DFMA Back to Its Roots

The Evolution and Application of DFMA

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Abstract

This paper will look at the evolution of DFMA and how its construction made it the flexible tool that it is today: used throughout the entire product design cycle from napkin to full volume production.

Setting the Stage

During the mid 1970's to the early 1980's a sense of optimism that the robot revolution would arrive existed; soon everything would be manufactured by robots in highly automated factories. The consultant phrase at the time was "Integrate, Automate, or Evaporate", catchy, creating many consulting dollars. Driven by the need to implement this coming manufacturing revolution, manufacturers discovered peripheral equipment feeders and grippers to present parts so that a robot could place them appropriately in the product assembly. With funding from the NSF, Boothroyd and Dewhurst did pioneering work in assembly automation which included the analysis of parts for automated feeding. (Boothroyd, 1991) The robotic revolution faded in the United States, mainly because inserting a robot to replace a worker to automate traditional hand assembled products was more difficult than initially believed.[1] The area of design for manufacturing and assembly (DFMA) shifted focus as a result to the analysis of whole products and their constituent parts and subassemblies. In 1983 using their academic research, Boothroyd and Dewhurst incorporated and began selling its DFMA software.

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[1] On a personal note, at the time I worked for Digital Equipment Corporation in the Advanced Manufacturing Technology group. The group created robotic work cells inside of miniature clean rooms. Our group purchased the first ever Adept robot when the company was just a start up and as a precaution we asked that its robot drawings be placed in a bank safe in case the company failed.

The philosophy behind the Design for Manufacturing and Assembly tool that you use today took shape between 1983 and 1988. Initially the NSF (9 years) funded research on DFMA. Later a number of companies, namely, Xerox, GE, DEC, AMP Inc., IBM, Gillette, and Westinghouse provided funding and formed in 1988 the Committee for the Advancement of Competitive Manufacturing (CACM). Members of (CACM) also included GM, Ford, Loctite, Navistar and Allied Signal, who were also instrumental in shaping DFMA into the tool that it is today. Funding for various research topics came from CACM members to create the DFMA tools CACM members needed for their design work. These research topics were then added to Boothroyd & Dewhurst's DFMA tool. Not all the research from that period successfully transitioned to the current day. For example, a lot of work that was done on environmental compliance that was way ahead of its time did not gain traction. Below is a time line of the development of the DFMA software that you know today.

DFMA Time Line

- 1977 – 1980 Boothroyd starts DFA research, first NSF funding, Dewhurst joins University of Massachusetts faculty.

- 1980 -1983 Boothroyd and Dewhurst (B&D) begin partnership, Development of DFA software for Apple II, conversion of software for IBM PC, DFA handbook published.

- 1983 – 1986 DFA PCB research begins, and Boothroyd and Dewhurst become University of Rhode Island (URI) faculty. W.A. Knight moves to URI, release of robotic assembly software, first DFMA conference held.

- 1986 - 1989 Work begins on DFM, publication of DFA handbook, machine parts and injection molding software release.

- 1988 Committee for the Advancement of Competitive Manufacturing formed, Members included GM, Ford, Loctite, DEC, Navistar, Allied Signal.

- 1989 - 1991 DFA 5.0 released with PCB analysis, Sheet metal DFM released, DFA 5.1 released supporting Macintosh and VMS, Die casting and Powder metal DFM software released.

- 1991 – 1994 Newer versions of DFA, Large parts DFA, and Design for the Environment, and additional DFM modules released.

- 1991 National Medal of Technology Recipients

  "For their concept, development and commercialization of DFMA, which has dramatically reduced costs, improved product quality and enhanced the competitiveness of major U.S. manufacturers."

- 1994 -1997 Updated versions of DFA and DFM, and Design for Service software release.

- 1997 - 2015 versions 7, 8, 9, 10 of DFA released as well DFM concurrent costing 2.0, 2.3, Major software rewrites kept in step with Microsoft operating systems releases.

- 2018 Introduction of CAD model data usage and integration into the software.

The modular design of the various elements of DFA & DFM along with the software's ability for customization of standard applications have made DFMA a flexible and versatile tool. It can truly be used from napkin sketch all the way to production. Because the software is customizable, it can be used throughout the design and production process:

- Competitive product benchmarking
- Concept Selection
- Early product costing
- Early product costing at sub assembly level (metrics)
- Creation of time standards
- Creation of assembly instructions
- Design simplification
- Material selection
- Cost reduction activities
- Outsourcing to far east
- Vendor quotation verification
- Helps generate IP
- Bid tool for customized products
- Other applications ....[2]

Other Design Methodologies

A number of design methodologies exist that attempt to help the designer explore the complicated space of mechanical, electrical, materials, and software into making a product. For example, G. Pahl's and W. Beitz's *Systematic Engineering Design* explores all facets of a design from basic engineering principles to optimize a final design. Nam Suh's *Axiomatic Design* aims to represent the product design as a high-level system architecture – domain and design axioms which allow for the creation of corollaries and theorems that can be used as design rules to optimize a product design.

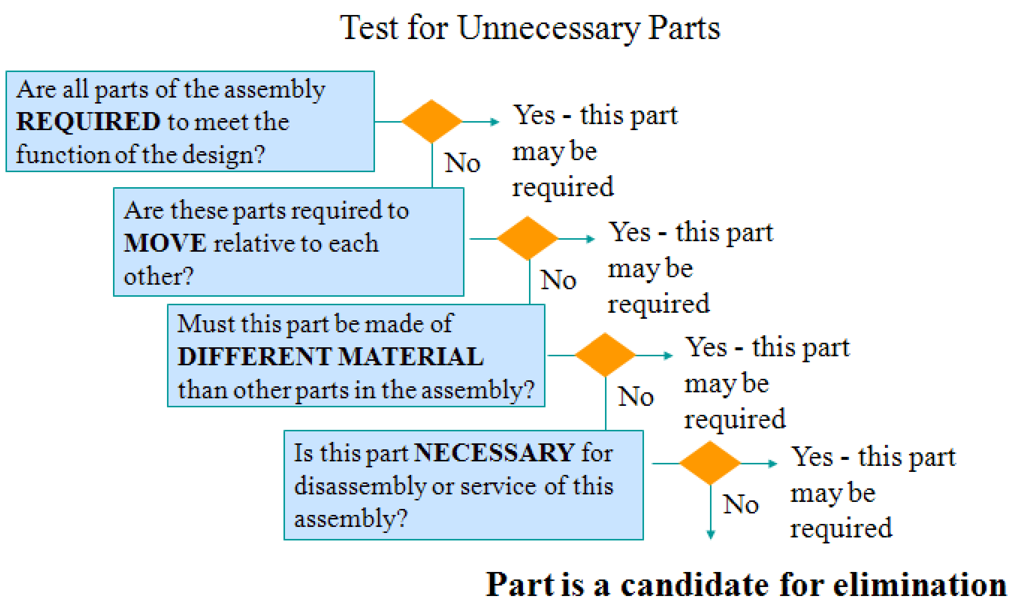
Unfortunately, many of these design methodologies seem to produce designs that fall short of optimal. A great recent example of this can be found in the kick starter product, Juicero, so over-engineered that it eventually failed in the market place.

Design for Manufacturing and Assembly is still one of the most powerful design impact philosophies enabling mere engineers and designers to create great products. The notion that every product can be built with a theoretical minimum part count (TMPC) can be reliably calculated and simplify designs from concept to production.

[2] See previous DFMA conference papers by author for examples of all these applications.

I argue that striving to reach that (TMPC) number drives innovation and creativity that helps to create classic products. If 70 – 80% of a product's final cost results from its materials, it stands to reason the fastest way to reduce cost would be to eliminate parts/subassemblies.[3] [4]

During the DFMA analysis determining if a part is a candidate for elimination requires a set of simple questions:



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 remains left to the design team's imagination and creativity but part count reduction produces the greatest cost reduction.[5]

Classic DFMA Case Study Epson MX80 vs IBM Proprinter

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

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

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

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

employ DFMA and the power of using theoretical part count was the IBM ProPrinter.[6] 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.

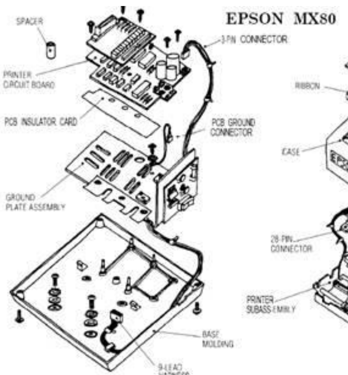


FIG. 1
The EPSON MX80 dot matrix printer final assembly consists of 49 parts or subassemblies as shown in this exploded view.

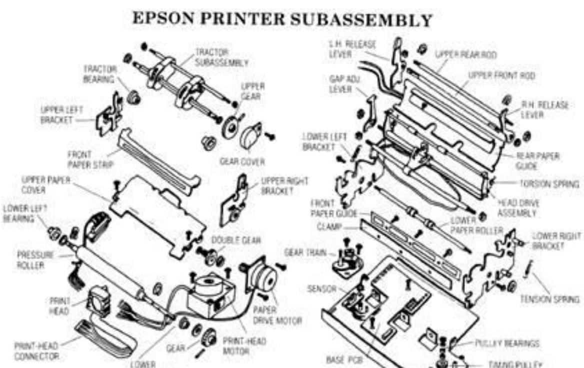


FIG. 3
Exploded view shows components for printer subassembly.

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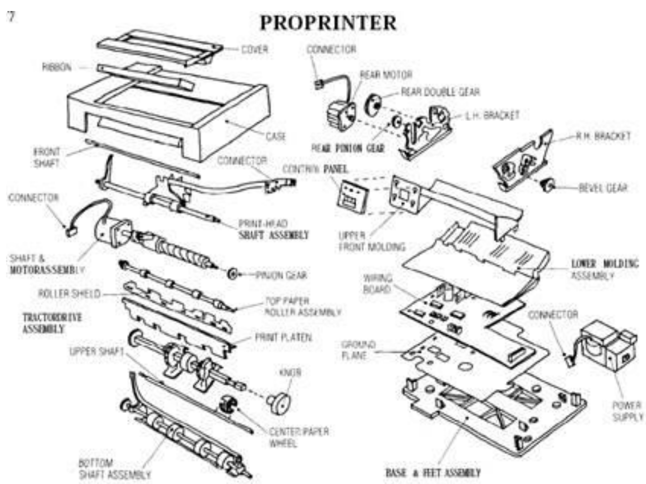


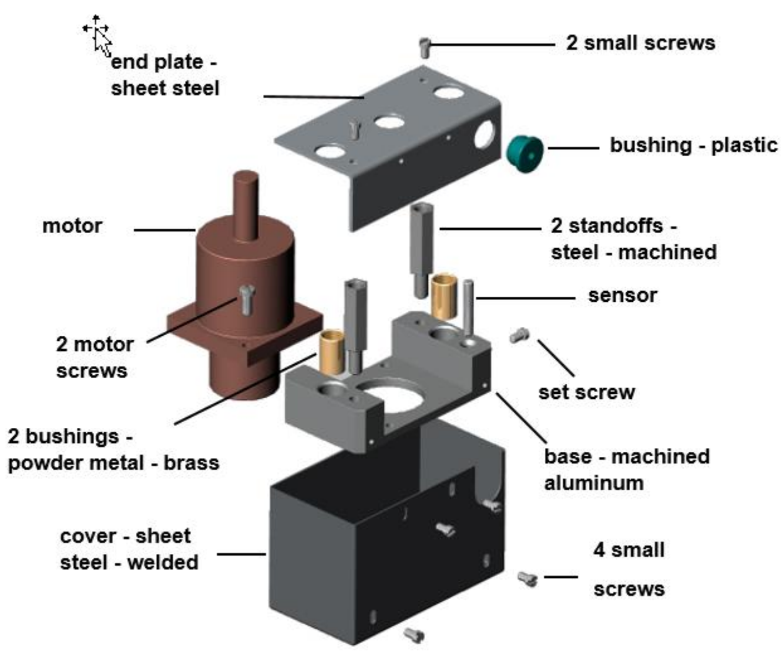
FIG. 5
Exploded view of IBM Proprinter highlights design simplification in this product.

[6] Design for Assembly in Action, *Assembly Engineering,* January 1987

Epson MX 80		IBM PRO Printer	
Total Assembly time (sec.)	1866	Total Assembly Time (sec.)	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

Theoretical Minimum Part Count: Motor Case Study Example

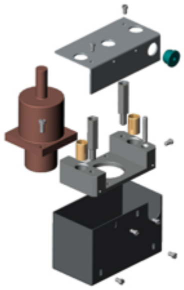
The motor case study is from a real project (Number and Vendors have been altered for confidentiality issues) – The subassembly senses the distance between calendaring rollers and adjusts the distance between them. The original design is pictured below:[7]



[7] David, Meeker & Nick Dewhurst, "The Best Tool in the Designers Toolbox", 29th International DFMA Conference, Warwick RI., June 2014

Shown below is the costed BOM for the Motor subassembly

Motor BOM



Category	Part Name	Qty	Part Num	Item Cost ($)	Supplier
Purchased Items					
	Motor	1	616-BDI-03	$ 12.55	ACME Motor
	Sensor	1	109-BDI-03	$ 1.58	Sensor-Rama
	Plastic Bushing	1	279-BDI-03	$ 0.22	Bushings R Us
	Brass Bushings	2	643-BDI-03	$ 1.53	Bushings R Us
Manufactured Items					
	Motor Base	1	074-BDI-03	$ 16.38	USA Machine
	Standoffs	2	012-BDI-03	$ 4.87	USA Machine
	End Plate	1	257-BDI-03	$ 1.44	Joe's Sheetmetal
	Cover	1	753-BDI-03	$ 2.08	Joe's Sheetmetal
Hardware					
	Cover Screws	4	975-BDI-03	$ 0.03	Fasteners, Inc.
	End Plate Screws	2	123-BDI-03	$ 0.03	Fasteners, Inc.
	Motor Screws	2	245-BDI-03	$ 0.05	Fasteners, Inc.
	Set Screw	1	097-BDI-03	$ 0.03	Fasteners, Inc.

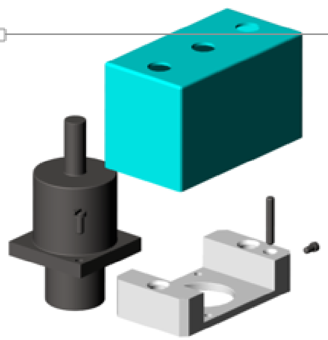
Below is an analysis of the Motor Case using the TMPC questions? As you can see there is a substantial difference between the current design part count and the TMPC target.

Minimum Parts Worksheet

Base	1	Base
Bushings	2	None
Motor	1	Movement
Motor screw	2	Fastener
Standoff	2	None
Sensor	1	Material
Set screw	1	Fastener
End plate	1	Assembly
End plate screw	2	Fastener
Grommet	1	None
Reorientation	1	None
Feed Wires	2	None
Cover	1	None
Cover screws	4	Fastener
Total	22	4 meet theoritical min.

At this point the product development team earns their pay by creating a new design that attempts to hit the TMPC goal. One resultant design is shown below.

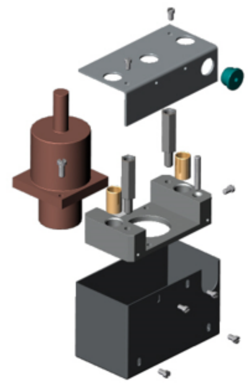
Motor BOM – Design Change

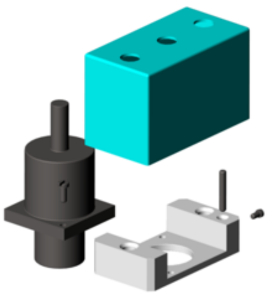


Part Name	Qty	Part Num	Item Cost ($)	Cost Estimate	Supplier
Motor	1	616-BDI-03	$ 12.55	$ 12.55	ACME Motor
Sensor	1	109-BDI-03	$ 1.58	$ 1.58	Sensor-Rama
Motor Base	1	074-BDI-03	$ 16.38	$ 13.45	USA Machine
Cover	1	753-BDI-03	$ 2.08	$ 1.10	Molds R Us
Motor Screws	2	245-BDI-03	$ 0.05	$ 0.03	Fasteners, Inc.
Set Screw	1	097-BDI-03	$ 0.03	$ 0.03	Fasteners, Inc.

The results speak for themselves, the cost estimates show there is money to be saved by going back and negotiating with the suppliers, and the biggest benefit is from the part count reduction both in direct savings as well as indirect intangible savings as well.

- 63 percent reduction in parts
- 4 suppliers removed from supply chain
- 63 percent reduction in detail drawings
- 74 percent reduction in assembly time
- Equal reduction in labor cost





And let's not forget….

46% Reduction in Total Cost of the product

Conclusion

By using DFMA philosophy and its analysis tools during product design, engineers can optimize and refine their products. Because of the simplicity of its process, and tools structure it can be utilized from product concept through product end of life. Faithful practitioners have over the years expanded its capabilities and area of usage. In the final analysis it offers the best return of any of the design analysis tools currently available.

"Perfection is reached not when there is no more to add but when there is no more to take away."

Antoine de St. Exupery

(1900-1944)