Design for Manufacture and Assembly

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Contents

ETD 313 Design for Manufacture and Assembly

Course Description: Principles and methodologies for designing parts and products for: ease and efficiency of manufacture and assembly; maintenance and usability during the service life, along with disposal and recycling at the end of service. Students will be able to apply DFMA principles to lower the cost of designing, commissioning, and using new products.

1. Identify appropriate methods of designing parts based on the manufacturing process used during the part creation.
2. Demonstrate the ability to apply DFMA principles to lower design costs.
3. Explain methods used to improve designs to reduce waste.
4. Apply appropriate materials to design to improve the recyclability of the final product.

Chapter 1: Introduction to DFMA

The History of DFMA

Review the DFMA timeline below to become familiar with the most significant milestones leading to the development and use of DFMA in engineering practices. Select the arrow on the right side of the interactive timeline to progress through the decades. You can also select the icon in the upper right corner to expand your view.

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So, what is DFMA?

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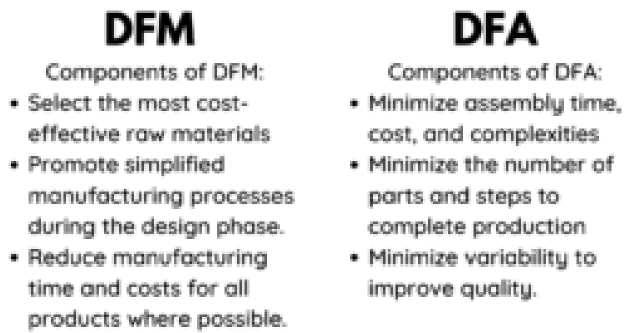
Design for Manufacture and Assembly (DFMA) is an engineering methodology which focuses on reducing time-to-market and total production costs by prioritizing the following during the early design phases of the product life cycle.

1. Ease of manufacture for the product's parts.
2. Simplified assembly of those parts into the final product

DFMA is comprised of two components: Design for Manufacturing (DFM) and Design for Assembly (DFA).



A comparison of DFM and DFA.

The goal is to design a product which makes the customer happy and is the lowest overall cost, but there are other factors as well:

- Best material for the process and product
- Minimum number of components
- Easy to acquire to the components
- Easy to assemble
- Easy to maintain the device
- Easy to recycle at the end of the product's life

The product starts and ends with the customer. It could be called the voice of the customer, stakeholder input/analysis, customer request, scope of work, or critical quality requirements. Learn more about how to manufacture success by reviewing the following plan by [David M. Vranson: A Plan for Manufacturing Success](#) (2011)

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Chapter 2: DFMA Goals

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How does reducing costs make an impact?

Reducing costs increases profitability, but only if sales and prices are constant. If costs reductions affect quality, then potential games are lost or sales occur. And, this could lead to profit or net losses. It is important that when making change **total costs** are being evaluated rather than simply reducing materials or manufacturing costs.

Total Cost = Materials + Manufacturing + Assembly + Labor + Overhead + Cost of Poor Quality

How much money can be saved?

On average, according to DFMA (2023), these are the expected results:

- 50% cost reduction
- 60% time reduction in assembly
- 45% product development time reduction
- 54% reduction in part counts

Case Study

Before moving on, please read this article on How to Manufacture Success. After you've read the article, review the following slides and answer the check your understanding questions.

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Additional Case Studies:

- DFMA-Oriented Modular and Parametric Design and Secondary Splitting of Vertical PC Components (Dong et al., 2023)
- DfMA and DfD in the Construction Industry: Challenges, trends and developments (Roxas et al., 2023)

- Design for manufacturing and assembly methods in the product development process of mechanical products: A systematic literature review (Formentini et al., 2022)
- Design for Manufacturing and Assembly: A Method for Rules Classification (Favi et al., 2021)
- The Integration of DFMA and Reverse Engineering Applied to a Landing Gear Redesign (de Oliveira et al., 2021)
- Design for manufacturing and assembly: A BIM-Enabled generated framework for building panelization design. (Liu et al., 2021)

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Chapter 3: Concurrent Engineering and the Design Process

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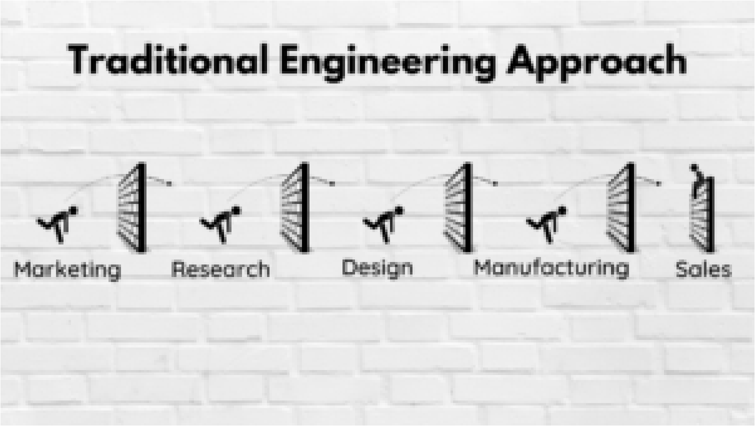
Traditional Engineering

Traditional engineering was carried out through sequential or "over-the-wall" methods. The engineer (or customer) would have created and designed it, then sent it "over-the-wall" to purchasing and manufacturing. Across-department communication is minimal and also expected. The time spent designing is shortened, resulting in some challenges.

- Departments develop designs without good input from other stakeholders.
- Challenges are not identified early and then either must go back for re-design or waste becomes "designed into product"
- Overall time to produce a good quality product is increased.
- Costs associated with poor design for manufacturability are locked in for the lifetime of the product.

Learn more about Sequential Engineering by selecting this link: What is Sequential Engineering?

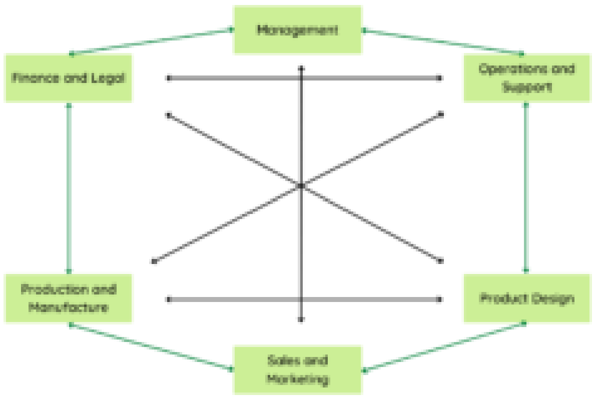


The image above is a visual representation of the "over-the-wall" design process, also known as synchronous design.

Concurrent Engineering

In order to better plan for the attributes of manufacturability, a new approach called concurrent engineering is utilized for DFMA. Concurrent engineering (also known as integrated product development and simultaneous engineering) is a method of manufacturing where different departments are working simultaneously on product development. If the process works as intended, the process is significantly more efficient, reducing time and overall costs while improving the quality of the end product (Engineering Product Design, 2023). Below is an example of the different interactions occurring simultaneously. Learn more about the benefits of DFMA by reading the following article: Understanding DFMA

For concurrent engineering to be effective, increased departmental collaboration and communication must occur early and often in the design process. This can be challenging, as many engineers prefer to design independently and meetings can be both challenging to schedule and also time intensive.

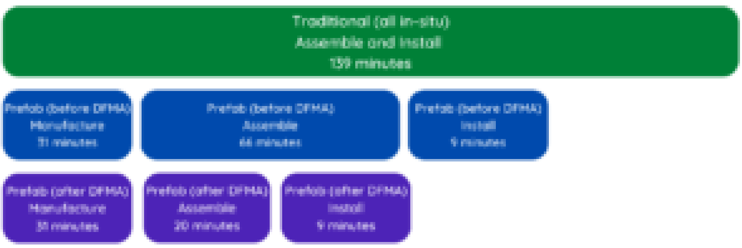


Concurrent engineering interactions (Adapted from Engineering Product Design, 2023)

However, even though concurrent engineering increases the time spent in the planning phases, it dramatically decreases the overall time for full speed production. This happens by greatly reducing the need for engineering changes, rework, and long-term manufacturing process changes and delays due to designs whih were not effectively planned for manufacturability.

Here is an example, comparing traditional and DFMA sequences ([from Vaz-Serra & Marfella (2019)](#))

Step	Traditional Assembly Sequence	DFMA Sequence
1	Drywall marking and installation of metal tracks (top, bottom, vertical).	Drywall marking and installation of metal tracks (top, bottom, vertical).
2	Inform the supervisor.	Inform the supervisor.
3	Plumbing trade to arrive on-site and mark noggins.	Plumbing trade installs the flat wall.
4	Inform the supervisor.	Inform the supervisor.
5	Drywall trade to install noggins.	Drywall trade to finish the wall installation with plasterboard, tiling, and painting.
6	Inform the supervisor.	Plumbing trade to install final fittings on the wall.
7	Plumbing trade to install pipes and support for fittings.	
8	Inform the supervisor.	
9	Drywall trade to finish the wall with plasterboard, tiling, and painting.	
10	Inform the supervisor.	
11	Plumbing trade to install final fittings on the wall.	



A comparison of time requirements between traditional, prefabricated, and DFMA improved methods of construction of plumbing high rise wet areas (from Vaz-Serra and Marfello, 2019).

Best practices for concurrent engineering

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Chapter 4: Elegant and Creative Design

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Overview: Elegant Design Defined

One way to define Elegant Design is like this: In 2010, at the International Aeronautical Congress, former NASA Administrator, Dr. Michael Griffin presented a paper entitled "How do we fix systems engineering?". In that paper Dr. Griffin introduced the properties of Elegant Design. The four properties of an elegant design are that it effective, it is robust, it is efficient, and it minimizes unintended consequences. Read more about these ideas by reviewing "Building a Path to Elegant Design" by Watson et al. (2014).

Another way to define Elegant Design is like this: Bill Shust, Mechanical Engineer and author of many publications regarding design and design analysis defines "elegant" engineering in the same way we define art: it's value is largely determined by the individual's perspective. Some criteria for an elegant product design are:

- The device or solution is simple
- It is intuitive to use ("user-friendly")
- Works all the time, every time
- Often accomplishes more than one goal simultaneously, yet again simply

- Often circumvents a failure mode which may plague more complicated, but similar devices
- There may be bonus features, such as exploiting a well-known scientific principle in a covert way or it is aesthetically pleasing (or results in something which is aesthetically pleasing).

Here are some examples, see if you can determine which is the elegant solution.

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A third definition is provided below in a video about Mark Sanders.

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Creative Design Process

The Creative Design Process should involve the following steps, at a minimum:

- Identify product and process development team.
- Identify customer needs and expectations.
- Brainstorm concepts.
- Evaluate concepts.

Remember: allow sufficient time for brainstorming and evaluation, as well as re-iterations as needed, before selecting the final concept. Additionally, while taking more time here may feel like it is extending the overall time to market, it is very often reducing time to market by 45%. The use of proper DFMA practices can streamline the approach and improve efficiency.

Team Approach to Product Design and Development (PDD)

As we have discussed already, Concurrent Engineering and effective DFMA requires an effective team approach to Product Design and Development. It is imperative that all product and process stakeholders are identified and represented in the PDD process. While it is not necessary for formal meetings to include all stakeholders, teams should always ask at each meeting (start and finish) whether all the correct stakeholders are present. The topic of team effectiveness and communication will be discussed in a later chapter.

Identify Product and Process Development Team

Planning and creation of a cross-functional team which represents the external customer, suppliers, and internal departments is critical. Leaving product or process stakeholders out of the conversation inevitably leads to problems, lost time, and/or redesign. All of which are very costly and in opposition to the goals of DFMA.

Design decisions gather inertia and the further the design progresses, the harder (and costlier) it can be to go backwards and re-design. Engineers become invested in their drawings/models. Commitments to suppliers and materials are made. New equipment and/or tooling for manufacturing is ordered,etc. However, when stakeholders (like external customers, process operators, purchasing managers, etc.) are included in the process, challenges can be identified early and corrected. This prevents locking in design decisions which would be detrimental and costly which is fundamental to DFMA.

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Identification of Customer Needs and Expectations

Brainstorm Concepts

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Evaluate Concepts

The next step is choose the best concepts to more fully develop. There are many ways to do this, voting or multivoting is often very common. However, for engineering design concepts a more structured approach will help ensure that the design is customer-focused, best suited for manufacturing processes, and the concept selections are data-based rather than emotionally-charged decisions.

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Chapter 5: Design for Manufacture and Assembly Best Practices

In the Chapter 2 case study, we learned that the most effective implementations of DFMA start at the product design state and use a concurrent engineering approach to simplify the design both in part quantity and costs for manufacture and assembly. Simplification introduces the concepts of design elegance with a focus on the attributes of manufacturability, including:

- Part count reduction
- Ease of part handling at the point of assembly
- Ease of part insertion into the assembly
- Minimal use of tools (if any)
- Minimal use of standard or special processing

You will see many additional best practices are included in this chapter. These are truly a starting point, as all industries continue to evolve and improve. When designing a product, sue these general guidelines to guide the DFMA process and always take the time to research and incorporate the current industrial best practices which are appropriate.

Review

Before moving on, please review this article from Chapter 2 on How to Manufacture Success. After you've read the article, review the following slides and answer the check your understanding questions.

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It all sounds so simple, right? Each of these topics can require significant research and application of DFMA tools. In this chapter, we will expand on these topics to better support implementation of the DFMA process.

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Reducing Part Count

How can we determine which parts are necessary and which parts can be eliminated? Conduct a DFMA functional analysis to determine what parts are essential and what parts could be eliminated.

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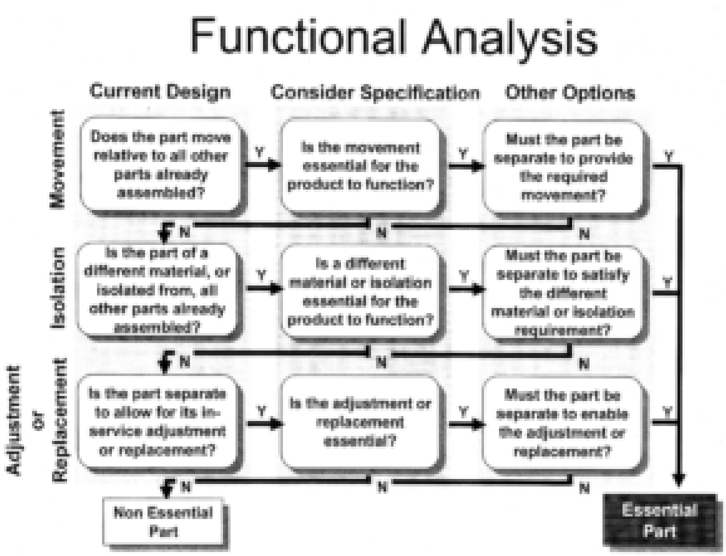

Theoretical Part Count

Below is a functional analysis flow chart. The flow chart evaluates the current design on movement, isolation, and a final category related to service, adjustment, and replacement. The questions require the evaluator to consider the current design of an element, specifications, and potentially other options. If, when evaluating, the answers to all of the questions are **yes,** then the part is considered essential. Otherwise, there may be a way to design the product without the part. The number of essential parts identified determines the number of minimum parts, which is called the **theoretical part count**. The functional analysis defines the theoretical part count, but there are some practical considerations to be made; for example: what are some potential risks for eliminating all fasteners?

Theoretical Minimum Part Count Guidelines

- One base part is always essential.
- Additional parts are considered non-essential until proven otherwise by the questionnaire
- Multiples of fasteners are always considered non-essential. Challenge whether a fastener is needed at all.
- Processes for coatings, finishing, adhesives, or lubricants should be captured in the analysis.
- Just because a part is in an assembly, moves independently, is made of a different materials, previous required (and so on), does not mean it still should be; the goal is to challenge the existing design with new creative ideas.
- The minimum part count is rarely ever fully achievable, it is a **goal** given the current functionality requirements. The final design will be measured against the goal.

Practical Part Count

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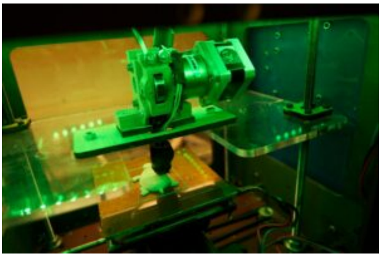
Simplify Manufacture and Assemble

Research Off-The-Shelf (OTS) Parts

"Anderson's Law -Never design a part you can buy out of a catalog unless you can clearly justify the choice (e.g. to save weight (if that's an important design goal), to reduce size for improved packaging, to use an alternate material, etc.). Off-the-shelf (OTS) parts are significantly less expensive considering the cost of design, documentation, prototyping, testing, improving and the overhead cost of purchasing all the constituent parts. Suppliers of off-the-shelf parts are more efficient at their specialty because they are more experienced on their products, continuously improve quality, have proven reliability records, design parts better for DFM and have dedicated production facilities that can produce parts at lower cost (it's difficult to compete on the price of twenty parts with a company that manufactures the same part by the thousands). Using OTS parts helps us focus on our real mission: designing and building products."(From University of Florida)

Understand Process Limitations



When designing a product, an understanding of the manufacturing processes is critical. For example, an Injection Mold manufacturing process is very different from an additive manufacturing process such as 3D printing. The machine and tooling/die costs, time to process, limitations in part geometry which can be created, and dimensional tolerances that can be achieved are very different. While it is sometimes a chicken or the egg challenge to determine which comes first—the part design and the manufacturing process decisions greatly impact one another. Often a manufacturer already possesses standard equipment, and the engineer is designing product to be produced on the established equipment.

Document Product and Process Limitations

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Use Modular Design Principles

Designing families of products that use similar components drastically reduces the demands on manufacturing and overall cost to produce.

Ease of Part Handling at the Point of Assembly

While it is understandable that every component will have time and cost associated with for the actual assembly process, we often overlook the fact that these components must be picked up and oriented properly before installation. This is true regardless of whether the component is manually assembled or assembled with the assistance of automation equipment. However, the increasing use of automation in manufacturing processes has highlighted the need to design components for ease of handling and orientation. Imagine for instance, a robot picking up a steel ball for assembly. While it may be challenging to grab just one, the symmetry eliminates the need for orientation. If the part were instead a gear, the part geometry would require more time to properly orient it before assembly. Design Engineers can dramatically reduce the cost for part handling and orientation by incorporating some design best practices.

Part Symmetry

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Additional Concepts for Easing Part Handling

- **Part Size**: Very large and Very small parts create challenges for handling often requiring assistive tools like fork trucks, lifts, or tweezers. Additional tools add cost to the process and also typically increase the handling time.
- **Reduce Nesting**: Nesting is created when parts get tangled or joined together in storage making it difficult to separate individual units. Paper clips are an excellent example of parts which nest very easily. Thought should be given to how the parts will be packaged both from a supplier and between manufacturing processes and efforts should be taken in the part and packaging design to avoid nesting.
- **Reduce Sharps/Hazards:** Any part which creates a potential safety risk during handling will require additional time and possibly equipment for handling. Consider the assembly of a exacto blade compared to a similar sized ink pen. One blade must be removed from the supply of blades and then assembled into a knife handle to create a finished exacto blade. This would require more time and care than assembling the ink tube into a pen case.

Minimal Use of Fasteners and Tools (if any)

While tools and automation are often added to improve manufacturing, the goal in the product design is to minimize the need for tooling. For instance, a snap fit case requires no tooling and is much faster to assemble than a threaded fastener which requires a tool.

If fasteners have to be used, then some guides should be followed for selecting them. For more details, select the following link for information from University of Minnesota: [Design for Manufacturing]

- Minimize the number, size, and variation used.
- Utilize standard components whenever possible.
- Avoid screws that are too long, too short, separate washers, tapped holes, round/flathead screws (not good for vacuum pickup).
- Self-tapping and chamfered screws are preferred because the improve placement success.
- Screws with vertical side heads should be selected due to vacuum pickup.

Ease of Part Insertion into the Assembly

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  Design for a base part to locate other components.
- Emphasize Top-Down assemblies: The part can be all assembled from one orientation without needing to re-orient. Tools such as drills, screw guns, and so on can all be used from above and not from other angles including from underneath the base part.
- Considering the current insertion (locate and secure) technique: based on difficulty required for each component insertion.
  - Is the part secured immediately upon insertion?
  - Is it necessary to hold down part to maintain location?
  - Is the part easy to align/position?
- Part insertion considerations
  - Self-aligning parts
  - Self-locating parts
  - Adequate access and visibility
  - One-way orientation
  - Avoid reorientation during assembly

Incorporate Mistake Proofing (Poka-Yoke)

- Integrate where needed to avoid quality errors or safety hazards.
- Design in mistake-proofing into assembly to prevent wrong parts being assembled, parts being omitted, and assembling parts in the wrong orientation. Examples include using bsses, tapers, locating holes, part symmetry, and part asymmetry.

Minimal Use of Standard or Special Processing

If possible, avoid the use of special coatings, treatments, finishing, handling, machining operations etc. Whenever possible, evaluate the design for alternatives which would reduce this extra cost and processing which could also lead to quality errors.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.palni.org/designmanufactureassembly/?p=28#h5p-21

This is where you can add appendices or other back matter.