A Practical Guide to Design for Manufacturability
In this article, we provide an overview of design for manufacturability (DFM), a crucial methodology utilized by designers and engineers to avoid costly mistakes in the early stages of product modeling that could complicate and delay the manufacturing process.

This guide defines this methodology, looks at its importance for manufacturing organizations, outlines some fundamental principles, and concludes with a look at some real examples of design for manufacturability in action.
The Basics of Design for Manufacturability

Manufacturability Definition: What is Manufacturability?

Manufacturability describes the degree to which a product can be effectively manufactured given its design, cost, and distribution requirements.

A manufacturability issue, therefore, could center on either or both:

OVERALL FEASIBILITY
A design using a routing that simply cannot be produced in the manner specified.

EXCESS COST
Manufacturability is a serious and multi-faceted concern. And, because a product’s requisite manufacturing process is effectively locked-in once a design is finalized, product designers ideally need a methodology for modeling manufacturing cost outcomes while designing a product.
Design for Manufacturability Definition

Design for manufacturability is the engineering practice of designing products to optimize their manufacturing ease and cost given form, fit, and function requirements.

Because manufacturing processes are so numerous and varied, effective design for manufacturability may hinge on very different analyses for different products, including anything from cooling times for molded parts to the type of material or machine selected.

Applications of Design for Manufacturability

The precise applications of DFM can be as varied as production processes themselves.

_We take a look at some specific case studies later in the article._

Some high-level examples of DFM tasks include:

- Comparing design alternatives to understand which one has the least manufacturability issues and is least expensive to produce.
- Identifying design features that unnecessarily drive requirements for additional manufacturing operations.
- Uncovering why a design is returning higher bids from supply chain partners than expected.
- Ensuring that manufacturing issues don’t surface in the later stages of the design lifecycle and hold up a time-sensitive product rollout.

With a large number of manufacturing processes and complex cost drivers, DFM product modeling has, historically, been a serious analytical challenge. Today, however, digital manufacturing simulation tools are enabling engineering organizations to institute deep DFM modeling that would have been computationally prohibitive in the past.
History of Designing for Manufacturability

Any commercial design process is presumably conducted with at least some attention to how the underlying product will ultimately be produced. But design for manufacturability today describes a more formalized, analytical approach to this underlying concern—a dramatic break from historical practices.

Historically, designing for manufacturability:

- **Relied on trial and error**: Outside of scaling up pilot production lines, manufacturers have had limited capabilities for truly modeling production. This limitation has evolved over the past 3-5 years with the mainstream adoption of 3D printing—but even this can be time consuming and expensive.

- **Leaned heavily on past experience**: In the absence of digital manufacturing simulation, comparable past projects are the only reliable source of data on manufacturability.

- Were limited to relatively **ad hoc calculations**. While tools like spreadsheet software are helpful for straightforward manufacturability calculations, they have few mechanisms for analyzing complex interrelationships between design, manufacturing process, and cost structure.

- Existed in a **separate organizational silo** from design. Completely separating the professional responsibilities of design and production engineers can be highly problematic since so many production parameters are effectively locked in at the design phase.

Today, powerful new software tools for DFM analysis have allowed organizations to bring a far more comprehensive understanding of manufacturability issues into their design process. We provide more details on this software and its functionality below.
02. Key Benefits of DFM

- Without robust DFM modeling, manufacturability issues risk coming to light once a product has already gone to production. The right DFM tools can identify manufacturability issues while a product is still being designed, dramatically de-risking new product development.

- The most powerful design for manufacturability tools don't just provide warnings about manufacturing issues, but actionable recommendations for resolving them. In many cases, a relatively simple design tweak can avert the potential issue.

- For existing product offerings, pinpointing opportunities for manufacturing process optimization may uncover opportunities to lower costs without unduly affecting a design’s form, fit, and function. Optimizing designs for manufacturability can also help shorten production and distribution timelines.

- For organizations that design products and outsource manufacturing, sophisticated DFM analysis capabilities can speed up product development timelines. Instead of waiting for suppliers to provide quotes and feedback on manufacturability for each design iteration, engineers can analyze manufacturability in-house.

However vital, design for manufacturability is only one part of the puzzle when it comes to optimizing product costs. For a deeper look at cost reduction, we recommend our whitepaper here.
Who is Responsible for DFM?

Design for manufacturability can be the domain of several types of different professionals depending on the organizational context.

- For organizations developing new products, designers and engineers can utilize DFM tools and methodologies to proactively prevent manufacturability issues and cost overruns.
- Cost engineering professionals may bring DFM analyses to bear on current product offerings to pinpoint opportunities for manufacturability-driven cost reduction opportunities.

Design for Manufacturability vs Design for Assembly

It can be helpful to distinguish design for manufacturability from the closely related idea of a design for assembly.

Design for assembly refers to designing a product to maximize how easily it can be assembled and disassembled for repairs and maintenance. This approach often focuses on principles like minimizing the total number of parts used, ensuring that parts are easily insertable, and confining assembly requirements to simple, repetitive motions.

This focus is much more specific than design for manufacturability, which can cover manufacturing processes ranging from sheet metal fabrication, to plastic molding, casting and machining.
We outline some of the most important foundational concepts of design for manufacturability below.

Each of these principles shares a common theme: tying manufacturability issues directly to design decisions is itself a substantial analytical feat.

Truly understanding how each and every design decision affects overall manufacturing needs requires tools capable of actually simulating dozens of different manufacturing processes based on design-level inputs like 3D CAD files. While the principles are a great start, digital manufacturing simulation is the key to unlocking the analytical problem at the heart of DFM.
MANUFACTURING PROCESS CHOICE
The choice of production processes has huge implications for a product's overall cost structure. Functional design requirements often leave room to choose between multiple production methodologies if different component designs are being considered. A fully rationalized DFM strategy needs the ability to model each of these alternatives across multiple criteria: for instance, one production method may be marginally cheaper on a per-unit basis but introduce distribution costs far in excess of this production advantage.

DESIGN CHOICES REFLECTING MANUFACTURING REALITY
We look at using should costs to nurture more effective supplier negotiations and relationships below. For a cost-oriented redesign, manufacturing cost modeling software can help pinpoint the precise factors causing a component to exceed cost targets—the ultimate cause could include anything from excess weight driving high transportation cost to manual welding needs pushing up labor costs.

SMART/MODULAR COMPONENT SELECTION
In many cases selecting off-the-shelf parts (or parts already being manufactured for another design) may greatly simplify manufacturability without hampering overall function. The right DFM tools should enable an apples-to-apples comparison of the manufacturability/cost implications of selecting off-the-shelf versus custom manufactured parts.
REQUIREMENT-DRIVEN TOLERANCES AND SPECIFICATIONS
Materials that are over-specified (or too broadly specified) relative to functional needs can necessitate the use of a much more costly production process than is necessary. Ideally, DFM tools can be used to more precisely optimize material specifications given functional requirements and cost targets.

TOOLING MATTERS
Even a component that is not particularly costly on a per-unit basis can dramatically complicate production if it requires an entirely different tooling setup or production line. A robust DFM approach needs to estimate the total costs imposed by tooling needs associated with different design decisions. A part that is slightly more expensive may end up being optimal, for instance, if it prevents the products from needing to be transported to a separate production line.

COMPLIANCE/TESTING
In many industries where quality is enforced by regulatory agencies, compliance concerns, along with the direct costs of testing different design alternatives, should be treated as an integral aspect of broader manufacturability.
Cost-Visibility at the Speed of Business

A design for manufacturability strategy goes hand-in-hand with other contemporary methodologies for integrating a more holistic understanding of cost structure with product design.

The same simulation-driven tools that make it possible to quickly generate process-specific manufacturability analyses are bringing unprecedented precision to manufacturing cost modeling, for example.

We go into greater detail about how a comprehensive digital manufacturing simulation solution can provide in-depth manufacturing cost models faster than ever.
The Key Role of the Manufacturing Cost Modeling Software in Fact-Based Negotiations

Generating actionable factors on suppliers’ product costs requires detailed insight into underlying factors including:

- Material Costs/Manufacturing Process Costs
- Labor Costs
- Overhead
- Tooling/Facilities Investments

Calculating how these factors interact to contribute to a component’s ultimate cost structure is a very complex analytical challenge. A tweaked materials selection, for instance, may require a different manufacturing process only available at a different manufacturing facility with far higher rental and transportation costs.

The right manufacturing cost modeling software makes it far easier to generate detailed insight into cost structure that can impactfully inform supplier negotiations.
Three Steps Toward Instituting

1. Incorporate DFM Analysis as Early as Possible in the Design Process

The earlier manufacturing is considered; the more changes can be made. Once tooling has begun, options for re-engineering become increasingly limited.

Unlocking all the benefits associated with DFM effectively requires a variety of computationally intensive analyses, all of which are most impactfully conducted when a product is still being designed. The right software is essential to conducting this in-depth analysis without inhibiting innovation or delaying product development timelines.

2. Recognize Opportunities for Cooperative Product Development

If manufacturing is conducted in-house, DFM modeling needs to be a point of cooperation between production and design engineers, with manufacturing experts working directly with designers to facilitate optimal design choices for the manufacturing resources and constraints at hand.
Similarly, when working with suppliers to manufacture new product designs, DFM provides a collaborative bridge between these two parties to improve identification and elimination of manufacturability issues early in the design lifecycle.

This type of constructive collaboration has become even more essential as Original Equipment Manufacturers have increasingly outsourced product manufacturing to supply chain partners that may be located in another country, in another time zone, and possibly do not even speak the same language. DFM analysis is based on digital manufacturing simulation that facilitates review and markup of new designs allowing these parties to collaborate in a way that was simply not possible even five years ago.

3. Integrate with a Broader Strategy for Manufacturing Cost Modeling

Manufacturability is one of the factors that can be most difficult to effectively analyze at the design stage, but it’s not the only factor that can be decisive for a product's cost structure. Concerns ranging from product weight and size, to material utilization and scrap, to tooling costs, to labor and overhead costs all have huge implications for product cost structure (and are closely interrelated with manufacturability). We take a more comprehensive look at instituting a strategic approach to managing product costs in our white paper here.
We provide three specific examples of design for manufacturability below. These companies are real clients who used aPriori digital manufacturing simulation software to bring greater manufacturability modeling capabilities to their design process. We provide more detail on selecting design for manufacturability software below.

**Rafael Uses DFM to Reduce Costs and Improve Sourcing**

The Israeli aerospace company Rafael uses aPriori as their enterprise digital manufacturing simulation software, including DFM analyses. They were struggling with a part that was returning all no-bids and decided to analyze the part using aPriori.

aPriori showed an almost impossible under cut in the routing. This design feature ended up being a largely arbitrary choice and eliminating it reduced cost by over 50%. The new design was not only far more cost-effective but drew far more bids from potential suppliers. You can learn more about this Rafael success story in our video here.
Honeywell Aerospace Uses DFM as Part of a Broader Cost Management Strategy

DFM simulation drives even more value when deployed as part of a broader cost management campaign. Honeywell Aerospace, a globally recognized maker of aircraft engines, avionics, and other systems, provides a great real-life example.

In the video available here, you’ll see real examples of Honeywell using aPriori for Should Costing Analysis, supplier negotiation, manufacturability analysis, and more. You’ll see how Honeywell engineers preemptively discovered potential manufacturing issues in a key redesign effort. In addition to eliminating these issues, Honeywell was able to source bids for this part that were closer to estimates than ever before.

Spirit Aerosystems Pinpoints Design Choices Driving Manufacturing Cost Outliers

Spirit Aerosystems is the world’s largest tier one aerostructures manufacturer.

In the video linked below, you’ll see a great example of how a few seemingly innocuous design choices can have serious implications for cost structure by making a part more complicated to produce. In this case, a few features like external radii and fine aesthetic filleting were causing a part to cost 11% more than necessary.
To maximize its impact, design for manufacturability software not only needs highly-specific analytical capabilities covering many different manufacturing processes, but the ability to deliver this insight to design engineers in real-time—enabling designers to rapidly look at the implications of different manufacturing scenarios for different design alternatives.
DFM Software Should Be Fast and Easy to Use

To generate manufacturing analyses during the design stage, your software must be extremely fast and very easy to use. With aPriori, for instance, the modeling process begins by analyzing a 3D CAD model to generate a digital twin. After specifying a few basic inputs such as production volume, manufacturing process, and manufacturing location, aPriori can then simulate production in a “digital factory” to generate manufacturability and cost models in seconds.

In addition to running manufacturing simulations very fast, the output of the analysis should be extremely easy to interpret. Identification of potential manufacturability issues should be highly graphical and pinpoint areas for improvement. For example, the system should be able to quickly identify any machining operations where the cycle time is abnormally high. While there may be a good reason for this, it may also identify a design flaw that if corrected could dramatically accelerate the manufacturing process and accordingly drive down cost.
DFM Software Needs the Ability to Simulate Key Manufacturing Processes

To generate in depth DFM insights, there is no substitute for detailed digital manufacturing simulation.

This simulation needs to include a wide variety of potential production processes so that the digital factory can be ready to model nearly any potential design. For instance, a short representative list of manufacturing processes supported by aPriori out-of-the-box include:

- Sheet Metal (Soft Tooled/Stamping/Die Stamping/Hydroforming)
- Metal Casting (Die Casting, Sand Casting)
- Extrusions
- Plastic Molding
- Machining (Milling/Turning/Grinding)
- Wire Harness & PCB Assembly
- Welding & Other Joining/Assembly processes
- Heat & Surface Treatments

For the full list of models employed by aPriori, download our data sheet.
As we have explored in this article, the analytical capabilities needed to truly understand a design's manufacturability can drive multifaceted business value: accelerated product development timelines, unprecedented cooperation between designers and manufacturing engineers, and, ultimately, products that are as cost-competitive as possible.

To leave no stone unturned in this analysis, DFM software needs to be comprehensive, with the ability to estimate manufacturability implications ranging from production, to labor, to distribution. But even the most comprehensive analysis won’t unlock the benefits discussed in the article if it’s not usable in the context of fast-paced, collaborative design effort. That’s precisely why selecting the right DFM toolkit is so important.

If you’re interested in a detailed guide to picking the right software for your business, we’ve created a resource specifically to help prospective buyers select the most impactful possible software. Click here to read our article on what to look for in Manufacturing Cost Estimation Software here.
aPriori Provides Actionable Insight for Better Manufacturing

aPriori is the leading provider of digital manufacturing simulation software. By leveraging the digital twin with our digital factories, we automatically generate Design for Manufacturability (DFM) & Design to Cost (DTC) insights, helping manufacturers collaborate across the product development process to make better design, sourcing and manufacturing decisions that create higher value products in less time.

aPriori works with manufacturers to bring simulation-driven cost estimation into the design process, empowering organizations to treat cost as a true independent variable in the design process.

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