Quantifying Design for Manufacturability

John Rokus

It was the scientist Lord Kelvin who said, "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind." So, if you are among those in the medical device industry who are struggling to keep DFM alive and well within your organization, or you plan to kick off a DFx initiative, this article is for you.

While Google and Wikipedia were both fruitless in providing a definitive answer as to the origins of Design for Manufacturability (DFM), it does not diminish the profound impact the process can have on real profitability. The vast majority of medical device engineers and engineering managers are familiar with DFM or Design For “x” (DFx) concepts but relatively few have implemented methods to measure the effectiveness of their efforts.

Consider the following formula: Price = Cost + Profit. In a noncompetitive environment, a company may get away with assuming Cost and Profit are fixed amounts by which they determine the Price they will charge for their product.

Now consider this version of the formula; Profit = Price – Cost, where Price is fixed by what the market will bear and Cost is the true variable by which Profit can be maximized.

Designing for manufacturability is an essential core competency for any design or manufacturing company that is seeking customers in a competitive environment because it supports a holistic approach to cost and profitability. Think of it as lean design if you’re in a company practicing Lean. It helps analyze designs and make decisions that lower overall costs, not just product costs. Combining DFM with new product development will yield significant cost reductions by:

- Increasing manufacturing throughput
- Reducing damage rates of products and people
- Obtaining higher first time quality
- Streamlining logistics
- Faster development and delivery of new products.

When to apply DFM

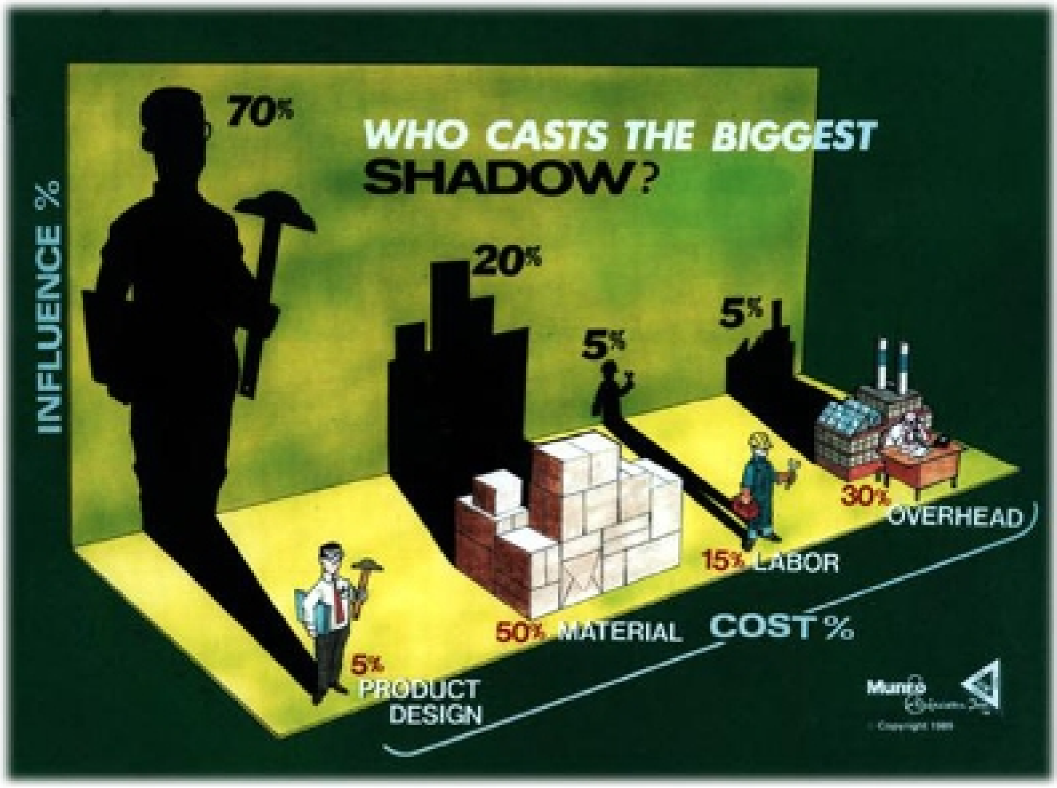

Figure 1. Influencing Product Cost

Design engineering will often cry, "It's too early, the design isn't far enough along for critique" only to find themselves later saying, "Oh, we should have done this six months ago because the tooling has already been cut"

Most DFM experts will agree that approximately 65% of the total product cost will be dictated by the specified materials and required labor to assemble with only 5% accounted for in product design efforts. Ironically, the tiny proportion of the product cost consumed by design engineering will account for 70% of influence on the total product cost. A quick study of Figure 1 will highlight the importance of product design on product cost relative to its financial investment over the life of the product.

So, with this realization, it becomes apparent that we must initiate DFM efforts earlier than intuition would suggest. Most organizations can accept this suggestion as long as the effort is type cast correctly and void of process ambiguity. This brings us to our first and most fundamental way to quantify our efforts through Conceptual DFM analysis and "The Part Value Challenge".

Conceptual DFM
What is it? – Conceptual DFM helps analyze the design concept through the part value challenge but it also facilitates other high level discussion that is design related but often times not discussed within new product development teams as early as it should be in order to maximize manufacturing, procurement and quality systems.

When do we do it? – After customer requirements are gathered and before any significant amount of CAD work starts.

Who should facilitate? - Project Manager or Design Engineer

Does it have to be done on the entire assembly? – No, conceptual DFM analysis sessions can be broken down to smaller subassemblies. Especially in the case where some parts of the design are further along than others.

Who should attend?
Design Engineering
Manufacturing Engineer
Quality
Procurement
Suppliers as appropriate

*What should be brought to the meetin*g?
1. Any tangible product or products that will help visualize the concept design.

2. Customer requirements

Function specific questions to be asked:

Manufacturing:

- Are we designing in parts or processes that will require unfamiliar equipment or methods? If so, does the project plan incorporate related milestones to bring the equipment in and get it and it's processes validated?
- What fixtures or assembly aids will be required in assembly? Can we design them out?
- Procurement:
  Are we designing in any parts with lead times longer than xx weeks>
- Are any of the parts single sourced? What would it take to make them dual sourced?
- Are we designing in any parts with risk of going obsolete within the product life cycle?

Quality - Considering other similar products, what quality or reliability issues stand out that need to be addressed or avoided on this new design?

Test Engineering - Do we have a concept for end of line production testing and will it comply with internal best practices for cycle time and repeatability?

Part Value Challenge

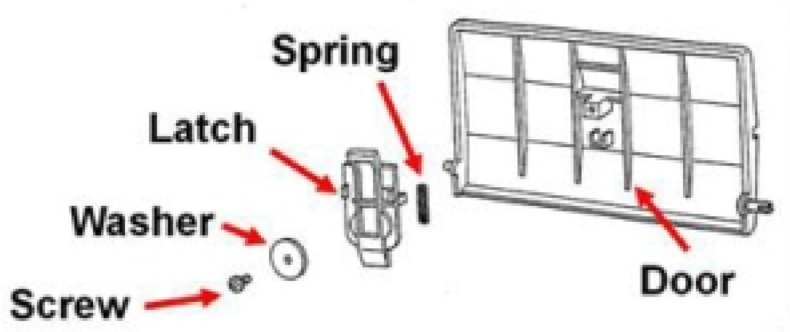

Figure 2.Original Door Design

The intent of the part value challenge is to provide a high level assessment of the parts intended to be used in the makeup of the product. This tool is used to help safeguard against putting hours of detail design work into a concept that is way off the mark in terms of being DFM friendly.

Here's how it works. Conceptually or literally, the designer creates a bill of material to the best of his ability (actual piece part dimensions may be unknown but material, quantity and basic description will suffice). The DFM team evaluates each part against predetermined criteria and labels each part good or bad. Calculating the ratio of good parts to the total number of parts results in a metric titled: Design Efficiency. If the design efficiency is less than 30%, stop the current design, develop a new concept and reanalyze.

For printed circuit board components, we ask the following questions and if the answer is yes to any of these questions then the part is considered bad.

1. Can the part's function be combined within other parts or components?
2. Does the component require manual soldering?
3. Can the component utilize surface mount technology?

Note: wires, threaded fasteners and loose interconnects are always candidates for elimination.

For parts other than circuit boards, the following questions can be used:

1. Does the part have to move?
2. Does the part have to be a fundamentally different material?

Individual companies who experiment with the part value challenge will often derive a set of customized questions to better serve their industry and tribal knowledge of design elements that have hurt them in the past

- Conceptual DFM deliverables:

Design Efficiency %......Go or no go decision on the current concept (Design efficiency less than 30% requires fundamental redesign)
- List of ideas and action items to be followed up on in order to improve manufacturability, testability, reliability, serviceability, quality, procurement and mistake proofing, etc.

Practical DFM

What is it?—A workshop that applies a method for analyzing the parts and associated assembly operations in an attempt to apply standardized penalty points to the design so that a design team can:

- Use the scores to compare different design alternatives
- Establish benchmarks and “target” design scores for similar designs in the future
- Think holistically and get all of the benefit from the design review instead of cherry picking a few good ideas.
- Stimulate creative thinking
- Heighten the design engineers’ awareness of manufacturing problems and make manufacturing engineers aware of functional problems

The scoring system is organized into six categories. Each category contains a set of related penalties with pre-defined descriptions and points to be applied when applicable.

1. Pick-up Part
2. Part to Operator Interface
3. Part to Part Interface
4. Tools
5. Operations
6. Fastening

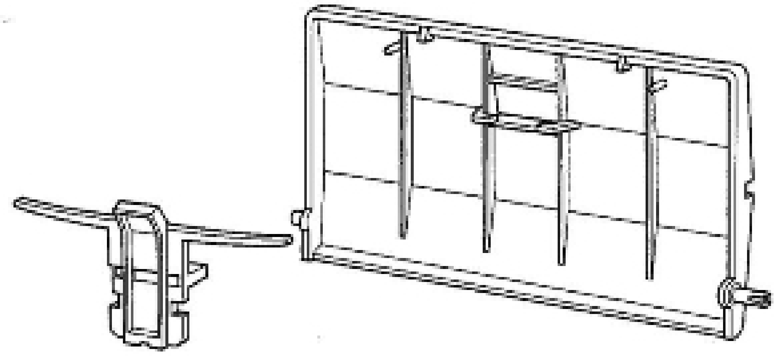

Figure 3. DFM Door Design

For example, every part that has to be picked up prior to being added to the assembly must be assessed for its Pick-up Part score. A part requiring one hand to pick it up gets two points. A two hand pick-up gets 3 points and parts having to use any sort of assist device is burdened with 30 penalty points. All parts are analyzed with all six categories until a cumulative score is obtained for the entire assembly.

In addition to this penalty score, it is highly recommended to capture or estimate additional metrics such as labor associated with each assembly step, number of assembly steps, number of parts, number of “good” parts, number of fasteners and the number of opportunities for incorrect assembly (Poka Yoke issues).

How do you do it? – While software is available from more than one supplier, it is possible to develop your own methodology and use Excel, Visio or plotter paper and sticky notes to document the scores for each part and category.

How long does it last? –Workshops can last several hours, depending on the complexity of the assembly and the experience of the team. It is not unusual to spend three hours to score a design and 1 hour to brainstorm and prioritize DFM improvements.

When to do it? – Practical DFM can take place any time after the conceptual session as long as the window for design changes is open.

What preparation is required? – In particular, the manufacturing and design engineers use of concurrent engineering prior to the Practical DFM session should have allowed the manufacturing engineer to developed a preliminary manufacturing plan inclusive of process steps broken down to the piece part level, a list of tools and fixtures required in each step and assumptions for fastening methods if they are not already defined.

Practical DFM example

Consider the simple compartment door design shown in figure 2.

Now consider its potential for redesign as shown in figure 3.

In this example, the proposed design accomplishes several key DFM objectives:

- Reduction in the overall part count
- Reduced assembly labor
- Reduction for incoming inspection
- Reduction in the number of suppliers
- Reduction in the number of opportunities for operator assembly error
- Elimination of threaded fasteners
- Elimination of a tool required for assembly
- Elimination of part types with potential to rattle

A typical format for summarizing the results and facilitating decision making is shown in table 1. The table provides a simplified quantitative comparison the original and proposed designs. While most of the entries are self-explanatory, notice the entries for Quality Burden. In some cases this is a subjective number but in many cases, a company will have historical quality records to substantiate the cost of poor quality.

DFM Executive Summary

Product: Compartment Door

Date: 01/26/12

Team members: Jeff, Hayley, Eric, Caitlyn, Ron, Brad

	Original Design	DFM Re-Design
Parts	5	2
Good Parts	2	2
Process/Assembly Steps	11	4
Process/Assembly Time	55 sec	8 sec
Fasteners	1	0
Opportunities for Assembly Error	1	0
Total Material Cost	$0.31	$0.30
Total Labor Cost	$0.46	$0.07
Quality Burden	$0.03	$0.00
Total Cost	$0.80	$0.37
Investment Cost	0	$100,000
Annual Production volume	600,000	600,000
Annual Savings	N/A	$258,822
Simple Payback	N/A	5 months

Table 1.Executive DFM Summary

Summary:
The beauty of DFM metrics is in its ability to help communicate several cost variables instead of focusing on individual piece part costs. Manufacturing engineers and Operations managers need a way to quantify their hidden factories that are negatively impacted by designs that are all too often thrown over the wall with little DFM applied. A final product design is essentially a life sentence to the assemblers and all those who support the product in production. New product development teams must accept the responsibility as the stewards of all those who build and support the product. This is one of those rare opportunities we have to satisfy the worker and Wall Street at the same time.

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allowing the reproduction of a portion of their training material including the structured methodology for calculating the design efficiency and the method described to score an entire assembly.

John Rokus was formerly Vice President of Continuous Improvement for Micro Power Electronics, Inc. [1] *A subsidiary of Electrochem Solutions, Inc., Micro Power supplies custom battery systems to the portable medical, handheld Automatic Identification and Data Collection (AIDC) and commercial military markets. Micro Power is ISO 13485 and 9001:2008 certified, as well as ITAR registered.*

Links:
[1] http://www.micro-power.com/