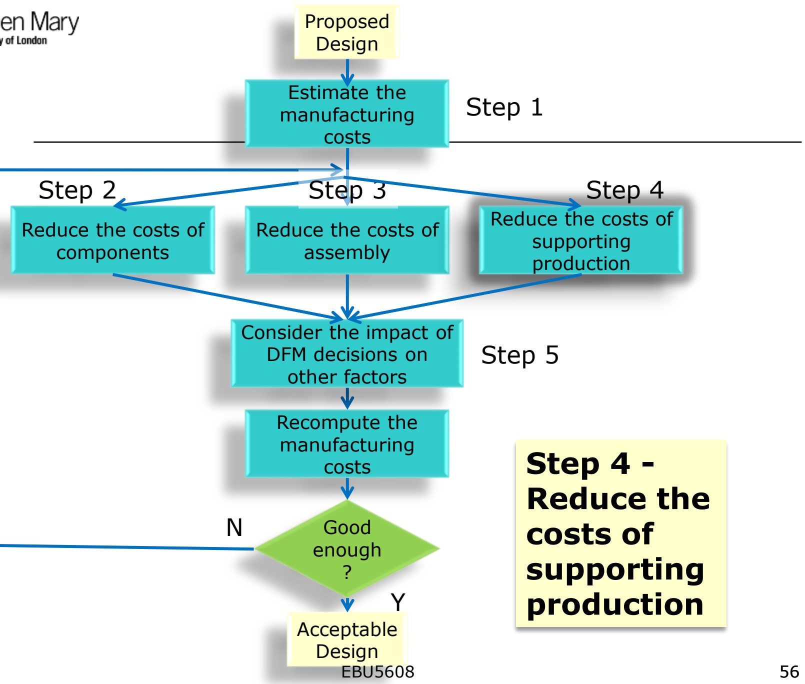
Maximise Ease of Assembly

- Part is inserted from the top of the assembly
- Part is self-aligning
- Part does not need to be oriented
- Part requires only one hand for assembly
- Part requires no tools
- Part is assembled in a single, linear motion
- Part is secured immediately upon insertion

Queen Mary
University of London

Consider Customer Assembly

- Customers will tolerate some assembly
- Design product so that customers can easily and assemble correctly
- Customers will likely ignore directions



Step 4 - Reduce the costs of supporting production

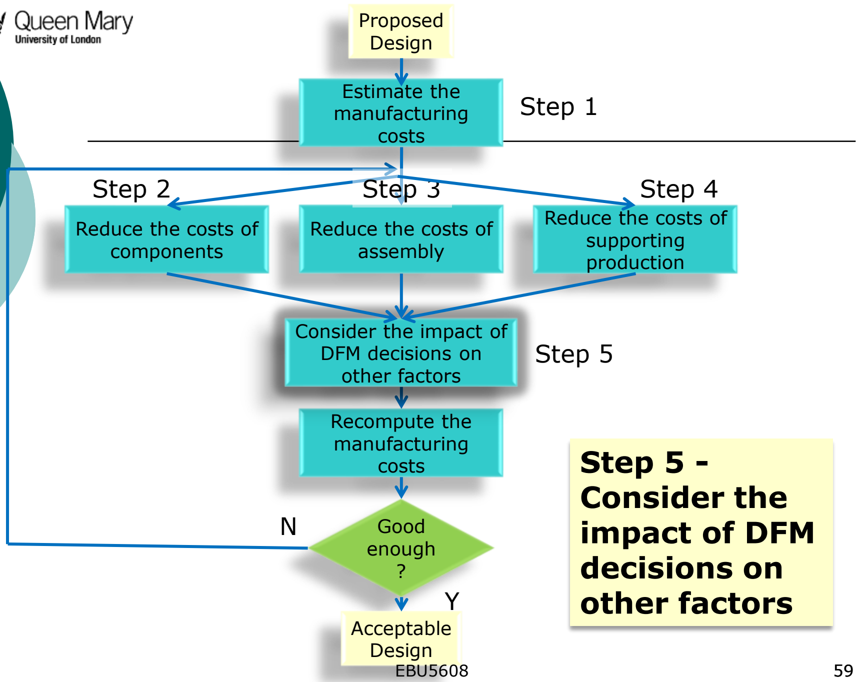
Queen Mary
University of London

Step 4 – Reduce the costs of supporting production

- As a result of reducing the costs of **components** and the costs of **assembly**, the team may also achieve reductions in the demands placed on the **production support** functions

Step 4 – Reduce the costs of supporting production

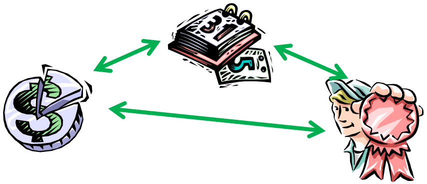
- Examples
  1. A reduction in the number of **parts** reduces the demands on **inventory management**
  2. A reduction in **assembly content** reduces the number of **workers** required for production, and therefore reduces the cost of **supervision** and **Human Resource** Management
  3. **Standardised** components reduce the demands on **engineering support** and **quality control**



Step 5 - Consider the impact of DFM decisions on other factors

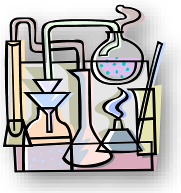
Step 5 - Consider the impact of DFM decisions on other factors

- Product development is not **only** focused on **cost** reductions
- DFM can have an impact on other **aspects of product** development in addition to cost reductions:
- The **balance** between **cost**, **quality** and market launch (e.g**. timing**) is continually being **reassessed**



Step 5 - Consider the impact of DFM decisions on other factors

- The impact of DFM on **development time**
  - DFM has a focus on **cost reduction**, which usually includes the **design** of individual components to reduce steps in **production** and therefore cost
  - However, if these design decisions would **increase** development time and **delay** the release, then the priorities of the organisation will have to be considered



Step 5 - Consider the impact of DFM decisions on other factors

- The impact of DFM on **product quality**
  - Will any decision stemming from DFM affect the product's **quality**?
    - The **majority** of improvements to the **manufacturing** process will usually result in an improvement to the **quality** of the product
    - In most cases a reduction in **components** that require subsequent **integration** and **testing** improves quality
  - However, this is not always the case and **decisions** regarding trade-offs will need to be taken in line with the organisation's product strategies

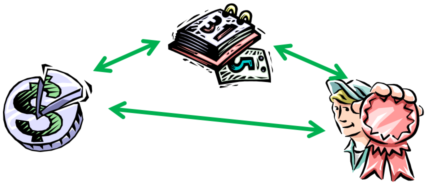
Step 5 - Consider the impact of DFM decisions on other factors

- The impact of DFM on **external factors**
  - Component reuse
  - Life cycle costs

Queen Mary
University of London

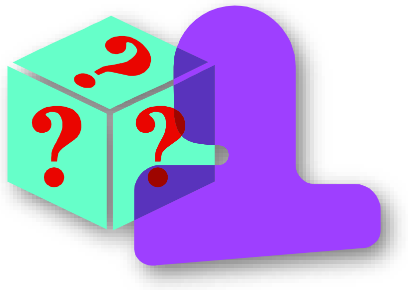
Summary

DFM is aimed at reducing manufacturing costs while simultaneously improving (or at least not inappropriately compromising) product **quality**, development **time**, and development **cost.**



Queen Mary
University of London

Questions?



Go to www.menti.com to post your questions

Mentimeter

Queen Mary University of London

Reading

- **Core Textbook** (Ulrich & Eppinger, 7th Edition)
  - Chapter 13. Design for Manufacturing
    pages 261 - 283

References

1. Product Design and Development, Karl T Ulrich and Steven D Eppinger, International Edition (3rd) McGraw-Hill, 2003, pg 213
2. .. Pg. 214
3. .. Pg. 218
4. .. Pg. 219
5. http://www.tomshardware.com/news/apple-battery-patent-ipad-iphone,14155.html
6. http://rainwillow.com/2012/04/integrated-versus-modular-architectures/