Systematic DFMA Deployment, It Just Could Resurrect US Manufacturing
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We have lost our way. For too long we have praised financial enterprises for driving economic growth knowing full well that moving and repackaging financial vehicles do not create value and cannot provide sustainable growth. All the while, manufacturing has taken it on the chin with astronomical job losses, the thinnest capital investments, and, most troubling, a general denigration of manufacturing as an institution and profession. However, we can get back to basics where sustainable economic growth is founded on the bedrock of value creation through manufacturing.

Continuing with the back-to-basics theme, manufacturing creates value when it combines raw materials and labor with thinking, which we call design, to create a product that sells for more than the cost to make it. The difference between the costs (raw materials, labor) and price is profit. An equation for profit from a single part is

$$\text{profit per part} = \text{price} - \text{cost}. \qquad [1]$$

Where cost is materials and labor, eq. [1] becomes

$$\text{profit per part} = \text{price} - (\text{materials} + \text{labor}). \qquad [2]$$

Total profit is a function of the number of parts sold, so modifying eq. [2] for volume (the number of parts sold)

$$\text{profit} = [\text{price} - (\text{materials} + \text{labor})] \times \text{volume}. \qquad [3]$$

The market sets price and volume. Therefore, manufacturing is left only to with materials and labor to influence profit. There, I have said it. At the most basic level, manufacturing must reduce materials and labor to increase profit. We can get no more basic than that. This is so important it must be written as a formula:

Increased Profits from Manufacturing result from reduced Materials and Labor costs. [4]

How do we use the simple fundamentals of eq. [4] to resurrect US manufacturing? I propose we must change our designs to reduce Material and Labor costs using Systematic DFMA Deployment.

Systematic DFMA Deployment

Design for Manufacturing and Assembly (DFMA) is typically thought of as a well-defined toolbox used to design out product cost. However, this definition is too narrow. More broadly, DFMA is a methodology to design lower cost products and not just a toolbox. Here are working definitions to formalize the point:

> Working Definition 1. Design for Manufacturing is methodology to change a design to reduce the cost of making parts while retaining product function.
>
> Working Definition 2. Design for Assembly is a methodology to change a design to reduce the cost of putting things together while retaining product function.

Savings from Systematic DFMA Deployment
The potential savings are significant from DFMA Deployment. Many studies have presented radical savings from DFMA work, and Material and Labor reductions of 20-50% are commonplace. Yet, companies don't use the methods.

Figure 1 is a graph of profit per square foot and warranty costs data over the 5 years between 2003 and 2008. Both sets of data have been normalized to show trends in the data and allow comparisons to other products. In blue is profit per square foot which is (price – cost), or profit, divided by the square footage of factory floor space used to produce the product In orange is warranty cost per unit, defined as warranty expense per month divided by number of units in the warranty period.

Normalized profit per square foot increased from $1 per square foot in 2003 to $7 in 2008, a 600% increase. The increase came about by designing new products with reduced material cost (increased profit per unit) and reduced labor time (50% reduction), which, in turn, reduced the floor space needed to assemble the units. And, because the new units functioned better and the price was less than the old products, more products were sold. The jaggedness is month-to-month variation due to the make-to-order production system.

Normalized warranty cost per unit which decreased from $4 in 2003 to $1 in 2008, a 75% decrease. The jaggedness is month-to-month variation due to batching of warranty claims.

It is clear that the DFMA methods resulted in lower cost products, a reduction in required floor space, and more robust products (as indicated by reduced warranty cost per unit). Needless to say, your management team would like these types of improvements. You might even get a promotion if you delivered results like these.

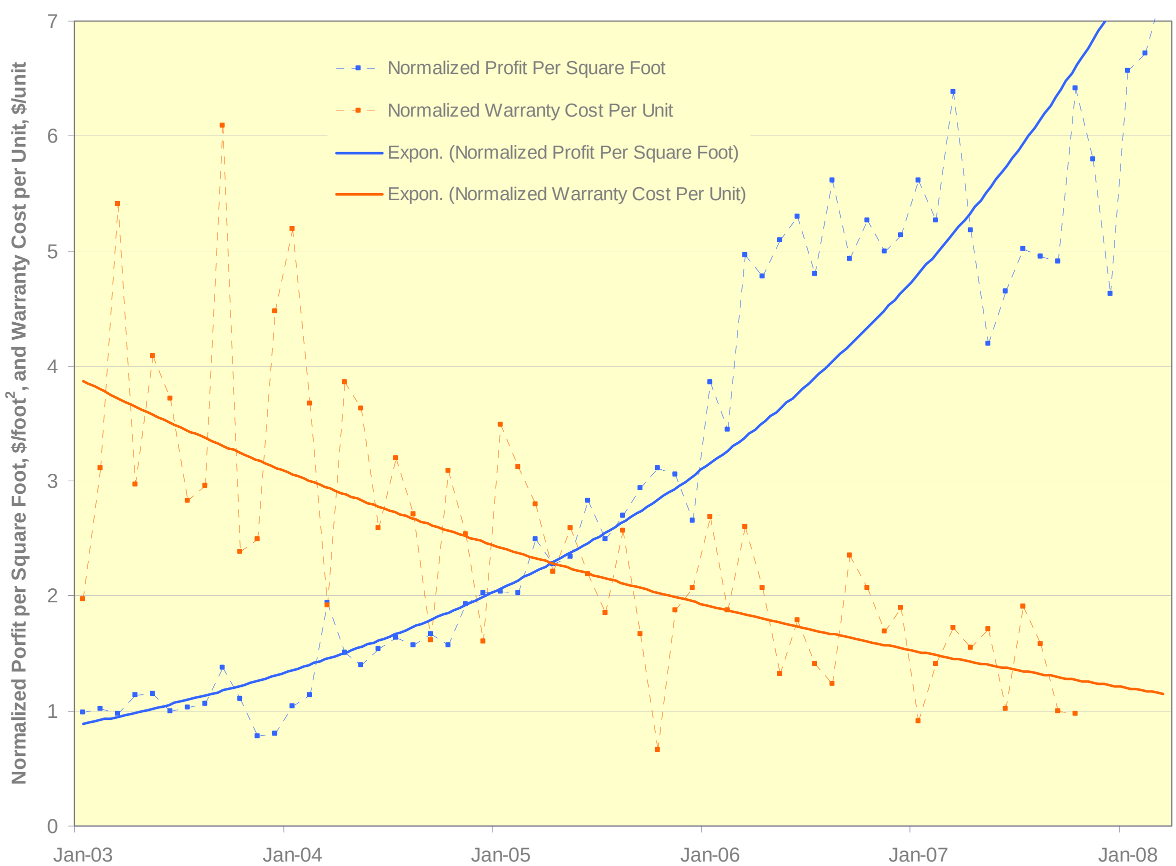


Figure 1. Monthly data of profit per square foot and warranty cost per system between 2003 and 2008.

Paradoxically, the significance and breadth of the savings cause some to shy away from DFMA. Leaders think – we have been working tirelessly for 2-3% savings year on year. How can we possibly design out 10 times that amount? Mike, you are out of your mind. Of course I am, but that has nothing to do with it. Actually, there must be some degree of boldness in the approach to rip the design community out of their comfort zone. Without a change in thinking, the full savings cannot be realized.

Mike, you have warmed us up sufficiently. Can you please get on with it and tell us about Systematic DFMA Deployment?

Okay, here we go.

Systematic DFMA Deployment
DFMA Deployment is a business methodology similar to the better known systematic methodologies of lean, six sigma, and design for six sigma (DFSS). Figure 2 shows how DFMA Deployment fits relative to the other methodologies. Lean is a systematic methodology that works primarily with the of manufacturing processes; six sigma works with the quality of manufacturing processes; DFSS works with the quality (functionality) of the product design; DFMA Deployment fills the gap at the intersection of product design and product cost.

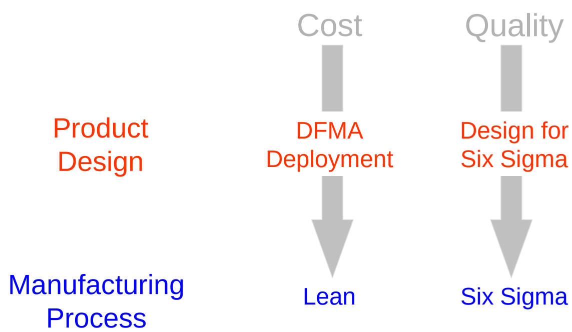


Figure 2. DFMA Deployment is a systematic methodology like Lean, Six Sigma, and DFSS, that fills a gap at the intersection between product design and cost.

Like the big three, DFMA Deployment is more than a toolbox - six sigma is not Minitab, lean is not value stream mapping, and DFMA Deployment is not the DMFA toolbox. To be successful, a complete business methodology requires all quadrants - tools, business processes, organization, and infrastructure to sustainably realize benefits. The quadrants for DFMA Deployment are shown in Figure 3.

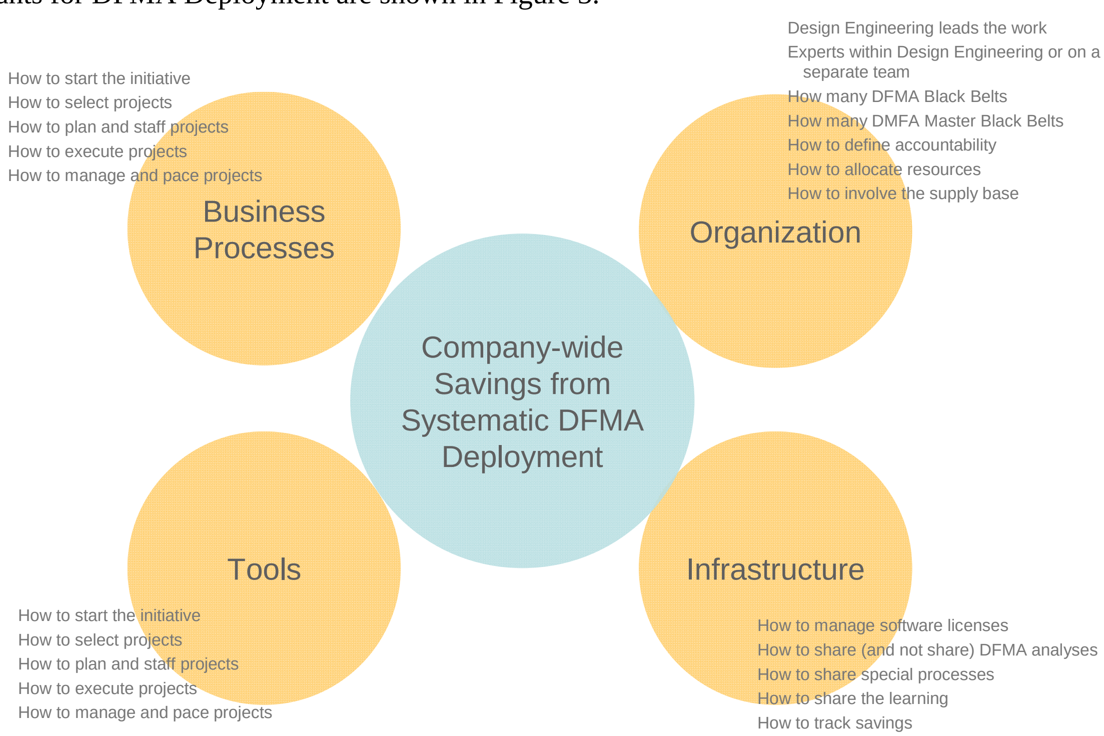


Figure 3. The quadrants of DFMA Deployment.

The lower right quadrant is infrastructure. The needs are relatively light, but important. Computer resources are needed to store DFMA analyses and some thought must be given to how to share and reuse the analyses. However, the most important infrastructure component is file security. DFMA analyses should be treated as proprietary information as they are recipes to lower cost products. While it is important to share the analyses across your company and its supply base, it is critical to keep them out of the hands of your competitors.

In the upper right quadrant is organization. Design engineering leads the work – no questions. Remember, the D in DFMA stands for design, not purchasing. However there are several things that must be decided. First, are the DFMA experts the engineers themselves; are they experts within the engineering teams; or are the experts outside the engineering teams? Second, how many of these specialists (DFMA Black Belts) are needed? Who is the customer of the DFMA reviews? Who allocates the resources? How is the supply base involved? All these questions must be answered to help the program succeed.

The left two quadrants (business processes and tools) are considered together. How to start; how to select projects; how to plan projects; how to staff and manage projects? All these questions must be answered with a business process and a set of tools.

Now let's dig into the milestone process and the tools.

Systematic DFMA Deployment Milestone Process

There are five milestones in the DFMA Deployment process – M1 to M5. M4 project execution, the largest, is broken out into 5 sub-milestones (see table 1). The next section will provide a detailed description of the milestones, starting with M1 – Goal Setting.

Table 1. The milestone phases of DFMA Deployment

- M1 Goal Setting
- M2 Project Selection and Planning
- M3 Resource Allocation
- M4 Project Execution
  - M4.1 Signature of baseline product and process
  - M4.2 DFMA tools on baseline design
  - M4.3 Goals and design approach
  - M4.4 DFMA tools on new design
  - M4.5 Validation of product function
- M5 – Design Review

M1 – Goal Setting

The first phase starts with setting objectives of the work. It is best that the objectives link tightly to company objectives. The best company objective is company profitability. If everyone sees DFMA Deployment as the mechanism to achieve company profitability the work will go well.

Company leadership sets company objectives and should also set DFMA Deployment objectives. At the highest level, company leadership defines the desired savings and the level of resources that can be allocated to the work. Leadership cannot define savings objectives without allocating resources. That is an unfunded mandate that will not work, and will give DFMA Deployment a bad name. So, to do it right, company leadership must understand the level of savings of the various project types and the level of resources.

Savings and Resources – The Inverted Triangle

The inverted triangle of Figure 4 illustrates the relationship between project type, savings, and resources. The width of the inverted triangle's base indicates the relative savings and resources for the project types, with both increasing from bottom to top. At the bottom is target costing which does not consume many resources, but the savings are small (on the order of 2%) and usually come out of the supplier's hide. Moving north is DFM of existing parts, with increased savings (on the order of 5%), but engineering resources are needed to change the design. Next is DFA of sub assemblies where parts are eliminated (savings of about 10%); up one level, DFA is used on an entire product (savings of 15%); at the top, with the most savings (20-50%) and resource needs, is DFA and DFM on new products. The savings estimates are not meant to be exact, but relative. The important point is savings and resources increase together when moving toward the top of the triangle. Stated differently the basic message is: resources are needed to achieve savings and more savings require more resources.

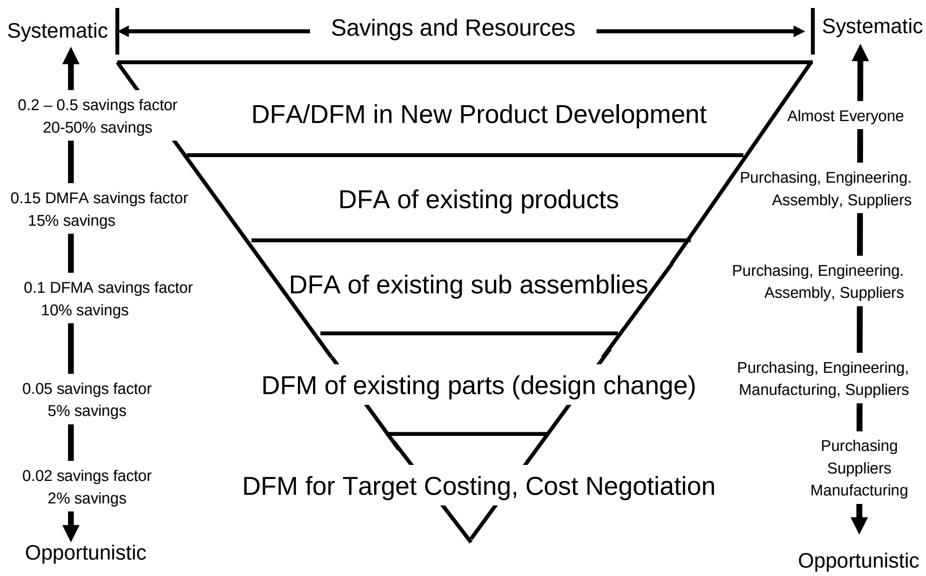


Figure 4. Inverted triangle showing relationship between savings and resources for the range of project types.

The Savings from First Principles

From DFA and DFM working definitions it is clear that DFMA Deployment is strongly aligned with the fundamentals of eq. [4] with a strong focus on reduction of material and labor costs.

Using eq. [4] and replacing Profits with DFMA savings, the savings are written generically as

$$\text{DFMA savings} = S \times (\text{material} + \text{labor}) \qquad [5]$$

where DFMA savings factor, S, is

$$S = (\text{material} + \text{labor of new design}) / (\text{material} + \text{labor of old design}). \qquad [6]$$

DFMA savings factors are different for different project types and can range from 0.02 to 0.5, and there are two rules that govern the savings factor:

Rule 1. Savings factors are larger for projects that change the design more significantly.

Rule 2. Savings factors for DFA projects are 12 times larger than those for DFM projects.

DFMA savings factors, S, of 0.3 (30% cost reduction) are good, but not sufficient. The problem is that DFMA savings factors are typically realized only over a small fraction of a company's product line such as one or two subassemblies or one or two high volume part numbers, so the total savings are not significant at the company level. The savings become radically significant only when DFMA is systematically deployed over a large fraction of the company's total product line. Deployment factor, D, is a measure of the degree of deployment where

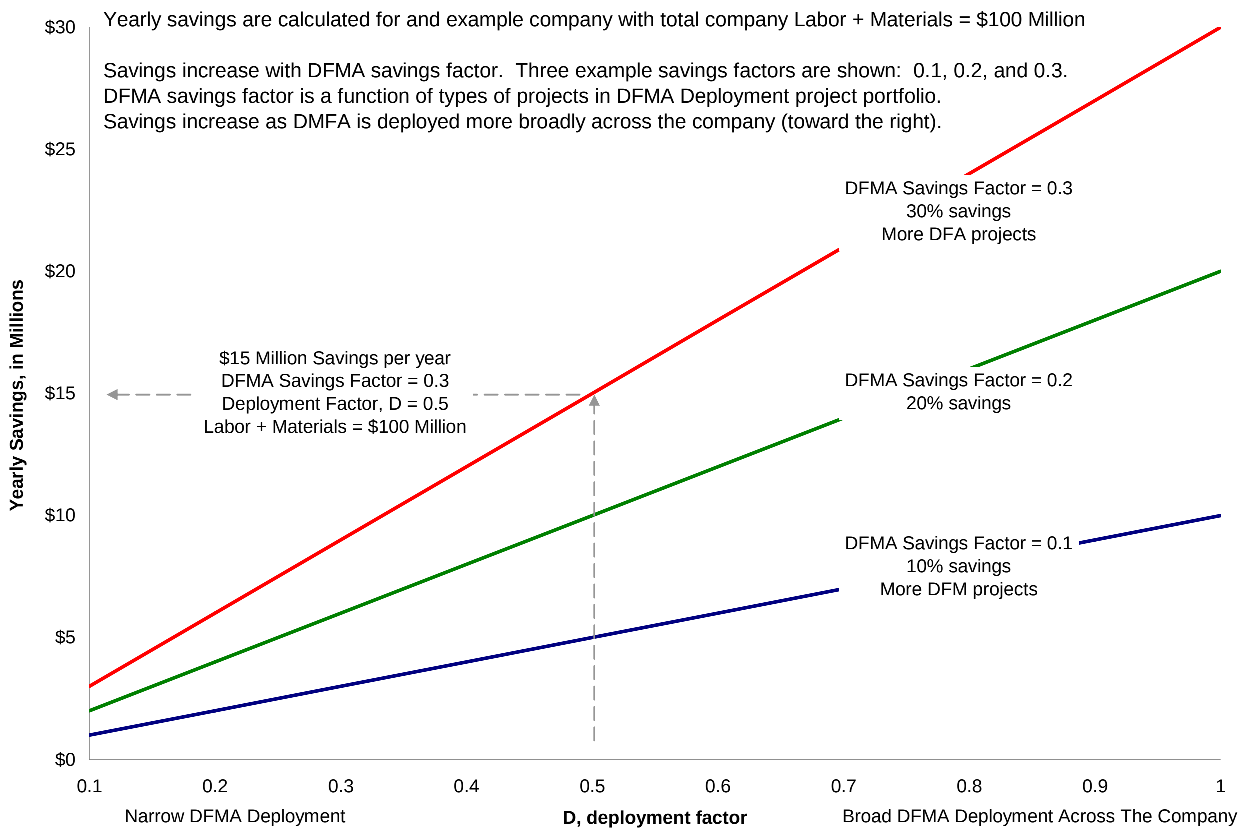
$$D = \text{Number of DFMA'd products / total number of products.} \qquad [7]$$

D equals 0.5 if 50% of products are DFMA'd, and D equals 1 if all products are DFMA'd.

Savings from Systematic DFMA Deployment are calculated using eq. [5] and eq. [7]

$$\text{DFMA Deployment Savings} = S \times (\text{material} + \text{labor}) \times D. \qquad [8]$$

Using eq. [8], Figure 5 is a contrived graph that shows the total savings for a range of savings factors and deployment factors, D, for an example company with total material and labor costs of $100 million per year.



<u>Figure 5. Yearly savings for an example company with Material and Labor costs of $100 million per year. Savings increase with more broad deployment and with increasing savings factor. Savings factor is a function of the types of projects.</u>

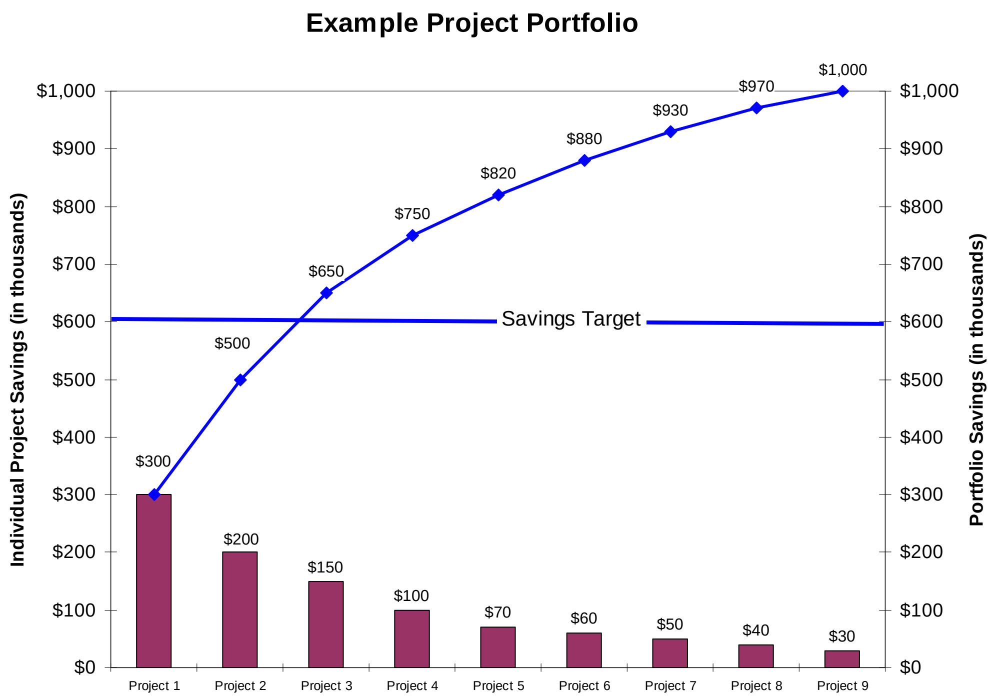
The contrived example of three project portfolios with savings factors of 0.1, 0.2, and 0.3 are normalized to a $100M spend in labor and materials to allow scaling to smaller or larger companies. The blue line represents a project portfolio made up of mostly DFM projects that save 10%, or savings factor S of 0.1. The green line represents a project portfolio with more DFA projects, with savings of 20%, or savings factor S of 0.2. Last is the red line which represents a project portfolio with still more DFA projects, with an average savings of 30%, or savings factor S of 0.3. Running from left to right at the bottom is the degree of deployment, D. On the left is a narrow deployment starting at 10% (D = 0.1). That means, DFMA deployment is used on 10 % of the company's products. All the way to the right is broad deployment (D = 1), where DFMA deployment is used on 100% of a company's products. Savings increase with increasing deployment factor and savings factor as defined in eq. [8].

In the example shown with the dotted arrows, DFMA deployment is used on 50% of the products, with an average savings of 30% resulting in $15M savings per year for a $100M spend on labor and materials.

M2 - Project Selection and Planning

With knowledge from the inverted triangle (Figure 4) and the formulaic savings of Figure 5, the engineering leaders create a formal list of potential projects and associated savings for the projects. Figure 6 is a contrived Pareto chart of potential projects – a project portfolio. The horizontal blue line is the hypothetical savings target of $600k. The increasing blue line is the cumulative value of the projects running left to right. So, the sum of the first two is $500k. Executing the first three projects is worth $650k, which meets the savings target of $600k.

It is important that the engineering team creates the project portfolio and the estimated savings since they are the ones who have to meet the savings targets and implement the projects.



<u>Figure 6. Contrived Pareto chart of potential projects and associated savings.</u>

M3 - Resource Allocation

A formal schedule is created with resources from all the teams needed to do the work, such as engineering, manufacturing, purchasing, and supply base. And, here is the tricky part: resources are actually allocated to the projects. A contrived schedule is shown in Figure 7.

The project schedule is created by the engineering team since they are the ones who are accountable to do the work and achieve the savings. Company leadership is accountable to keep the resources on the projects until they are completed. This is a tough one, but not impossible. The magnitude of the savings can be used as a carrot to keep the resources in place.

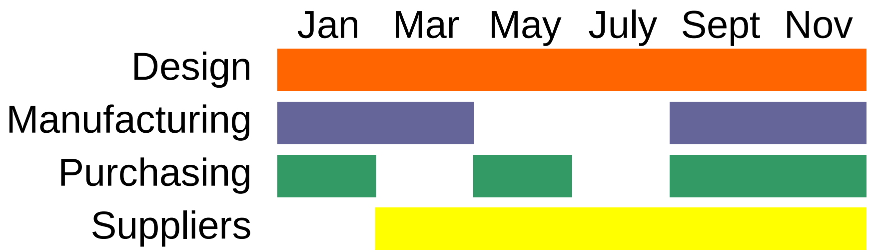


Figure 7. A contrived schedule showing resource needs and timing.

M4 - Project Execution
Project execution is the largest phase, consisting of four sub-milestones (see Table 1).

M4.1 – Signature of Baseline Product with DFMA Tools
You can't design out cost and parts without understanding the cost and part count of the existing, or baseline, design. So, the engineers must create baseline data on part count, cost, and product function. The engineers themselves must count the parts, roll up the costs, as well as formally quantify product function. Figure 8 is an actual Pareto chart of part count by part type created by the engineers. None of the engineers would have guessed there were 668 fasteners. Figure 9 is an actual Pareto chart of the cost by sub assembly created by the engineers. The subassembly on the left is most expensive by far, representing 20% of the product cost. That one should be attacked first. Figure 10 is a contrived plot of product functionality. The new design must perform better than the baseline design, so the engineers must quantify performance of the baseline design before they can improve it. Again, this plot and the others are created by the design engineers.

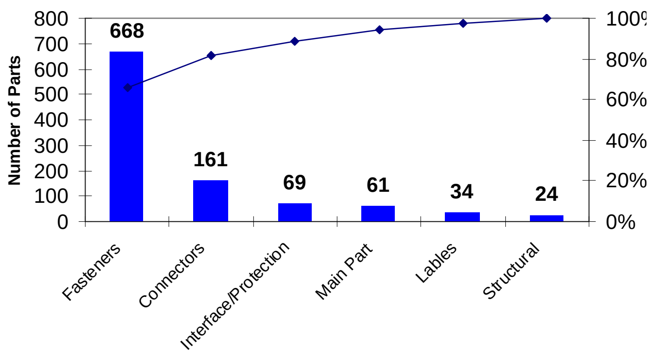


Figure 8. A Pareto chart of part count by part type

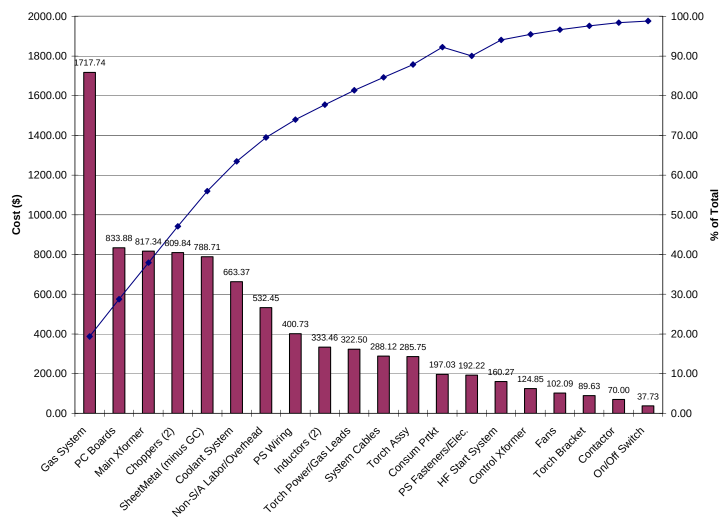


Figure 9. Parato chart of cost breakdown by major subassembly.

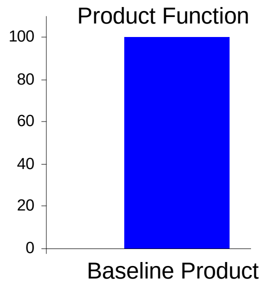


Figure 10. A contrive plot of product functionality of the baseline design.

M4.2 – Evaluation of Baseline Product with DFMA Tools

In keeping with the mantra that you can't improve what you don't understand, the design engineers use the DFMA tools on the baseline design. This is a great way to train the engineers on the toolbox while providing the baseline data on assembly time and number of assembly steps. Figures 11 and 12 shows two summary reports from an actual design showing an estimated assembly time, assembly time, and part count.

Design for Assembly: Product Worksheet
Boothroyd Dewhurst, Inc.

No.		Name	Part number	Type	Repeat count	Total count	Securing method	Minimum items	Minimum part criteria
1	⊟	ht2000 torch	120584	Main					
2	⊟	current ring sub		Sub	1	1	Sep. op		None
3		current ring		Part	1	1	Sep. op	1	Base part
4		shield tube		Part	1	1	Sep. op	0	Connects
5		torch braze large part		Lib Op	1	1			
6		internal o-rings		Part	2	2	Snap	0	None
7		Grease radial o-ring		Lib Op	2	2			
8	△	Totals for current ring sub				7		1	
9		current ring face seal o-rings		Part	4	4	Sep. op	0	None
10		insulator		Part	1	1	Sep. op	1	Material
11		insulator screws		Part	3	3	Thread	0	Fastens
12		screw insulators		Part	3	3	Thread	0	Fastens
13		insulator face seal o-rings		Part	2	2	Sep. op	0	None
14	⊟	cathode sub		Sub	1	1	Sep. op		None
15		cathode		Part	1	1	Sep. op	1	Material
16		tubes		Part	4	4	Sep. op	0	Connects
17		torch braze large part		Lib Op	1	1			
18		teflon tubes		Part	8	8	Sep. op	0	None
19		reorientation of assembly		Lib Op	1	1			

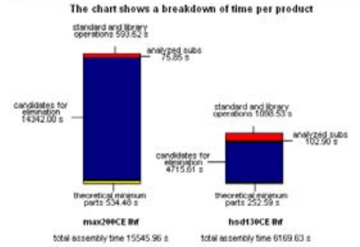
5

Figure 11. DFA Analysis.

Executive Summary Comparison - DFA
Boothroyd Dewhurst, Inc.

Per Product data		max200CE lhf	hsd130CE lhf
Entries (including repeats)	Component parts	1591	617
	Subassemblies partially or fully analyzed	12	14
	Subassemblies not to be analyzed (excluded)	0	0
	Standard and library operations	206	130
	Total Entries	**1809**	**761**
Labor Time, s	Component parts	14876.49	4968.20
	Subassemblies partially or fully analyzed	75.85	102.90
	Subassemblies not to be analyzed (excluded)	0.00	0.00
	Standard and library operations	593.62	1098.53
	Total Assembly Time	**15545.96**	**6169.63**
Labor Cost, $	Component parts	218.77	73.06
	Subassemblies partially or fully analyzed	1.12	1.51
	Subassemblies not to be analyzed (excluded)	0.00	0.00
	Standard and library operations	8.73	16.15
	Total Assembly Cost	**228.62**	**90.73**

The chart shows a breakdown of time per product



www.dfma.com

Figure 12. Executive Summary of Analysis

M4.3 – Set Formal Goals: Part Count, Assembly Time, Cost

Explicit reduction goals are set at this milestone. The three best are: part count, cost, and labor time. The goals must be explicit; set tough goals and help the team get there. Since the engineers know the cost and part count signatures of the baseline product, they will be comfortable with significant savings goals. The design approach is formalized which is informed by the new found understanding of the lousy baseline design.

M4.4 – Design New Product: Use DFMA Tools on New Design

The new product is designed using the DFMA tools. Big-bar-little-bar charts are created by the engineers showing metrics of the baseline and new designs side-by-side. Figure 13 show actual big-bar-little-bar charts for a DFMA deployment project.

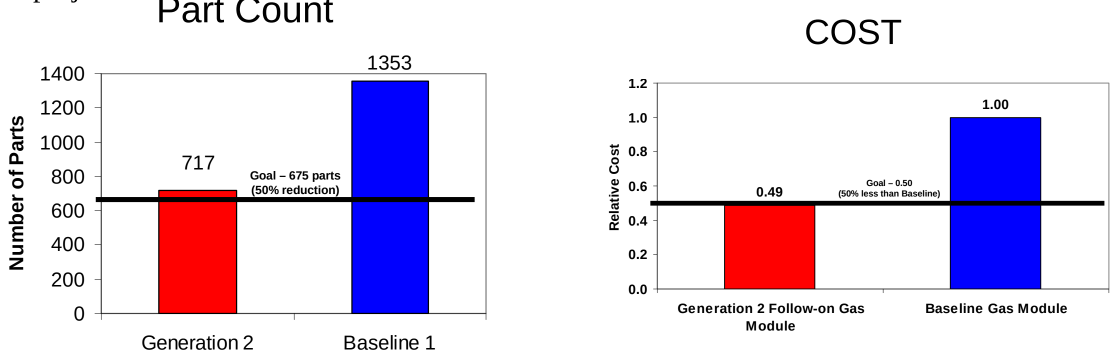


Figure 13. Big-bar-little-bar charts from a DFMA Deployment project – cost and part count.

M4.5 – Validation of Product Function

At this milestone the engineers create a big-bar-little-bar chart for product function showing functionality for the baseline design and new design side by side. Figure 14 shows a contrived example. Quantification of the baseline design is important so improvement can be demonstrated.

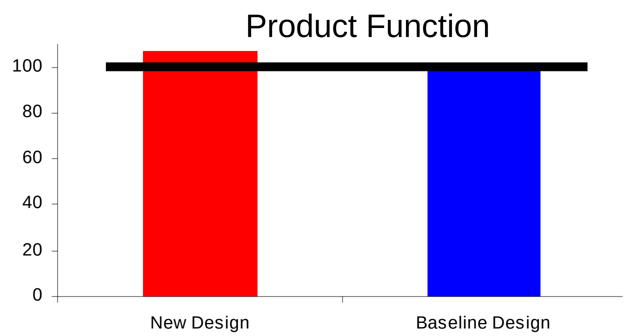
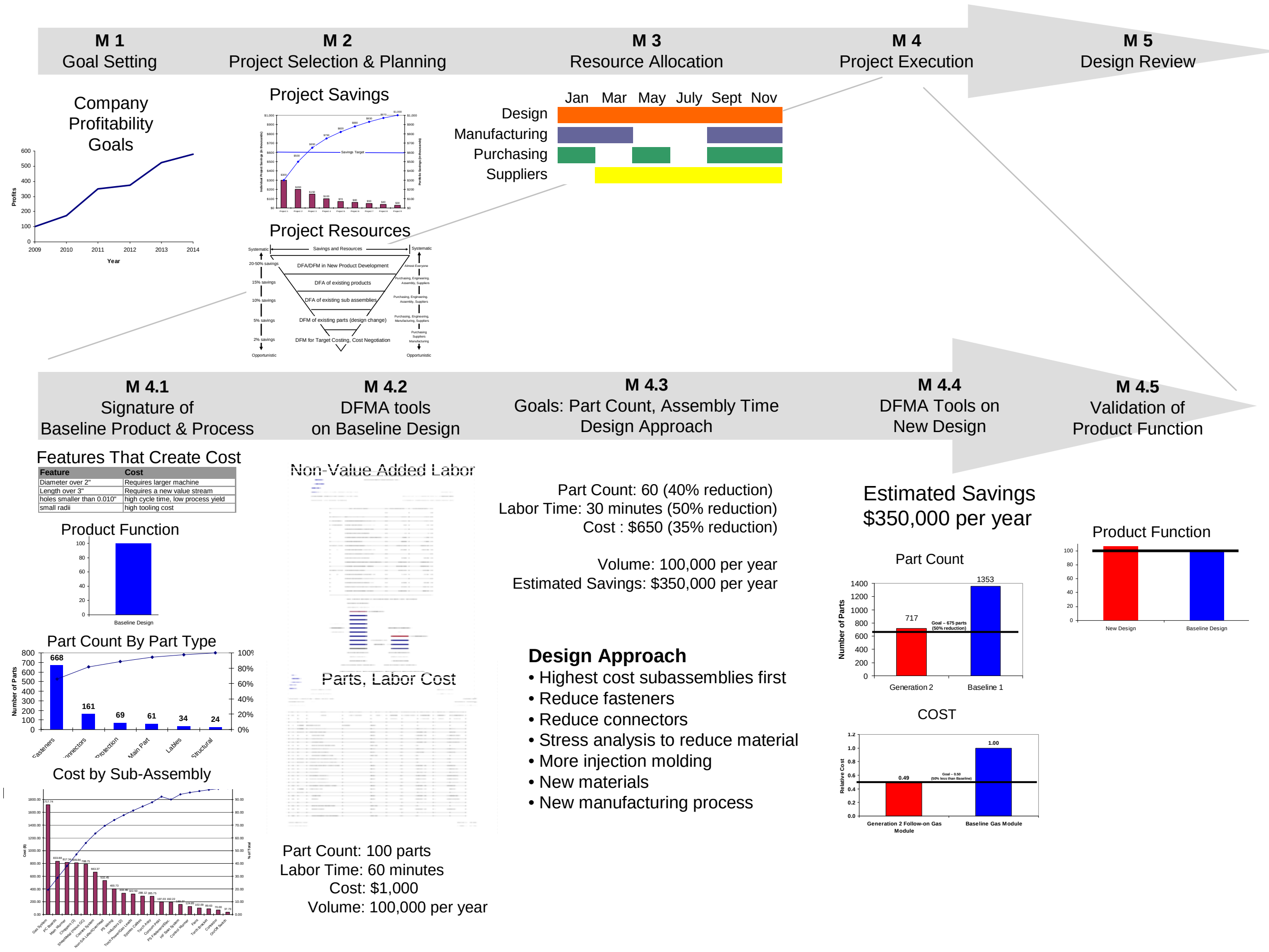


Figure 14. Contrived big-bar-little-bar charts from a DFMA Deployment project – product function.

M5 – Design Review

The DFMA team presents the metrics to the Leadership Team. Projected savings, product cost, product functionality are presented by the engineers. The Leadership Team decides if the new design is ready to be cut into production.

Figure 15 shows the DFMA Deployment milestones and related tools.



<u>Figure 15. DFMA Deployment milestones and related tools.</u>

Summary

Systematic DFMA Deployment is a rigorous process that can guide manufacturing comings toward increased profitability. The methods can, I believe, resurrect US manufacturing, and re-elevate manufacturing as a profession so our children are attracted to manufacturing so they can provide a robust, sustainable economy for the next generation. It is my hope that some companies use the methods, realize the savings, and teach other companies how to do the same. Ultimately, so our children will know how to do it.