What for Excellence (Design for X)?
Design for Excellence (aka **Design** for **X**, DFX) is a systematic approach to achieve a targeted objective. **X** represents targeted objectives or characteristics. DFX comes under the topic of Design for Six Sigma, a cross-functional team

Key Objective Areas for Design For X
What are we designing for?

- Design for manufacturing (DFM):
  - Reduce BOM, material tradeoffs, cost reductions

- Design for assembly (DFA) & DFM processes:
  - Reduce BOP or process steps, reduce labor
  - Reduce capital equipment, tooling costs
  - Reduce scrap, improve yield

- Design for test
  - Ability to test parts and sub-assemblies in production to catch issues early
  - Ability to test performance before placing in inventory

- Design for reliability, durability, design for operating environment:
  - Consider noise, vibration & harshness (NVH) loading conditions
  - Temperature operating environment, engineer for lifetime

- Design for system integration:
  - Consider form/fit/function, system operating dynamics, transient impacts on connecting components

- Design for maintenance and serviceability:
  - Product design to incorporate ease of service & maintenance

- Design for packaging and logistics:
  - Consider product protection, shipping logistics, transportation costs

- Design for sustainability:
  - Use of bio-based materials, allow for recyclability/biodegradable products & packaging
  - Reduce waste materials in operations, cradle to cradle waste to input materials

- Design for customer use and market acceptance:
  - Customer interface, acceptance, installation
  - Market regulations, certification requirements

- Design for compliance and redgulatory compliance:
  - Incorporate product safety design principles at all stages of product development
  - Keep regulatory strategy and industry standard in mind

Design for Manufacturing

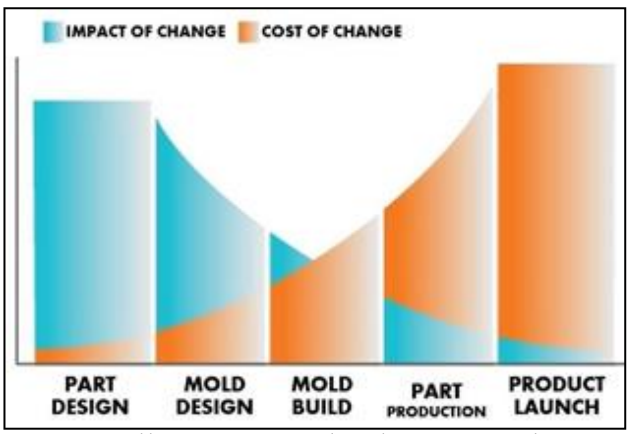
How: Five Principles to consider under each Design for Manufacturing:

1. Process
2. Design
3. Material
4. Environment
5. Compliance/Testing

When:

- Early in the design process: before tooling has begun
- Include all the stakeholders: engineers, designers, contract manufacturer & material supplier.
    - *Challenge* the design — to look at the design at all levels: component, sub-system, system, and holistic levels

***Chart Purpose: Design changes become more* expensive and difficult to implement over time.**



Source:https://news.ewmfg.com/blog/manufacturing/dfm-design-for-manufacturing
East West Manufacturing 404.252.9441

***Chart Purpose:* Potential DFM Savings:**

Labor Cost	42%
Part Count	54%
Separate Fasteners	57%
Weight	22%
Assembly Time	60%
Assembly Cost	45%
Assembly Tools	73%
Assembly Operations	53%
Product Development Cycle	45%
Total Cost	50%

Source: Boothryoyd Dewhurst, Inc.
Results compiled from over 100 published case studies.
https://www.dfma.com/software/dfma.asp

The following DFM review was created by East West Manufacturing. To see the full presentation and excellent video explanations for to: https://news.ewmfg.com/blog/manufacturing/dfm-design-for-manufacturing

Table of Content:

Design for Manufacturing (continued)

A. 5 PRINCIPLES OF DFM: A CLOSER LOOK

1| PROCESS

Consider:

- Equipment/process align with quantity and point in product commercialization
- Quantity needed and potential need to scaling
- Material being used and why
- Complexity of the surfaces
- Tolerances required (unnecessarily high tolerances are costly)
- Secondary processes:
  - Can they be built into first process?
  - Can they provide alternative to more complex first process?
- Time to market

2 | DESIGN

Design is essential. The actual drawing of the part or product must conform to good manufacturing principles for the manufacturing process you've chosen.

In the case of plastic injection molding, for example, the following principles would apply:

- Constant wall thickness, which allows for consistent and quick part cooling
- Appropriate draft (1 - 2 degree is usually acceptable)
- Texture - need 1 degree for every 0.001" of texture depth on texture side walls
- Ribs = 60 percent of nominal wall, as a rule of thumb
- Simple transitions from thick to thin features
- Wall thickness not too small - this increases injection pressure
- No undercuts or features that require side action - all features "in line of pull/mold opening"
- Spec the loosest tolerances that allow a good product - and consult the trade organization for your manufacturing process on what is reasonable for that process

Be sure to discuss the design with your contract manufacturer, who can ensure that your design conforms to good manufacturing principles for the selected process.

3 | MATERIAL

It's important to select the correct material for your part/product. Some material properties to consider during DFM include:

- **Mechanical properties** - How strong does the material need to be?
- **Optical properties** - Does the material to be reflective or transparent?
- **Thermal properties** - How heat resistant does it need to be?
- **Color** - What color does the part need to be?
- **Electrical properties** - Does the material need to act as a dielectric (act as an insulator rather than a conductor)?
- **Flammability** - How flame/burn resistant does the material need to be?

Again, be sure to discuss the material with your contract manufacturer, who might have access to existing materials in their portfolio which would allow you to secure lower material pricing.

Design for Manufacturing (continued)

B. 5 PRINCIPLES OF DFM: A CLOSER LOOK (continued)

4 | ENVIRONMENT

Your part/product must be designed to withstand the environment it will be subjected to. All the form in the world won't matter if the part can't function properly under its normal operating conditions:

5 | COMPLIANCE/TESTING

All products must comply with safety and quality standards. Sometimes these are industry standards, others are third-party standards, and some are internal, company-specific standards.

Your manufacturer should have ISO-certified testing facilities. **Find out:** Who will provide UL, ETL and other third-party testing? Where will that testing take place?

C. FACTORS THAT AFFECT DFM

The goal of DFM is to reduce manufacturing costs without reducing performance. In addition to the principles of DFM, here are five factors that can affect design for manufacturing and design for assembly:

1 | Minimize Part Count

Reducing the number of parts in a product is the quickest way to reduce cost because you are reducing the amount of material required, the amount of engineering, production, labor, all the way down to shipping costs.

2 | Standardized Parts and Materials

Personalization and customization are expensive and time-consuming. Using quality standardized parts can shorten time to production as such parts are typically available and you can be more certain of their consistency.

Material is based on the planned use of the product and its function. Consider:

- How should it feel? Hard? Soft?
- Does it need to withstand pressure?
- Will your part or product need to conduct heat, electricity?

3 | Create Modular Assemblies

Using non-customized modules/modular assemblies in your design allows you to modify the product without losing its overall functionality. A simple example is a basic automobile that allows you to add in extras by putting in a modular upgrade.

4 | Design for Efficient Joining

Can the parts interlock or clip together? Look for ways to join parts without the use of screws, fasteners, or adhesives. If you must use fasteners, here are a few tips:

- Keep the number, size, and variation of fasteners to a minimum
- Use standard fasteners as much as possible.
- Use self-tapping and chamfered screws for better placement.
- Stay away from screws that are too long or too short, separate washers, tapped holes, round heads and flatheads.

Source: East West Manufacturing https://news.ewmfg.com/blog/manufacturing/dfm-design-for-manufacturing

Design for Manufacturing (continued)

C. FACTORS THAT AFFECT DFM (continued)

5 | Minimize Reorientation of Parts During Assembly & Machining
Parts should be designed so that a minimum of manual interaction is necessary during production and assembly.

6 | Streamline Number of Manufacturing Operations/Processes
The more complex the process of making your product, is the more variables for error are introduced. Remember what Jeff said: *All processes have limitations and capabilities. Only include those operations that are essential to the function of the design.*

7 | Define "Acceptable" Surface Finishes
Unless it must be trade show grade, go with function rather than flashy for your surface finish.

D. BONUS: 4 KEY QUESTIONS ABOUT PLASTIC INJECTION MOLDING & DFM

Jeff talked a good bit about plastic injection molding in the videos. Here are four important questions to keep in mind about DFM and the injection molding process:

Which direction will the tool pull?
Here's how it works: A tool (or mold) is made of two halves. The hot plastic liquid is poured into the mold, then quickly cooled. The two halves are pulled apart and there's your part. If any feature in your part moves in a direction other than the pull of the mold, that will complicate the tooling and the tool will cost more.

Are there undercuts or features that will get trapped?
Undercuts are protrusions or recesses in the design that prevent the mold from sliding away from the part. They can get caught in the tool and cause damage. If the design element causing the undercut is necessary it's possible to get around it by using a slide, but that increases the price of the tool. Better to get rid of the undercut by changing the design.

How consistent are the wall thicknesses?
The thick areas on plastic parts are designed that way for strength. But thickness also dictates how long it takes for the part to cool, and the longer it takes to cool the greater the chance for sink. Sink is not good. It is an area of weakness in the part. Also, longer cycle times increase part cost, as the amount of press time to mold the part is increased.

To address this problem, an engineer will thin a thick area out and reinforce it with ribs. Thin walls are not good either, however. Walls that are too thin can easily break. Depending on the part, wall thicknesses will run from 3 mm to 5 mm in thickness. Engineers will also look for transitions between thin and thick walls, making sure the transition is gradual.

Does the design need draft angles?
Straight sides or walls cause the part to stick to the mold, making the parts difficult to remove from the tool. Draft angles are slight tapers of the walls or sides of the mold which assist in the part ejecting properly from the mold. The greater the draft angle, the easier it is to get the part out.

Design for Manufacturing (continued)

D. 10 OUTCOMES OF AN EFFECTIVE DFM

The book *Computer-Aided Manufacturing* offers 10 generally accepted Design for Manufacturing principles that were developed to help designers decrease the cost of and complexity of manufacturing a product. The results of a successful DFM are quantifiable in a host of ways.

1. **Minimize the number of product parts.** Limiting the number of parts in your product is an easy way to lower the cost of a product. Why? Because it automatically reduces the amount of material and assembly labor required. Reducing the number of parts also means less engineering, production, labor, and shipping costs.

2. **Use standardized parts wherever possible.** Customization is not only expensive, but also time consuming. Standardized parts are already made to meet the same quality metrics, every time. They are already tooled. So, you save costs, and you won't have to wonder whether they'll pass inspection.

3. **Create a modular design**. Using modules can simplify any future product redesign and allows for use of standard components and the re-use of modules in other projects.

4. **Design multi-functional parts.** This seems rather obvious, but it's a simple way to reduce the total number of parts: design parts with more than one function.

5. **Design multi-use products.** Building on the point above, different *products* can share parts that have been designed for multi-use. Can your product use standardized parts that can be used in multiple products?

6. **Design for ease of fabrication**. Choose the ideal combination between the material and manufacturing process that will minimize production costs. Ridiculously tight tolerances are a no-no. [More about that below.] Avoid expensive and labor extensive final operations such as painting, polishing and finish machining.

7. **Design your product to join without using screws, fasteners, or adhesives.** Is it possible for your product to interlock or clip together? Screws add only about 5% to the material cost, but 75% to the assembly labor. Remember: if fasteners are required, try to keep the size, number, and type to a minimum and use standard fasteners whenever possible.

8. **Design your part to minimize handling, especially during production and assembly**. Handling includes positioning, orienting, and fastening the part into place. For orientation purposes, use symmetrical parts wherever possible.

9. **Minimize assembly direction.** If possible, your parts should assemble from one direction. Ideally, parts should be added from above, parallel to the gravitational direction (AKA downward.) This way assembly is facilitated by gravity rather than fought by it.

10. **Design your part to maximize compliance.** Rely on built-in design features like tapers or chamfers, or moderate radius sizes to guide insertion of equipment and to protect the part from damage.

It's been said that about 70 percent of manufacturing costs of a product — the cost of materials, processing, and assembly — are determined by design decisions. If that's the case, then you want to make sure you are adhering to the best design practices possible.

Source: East West Manufacturing https://news.ewmfg.com/blog/manufacturing/dfm-design-for-manufacturing

E. THE DANGER OF TIGHT TOLERANCES IN DFM

Any engineer worth their salt is going to also take a very close look at the tolerances specified in the part's drawings. Tolerance is the total amount a specific dimension can vary, and manufacturers often receive drawings from customers with unreasonably tight tolerances that can wreak havoc on an RFQ.

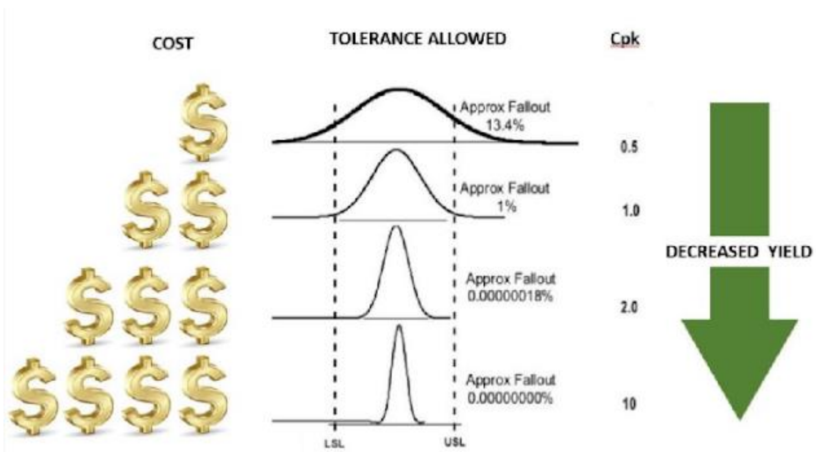
Why you should ease up on tolerances:

Lower cost for tooling

- Ease of manufacturing
- Fewer defects
- Greater yields

The chart below shows the drop in yield and the rise in cost as the tolerance increases.

The bell curve shows measurements on a particular dimension, including the **Upper Spec Limit (USL)** and **Lower Spec Limit (LSL)**, which is based on the tolerances. The tighter the tolerance, the narrower the bell curve must be for the dimensions to be in spec.



All manufacturing processes have limits on what is reasonable to manufacture — that's the gap between USL and LSL. Consult with your contract manufacturer or the trade organization for the process if you are unsure. There is a lot of data on most common processes to give you guidance on what is reasonable to specify. One reference is the International Tolerance Grades

Tolerances should be driven by three things:

- the manufacturing processes.
- the material used.
- the sensitivity of the features to variations.

Managing tolerances is an essential part of a good DFM, and there should always be a justification for the numbers on the drawing.

Source: East West Manufacturing https://news.ewmfg.com/blog/manufacturing/dfm-design-for-manufacturing

F. HOW LONG WILL THE DFM TAKE?

You might be wondering what kind time you'll have to invest in the DFM? That really depends on the quality of the design that you start with.

One of our engineers likened it to proofreading an essay. For example, if you understand the writer's intent, it's much easier to make the corrections in the text. But if you're reading the essay without a clear understanding of intent, you might go back and forth with corrections before you come up with a finished copy.

The DFM is similar. Perhaps the design is clean, answering all questions for all parties. You'll be ready to go in a day or two. But depending on the number of questions, their difficulty, and the speed and thoroughness of the answers, you might be waiting a week or more. Take a deep breath. Your contract manufacturer will be able to give you a better idea of how long they think it will take. Remember speed isn't the goal: a quality product is.

A good DFM hopefully concludes by reducing the complexity of the design and satisfying the customer's requirements for price, specification, material, and scheduling.

In other words, the design is deemed manufacturable and ready for the next step on the road to production.

--END OF EAST WEST MATERIAL--

DESIGN FOR ASSEMBLY

Stake Holders

- **Customer**: DFMA ensures that the assembly and manufacturing processes meet customer requirements

- **Supplier**: well-designed manufacturing and assembly processes help suppliers deliver a quality product (This reduces the amount of iteration required during quoting and scale-up)

- **Business plan**: How scalable is your assembly plan? Doing things by hand and requiring "tweaks" may work at low volume, but is it scalable

Design for Assembly Benefits: *Parts reduction and consolidation*

- Reduced design costs:
  - Fewer parts need to be designed; however, the remaining parts may be more complex

- Reduced inventory costs:
  - Fewer stock keeping units (SKU) must be maintained and tracked
- Reduced handling costs:
  - Fewer parts need to be sited for assembly
  - Lower complexity operation and administration
  - Fewer SKUs results in lower tracking and maintenance costs

Design for Assembly General Guidelines:

- Avoid mechanical fasteners
  - Screwing or riveting parts together takes time and can lead to mistakes
  - Snapfits allow for joining with mechanical fasteners

- Standardize whenever possible
  - Using the same component can reduce cost and assembly complexity
- Parts should be easily grasped and oriented
- Reduce awkwardly shaped or sized parts
- Unidirectional assembly is preferred (**top-down** is best)
- Provide features to reduce resistance to insertion, such as chamfered holes and parts

- Part symmetry should be promoted, or asymmetry exaggerated:

  - A part should be able to be assembled either anyway or only one way
  - If a part must be inserted with a specific orientation, ensure that it doesn't fit any other way
  - Assembled parts should have self-locating features (It should be easy to "feel" where something should go)
- When use of springs is unavoidable
  - Leaf springs: can be placed and loaded
  - Extension springs: require force to be loaded
  - Compression springs: must be held down for assembly
- When use of mechanical fasteners is unavoidable
  - Avoid fasteners design parts "to snap-fit" together easily
  - Bending of plastic: parts come together
  - Rivets: require quick forming
  - Screws: require correct alignment and insertion

DESIGN FOR RELIABILITY

<u>Design priorities</u>

- Avoid under-reliability and customer dissatisfaction costs
- Avoid over-reliability cost without increase to market demand

<u>Schedule predictability</u>

- Avoid time-to-market delays and cost implications

<u>Failure-rat predictability</u>

- Warrant burden and service costs