DFMA – The Best Tool in the Engineer's Toolbox

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Abstract

This paper looks a DFMA and its potential impact on product design. Discussion of potential analysis capabilities, and finally focuses on theoretical minimum part count which drives an understanding of why part count is one of the most impactful criteria when considering product cost.

Setting The Stage

In the 1970's manufacturers discovered the need for peripheral equipment feeders and grippers to present parts so that a robot could place them appropriately in the product assembly. Boothroyd and Dewhurst did pioneering work in assembly automation in product design which included the analysis of parts for automated feeding. (Boothroyd, 1991) As the robotic revolution faded in the United States, analysis in the area of design for manufacturing and assembly (DFMA) shifted focus to the analysis of whole products and their constituent parts and subassemblies. If 70 – 80% of a product's final cost derives from materials, it stands to reason the fastest way to reduce cost would be to eliminate parts/subassemblies.[1] Although the DFMA process can do many types of analysis[2] ie; Early Product Costing, Competitive product benchmarking, Concept selection, Creation of time standards, Assembly Instructions, Design Simplification, Cost reduction, Quality improvements, Vendor quote verification, Estimating hard tooling, and material process selection the biggest bang for the buck is still analyzing an assembly with an eye to part count reduction.

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[1] Meeker, David and Nicholas Dewhurst. "DFMA and its Role in Cost Management" *The 20 th Annual International Conference on DFMA* Warwick, RI June (2005)

[2] Meeker,David. "DFMA a multifunctional Analysis Tool" *The 22nd International Conference on DFMA* Warwick, RI June (2007)

Why is part count reduction so important?

The design of the product, and perhaps more specifically its resulting part count are likely what control and determine everything else that happens downstream. Think for a few minutes about the journey of a part in a product. First a design engineer envisions a need for a part as being a critical component of a product. It's critical because if it wasn't he or she wouldn't have taken the time to design it in the first place. That part now becomes a CAD model, it's assigned a part number, and a place in the 'system'. It's added to the bill of material (BOM). Next a drawing is created for it. Its dimensions and appropriate tolerances are applied to make it function as desired in the product. Its checked (hopefully) and signed off on by a senior team member. That parts drawing then makes it way to purchasing and is sent to suppliers for quotes. Quotes are received, reviewed, and a supplier is selected. The supplier gets the purchase order and production of the part begins. It's made, inspected, issues with its manufacture are dealt with and finally it's shipped to the company. The company receives the part, inspects it, documents that its now in inventory and places it on a shelf in the warehouse. The assembly line now needs the part so it's retrieved from inventory, moved to the assembly station where it's used and then finally the assembly worker picks that part up and installs it into the product that uses it. This journey takes place hundreds or even thousands of times depending on the company and the products it is producing. Just take a few minutes to think about all of that time and energy and ultimately cost that is being incurred to add a part to a product. When we think about it in this amount of detail it seems ridiculous that we rarely take the time to ask ourselves whether that part actually needs to be in the product in the first place. It's for these reasons, in addition to the obvious piece part and labor cost savings, that the part count reduction aspects of DFMA are so vitally important to the success of a product. Ultimately it's the design of the product or products that controls the bottom line profitability of a business. Given all that's at stake it's hard to understand why we wouldn't make part count reduction and techniques available to help us accomplish it a normal part of the way we do product design. What would enhance this argument is if anyone out there could truly document the cost of a part to an organization "What it cost to own a part number"

As documented by the Parts Standardization and Management Committee in Reduce Program Costs through Parts Management, the cost of adding a new part into the inventory derives from Six different program areas: engineering and design, testing, manufacturing, purchasing, inventory, and logistics support. Table 1 summarizes these average costs by program activity. While it is possible that in some cases the added costs of adopting a unique part design could be offset by lower manufacturing or purchasing costs, such choices would need to be carefully justified and documented. [3]

[3] This document can be found at http://www.convergencedata.net/Docs/PartsMgt.pdf.

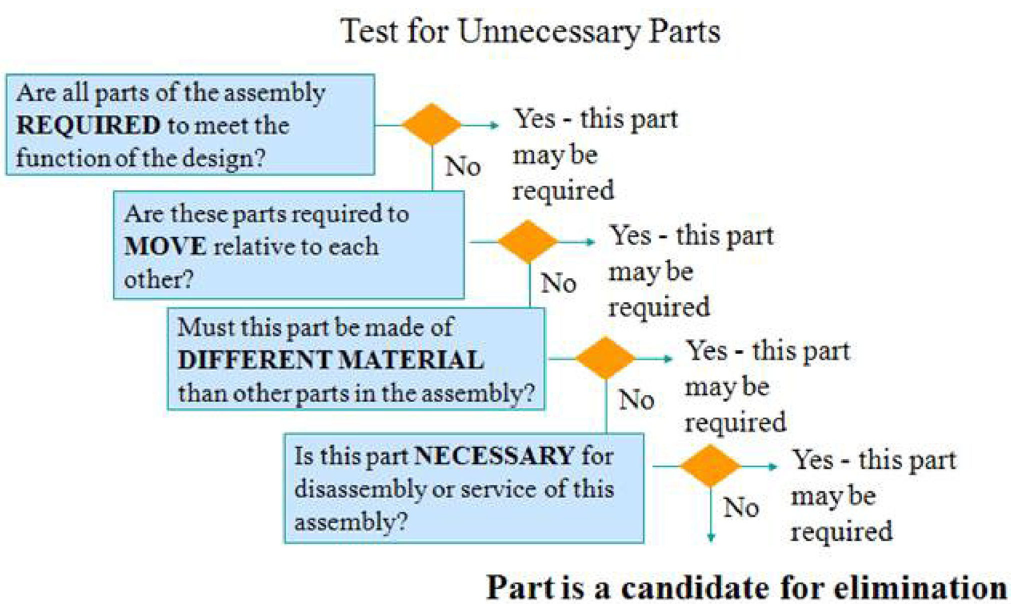
Table 1. Average Costs for Adding a Part into a System

Activity	Cost
Engineering and design	$12,600
Testing[a]	1,000
Manufacturing	2,400
Purchasing	5,200
Inventory	1,200
Logistics support	5,100
Total	$27,500

[a]The testing cost was reduced significantly because not every part added to inventory requires testing. However, every part needs to be evaluated, either by similarity, bench test, or analysis.

Boothroyd and Dewhurst (B&D) developed the concept of theoretical minimum part count [4] which serves as a goal for the product designer to quickly determine the parts that are required to accomplish a products end function. To this end Geoffrey Boothroyd and Peter Dewhurst created a simple set of criteria for this

To determine if a part was a candidate for elimination a set of simple questions were developed.



If the answer to all of these questions is “NO” then this part is a good candidate for elimination. The exercise of how to design the product and hit the theoretical minimum part count was left to the imagination and creativity of the design team.

[4] Manufacture and Assembly 2nd edition, G. Boothroyd, P.Dewhurst, W. Knight, Marcel Decker NY, NY, 2009. Pg’s 12 & 94

THAT CREATIVE SPARK

When you look at a product design, many of its constituent parts, like brackets, fasteners, and sheet metal trays create internal structure. The only real purpose of the infrastructure is to hold together all the parts and subassemblies that need to be interconnected so that the product will function. As such, these parts are the ones most often highlighted for elimination when the theoretical minimum part count questions are asked. One of the earliest products to employ DFMA and the power of using theoretical part count was the IBM ProPrinter.[5] By using the theoretical minimum part technique as a target, IBM was able to eliminate all the fasteners, brackets and unnecessary pieces of hardware from its ProPrinter. In the ProPrinter, the base tray played a major role in fastener / bracket elimination. After redesign, every part in the ProPrinter fastened to the base tray via a snap fit, and subsequent parts snap fitted into parts already in place. In contrast, Epson's PC printer the MX80 used a lot of hardware to fasten parts and subassemblies together and secure the final product assembly. As a result, the MX80 possessed 111 parts more than theoretical minimum, compared to three for the ProPrinter.

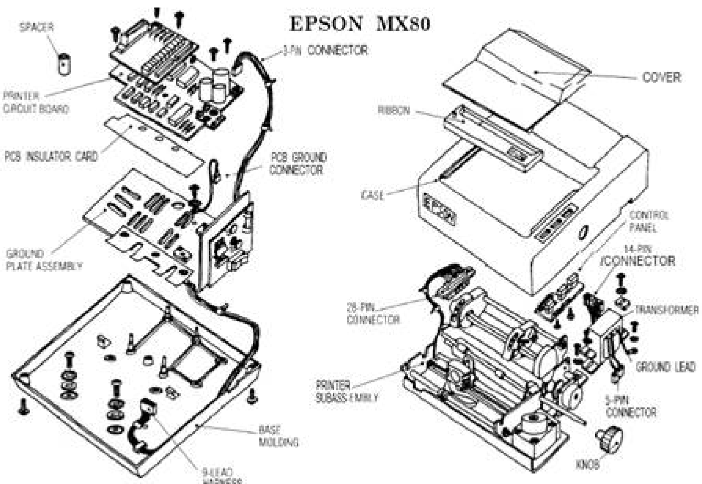


FIG. 1
The EPSON MX80 dot matrix printer final assembly consists of 49 parts or subassemblies as shown in this exploded view.

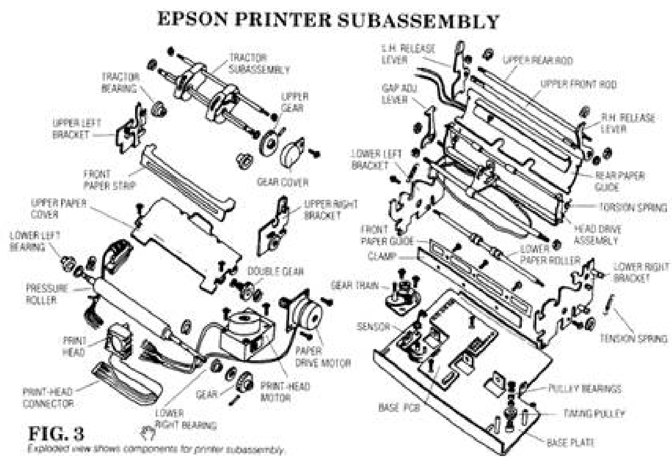


FIG. 3
Exploded view shows components for printer subassembly.

[5] Design for Assembly in Action, Assembly Engineering January 1987

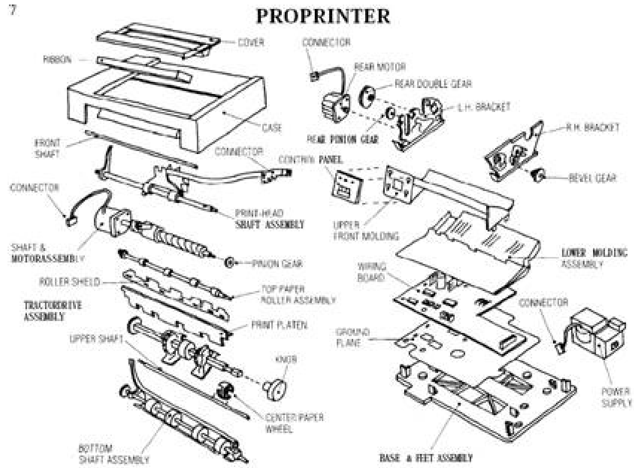
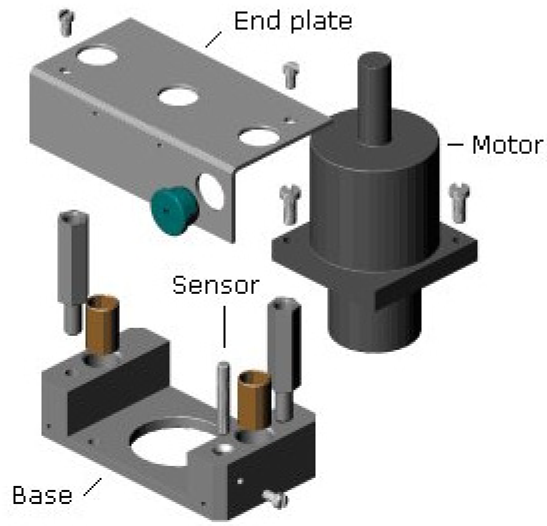


FIG. 5
Exploded view of IBM Proprinter highlights design simplification in this product.

Epson MX 80		**IBM PRO Printer**	
Total Assm. time sec.	1866.	Total Assm. Time	170.
Total Number of operations	185.	Total number of operations	32.
Total parts/subs.	152.	Total parts/subs.	32.
Theoretical part count	41.	Theoretical part count	29

Minimum Part Criteria Evaluation

Since the minimum part criteria is a little bit of an abstract concept it’s important that the answers to the questions be considered carefully. Many times when parts are evaluated against the questions the wrong answers are chosen because of a lack of true understanding of their application. First, and perhaps most importantly, the answers to these questions should be given from the perspective of “in some future redesign of the product, and not as they currently exist in the product or in the design concept today. Below is a case study of a motor that is used to control the gap between two rollers on a printing press. The unit has a small sensor that senses the gap between the rollers and tells the motor to move. The motor then moves the device up and down two hardened steel rails that run through the bushings. In the image below let’s look at how we evaluate the minimum part criteria for these brass bushings that are a bearing surface for the hardened steel rails over which the unit moves.



The bushings serve the function of providing a bearing surface on two hardened steel rails that run through them. One of the minimum part criteria questions asks if the bushings need to be a different material than others in the product. Many people answer this question by saying yes that the bushings do need to be made of a different material. In fact the opposite of this is true. The question really should be posed as "in some theoretical redesign of the motor do the bushings HAVE to be made of a different material". The answer to this question is clearly No as we could simply machine the base from the bushing material. This would provide a design where the three parts currently providing this function could be combined into one. We would then need to further investigate whether or not this would meet our cost targets by conducting a cost analysis on the new part. Note that the part could also be made from some other material that could provide this function; it doesn't have to be brass or aluminum. In the actual redesign of the product Nylon was used to machine the base.

The one mistake most people make when answering the questions is to not answer them literally. Just because you can't think of a way to design a part out of a product yet doesn't mean that it meets the theoretical minimum. A part being necessary for assembly (the third minimum part criteria) is typically the criteria people will choose when they have decided for themselves that they can't design the part out. This is the part of the process that requires thought and lots of creativity.

In Conclusion

The DFMA approach to product design is an important tool in the product designer tool kit. DFMA has been in existence for 31 years and has helped companies accomplish analysis in the following areas:

- Early Product Costing
- Competitive product benchmarking
- Concept selection
- Creation of time standards
- Assembly Instructions
- Design Simplification
- Cost reduction
- Quality
- Vendor quote verification
- Estimate hard tooling

The single largest impact to the product cost and the bottom line profitability of the business can be tied to part count reduction. The rigorous application of theoretical minimum part count will ensure a product is constructed of only parts that add value to its function. This conclusion is further bolstered by the results from a BDI study of 119 published DFMA case studies. These case studies covered a wide range of products, from consumer goods to military. The case studies showed an average of 54% part count reductions, yielded a 50% reduction in total cost.