

EBU5608 Product Development and Management

Topic 11 – Design for Manufacturing

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Agenda

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



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Design for X Topics

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



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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






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Design for Manufacturing (DFM)

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

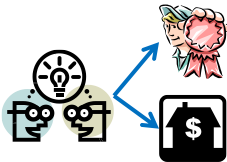

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Focus on manufacturability

- 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**


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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



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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

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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



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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



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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



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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**



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

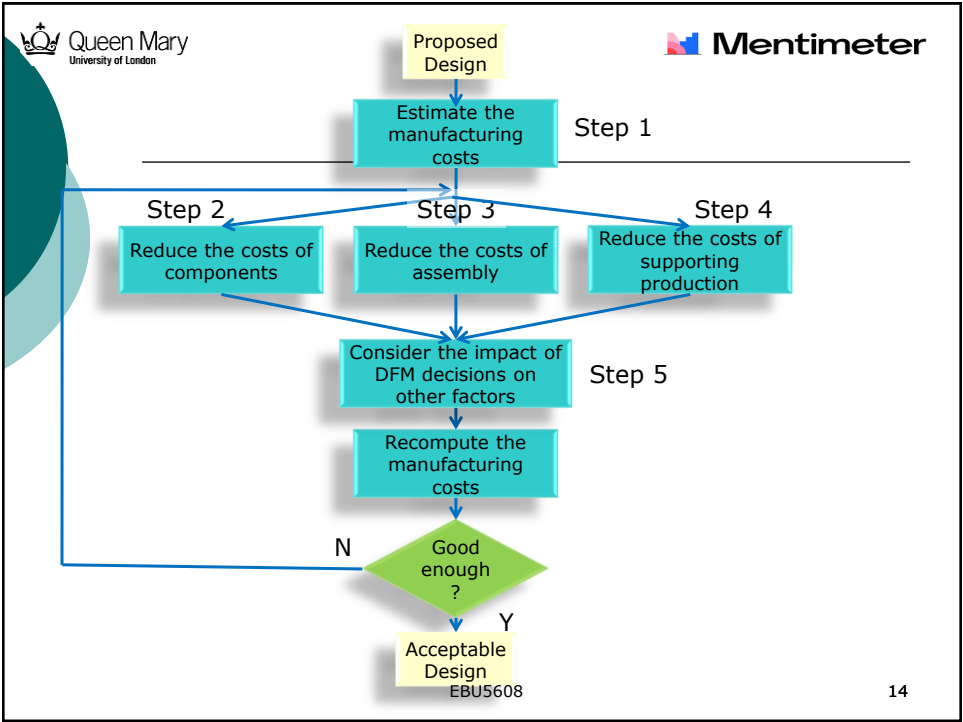
- Ulrich and Eppinger propose a DFM method with **five steps**
 - plus interactions
- This is shown on the next slide




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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



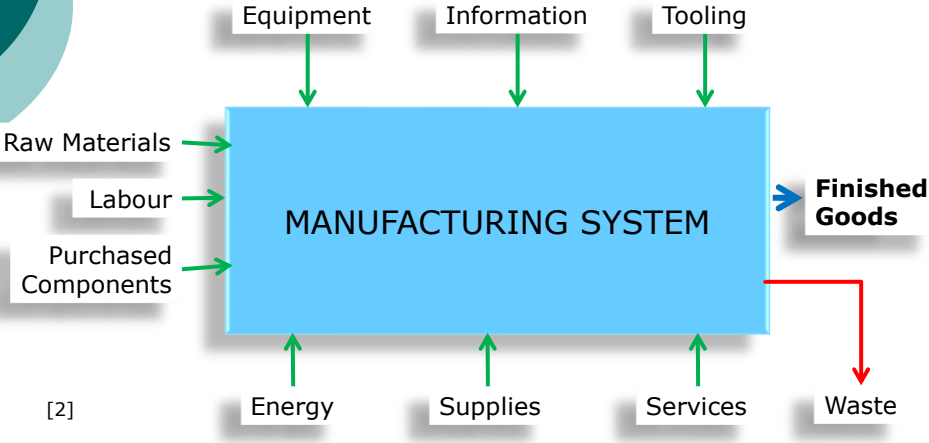
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Step 1 - Estimate the manufacturing costs




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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'!

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Manufacturing cost categories

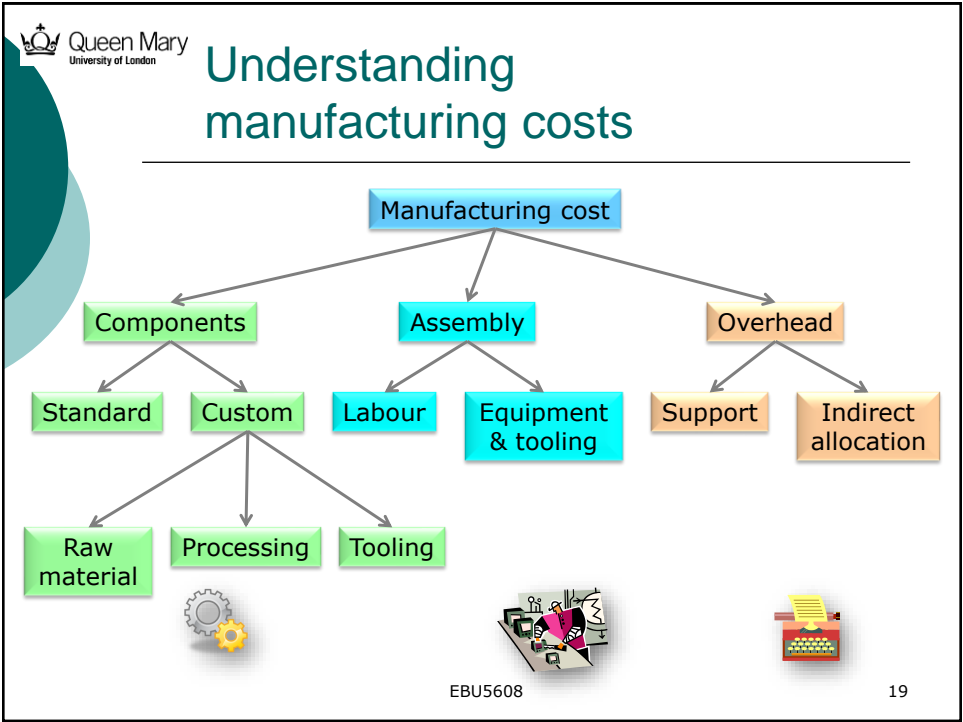
- There are three categories of costs which make up manufacturing costs:
 - Component costs
 - Assembly costs
 - Overhead costs
 - These are shown in more detail on the next slide




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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



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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



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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

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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**



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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)




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Estimating costs




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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



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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**



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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



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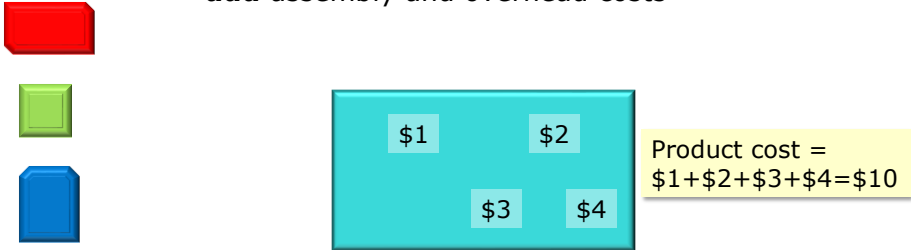
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Estimating the costs of custom parts

- 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



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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)

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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



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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




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Example of the calculation for cost of assembly

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

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1.50+1.50

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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)

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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

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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

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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

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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		45x(31.70/3600)		\$0.40

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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**



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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

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Estimating the overhead costs - an example

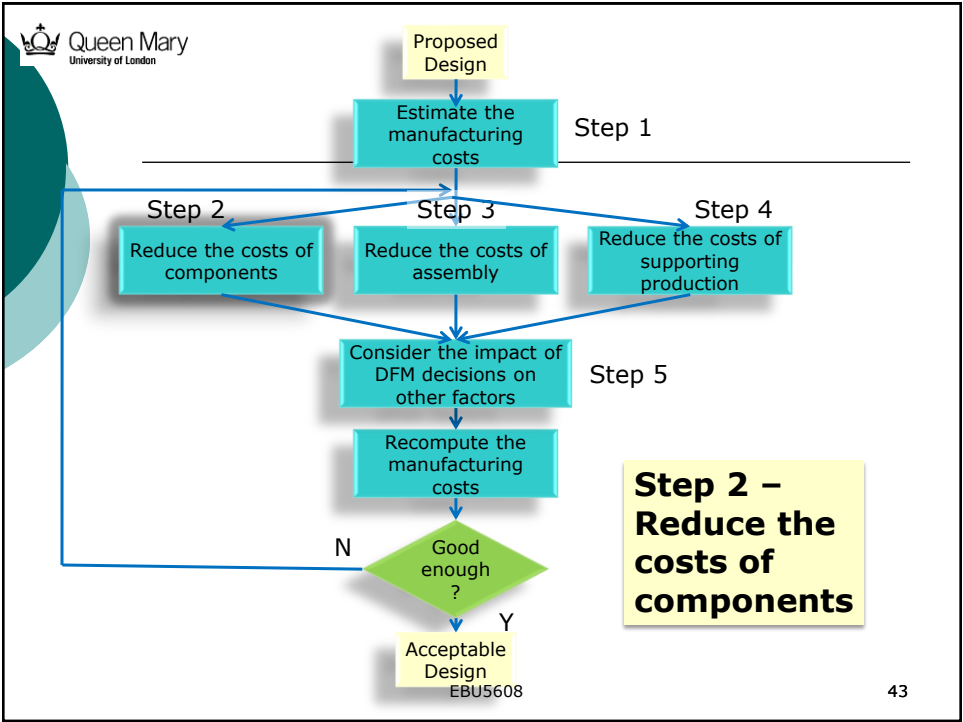
- The overhead rate for purchased **materials** for a product is **10%** (of the purchased cost)
- The overhead rate for assembly **labour** for the product is **80%** of the labour costs
- A product containing \$100 of purchased components and \$10 of assembly labour

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

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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



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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**





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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




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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

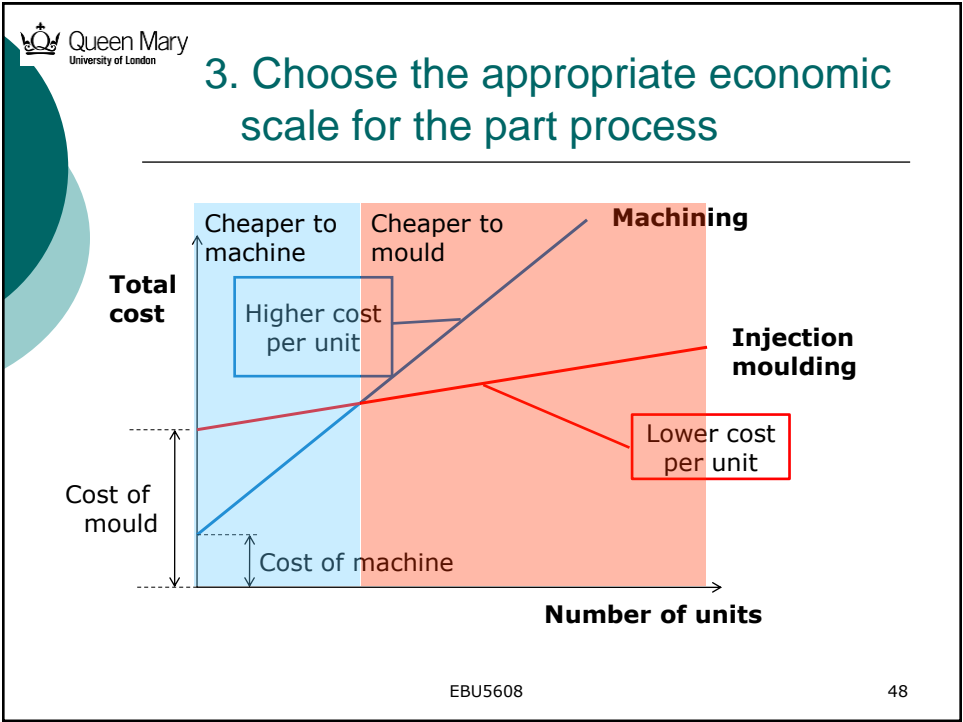





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4. Standardise components and processes

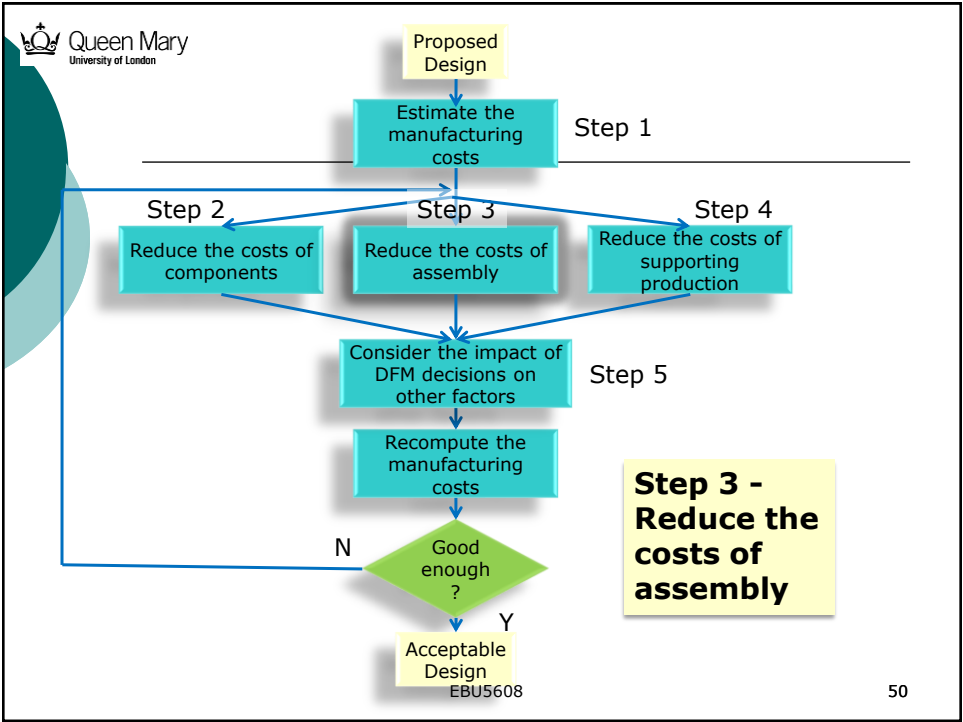
- Continual identification of **standardisation** is key to the reduction of production costs
- Standardised components lead to
 - the achievement of **economies of scale**
 - a lower cost per unit from **suppliers**
- They also allow an organisation to have a **range of products** available to the customer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



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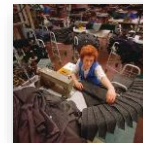
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Step 3 – Reduce the costs of assembly

- '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



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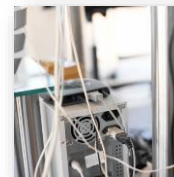
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Design for Assembly rules

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



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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>

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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

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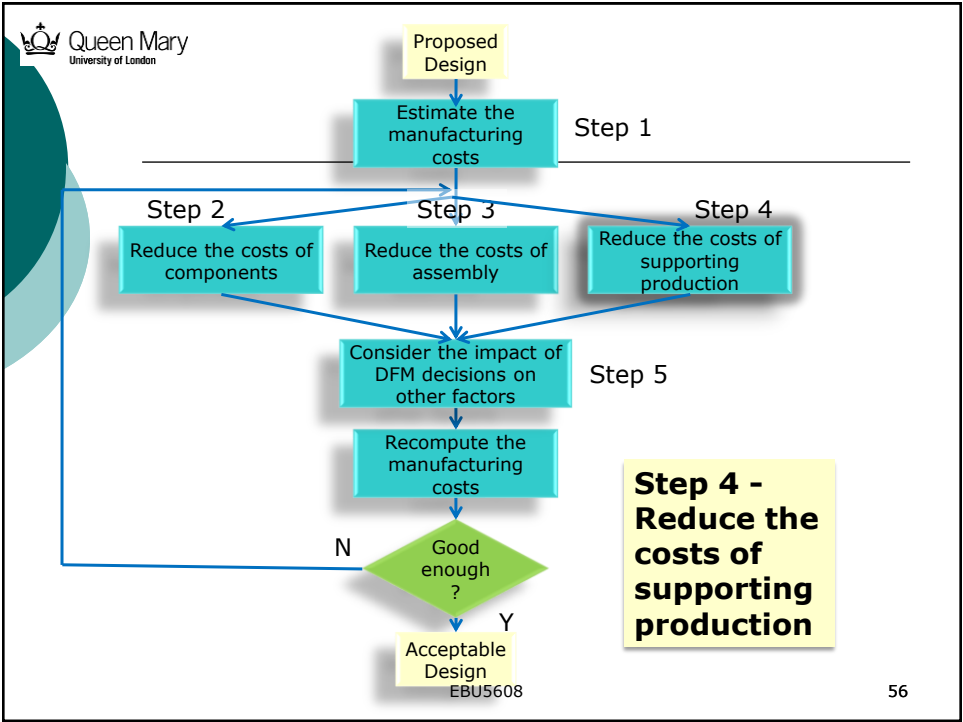
Consider Customer Assembly

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


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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


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Step 4 – Reduce the costs of supporting production



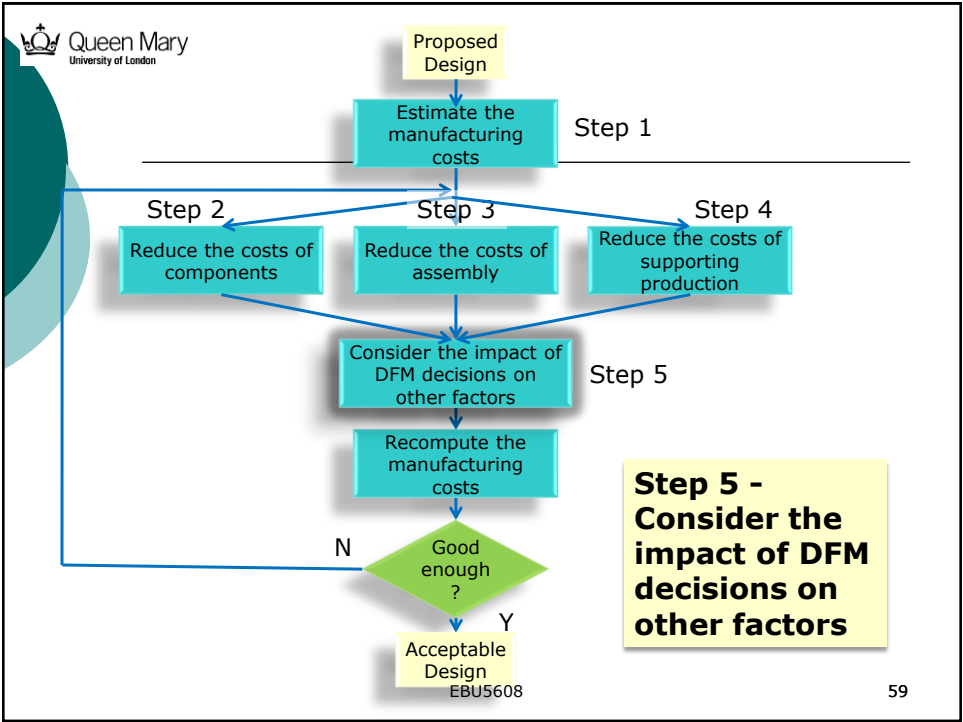
- Examples
 1. A reduction in the number of **parts** reduces the demands on **inventory management**
 2. A reduction in **assembly content** reduces the number of **workers** required for production, and therefore reduces the cost of **supervision** and **Human Resource** Management
 3. **Standardised**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


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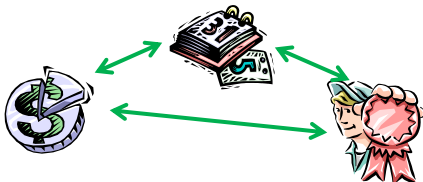


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Step 5 - Consider the impact of DFM decisions on other factors

- 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**



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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




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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




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


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



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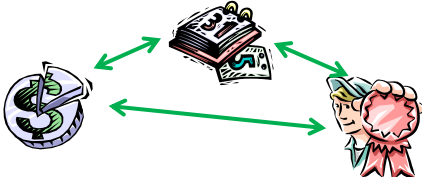
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Summary

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



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Questions?



Go to www.menti.com to post your questions




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Reading

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



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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/>