PART 1

MANUFACTURING

CHAPTER 1

PRODUCT DESIGN FOR MANUFACTURING AND ASSEMBLY (DFM&A)

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1 INTRODUCTION

Major changes in product design practices are occurring in all phases of the new product development process. These changes will have a significant impact on how all products are designed and the development of the related manufacturing processes over the next decade. The high rate of technology changes has created a dynamic situation that has been difficult to control for most organizations. There are some experts who openly say that if we have no new technology for the next five years, corporate America might just start to catch up. The key to achieving benchmark time to market, cost, and quality is in up-front technology, engineering, and design practices that encourage and support a wide latitude of new product development processes. These processes must capture modern manufacturing technologies, piece parts that are designed for ease of assembly, and parts that can be fabricated using low-cost manufacturing processes. Optimal new product design occurs when the designs of machines and of the manufacturing processes that produce those machines are congruent.

The obvious goal of any new product development process is to turn a profit by converting raw material into finished products. This sounds simple, but it has to be done efficiently and economically. Many companies do not know how much it costs to manufacture a new product until well after the production introduction. Rule #1: The product development team must be given a cost target at the start of the project. We will call this cost the *unit manufacturing cost* (UMC) target. Rule #3: The product development team must be held accountable for this target cost. What happened to rule #2? We'll discuss that shortly. In the meantime, we should understand what UMC is.

$$\text{UMC} = \text{BL} + \text{MC} + \text{TA}$$

where BL = burdened assembly labor rate per hour; this is the direct labor cost of labor, benefits, and all appropriate overhead cost

MC = material cost; this is the cost of all materials used in the product

TA = tooling amortization; this is the cost of fabrication tools, molds and assembly tooling, divided by the forecast volume build of the product

UMC is the direct burdened assembly labor (direct wages, benefits, and overhead) plus the material cost. Material cost must include the cost of the transformed material plus piece part packaging plus duty, insurance, and freight (DIF). Tooling amortization should be included in the UMC target cost calculation, based on the forecast product life volume.

Example UMC Calculation **BL + MC + TA**

Burdened assembly labor cost calculation (*BL*)

$$\mathrm{BL} = (\underbrace{\$18.75}_{\text{Wages+Benefits}} + \overset{\text{Labor}}{\underbrace{138\%}_{\text{overhead}}}) = \$44.06/\mathrm{hr}$$

Burdened assembly labor is made up of the direct wages and benefits paid to the hourly workers, plus a percentage added for direct overhead and indirect overhead. The overhead added percentage will change from month to month based on plant expenses.

Material cost calculation (*MC*)

$$\begin{array}{llllll} & (\text{Part cost} & + \text{ Packaging}) & + \text{ DIF} & + \text{ Mat. Acq. cost} & = \\ \mathrm{MC} = & (\$2.45 & + \ \$.16) & + \ 12\% & + \ 6\% & = \\ \mathrm{MC} = & \$2.61 & & + \ \$.31 & + \ \$.15 & = \underbrace{\$3.07}_{\text{Material FOB assm. plant}} \end{array}$$

Material cost should include the cost of the parts and all necessary packaging. This calculation should also include a percent adder for duty, insurance, and freight (DIF) and an adder for the acquisition of the materials (Mat. Acq.). DIF typically is between 4 and 12% and Mat. Acq. typically is in the range of 6 to 16%. It is important to understand the MC because material is the largest expense in the UMC target.

Tooling amortization cost calculations (*TA*)

$$\begin{array}{l} \mathrm{TA} = \overset{\text{(Tool cost)}}{\mathrm{TC}} / \overset{\text{\# of parts}}{\mathrm{PL}} \\ \mathrm{TA} = \$56{,}000/10{,}000 = \$5.60 \text{ per assembly} \end{array}$$

TC is the cost of tooling and PL is the estimated number of parts expected to be produced on this tooling. Tooling cost is the total cost of dies and mold used to fabricate the component parts of the new product. This also should include the cost of plant assembly fixtures and test and quality inspection fixtures.

The question is, "How can the product development team quickly and accurately measure UMC during the many phases of the project?" What is needed is a tool that provides insight into the product structure and at the same time exposes high-cost areas of the design.

2 DESIGN FOR MANUFACTURING AND ASSEMBLY

Designing for Manufacturing and Assembly (DFM&A) is a technique for reducing the cost of a product by breaking the product down into its simplest components. All members of the design team can understand the product's assembly sequence and material flow early in the design process.

DFM&A tools lead the development team in reducing the number of individual parts that make up the product and ensure that any additional or remaining parts are easy to handle and insert during the assembly process. DFM&A encourages the integration of parts and processes, which helps reduce the amount of assembly labor and cost. DFM&A efforts include programs to minimize the time it takes for the total product development cycle, manufacturing cycle, and product life-cycle costs. Additionally, DFM&A design programs promote team cooperation and supplier strategy and business considerations at an early stage in the product development process.

The DFM&A process is composed of two major components: *design for assembly* (DFA) and *design for manufacturing* (DFM). DFA is the labor side of the product cost. This is the labor needed to transform the new design into a customer-ready product. DFM is the material and tooling side of the new product. DFM breaks the parts fabrication process down into its simplest steps, such as the type of equipment used to produce the part and fabrication cycle time to produce the part, and calculates a cost for each functional step in the process. The program team should use the DFM tools to establish the material target cost before the new product design effort starts.

Manufacturing costs are born in the early design phase of the project. Many different studies have found that as much as 80% of a new product's cost is set in concrete at the first drawing release phase of the product. Many organizations find it difficult to implement changes to their new product development process. The old saying applies: ''only wet babies want to change, and they do it screaming and crying.'' Figure 1 is a memo that was actually circulated in a company trying to implement a DFM&A process. Only the names have been changed.

It is clear from this memo that neither the engineering program manager nor the manufacturing program manager understood what DFM&A was or how it should be implemented in the new product development process. It seems that their definition of concurrent engineering is, ''Engineering creates the design and manufacturing is forced to concur with it with little or no input.'' This is not what DFM&A is.

2.1 What Is DFM&A?

DFM&A is not a magic pill. It is a tool that, when used properly, will have a profound effect on the design philosophy of any product. The main goal of DFM&A is to lower product cost by examining the product design and structure at the early concept stages of a new product. DFM&A also leads to improvements in serviceability, reliability, and quality of the end product. It minimizes the total product cost by targeting assembly time, part cost, and the assembly process in the early stages of the product development cycle.

The life of a product begins with defining a set of product needs, which are then translated into a set of product concepts. Design engineering takes these product concepts and refines them into a detailed product design. Considering that from this point the product will most likely be in production for a number of years, it makes sense to take time out during the design phase to ask, ''How should this design be put together?'' Doing so will make the rest of the product life, when the design is complete and handed off to production and service, much smoother. To be truly successful, the DFM&A process should start at the early concept development phase of the project. True, it will take time during the hectic design phase to apply DFM&A, but the benefits easily justify additional time.

DFM&A is used as a tool by the development team to drive specific assembly benefits and identify drawbacks of various design alternatives, as measured by characteristics such as total number of parts, handling and insertion difficulty, and assembly time. DFM&A converts time into money, which should be the common metric used to compare alternative designs, or redesigns of an existing concept. The early DFM&A analysis provides the product

Memorandum: ***Ajax Bowl Corporation***

DATE:	January 26, 1997
TO:	Manufacturing Program Manager, Auto Valve Project
FROM:	Engineering Program Manager, Auto Valve Project
RE:	Design for Manufacturing & Assembly support for Auto Valve Project
CC:	Director, Flush Valve Division

Due to the intricate design constraints placed on the Auto Valve project engineering feels they will not have the resources to apply the Design for Manufacturing and Assembly process. Additionally, this program is strongly schedule driven. The budget for the project is already approved as are other aspects of the program that require it to be on-time in order to achieve the financial goals of upper management.

In the meeting on Tuesday, engineering set down the guidelines for manufacturing involvement on the Auto Valve project. This was agreed to by several parties (not manufacturing) at this meeting.

The manufacturing folks wish to be tied early into the Auto Valve design effort:

1. This will allow manufacturing to be familiar with what is coming.
2. Add any ideas or changes that would reduce overall cost or help schedule.
3. Work vendor interface early, manufacturing owns the vendor issues when the product comes to the plant, anyways.

Engineering folks like the concept of new ideas, but fear:

1. Inputs that get pushed without understanding of all properly weighted constraints.
2. Drag on schedule due to too many people asking to change things.
3. Spending time defending and arguing the design.

PROPOSAL—Turns out this is the way we will do it.

Engineering shall on a few planned occasions address manufacturing inputs through one manufacturing person. Most correspondence will be written and meeting time will be minimal. It is understood that this program is strongly driven by schedule, and many cost reduction efforts are already built into the design so that the published budget can be met.

The plan for Engineering:

- When drawings are ready, Engineering Program Manager (EPM) will submit them to Manufacturing Program Manager (MPM).
- MPM gathers inputs from manufacturing people and submits them back in writting to EPM. MPM works questions through EPM to minimize any attention units that Engineering would have to spend.
- EPM submits suggestions to Engineering, for one quick hour of discussion/acceptance/veto.
- EPM submits written response back to MPM and works any Design continues under ENG direction.
- When a prototype parts arrives, the EPM will allow the MPM to use it in manufacturing discussions.
- MPM will submit written document back to EPM to describe issues and recommendations.
- Engineering will incorporate any changes that they can handle within the schedule that they see fit.

Figure 1

development team with a baseline to which comparisons can be made. This early analysis will help the designer to understand the specific parts or concepts in the product that require further improvement, by keeping an itemized tally of each part's effect on the whole assembly. Once a user becomes proficient with a DFM&A tool and the concepts become second nature, the tool is still an excellent means of solidifying what is by now second nature to DFA veterans, and helps them present their ideas to the rest of the team in a common language: cost.

DFM&A is an interactive learning process. It evolves from applying a specific method to a change in attitude. Analysis is tedious at first, but as the ideas become more familiar and eventually ingrained, the tool becomes easier to use and leads to questions: questions about the assembly process and about established methods that have been accepted or existing design solutions that have been adopted. In the team's quest for optimal design solutions, the DFM&A process will lead to uncharted ways of doing things. Naturally, then, the environment in which DFA is implemented must be ripe for challenging pat solutions and making suggestions for new approaches. This environment must evolve from the top down, from upper management to the engineer. Unfortunately, this is where the process too often fails.

Figure 2 illustrates the ideal process for applying DFM&A. The development of any new product must go through four major phases before it reaches the marketplace: concept, design, development, and production. In the concept phase, product specifications are created and the design team creates a design layout of the new product. At this point, the first design for assembly analysis should be completed. This analysis will provide the design team with a theoretical minimum parts count and pinpoint high-assembly areas in the design.

At this point, the design team needs to review the DFA results and adjust the design layout to reflect the feedback of this preliminary analysis. The next step is to complete a design for manufacturing analysis on each unique part in the product. This will consist of developing a part cost and tooling cost for each part. It should also include doing a producibility study of each part. Based on the DFM analysis, the design team needs to make some

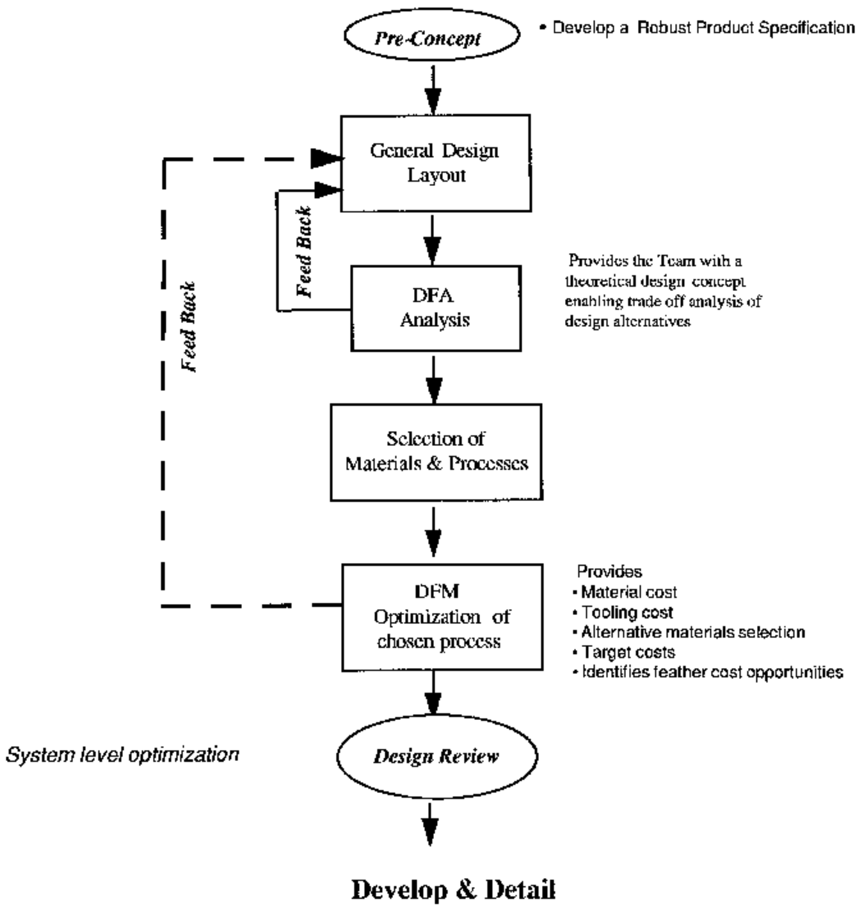

Figure 2 Key components of the DFM&A process.

additional adjustments in the design layout. At this point, the design team is now ready to start the design phase of the project. The DFM&A input at this point has developed a preliminary bill of material (BOM) and established a target cost for all the unique new parts in the design. It has also influenced the product architecture to improve the sequence of assembly as it flows through the manufacturing process.

The following case study illustrates the key elements in applying DFM&A. Figure 3 shows a product called the *motor drive assembly.* This design consists of 17 parts and assemblies. Outwardly it looks as if it can be assembled with little difficulty. The product is made up of two sheet metal parts and one aluminum machined part. It also has a motor assembly and a sensor, both bought from an outside supplier. In addition, the *motor drive assembly* has nine hardware items that provide other functions—or do they?

At this point, the design looks simple enough. It should take minimal engineering effort to design and detail the unique parts and develop an assembly drawing. Has a UMC been developed yet? Has a DFM&A analysis been performed? The DFA analysis will look at each process step, part, and subassembly used to build the product. It will analyze the time it takes to ‘‘get’’ and ‘‘handle’’ each part and the time it takes to insert each part in the assembly (see Table 1). It will point out areas where there are difficulties handling, aligning, and securing each and every part and subassembly. The DFM analysis will establish a cost for each part and estimate the cost of fabrication tooling. The analysis will also point out high-cost areas in the fabrication process so that changes can be made.

At this point, the DFA analysis suggested that this design could be built with fewer parts. A review of Table 2, column 5, shows that the design team feels it can eliminate the bushings, stand-offs, end-plate screws, grommet, cover, and cover screws. Also by replacing the end plate with a new snap-on plastic cover, they can eliminate the need to turn the

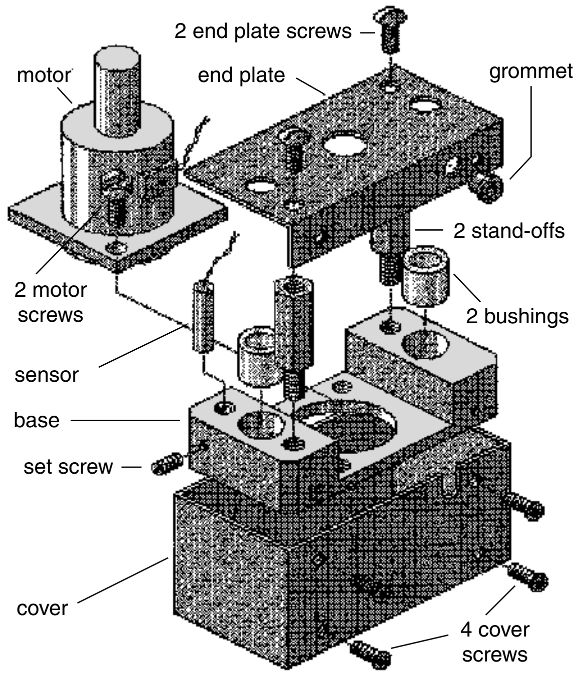

Figure 3 Proposed motor drive assembly. (From Ref. 1.)

Table 1

Motor Drive Assembly	
Number of parts and assemblies	19
Number of reorientation or adjustment	1
Number of special operations	2
Total assembly time in seconds	213.4
Total cost of fabrication and assembly tooling	$3590
Tool amortization at 10K assemblies	$ 0.36
Total cost of labor at $74.50/hr	$ 4.42
Total cost of materials	$ 42.44
Total cost of labor and materials	$ 46.86
Total UMC	$ 47.22

(reorientation) assembly over to install the end plate and two screws. Taking the time to eliminate parts and operations is the most powerful part of performing a DFA analysis. This is rule #2, which was left out above: DFM&A is a team sport. Bringing all members of the new product development team together and understanding the sequence of assembly, handling, and insertion time for each part will allow each team member to better understand the function of every part.

DFM Analysis

The DFM analysis provided the input for the fabricated part cost. As an example, the base is machined from a piece of solid aluminum bar stock. As designed, the base has 11 different holes drilled in it and 8 of them require taping. The DFM analysis (see Table 3) shows that it takes 17.84 minutes to machine this part from the solid bar stock. The finished machined base costs $10.89 in lots of 1000 parts. The ideal process for completing a DFM analysis might be as follows.

In the case of the base, the design engineer created the solid geometry in Matra Data's Euliked CAD system (see Fig. 4). The design engineer then sent the solid database as an STL file to the manufacturing engineer, who then brought the STL file into a viewing tool called *Solid View* (see Fig. 5). SolidView allowed the ME to get all the dimensioning and geometry inputs needed to complete the Boothroyd Dewhurst design for manufacturing machining analysis of the base part. SolidView also allowed the ME to take cut sections of the part and then step through it to insure that no producibility rules had been violated.

Today all of the major CAD supplies provide the STL file output format. There are many new CAD viewing tools like SolidView available, costing about $500 to $1000. These viewing tools will take STL or IGS files. The goal is to link all of the early product development data together so each member can have fast, accurate inputs to influence the design in its earliest stage.

In this example, it took the ME a total of 20 minutes to pull the STL files into SolidView and perform the DFM analysis. Engineering in the past has complained that DFM&A takes too much time and slows the design team down. The ME then analyzes the base as a die casting part, following the producibility rule. By designing the base as a die casting, it is possible to mold many of the part features into the part. This net shape die cast design will reduce much of the machining that was required in the original design. The die cast part will still require some machining. The DFM die casting analysis revealed that the base

Table 2 Motor Drive Assembly: Design for Assembly Analysis

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Name	Sub No. Entry No.	Type	Repeat Count	Minimum Items	Tool Fetching Time, sec	Handling Time, sec	Insertion or Op'n Time, sec	Total Time, sec	Labor Cost, $	Ass'y Tool or Fixture Cost, $	Item Cost, $	Total Item Cost, $	Manuf. Tool Cost, $	Target Cost, $	Part Number	Description
Base	1.1	Part	1	1	0	1.95	1.5	3.45	0.07	500	10.89	10.89	950	7.00	1P033-01	Add base to fixture
Bushing	1.2	Part	2	0	0	1.13	6.5	15.26	0.32	0	1.53	3.06	0	0.23	16P024-01	Add & press fit
Motor	1.3	Sub	1	1	0	7	6	13	0.27	0	18.56	18.56	0	12.00	121S021-02	Add & hold down
Motor screw	1.4	Part	2	2	2.9	1.5	9.6	25.1	0.52	0	0.08	0.16	0	0.08	112W0223-06	Add & thread
Sensor	1.5	Sub	1	1	0	5.6	6	11.6	0.24	0	2.79	2.79	0	2.79	124S223-01	Add & hold down
Set screw	1.6	Part	1	1	2.9	3	9.2	15.1	0.31	0	0.05	0.05	0	0.05	111W0256-02	Add & thread
Stand-off	1.7	Part	2	0	2.9	1.5	9.6	25.1	0.52	0	0.28	0.56	0	0.18	110W0334-07	Add & thread
End plate	1.8	Part	1	1	0	1.95	5.2	7.15	0.15	0	2.26	2.26	560	0.56	15P067-01	Add & hold down
End plate screw	1.9	Part	2	0	2.9	1.8	5.7	17.9	0.37	0	0.03	0.06	0	0.03	110W0777-04	Add & thread
Grommet	1.1	Part	1	0	0	1.95	11	12.95	0.27	0	0.12	0.03	0	0.12	116W022-08	Add & push fit
Dress wires—grommet	1.11	Oper	2	2	—	—	—	18.79	0.39	0	0.00	0.00	0	0.00		Library operation
Reorientation	1.12	Oper	1	0	—	—	4.5	4.5	0.09	350	0.00	0.00	0	0.00		Reorient & adjust
Cover	1.13	Part	1	0	0	2.3	8.3	10.6	0.22	0	3.73	3.73	1230	1.20	2P033-01	Add
Cover screw	1.14	Part	4	0	2.9	1.8	5.7	32.9	0.68	0	0.05	0.18	0	0.05	112W128-03	Add & thread
Totals =			22	9				213.4	4.42	850		42.33	2740	24.28		
								UMC = 47.22								

Production life volume = 10,000

Annual build volume = 3000

Assm. labor rate $/hr = $74.50

Note: The information presented in this table was developed from the Boothroyd Dewhurst DFA software program, version 8.0.[2]

Table 3 Machining Analysis Summary Report

Setups	Time Minutes	Cost $
Machine Tool Setups		
Setup	0.22	0.10
Nonproductive	10.63	4.87
Machining	6.77	3.10
Tool wear	—	0.31
Additional cost/part	—	0.00
Special tool or fixture	—	0.00
Library Operation Setups		
Setup	0.03	0.02
Process	0.20	0.13
Additional cost/part	—	0.03
Special tool or fixture	—	0.00
Material	—	2.34
Totals	17.84	10.89
Material	Gen aluminum alloy	
Part number	5678	
Initial hardness	55	
Form of workpiece	Rectangular bar	
Material cost, $/lb	2.75	
Cut length, in.	4.000	
Section height, in.	1.000	
Section width, in.	2.200	
Product life volume	10,000	
Number of machine tool setups	3	
Number of library operation setups	1	
Workpiece weight, lb	0.85	
Workpiece volume, cu in.	8.80	
Material density, lb/cu in.	0.097	

casting would cost $1.41 and the mold would cost $9050. Table 4 compares the two different fabrication methods.

This early DFM&A analysis provides the product development team with accurate labor and material estimates at the start of the project. It removes much of the complexity of the assembly and allows each member of the design team to visualize every component's function. By applying the basic principles of DFA, such as

- Combining or eliminating parts
- Eliminating assembly adjustments
- Designing part with self-locating features
- Designing parts with self-fastening features
- Facilitating handling of each part
- Eliminating reorientation of the parts during assembly
- Specifying standard parts

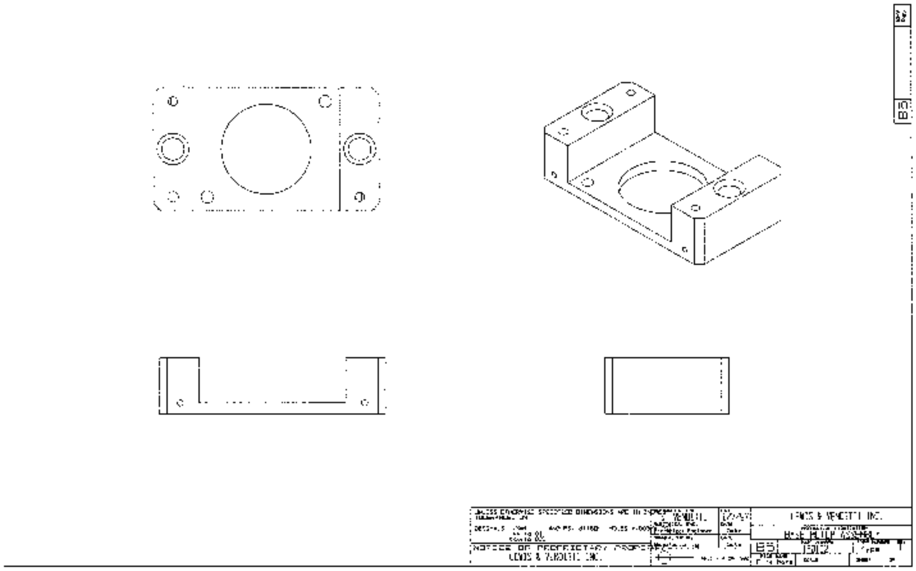

Figure 4

the design team is able to rationalize the motor drive assembly with fewer parts and assembly steps. Figure 6 shows a possible redesign of the original motor drive assembly. The DFM&A analysis (Table 5) provided the means for the design team to question the need and function of every part. As a result, the design team now has a new focus and an incentive to change the original design.

Table 6 shows the before-and-after DFM&A results.

If the motor drive product meets its expected production life volume of 10,000 units, the company will save $170,100. By applying principles of DFM&A to both the labor and material on the motor drive, the design team is able to achieve about a 35% cost avoidance on this program.

2.2 Getting the DFM&A Process Started

Management from All of the Major Disciplines Must Be on Your Side

In order for the DFM&A process to succeed, upper management must understand, accept, and encourage the DFM&A way of thinking. They must *want* it. It is difficult, if not impossible, for an individual or group of individuals to perform this task without management support, since the process requires the cooperation of so many groups working together. The biggest challenge of implementing DFM&A is the cooperation of so many individuals towards a common goal. This does not come naturally, especially if it is not perceived by the leaders as an integral part of the business's success. In many companies, management does not understand what DFM&A is. They believe it is a manufacturing process. It is not; it is a new product development process, which *must* include all disciplines (engineering, service, program managers, and manufacturing) to yield significant results. The simplest method to achieve cooperation between different organizations is to have the team members work in a common location (co-located team). The new product development team needs some nur-

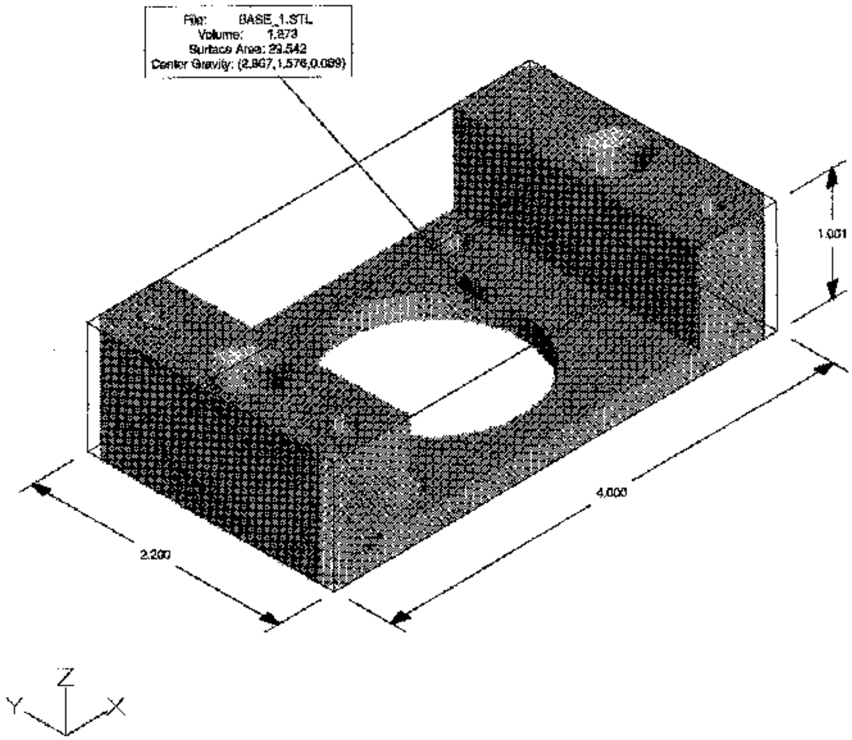

Figure 5

turing and stimulation to become empowered. This is an area where most companies just don't understand the human dynamics of building a high-performance team. Table 7 should aid in determining whether you are working in a team environment or a work group environment.

Many managers will say that their people are working in a team environment, but they still want to have complete control over work assignments and time spent supporting the team. In their mind, the team's mission is secondary to the individual department manager's

Table 4

	Die Cast and Machined	Machined from Bar Stock
Stock cost		$2.34
Die casting	$1.41	
$9050 die casting tooling/10,000	$0.91	
Machining time, min	3.6	17.84
Machining cost	$3.09	$8.55
Total cost	5.41	$10.89

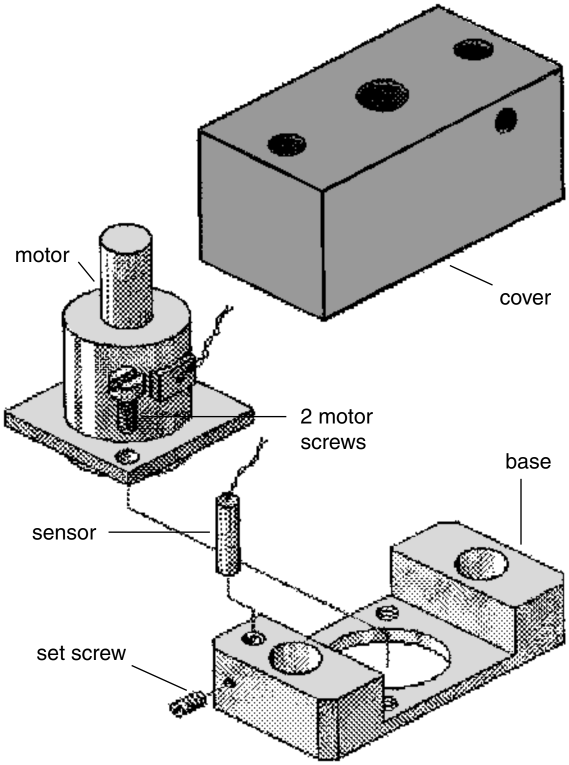

Figure 6 Redesign of motor assembly.

goals. This is not a team; it is a work group. The essential elements of a high-performance team are

- A clear understanding of the team's goals (a defined set of goals and tasks assigned to each individual team member)
- A feeling of openness, trust, and communication
- Shared decision-making (consensus)
- A well-understood problem-solving process
- A leader who legitimizes the team-building process

Management must recognize that to implement DFM&A in their organization, they must be prepared to change the way they do things. Management's reluctance to accept the need for change is one reason DFM&A has been so slow to succeed in many companies. Training is one way of bringing DFM&A knowledge to an organization, but training alone cannot be expected to effect the change.

2.3 The DFM&A Road Map

The DFM&A Methodology (A Product Development Philosophy)

- Form a multifunctional team
- Establish the product goals through competitive benchmarking

Table 5 Redesign of Motor Drive Assembly: Design for Assembly Analysis

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Name	Sub No. Entry No.	Type	Repeat Count	Minimum Items	Tool Fetching Time, sec	Handling Time, sec	Insertion or Op'n Time, sec	Total Time, sec	Labor Cost, $	Ass'y Tool or Fixture Cost, $	Item Cost, $	Total Item Cost, $	Manuf. Tool Cost, $	Target Cost, $	Part Number	Description
Base, casting	1.1	Part	1	1	0	1.95	1.5	3.45	0.07	850	3.09	3.09	9,050	3.09	1P033-02	Add base to fixture
Motor	1.2	Sub	1	1	0	3	6	9	0.19		18.56	18.56		15.00	121S021-02	Add & hold down
Motor screw	1.3	Part	2	2	2.9	1.5	9.6	25.1	0.52		0.08	0.16		0.08	112W0223-06	Add & thread
Sensor	1.4	Sub	1	1	0	5.6	6	11.6	0.24		2.79	2.79		2.79	124S223-01	Add & hold down
Set screw	1.5	Part	1	1	2.9	2.55	9.2	14.65	0.30		0.05	0.05		0.05	111W0256-02	Add & thread
Push/pull wire—easy	1.6	Oper	2	2	—	—	—	18.79	0.39		0.00	0.00		0.00		Library operation
Cover	1.7	Part	1	1	0	1.95	1.8	3.75	0.08		1.98	1.98	7,988	1.70	2P033-02	Add & snap fit
Totals =			9	9				86.34	1.79	850		26.63	17,038	22.71		
								UMC = 30.21								

Production life volume = 10,000

Annual build volume = 3000

Assm. labor rate = $74.50

Note. The information presented in this table was developed from the Boothroyd Dewhurst DFA software program, version 8.0.[2]

Table 6 Comparison of DFM&A Results

	Motor Drive Assembly	Redesign of Motor Drive Assembly
Number of parts and assemblies	19	7
Number of reorientation or adjustment	1	0
Number of special operations	2	2
Total assembly time in seconds	213.4	86.34
Total cost of labor at $74.50/hr	$4.42	$1.79
Total cost of materials	$42.44	$26.63
Total cost of labor and material	$46.86	$28.42
Total cost of fabrication tooling	$3590	$17,888
Tool amortization at 10K assemblies	$0.36	$1.79
Total UMC	$47.22	$30.21
Savings =	$17.01	

- Perform a design for assembly analysis
- Segment the product into manageable subassemblies or levels of assembly
- As a team, apply the design for assembly principles
- Use creativity techniques to enhance the emerging design
- As a team, evaluate and select the best ideas
- Ensure economical production of every piece part
- Establish a target cost for every part in the new design
- Start the detailed design of the emerging product
- Apply design for producibility guidelines
- Reapply the process at the next logical point in the design
- Provide the team with a time for reflection and sharing results

Table 7 Human Factors Test (check the box where your team fits)

Yes	Team Environment	Yes	Work Group Environment
	Are the team members committed to the group's common goals?	√	Are members loyal to outside groups with conflicting interests (functional managers)?
	Is there open communication with all members of the team?	√	Is information unshared?
	Is there flexible, creative leadership?	√	Is there a dominating leadership?
	Is the team rewarded as a group?	√	Is there individual recognition?
	Is there a high degree of confidence and trust between members?	√	Are you unsure of the group's authority?

This DFM&A methodology incorporates all of the critical steps needed to insure a successful implementation.

Develop a multifunctional team of all key players before the new product architecture is defined. This team must foster a creative climate that will encourage ownership of the new product's design. The first member of this team should be the project leader, the person who has the authority for the project. This individual must control the resources of the organization, should hand-pick the people who will work on the team, and should have the authority to resolve problems within the team.

The team leader should encourage and develop a creative climate. It is of utmost importance to assemble a product development team that has the talent to make the right decisions, the ability to carry them out, and the persistence and dedication to bring the product to a successful finish. Although these qualities are invaluable, it is of equal importance that these individuals be allowed as much freedom as possible to germinate creative solutions to the design problem as early as possible in the product design cycle.

The product development team owns the product design and the development process. The DFM&A process is most successful when implemented by a multifunctional team, where each person brings to the product design process his or her specific area of expertise. The team should embrace group dynamics and the group decision-making process for DFM&A to be most effective.

Emphasis has traditionally been placed on the design team as the people who drive and own the product. Designers need to be receptive to team input and share the burden of the design process with other team members.

The team structure depends on the nature and complexity of the product. Disciplines that might be part of a product team include

- Engineering
- Manufacturing
- Field service and support
- Quality
- Human factors or ergonomics
- Purchasing
- Industrial design and packaging
- Distribution
- Sales
- Marketing

Although it is not necessary for all of these disciplines to be present all of the time, they should have an idea of how things are progressing during the design process.

Clearly, there can be drawbacks to multidisciplinary teams, such as managing too many opinions, difficulty in making decisions, and factors in general that could lengthen the product development cycle. However, once a team has worked together and has an understanding of individual responsibilities, there is much to gain from adopting the team approach. Groups working together can pool their individual talents, skills, and insight so that more resources are brought to bear on a problem. Group discussion leads to a more thorough understanding of problems, ideas, and potential solutions from a variety of standpoints. Group decision-making results in a greater commitment to decisions, since people are more motivated to support and carry out a decision that they helped make. Groups allow individuals to improve existing skills and learn new ones.

Having the team located together in one facility makes the process work even better. This co-location improves the team's morale and also makes communication easier. Remembering to call someone with a question, or adding it to a meeting agenda, is more difficult than mentioning it when passing in the hallway. Seeing someone reminds one of an issue that may have otherwise been forgotten. These benefits may seem trivial, but the difference that co-location makes is significant.

As a team, establish product goals through a competitive benchmarking process: concept development. Competitive benchmarking is the continuous process of measuring your own products, services, and practices against the toughest competition, or the toughest competition in a particular area. The benchmarking process will help the team learn who the "best" are and what they do. It gives the team a means to understand how this new product measures up to other products in the marketplace. It identifies areas of opportunities that need changing in the current process. It allows the team to set targets and provides an incentive for change. Using a DFM&A analysis process for the competitive evaluation provides a means for relative comparison between those of your products and those of your competitors. You determine exactly where the competition is better.

Before performing a competitive teardown, decide on the characteristics that are most important to review, what the group wants to learn from the teardown, and the metrics that will be noted. Also keep the teardown group small. It's great to have many people walk through and view the results, but a small group can better manage the initial task of disassembly and analysis. Ideally, set aside a conference room for several days so the product can be left out unassembled, with a data sheet and metrics available.

Perform a design for assembly analysis of the proposed product that identifies possible candidate parts for elimination or redesign and pinpoints high-cost assembly operations. Early in this chapter, the motor drive assembly DFM&A analysis was developed. This example illustrates the importance of using a DFA tool to identify, size, and track the cost-savings opportunities. This leads to an important question: Do you need a formal DFA analysis software tool? Some DFM&A consultants will tell you that it is not necessary to use a formal DFA analysis tool. It is my supposition that these consultants want to sell you consulting services rather than teach the process. It just makes no sense *not* to use a formal DFA tool for evaluating and tracking the progress of the new product design through its evolution. The use of DFA software provides the team with a focus that is easily updated as design improvements are captured. The use of DFA software does not exclude the need for a good consultant to get the new team off to a good start. The selection of a DFA tool is a very important decision. The cost of buying a quality DFA software tool is easily justified by the savings from applying the DFA process on just one project.

At this point, the selection of the manufacturing site and type of assembly process should be completed. Every product must be designed with a thorough understanding of the capabilities of the manufacturing site. It is thus of paramount importance to choose the manufacturing site at the start of product design. This is a subtle point that is frequently overlooked at the start of a program, but to build a partnership with the manufacturing site, the site needs to have been chosen! Also, manufacturing facilities have vastly different processes, capabilities, strengths, and weaknesses, that affect, if not dictate, design decisions. When selecting a manufacturing site, the process by which the product will be built is also being decided.

As a team, apply the design for assembly principles to every part and operation to generate a list of possible cost opportunities. The generic list of DFA principles includes the following:

- Designing parts with self-locating features
- Designing parts with self-fastening features
- Increasing the use of multifunctional parts
- Eliminating assembly adjustments
- Driving standardization of fasteners, components, materials, finishes, and processes

It is important for the team to develop its own set of DFA principles that relate to the specific product it is working on. Ideally, the design team decides on the product characteristics it needs to meet based on input from product management and marketing. The product definition process involves gathering information from competitive benchmarking and teardowns, customer surveys, and market research. Competitive benchmarking illustrates which product characteristics are necessary.

Principles should be set forth early in the process as a contract that the team draws up together. It is up to the team to adopt many principles or only a few, and how lenient to be in granting waivers.

Use brainstorming or other creativity techniques to enhance the emerging design and identify further design improvements. The team must avoid the temptation to start engineering the product before developing the DFM&A analysis and strategy. As a team, evaluate and select the best ideas from the brainstorming, thus narrowing and focusing the product goals.

With the aid of DFM software, cost models, and competitive benchmarking, establish a target cost for every part in the new design. Make material and manufacturing process selections. Start the early supplier involvement process to ensure economical production of every piece part. Start the detailed design of the emerging product. Model, test, and evaluate the new design for fit, form, and function. Apply design for producibility guidelines to the emerging parts design to ensure that cost and performance targets are met.

Provide the team with a time for reflection and sharing results. Each team member needs to understand that there will be a final review of the program, at which time members will be able to make constructive criticism. This time helps the team determine what worked and what needs to be changed in the process.

Use DFM&A Metrics

The development of some DFM&A metrics is important. The team needs a method to measure the before-and-after results of applying the DFM&A process, thus justifying the time spent on the project. Table 8 shows the typical DFM&A metrics that should be used to compare your old product design against a competitive product and a proposed new redesign.

The total number of parts in an assembly is an excellent and widely used metric. If the reader remembers only one thing from this chapter, let it be to strive to reduce the quantity of parts in every product designed. The reason limiting parts count is so rewarding is that when parts are reduced, considerable overhead costs and activities that burden that part also disappear. When parts are reduced, quality of the end product is increased, since each part that is added to an assembly is an opportunity to introduce a defect into the product. Total assembly time will almost always be lowered by reducing the quantity of parts.

Table 8 DFM&A Metrics

	Old Design	Competitive	New Design
Number of Parts & Assemblies			
Number of Separate Assm. Operations			
Total Assembly Time			
Total Material Cost			
Totals			

Table 9 DFM&A New Products Checklist

Design for Manufacturing and Assembly Consideration	Yes	No
Design for assembly analysis completed:	☐	☐
Has this design been analyzed for minimal part count?	☐	☐
Have all adjustments been eliminated?	☐	☐
Are more than 85% common parts and assemblies used in this design?	☐	☐
Has assembly sequence been provided?	☐	☐
Have assembly and part reorientations been minimized?	☐	☐
Have more than 96% preferred screws been used in this design?	☐	☐
Have all parts been analyzed for ease of insertion during assembly?	☐	☐
Have all assembly interferences been eliminated?	☐	☐
Have location features been provided?	☐	☐
Have all parts been analyzed for ease of handling?	☐	☐
Have part weight problems been identified?	☐	☐
Have special packaging requirements been addressed for problem parts?	☐	☐
Are special tools needed for any assembly steps?	☐	☐
Ergonomics Considerations	**Yes**	**No**
Does design capitalize on self-alignment features of mating parts?	☐	☐
Have limited physical and visual access conditions been avoided?	☐	☐
Does design allow for access of hands and tools to perform necessary assembly steps?	☐	☐
Has adequate access been provided for all threaded fasteners and drive tooling?	☐	☐
Have all operator hazards been eliminated (sharp edges)?	☐	☐
Wire Management	**Yes**	**No**
Has adequate panel pass-through been provided to allow for easy harness/cable routing?	☐	☐
Have harness/cable supports been provided?	☐	☐
Have keyed connectors been provided at all electrical interconnections?	☐	☐
Are all harnesses/cables long enough for ease of routing, tie down, plug in, and to eliminate strain relief on interconnects?	☐	☐
Does design allow for access of hands and tools to perform necessary wiring operations?	☐	☐
Does position of cable/harness impede air flow?	☐	☐
Design for Manufacturing and Considerations	**Yes**	**No**
Have all unique design parts been analyzed for producibility?	☐	☐
Have all unique design parts been analyzed for cost?	☐	☐
Have all unique design parts been analyzed for their impact of tooling/mold cost?	☐	☐
Assembly Process Consideration	**Yes**	**No**
Has assembly tryout been performed prior to scheduled prototype build?	☐	☐
Have assembly views and pictorial been provided to support assembly documentation?	☐	☐
Has opportunity defects analysis been performed on process build?	☐	☐
Has products cosmetics been considered (paint match, scratches)?	☐	☐

A simple method to test for potentially unnecessary parts is to ask the following three questions for each part in the assembly:

1. During the products operation, does the part move relative to all other parts already assembled? (*answer yes or no*)
2. Does the part need to be made from a different material or be isolated from all other parts already assembled? (*answer yes or no*)
3. Must the part be separate from all other parts already assembled because of necessary assembly or disassembly of other parts? (*answer yes or no*)

You must answer the questions above for each part in the assembly. If your answer is ‘‘no’’ for all three questions, then that part is a candidate for elimination.

The total time it takes to assemble a product is an important DFM&A metric. Time is money, and the less time needed to assemble the product, the better. Since some of the most time-consuming assembly operations are fastening operations, discrete fasteners are always candidates for elimination from a product. By examining the assembly time of each and every part in the assembly, the designer can target specific areas for improvement. Total material cost is self-explanatory.

The new product DFM&A checklist (Table 9) is a good review of how well your team did with applying the DFM&A methodology. Use this check sheet during all phases of the product development process; it is a good reminder. At the end of the project you should have checked most of the *yes* boxes.

3 WHY IS DFM&A IMPORTANT?

DFM&A is a powerful tool in the design team’s repertoire. If used effectively, it can yield tremendous results, the least of which is that the product will be easy to assemble! The most beneficial outcome of DFM&A is to reduce part count in the assembly, which in turn will simplify the assembly process, lower manufacturing overhead, reduce assembly time, and increase quality by lessening the opportunities for introducing a defect. Labor content is also reduced because with fewer parts, there are fewer and simpler assembly operations. Another benefit to reducing parts count is a shortened product development cycle because there are fewer parts to design. The philosophy encourages simplifying the design and using standard, off-the-shelf parts whenever possible. In using DFM&A, renewed emphasis is placed on designing each part so it can be economically produced by the selected manufacturing process.

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