DFMA® in 10 Slides

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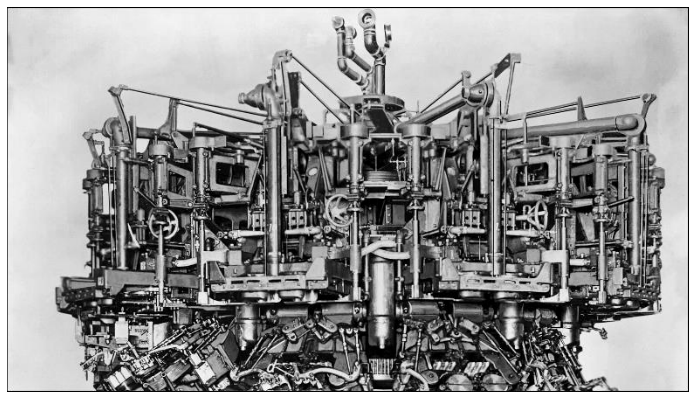
What is DFMA®?

DFMA®, also known as Design for Manufacture and Assembly, is more than just taking an hour to review drawings prior to their release. It is also more than Design for Manufacturability, which typically just evaluates the specific details of how a part is manufactured. DFMA® is a methodology for collaboratively evaluating the assembly efficiency of a product and identifying manufacturing cost drivers for the parts within that assembly. Product developers use the resulting data to achieve product simplification which leads to significant cost savings.



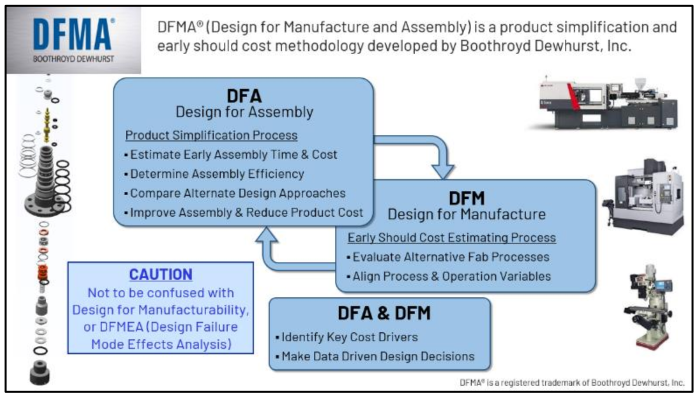
DFMA® is a well-defined process that provides maximum results when applied in the early conceptualization phase of a design project. It fosters collaboration and unleashes creativity among multi-discipline teams. The DFMA® methodology is utilized globally, within companies of all sizes, and is flexible enough to effectively be applied to products with high-volume production quantities, as well as customized products where only one unit is built.

So, what is DFMA®? Geoffrey Boothroyd and Peter Dewhurst originally developed the DFMA® algorithms almost half a century ago. DFMA® consists of two activities that are tightly integrated. DFA, Design for Assembly, is a tool that looks at simplifying product assemblies, while DFM, Design for Manufacture, is an early Should Cost estimating tool for the parts that comprise the assembly.

DFA analysis provides estimates for assembly time and product cost. The analysis assumes that the assembly will be performed manually. It also determines the efficiency of the assembly. One way to optimize a design is to consider alternative approaches for putting together a product. Discerning engineering leaders expect design engineers to provide multiple dissimilar design concepts before proceeding into the preliminary design phase. Rarely is one concept selected outright, but usually the subsequent design is a combination of ideas from the alternate proposals. DFA provides the objective data for comparing those different design approaches. Therefore, a thorough DFA analysis leads to improved ease of assembly, and a reduction in product cost.

It is highly encouraged to conduct DFA analysis with a cross-functional team. The input of preliminary data can be completed by an individual, but the actual analysis of answering questions and evaluating the assembly should be performed in a team environment. This will lead to many creative discussions and result in team ownership of the ideas that are generated.

DFM analysis helps identify the primary cost drivers affecting part fabrication. A broad selection of material and processes are evaluated to discover the most cost-effective manufacturing method for a part. For instance, the cost of a bracket originally designed as a machined part can be compared to the cost for a sheet metal, die-cast, or even reinforced plastic part. Each process requires a different design approach, leading to ingenious design solutions.



During DFM analysis, a variety of process and operation variables can be adjusted to determine their sensitivity. One variable to consider is the Batch Size associated with the parts, which assists in defining the optimum purchasing quantity during the life of the product. The information resulting from the DFM should cost analysis helps development teams make data driven design decisions, instead of relying on gut feel, outdated experience, or an oversimplified rule of thumb. The use of the DFA and DFM toolset is often an iterative process as the development team progresses toward the project goals.

A few notes of caution about DFMA®. Occasionally it is thought of as a Design for Manufacturability activity, where the focus is primarily on finding and avoiding manufacturing difficulties with the emphasis on meeting manufacturing guidelines and rules. Manufacturability reviews are narrowly focused, such as determining the appropriate hole diameter to length ratio for a machined part, or the proper draft angle on a die cast part. Usually, it seems that these cursory reviews take place prior to drawing release with a quick redlining of the drawings. DFMA®, and the DFM should cost analysis, typically steps back and takes a much bigger look at the product. It does include evaluation of manufacturability but is engaged much earlier and includes a comprehensive assessment with actionable cost data.

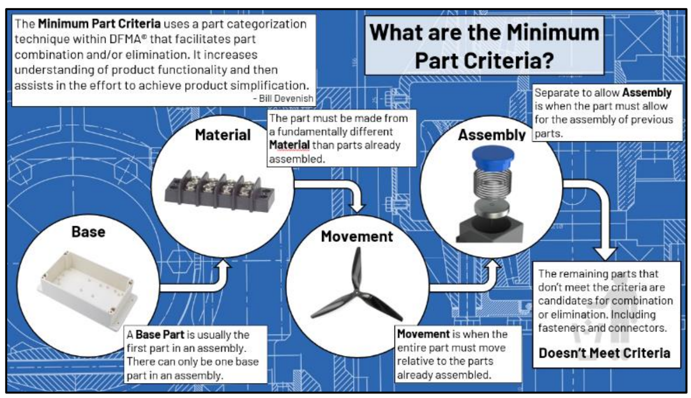
The other caution is to avoid confusing the DFMA® acronym with the similar acronym of DFMEA, which is Design Failure Mode Effects Analysis. DFMEA is focused on identifying failure modes and managing their risks during the design phase. This is quite different from DFMA®, which emphasizes product simplification and early should cost optimization. Generally, the output of initial DFMA® analysis provides input for the eventual DFMEA analysis.

What are the Minimum Part Criteria?

The most critical part of DFA analysis is determining the Minimum Part Criteria for each of the parts in the assembly. Application of the Minimum Part Criteria uses a part categorization technique that facilitates part combination and/or elimination. It increases understanding of product functionality and then assists in the effort to combine parts that meet required functions. It also provides justification for parts to exist as separate components in the design. The Minimum Part Criteria consists of four categories: Base, Material, Movement and Assembly. Parts that meet these criteria are considered theoretically necessary. A part that doesn't meet one of these criteria is considered a candidate for elimination.

A part that meets the criteria for **Base** part is usually the first part in an assembly and is the one that most all other parts are attached to. There can only be one base part in an assembly, therefore, it is typically found in the top level of a parts list. Lower-level subassemblies generally will not have parts that meet the criteria for Base part. Base parts are sometimes referred to as a Housing, Chassis, Enclosure, or Frame, etc.

A part that meets the criteria for **Material** must be made from a different material than the parts already assembled. It is important to only consider fundamental material properties, such as light permeability, sealing, applied force, life cycles or electrical conductivity. Some common examples of parts that meet the criteria for Material include a window, O-ring, or electrical insulator. Sometimes there might be multiple parts made of the same material in an assembly that could theoretically be consolidated into a single part, and in this instance the first part meets the criteria for Material, but subsequent parts do not meet the criteria. There may also be times when a collection of multiple materials grouped together are treated as one part, such as a circuit card assembly within an electronic product.



A part that meets the criteria for **Movement** is one where the entire part must move relative to the parts already assembled. During operation of the product, significant movement must take place between the part and the other assembled parts. Part movement that could theoretically be obtained by integral elastic elements, such as a living hinge or spring, does not meet the criteria for Movement. Some common examples of parts that do meet the criteria for Movement include a piston in a cylinder, a wheel rotating on an axle shaft, or a handle on a water faucet.

Finally, a part that allows for the assembly of previous parts is theoretically necessary, and so it meets the **Assembly** criteria. This is usually a cover, or the part that holds all the other parts together.

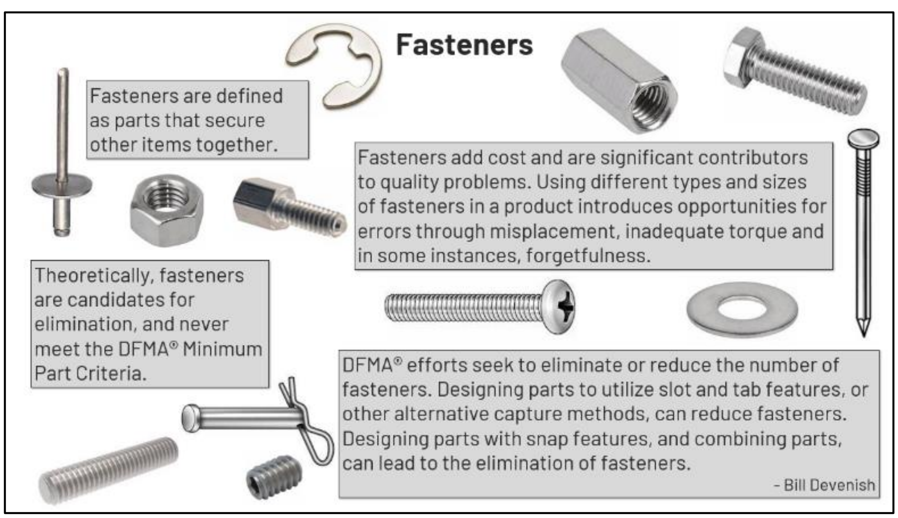
The remaining parts in an assembly that don't meet the criteria are candidates for combination or elimination. These don't meet the criteria.

When conducting a DFA analysis, all parts in the assembly must be evaluated against a Minimum Part Criteria category. Again, the purpose of the Minimum Part Criteria is to examine each part for the possibility of elimination or combination with other parts in the product. When assigning parts their respective category it is important to proceed in the order of the actual assembly process. This provides the opportunity to compare the current part against the parts that have already been assembled and not those expected to come later in the assembly.

Fasteners

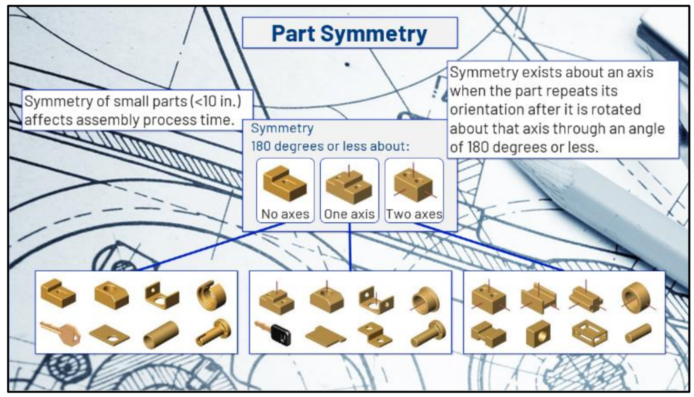
Fasteners, as well as connectors, never meet the Minimum Part Criteria, and are always considered candidates for combination or elimination. Fasteners are defined as parts that secure other items together. They include screws, washers, nuts, jack screws, studs, nails, bolts, rivets, set screws, pins, stand-offs and rings.

Fasteners add cost and are significant contributors to quality problems. Using different types and sizes of fasteners in a product also introduces opportunities for errors through misplacement, inadequate torque and in some instances, forgetfulness. DFMA® seeks to eliminate or reduce the number of fasteners in an assembly. Designing parts to utilize slot and tab features, or other alternative capture methods, can reduce fasteners. Designing parts with snap features, and combining parts, can likewise lead to the elimination of fasteners.



Part Symmetry

One of the part characteristics evaluated in DFA analysis is symmetry of the part that is inserted into an assembly. Symmetry impacts the handling and insertion times for parts that are smaller than 10 inches, and assemblies smaller than 15 inches. A part that is symmetric about an axis can be rotated 180 degrees, or less, around that axis, and still be inserted correctly into the assembly.



- The parts shown in the lower-left box of the slide have no axes of symmetry, because they only have one specific orientation that must be maintained during assembly, such as the house key. The parts in the lower-left box will have higher assembly times.
- The parts in the lower-middle box all have one axis of symmetry. They can be rotated 180 degrees about the axis of insertion and still be assembled correctly, such as the car key.
- The parts in the lower-right box have at least two axes of symmetry, such as the dowel pin in the far-right corner. Since these parts have the most orientation flexibility during assembly, they also have the lowest handling and insertion times.

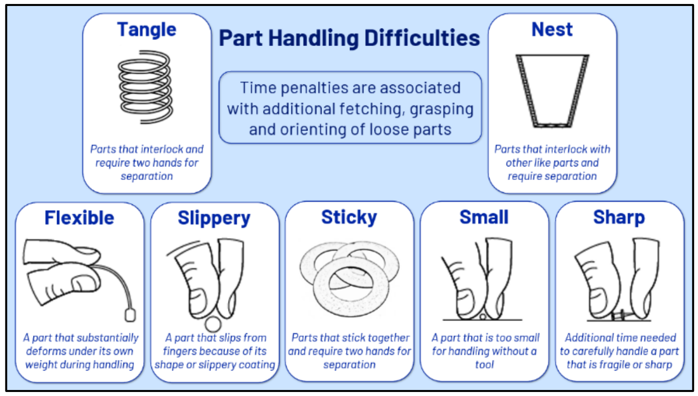
Evaluating part symmetry during DFA analysis can lead to team discussions for mistake-proofing the assembly.

Part Handling Difficulties

Part Handling is a characteristic of DFA analysis that evaluates how the individual parts are fetched, grasped, and oriented prior to insertion. The Handling Difficulties mentioned below add time to an assembly.

- Parts that tangle are usually interlocked and require the use of two hands for separation.
- Parts that nest also interlock with other similar parts and require separation, normally with two hands.

- Flexible parts don't maintain their shape when held at one end and are easily deformed.
- Slippery parts will slip from fingers because of their size, shape, or outer coating.
- Parts that stick together and require two hands for separation are considered sticky.



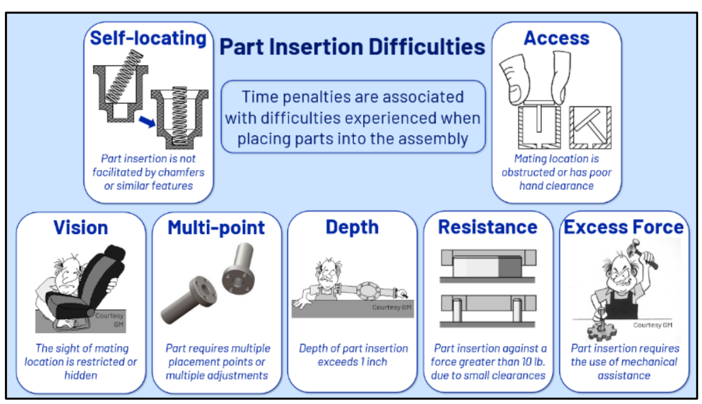
- Parts are considered small when they require a tool, such as tweezers, for handling.
- Some parts are sharp or fragile and require additional handling time to prevent operator injury or part damage.

Evaluating parts for Handling Difficulties identifies opportunities to reduce time penalties.

Part Insertion Difficulties

Part Insertion is a characteristic of DFA analysis that evaluates how the individual parts are placed into an assembly.

- Parts that have self-locating difficulties are those that have guiding features integrated into their design and do not require assistance from the operator to align the parts.
- Access difficulties are applied to parts where the mating location is obstructed or there is poor hand clearance.
- Vision difficulties exist when the sight of the mating location is restricted or hidden. Usually this relies on the tactile sense of the operator to install the part correctly.
- Multi-point difficulties arise when a part requires multiple placement points or adjustments during installation.



- A time penalty is also applied to parts that exceed 1 inch of insertion depth, such as long tubes and wires, or cable harnesses.

- Parts that require a force greater than 10 pounds due to small clearances have what is called a resistance difficulty.
- Excessive force insertion difficulties typically require the use of mechanical assistance, like a hammer or pry bar.

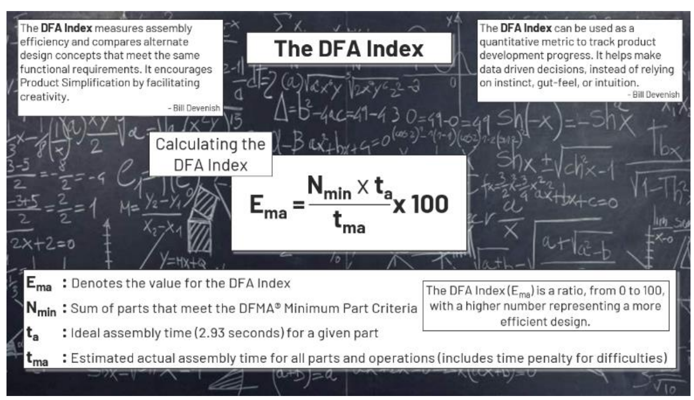
Evaluating parts for Insertion Difficulties also identifies opportunities to reduce associated time penalties.

The DFA Index

An essential ingredient of DFA, known as the DFA Index, provides a way to measure assembly efficiency. It is a ratio of the theoretically ideal assembly time over the actual assembly time. The range is from 0 to 100, with a higher number representing a more efficient design. The DFA Index is based on decades of performing time studies and collecting data by Boothroyd Dewhurst, and it can be used to compare alternate design concepts that have been created to meet the same functional requirements. The DFA Index can also be used to make data driven decisions, instead of relying on instinct, gut-feel, or intuition.

The formula for calculating the DFA Index is shown in the middle of the slide.

- E_{ma} represents the value for the DFA Index.
- The Numerator in the equation is defined by the theoretically ideal assembly time, where N_{min} is the Theoretical Minimum Number of Parts in the assembly multiplied by t_a, the Ideal Assembly Time for a given part, which is equivalent to 2.93 seconds.



- The Denominator is defined by the Estimated Assembly Time, t_{ma}, which includes penalties for handling and insertion difficulties, along with time penalties for operations and parts that don't meet the Minimum Part Criteria.

The DFA Index can be used as a quantitative metric to track the progress of product development. It also encourages Product Simplification by facilitating creativity.

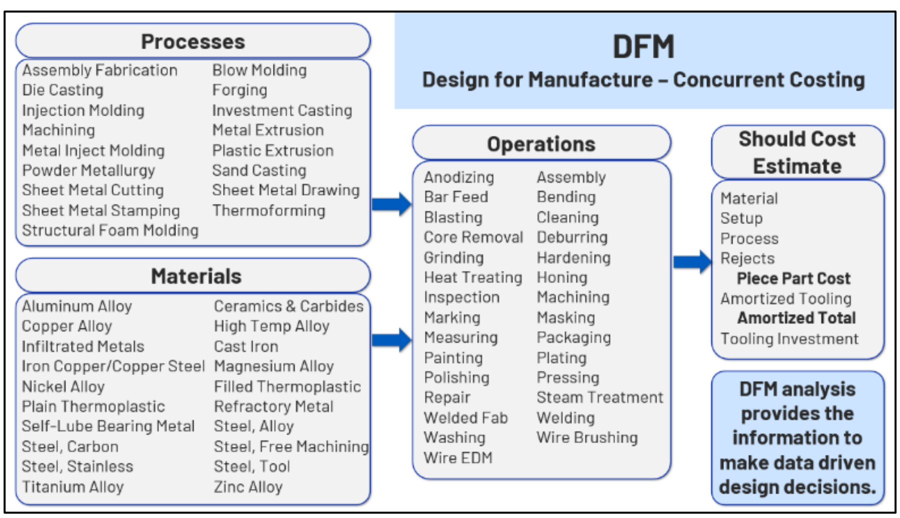
DFM – Concurrent Costing

Many creative solutions for simplifying a product assembly often lead to an important question. How much will it cost to make this redesigned, or combined, part? DFM, or Design for Manufacture, sometimes referred to as Concurrent Costing, can deliver the answers. Results from early DFM Should Cost analysis can provide the data necessary to make well-informed design decisions.

DFM analysis combines a variety of manufacturing processes with an abundance of commonly used materials associated with the creation of parts. Additionally, secondary operations provide the necessary details for determining a reliable Should Cost estimate.

An initial evaluation of manufacturability is performed when the DFM analysis variables are selected. For instance, if a die-casting process is chosen, then only compatible metal materials are presented for selection. Caution messages will also appear when part geometry and lifetime volumes are inconsistent with basic design guidelines.

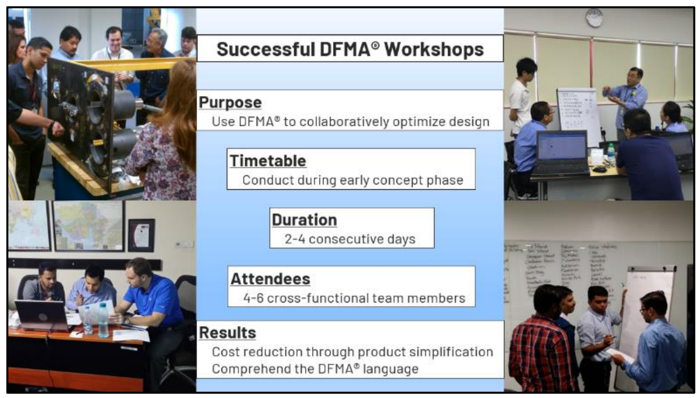
The cost results of DFM analysis are divided into different categories, such as the cost of material, setup charges, process costs, and rejects. The Piece Part Cost is the sum of these categories, which represents the cost of the part. If applicable, the tooling investment, including programming charges, is estimated, and then amortized to indicate the total cost of the part. The resulting Should Cost estimate provides the information to make data driven design decisions.



Successful DFMA® Workshops

DFMA® outcomes are significantly enhanced when the methodology is coupled with a DFMA® Workshop. The purpose of a workshop is to use the DFMA® tools to optimize product design through collaborative, multi-functional, teams. DFMA® Workshops achieve superlative results when conducted early in the concept phase of design before time and effort have been invested into a single concept that may not be optimal. Therefore, workshops are best held when a design idea is readily changeable.

Typically, a DFMA® Workshop is held throughout 2 to 4 consecutive days. The number of attendees ideally is between 4 and 6 and should consist of individuals with knowledge about the design requirements and constraints, as well as manufacturing people who have experience assembling similar products. Associated purchasing and quality personnel are also valuable contributors. If those attending the event have not previously participated in a DFMA® Workshop, the morning of the first day is spent conducting basic training about the DFMA® methodology and its associated language.



It is critical to set aggressive goals when establishing expectations for a DFMA® Workshop. And it is not surprising to see results of 50% improvement. Goals could include reduce number of fasteners by 50%, double throughput, eliminate 50% of the parts, etc. Setting a high bar will encourage creativity and innovation.

Conclusion

The intent of DFMA® analysis is to evaluate the efficiency of an assembly, understand the key part cost drivers, and unleash team creativity to improve the assembly by comparing alternate design approaches. The DFMA® methodology provides a structured approach to collaboratively assess and creatively develop optimized design concepts. Ultimately, DFMA® analysis leads to simplified product designs and helps teams achieve what might initially be thought as the impossible.

About the Author

Bill Devenish, president of The Devenish Group, is a long-time Design for Manufacture and Assembly advocate and recipient of the 2016 DFMA® Supporter of the Year award. As a global DFMA® expert, he has implemented DFMA® among numerous large and small companies, with products ranging from high-volume electronics to low-volume, customizable, assemblies. While R&D Manager at Nokia, Bill led the team that developed the first smart phone released in North America. He holds ten patents and has authored several papers related to DFMA®. Bill's facilitation skills and passion for DFMA® result in successful workshops, training and cost reduction efforts.

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