

# DFMA<sup>®</sup>

Design for Manufacture & Assembly



**Reduce Costs**  
**Increase Profits**

A White Paper for Corporate Management



**BOOTHROYD DEWHURST**

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# DFMA®

## Design for Manufacture & Assembly

### Reduce Costs

### Increase Profits

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*How to Use Design for Manufacture and Assembly Software to Slash Manufacturing Overhead, Make Products Competitive, and Bring New Efficiencies to the Manufacturing Process*

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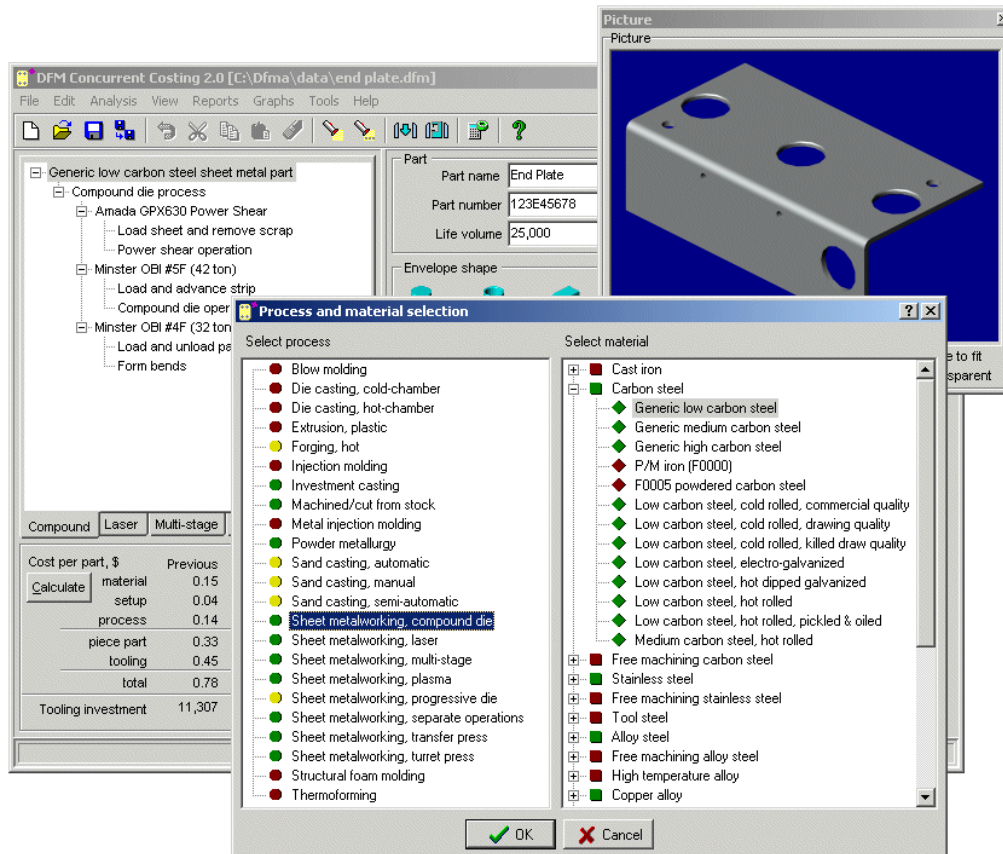
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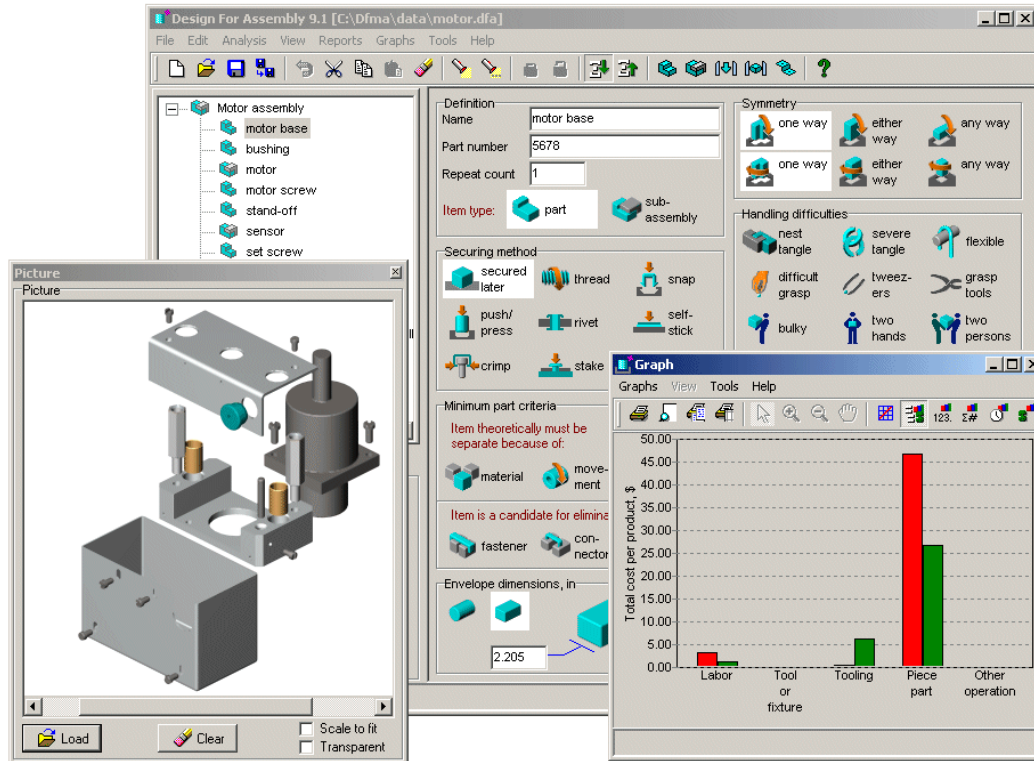
## Introduction

### What is DFMA?

**DFMA<sup>®</sup> (Design for Manufacture and Assembly):** Software that uses a question-and-answer approach to help determine the most cost-effective and efficient materials, manufacturing process, and assembly method for a particular part or product.



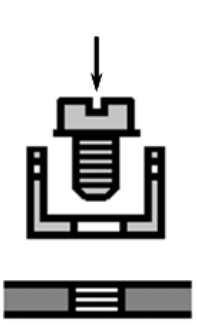
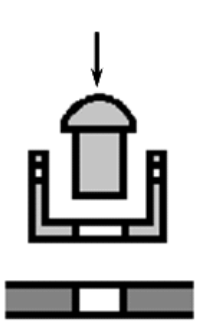
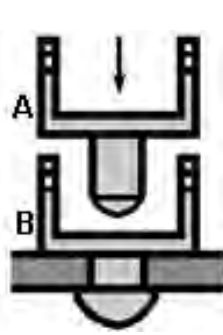
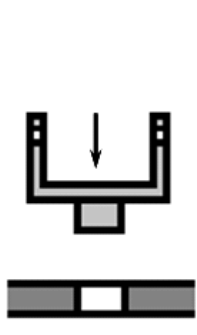
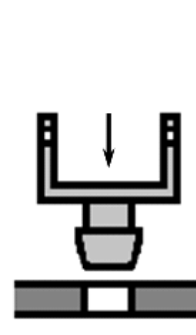
*Engineers employ Design for Manufacture software to obtain early cost estimates on a particular part or product, using the world's most comprehensive database of processes, materials, and machinery. DFM software gives engineers tools for deciding where cost is necessary in a design—and where cost can be removed—without compromising product function.*



Product design and manufacturing engineers use Design for Assembly software to analyze the various methods that could be used to manufacture a product. Using this tool, the design is simplified repeatedly until the assembly process is as streamlined as possible and the part count has reached a cost effective minimum.

Top companies use DFMA to achieve three main goals:

- 1. Improve their products while reducing cost.** They simplify their products, improve quality, reduce manufacturing and assembly costs, and quantify improvements.
- 2. Increase competitive advantage.** They study competitive products, determine quality and quantify manufacturing and assembly difficulties, and create superior products.
- 3. Hold suppliers accountable.** They use DFMA as a “should-cost” tool to predict costs, analyze and discuss supplier bids, and hold outside suppliers to best practices.

DFMA Design Improvement Example				
START				FINISH
				
<ul style="list-style-type: none"> <li>• 3 parts</li> <li>• Requires a screwdriver</li> <li>• Needs careful alignment</li> <li>• Time-consuming</li> </ul>	<ul style="list-style-type: none"> <li>• 3 parts</li> <li>• Requires a rivet gun</li> <li>• Alignment not as delicate</li> <li>• Assembly time less</li> </ul>	<ul style="list-style-type: none"> <li>• 2 parts</li> <li>• Integrated fastener &amp; cradle (A becomes B)</li> <li>• Requires machine to secure the head of the fastener</li> </ul>	<ul style="list-style-type: none"> <li>• 2 parts</li> <li>• Integrated fastener &amp; cradle</li> <li>• Requires machine to press part into place</li> </ul>	<ul style="list-style-type: none"> <li>• 2 parts</li> <li>• Integrated fastener &amp; cradle</li> <li>• Can be hand-pressed into place—even by the consumer—and can be removed</li> </ul>

**Product cost = \$0.66**  
**Assembly time = 20.92 seconds**



**Product cost = \$0.38**  
**Assembly time = 8.82 seconds**

*Here's an example of an assembly simplification process using DFMA. The product starts out easy to design but difficult to assemble. The engineer focuses on reducing parts, integrating parts, and simplifying assembly. The end result is a more sophisticated design that is much easier to assemble. The cost is reduced by 42% and the assembly time is cut by 58%.*

*Analysis of hundreds of DFMA case studies reveal, on average, a 42% reduction in labor costs, a 54% reduction in parts, a 60% reduction in assembly time, a 45% reduction in product development cycles, and a 50% reduction in cost.*

## How the world's leading companies use DFMA

Why do some companies consistently out-perform their competitors?

Dell Computer, for example, has been leading the PC market for years. Since Michael Dell founded the company with \$1000 in his University of Texas dorm room in 1984, Dell's revenues have grown steadily. As of 2009, revenues are at \$61.1 billion.<sup>1</sup> Dell is the market share leader in the PC industry, at 17.9 percent, up from 16.7 percent (HP is second with a market share of 15.8 percent, down from 16.2 percent).<sup>2</sup> "The interesting question is whether anyone can slow Dell down," writes Eric Bangeman in ARS Technica.

The five basic tenets of Dell's direct-to-the-customer model are:

- Find the most efficient path to the customer.
- Provide a single point of accountability.
- Build to order.
- Be the low-cost leader.
- Use standards-based technology.<sup>6</sup>

The company is famous for its manufacturing excellence and its "foremost competitive weapon—an unrelenting sense of urgency and speed."<sup>3</sup> *Fast Company* calls it "one of the fastest, most hyperefficient organizations on the planet."<sup>3</sup>

Dell has long practiced just-in-time inventory techniques. "Though it assembles nearly 80,000 computers every 24 hours, it carries no more than two hours of inventory in its factories and a maximum of just 72 hours across its entire operation," says *Fast Company*.<sup>3</sup> The company is able to deliver a custom computer to a customer within 5

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<sup>1</sup> Dell Financial Statement, 2008

<sup>2</sup> "Dell still king of the market share hill," by Eric Bangeman, ARS Technica, January 18, 2005

<sup>3</sup> "Living in Dell Time," by Bill Breen, *Fast Company*, November, 2004



days, in spite of the fact that the Dell creates those computers in manufacturing facilities all over the world.

Michael Dell has a well-deserved reputation for driving his company to continually improve. As *Fast Company* reports:

Dell is always on a mission to outdo itself. The [newest factory in north Austin] is expected to increase its production by some 30% by year's end. Michael Dell himself drove that point home when he recently toured the plant. A group from one of the packing lines showed him how they'd upped their processing rate from 300 to 350 boxes an hour. "Michael congratulated them, and there were high fives all around," recalls Dick Hunter [Dell's supply-chain manager for the Americas]. "But then he issued a challenge: 'How can we improve to 400?' He's pleased, but never satisfied." <sup>3</sup>

"Dell has brought a maniacal focus to shaving minutes off the time it takes to assemble and ship a computer," *Fast Company* reports. "By studying videotapes of 'the build,' as they call it, factory managers have slashed in half the number of times a computer is touched by workers. They've counted the screws in a PC and redesigned it so that the major components—hard drive, graphics card, CD player—simply snap in place....In a blur of synchronized movements, a veteran builder can piece together a Dell OptiPlex or Dimension PC in three minutes."<sup>3</sup>

What you have just read is a glimpse into how Dell uses DFMA (Design for Manufacture and Assembly) software to become "one of the fastest, most hyperefficient organizations on the planet." Here's a recent example of how Dell used DFMA to improve assembly time on their three most popular computers: Optiplex, Precision, and Dimension.

When the company's engineering and manufacturing team set out to improve assembly time on these models, they had already reduced assembly time on their Optiframe

design by 32%--on a computer that had recently earned an "A" from PC Magazine for service and reliability.<sup>4</sup>

As usual, while they were "pleased," they weren't "satisfied." Dell's engineering and manufacturing teams set out to have one chassis family serve all three types of computers; decrease assembly time by 25%; and increase ease of service.

They approached this challenge in classic Dell "best practices" fashion:

1. They assembled a cross-functional team.
2. They were willing to look at all possible options, even calling the project "DFX," where D=Design, F=for, and "X" could represent manufacturing, logistics, integration, modularity, assembly, safety, ergonomics, environment, quality, and service.
3. They created a "product features guide" which itemized 80 to 90% of the required features.
4. They then used DFMA to evaluate the functional purpose of each assembly and relationships between parts. The software provided a report that proposed a theoretically attainable optimum design. Each part was rated on its difficulty of orientation and assembly. DFMA software estimated the total assembly time and cost for the entire design.
5. One of their key goals was to eliminate fasteners. "Every screw you design out of a product reduces assembly time by approximately 8 seconds," explains Dwight Stimson, senior DFX engineer at Dell. "Integrated assembly...also cuts assembly time and logistics costs."<sup>5</sup> Dell engineers used the DFMA software to design an integrated system for attaching floppy, CD, and DVD drives. The drives were slid onto rails, with shock absorption built in to them.

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<sup>4</sup> "DFA Transforms Computer Chassis," *Assembly* magazine, June 2003

<sup>5</sup> "DFA Transforms Computer Chassis," *Assembly* magazine, June 2003

6. Cable routing was also built into the design, so suppliers could pre-install cables. Cables were color-coded for easier assembly.
7. A new box was designed for shipping that was smaller, lighter, and stronger. Each ½-inch of shrinkage resulted in savings of hundreds of thousands of dollars per year in outbound freight costs.
8. The final assembly is virtually “tool-free.” The operator picks up a component, slides it onto its rails, snaps the rails in place, plugs in the cable, and then repeats the process for each component.

The final result? Assembly time was reduced by 25 to 40%, depending on the configuration of the PC. The three different chassis designs now use common metal and plastic parts, reducing inventory and tooling expenses. Assembly and training has been standardized for all three types of computers, worldwide. Overall service time for the PCs has been reduced 20 to 30%.

DFMA plays a key role in Dell’s quest for revenues and market leadership. Shawn S. Jagodzinski, senior product engineer DAO product engineering strategy, and Bradley S. Keup, senior technical strategist PG operations strategy for Dell, wrote in *Desktop Engineering*:

“We rely on a number of software tools, especially those that allow us to predict manufacturing and assembly costs early in design. We use Design for Manufacture and Assembly (DFMA) software from Boothroyd Dewhurst, Inc. throughout product development to evaluate part cost, ease of assembly, and serviceability. DFMA is a fundamental business process for the Dell engineering team because it supports our holistic approach to cost. It helps us analyze our designs and make decisions that lower overall costs, not just product costs. Increased manufacturing throughput, reduced damage rates, higher quality, streamlined logistics,

and faster delivery are all outcomes of weaving DFMA into the development cycle.”<sup>6</sup>

Hundreds of companies use DFMA. Other leading companies using DFMA include Access Business Group, Agilent Technologies, Andrew Corporation, Applied Materials, Audi, Battelle, Bayer, BMW, Boeing, Bosch, Cymer, DataCard, Deere, Diebold, Ericsson, Ford, GE Plastics, General Motors, Harley-Davidson, Honeywell, Hughes Network Systems, HiLite Industries, ITT Industries, Jernberg, Johnson Controls, Kodak, Lear, Liebert, Lockheed Martin, Maytag, Mercedes Benz, Moen, Motorola, MTD Products, NCR, Nissan, Nokia, Nortel, Otis Elevator, PACCAR, Polaris, Raytheon, Rockwell Automation, Rolls Royce, Siemens, Solectron, Storage Technology, Tellabs, TRW, Visteon, Volkswagen, Volvo, Xerox, and Yale Security.

- **Abbott Laboratories** used DFMA to create new components for a large medical diagnostic machine that holds up to 135 vials of blood and other fluid samples for testing. The goal was to reduce administrative tasks associated with shipping, reduce wear and tear between part surfaces, and simplify product assembly. After using DFMA, Abbott Laboratories reduced part count from 86 parts to 46, reduced assembly time from 12 minutes to 5 minutes, and redesigned a major component so that it consisted of one part instead of 19. Wear and tear between the 19 individual parts is no longer an issue.
- **Access Business Group** used DFMA to create a new gourmet coffeemaker. Goals included precise temperature control, superior coffee taste, uniform coffee saturation, lighter-weight design, and a less-expensive design. DFMA analysis helped the company reach its product design goals while reducing part count from 122 to 81, the cost of assembly from \$3.20 to \$1.93, and assembly time from 721.08 seconds to 433.74 seconds.

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<sup>6</sup> “No New Factories,” by Shawn S. Jagodzinski and Bradley S. Keup, Desktop Engineering, January 2004

- **Boeing** used DFMA to reduce the number of parts on an F/A-18 C/D system by 84%, reduce part cost by 73%, weight by 11%, and assembly time by 89%.
- **MDS Sciex** used DFMA to get a product to market in record time. A cross-functional team utilized DFMA to stimulate discussions and guide the design of a hybrid mass spectrometer. Goran Marunic, mechanical engineer for MDS Sciex, says, “We answered the questions in the DFMA software one by one. The questions prompted a series of discussions about part count and assembly efficiency. Working closely with manufacturing engineering, we kept the design modular, aiming for more manageable development and better assembly and serviceability. We divided the design logically into subassemblies, each of which had its own bill of materials.”<sup>7</sup>
- **Whirlpool** used DFMA on its most popular microwave oven. Goals were to reduce in-plant costs, generate a lean design, and simplify or eliminate assembly processes. Results included a 29% reduction in parts, from 150 to 106, a 26% decrease in assembly time, and standardized cabling across product lines. Payback time was 6 months.

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<sup>7</sup> “Automating the Global Product Lifecycle,” by Gary Mitchell, Editor, Automation World, February 2004

## Organizational Advantages of DFMA

There are two ways to engineer and manufacture a product: the “over the fence” method and the cross-functional method.

In the first case, the company’s engineers design a product and then throw it “over the fence” to the manufacturing team. The result is predictable. The product is not as easily manufactured as it should be, or, in the worst cases, it cannot be manufactured as designed. The manufacturing engineers are forced to throw it back to engineering, requesting that changes be made. This game of toss-the-design continues until the part can be manufactured. Meanwhile, the company is unable to satisfy demand for that product. Precious market share and market window opportunities are squandered.

In the cross-functional method, product development engineers and manufacturing engineers work together from the start on the product design, using DFMA tools to explore and evaluate their options. Johan Dahm, mechanical engineer for Whirlpool, says of a recent project, “The early involvement of the production engineers was new and very valuable. We discovered that, before their involvement, we ran the risk of designing in assembly problems...even in the concept phase. Now, the production engineers help us to eliminate assembly problems before the design is finalized.”

### The role of DFMA in outsourcing

One of the main reasons given for outsourcing is “reducing labor costs.” However, typically labor is only 4% of the cost of a product, according to a study conducted by Boothroyd Dewhurst, Inc. and David Meeker, a consultant with Neoteric Product Development, in 2004.

DFMA analysis can identify savings in materials and manufacturing that can more than make up for labor cost differences. Plus, outsourcing involves hidden costs, such as communication and cultural roadblocks, quality problems, shipping, and potential patent infringement that is difficult to identify and prosecute.

On the other hand, if you are already committed to outsourcing, DFMA can make it easier to manufacture products, decreasing the engineering changes that occur after a product has gone into production. Overseas suppliers can be held to “best practice” costs, materials, and assembly methods. Innovations in materials can reduce weight—and shipping costs. Quality can be designed in from the start.

DFMA can help you cut costs to the point where outsourcing is no longer a cost-effective option. Or, if you are already outsourcing, it can bring new efficiencies and economies to your outsourced manufacturing.

*Labor costs for production workers in manufacturing, in U.S. dollars, as of 2007:*

United States	\$ 24.59
Japan	19.75
Singapore	8.35
Taiwan	6.58
Hong Kong	5.78

Source: US. Dept of Labor, Bureau of Statistics, 2007

DFMA improves communication between the two teams. The tool makes it possible for the product developers to document and present the results of their thinking as they explore various creative approaches to the design. DFMA provides the two disciplines—product development and manufacturing—with a common method for communicating and exchanging design data, reports, and manufacturing instructions. Stefan Wohnhaus of Whirlpool Europe, says, “One of the biggest benefits of DFMA is the facilitation of communication within cross-functional teams. DFMA provides fact-based data, that is easy to understand and to verify.”<sup>8</sup>

“The software allows engineers to talk in terms they are comfortable with, and that’s data,” says Dan O’Callaghan, director of product cost for Harley-Davidson. “It takes the emotion out of it and refines the model with each additional piece of data.”<sup>9</sup> Obviously, efficiency of communication and less back-and-forth activity have a direct impact on a company’s profits.

### **Management Advantages of DFMA**

Cross-team cooperation has always been a laudable management goal. But without the proper tools, more problems can be created than solved. For example, product development engineers and manufacturing engineers use a different set of metrics and even a different language to describe what they are doing and define the success of their efforts. DFMA provides a common problem-solving platform, a common language, and a common set of metrics for discussion and reporting results to management. Everyone is “on the same page,” to use a common phrase. This facilitates meaningful discussion and makes it easier for teams to agree on a profitable course of action.

George Valaitis, manager of mechanical engineering for MDS Sciex, says that DFMA acts as a catalyst to stimulate discussion and to guide technical analysis of the design.”<sup>7</sup>

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<sup>8</sup> International Forum on DFMA, June 1998

<sup>9</sup> “Cost Choppers,” by Gerry Kobe, Automotive Industries, June 2002

DFMA also provides management with a tool it can use to propel the company into world-class status. The leaders are already using these tools; they consider DFMA essential to competitive design. As Rhoda Miel noted recently in *Plastics News*:

Injection molder Nypro Inc. has specifically targeted design as a competitive strategy. With its partial ownership of design group Radius Product Development, the company is bringing forward new products that help itself and its customers. “You can move up through design—mechanical design, industrial design,” said Brian Jones, Nypro president and chief executive officer. “The customers are waiting for you to do it. They’re begging for you to do it.” Radius is even taking its expertise to China, bringing new design focus to a region previously considered only a low-wage competitor. The firm recently opened a center with 50 designers in Beijing.

Being a respected processor is not enough, said Craig Vogel, director of the Center for Design Research & Innovation at the University of Cincinnati [at the *Plastics News* Executive Forum in March of 2005]. An ability to produce good parts is the bottom step on the competitive ladder...When quality becomes a commodity, manufacturers must find another way to set themselves apart from the pack.

“Stop thinking of what you do in terms of products,” he said. “Think of them as a consumer would.”

Nypro has had to stop thinking of itself solely as a molder, Jones said. Instead, it comes up with solutions to customer’s problems—and uses plastics, as well as metals and other materials, to do so.

More money is available to those who are ahead of the curve, he said. A company that can come up with its own design improvements has a better chance of getting the complete manufacturing package. Jones estimates



Nypro has an 80 percent chance of taking home all of the business for products it takes part in creating.<sup>10</sup>

One of the reasons DFMA adds value to the product mix is it allows engineers to easily explore alternative methods. Engineers who rely solely on their existing knowledge—of processes, materials, and machinery—will not compete effectively against engineers who avail themselves of a comprehensive database of all types of processes, materials, machinery.

Even if the results of DFMA analysis were less impressive—less than the 50% cost reduction normally achieved, for example—engineers using DFMA could at least be sure that they had examined all possibilities and would not be blindsided in the marketplace by another company using DFMA methods.

One interesting side benefit of using DFMA is the way it imposes a go-through-all options discipline on engineers. Even those who use the DFMA processes frequently are surprised when they “assume” they’ve covered everything, but then take the design through the DFMA process and discover aspects of the design where they can significantly reduce cost without sacrificing quality.

Managers whose companies use DFMA are able to find cost savings in the design phase rather than in the manufacturing phase or the launch phase. Obviously, the earlier the better. In the design phase, changes are inexpensive and uncomplicated. In the manufacturing phase, changes are expensive, take time, reduce morale and momentum, and can affect dependent projects. And of course, no one wants to make changes in the launch phase—or after the product is on the market.

Harley-Davidson experienced this phenomenon first hand, after its engineers had already designed a new motorcycle frame. They were assuming that the frame would save them \$70 in cost, when compared to their current frame. Prior to putting the new frame into production, Harley-Davidson wanted to make sure that their \$70 savings

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<sup>10</sup> “Value key to competitive success, speakers say,” by Rhoda Miel, *Plastics News*, March 4, 2005

assumption was correct. First they analyzed the current frame using DFMA software; the DFMA results predicted the current frame's real-world cost within 0.5%.

Armed with this confidence in the DFMA results, Harley-Davidson engineers then analyzed the *new* frame with DFMA software. They discovered that the new frame was actually going to cost \$7 *more* than the old frame to manufacture, not \$70 less. They had other reasons for wanting to use the new frame design, so they started looking elsewhere for the assumed cost savings.

“With what we had done previously, we may not have uncovered [the additional \$7 cost] until we had launched,” said Dan O’Callaghan of Harley-Davidson.<sup>9</sup>

DFMA also gives company managers a way to produce products that are more marketable. Part reduction alone can make a significant difference in the quality, reliability, and durability of a product. These qualities provide marketing and sales people with solid, competitive “talking points,” which has a direct effect on revenue growth.

The most significant improvements in marketability come from products that address specific customer needs, as noted earlier by the CEO of Nypro. DFMA provides a cost-effective platform for design exploration. An engineer can start the design process with the customer's stated objective in mind, and work with DFMA until the objective has been met in a cost-effective manner.

Simpler, more reliable products also increase profits by cutting long-term overhead costs associated with training, customer service, inventory management, and replacement parts. Of course, more reliable products also contribute to the company's positive reputation, encouraging word-of-mouth referrals.

### **Engineering Advantages of DFMA**

Engineers excel at finding alternative solutions to problems.

Their natural talent in this area can be greatly aided by a sophisticated, real-world “what if” tool that helps them quickly establish the cost of a particular approach. Engineers aided by such a tool can explore a wider variety of materials and processes. Perhaps a particular part would be best made by a specific type of machine.

It doesn't matter if the engineer has never worked with that type of manufacturing process; he can select that process in the analysis procedure, and see what it would cost to make the part using that particular process and material combination. It may turn out that the part would be better made by a vendor who uses that type of machine.

Engineers using DFMA are not limited to the processes and materials they are personally familiar with. The DFMA tool contains an entire database of alternatives to explore, in the design process. The engineer is better able to incorporate business goals into his design—such as meeting a specific target retail price, or making use of a new material in order for the part to be more competitive.

Then, once the optimum materials and methods have been identified, Design for Assembly software can be used to optimize the actual assembly of the product. Engineers and manufacturing engineers can work in tandem to ensure that the design can be produced quickly and cost-effectively. The resulting streamlining of the design-to-manufacturing process cannot be over-emphasized. Discovering manufacturing “issues” early on can save a company man-months of rework and precious market window time. It can also help the company leapfrog the competition with a product that can be brought to market more quickly and produced less expensively. Products that are more easily assembled free up assembly personnel and resources for increased output and/or the assembly of other products.

A more subtle but significant result of using DFMA are the “lesson libraries” created as designs are optimized for cost (using Design for Manufacture) and for assembly (using Design for Assembly). Changes to designs can be analyzed and improved using the history of the analysis. This data can be helpful to any engineers starting to work on existing or even new projects.

“DFMA was designed from the start, by engineers for engineers, as a tool that would assist engineers in doing what they do best,” says John Gilligan, president of Boothroyd Dewhurst. “It supplements the natural ability of an engineer to explore alternatives, providing a real-world database of information on materials, processes, and machines.”

Engineers are the first to appreciate the power of following a process to achieve a desired result. In the course of answering the questions posed by DFMA software, engineers are reminded of all aspects of the structure of the product, the materials and production alternatives available, and the possible simplification of the design. The tool becomes a brainstorming partner. The best approaches for cost savings and for manufacturability are examined at the design phase, prior to the product moving into production.

### **Manufacturing Advantages of DFMA**

In most companies, manufacturing engineers receive designs from product development engineers, and are then expected to manufacture it in the best way possible. If they encounter a problem as they attempt to set up manufacturing, they must go back to the design engineers, present the problem, and work with the design engineers on a solution.

The more advanced companies have abandoned this process for one where the manufacturing engineers work in tandem with the product designers at the pre-production stage. Their expertise and knowledge is designed into the product from the start. Unnecessary steps, tools, and parts are designed out of the production process. Products are produced more quickly and get to market in time to meet customer demand—and faster than competitors.

Manufacturing engineers may assume that their jobs will be threatened by the DFMA software. In fact, just the opposite occurs. When implanted properly, manufacturing engineers are thoroughly involved in the product design process. Their expertise is

invaluable as the various methods are analyzed and optimized. Designs optimized with DFMA are then easier to manufacture.

Instead of spending their time trying to work around a designed-in manufacturing issue, they are free to focus on constant improvement, using methods similar to those that Dell and Whirlpool employs—videotaping and/or documenting the “build” and finding new ways to streamline the process. They are able to provide value both when the product is being designed and when it is being produced.

## The Evolution of DFMA

As Otis Port wrote in *Business Week* in 1989:

The practices now known as “design for assembly” (DFA) and “design for manufacture” (DFM) had their start in the late 1970s at the University of Massachusetts. Geoffrey Boothroyd and U-Mass colleagues had received a grant from the National Science Foundation to look at issues related to both assembly and manufacture.

Boothroyd estimates that although many industrial designers would ordinarily claim to have a good idea of what the manufacturing costs are for a particular design, these cost estimates typically don’t include the costs of assembly. “Especially,” he stresses, “if automatic assembly was involved.”

So there was a huge, untapped area of savings possibilities presented: cost minimization related to putting a product together, the parts and the processes. The researchers began to examine the product structure itself and the ways and means to take costs out of the parts that construct it. Boothroyd notes that there are often accompanying improvements in performance and reliability when the product and the constituting parts are analyzed prior to production.

Boothroyd was joined at U-Mass by Professor Peter Dewhurst, the other half of the B-D team.<sup>11</sup>

It soon became clear that industry-wide adoption of DFMA methods would be best facilitated by software. Thus Boothroyd Dewhurst Inc was formed in 1983 to develop DFMA software. The company released its first product that year.

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<sup>11</sup> “Smart Factories: America’s Turn? A few advanced plants now, a competitive arsenal soon,” by Otis Port in New York, with Zachary Shiller in Cleveland, Gregory L. Miles in Pittsburgh, Amy Schulman in Boston and bureau reports. *Business Week*, May 8, 1989

Since then, hundreds of companies have used DFMA methods to cut costs, improve quality, and streamline the assembly of their products. Ford Motor Company, for example, announced in 1988 that it had used DFMA to save \$1.2 billion on their Taurus line of automobiles. More recently, Raytheon saved an estimated \$2 million over the life of the Long Range Advanced Scout Surveillance System for the U.S.



Army;<sup>12</sup> Dell saved an estimated \$32 million in reduced direct labor by redesigning one product line and introducing the Optiframe chassis;<sup>13</sup> Nortel redesigned two of their broadband products and estimated savings over \$4 million annually.<sup>14</sup>

Drs. Geoffrey Boothroyd and Peter Dewhurst were awarded the National Medal of Technology by President George H.W. Bush in 1991.

The company has always encouraged its customers to exchange ideas and best practices. The first International DFMA conference was held in Newport, RI in 1986; the 25th International DFMA conference is being held in 2010.

The company has continuously improved its product. For example, a new version of Design for Assembly can display, in one window, all three components of the DFA analysis process: the Product Structure Chart, the DFA Question Panels, and the Results Box. Panels can be customized to suit the designer. To begin the DFA analysis of a product, the designer enters its list of parts, including subassemblies, into a treelike Structure Chart. The designer then answers specific questions about each part, such as whether the part is functionally necessary and whether it presents handling, insertion, fetching, or other assembly difficulties. With each question answered, the Results Box updates and displays assembly time and cost, providing a realistic and “real-time” view

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<sup>12</sup> “Get Lean and Improve Quality,” by Larry Adams, *Quality*, October 2002

<sup>13</sup> “Factories of the Future: Make it Simple,” by John Teresko, *Industry Week*, July 2002

<sup>14</sup> “It’s All In The Packaging,” by Dean Flockton, *Mechanical Engineering*, February 1999

of the ramifications of design decisions. Once the DFA analysis is complete, the designer can view the results in report and graphical format and can sort data according to time and cost criteria. The software provides suggestions for redesign in onscreen and printed reports.

The most recent release of DFM Concurrent Costing® can be used by engineers to learn about different materials and processes. They can evaluate competing part designs, including the cost details of machining setups and custom finishing. The software includes cost models for sheet metalworking and machining to cost models for plastic injection molding and diecasting and powder metals.

The current version of the DFM software gives designers a comprehensive understanding of the costs to manufacture parts by means of turret pressworking; laser and plasma cutting; sheet metal stamping with a variety of dies; machining; structural foam molding; plastic extrusion; injection molding; thermoforming; blow molding; cold and hot die casting; hot forging; powder metal processing; sand casting; and investment casting. The software also includes new cost models for producing parts using metal injection molding, deep drawing, and assembly fabrication.

DFM Concurrent Costing includes a Machine Library that provides machine characteristics and process rates. Engineers can add pictures of equipment and descriptive notes. Machine operation times and tooling costs can be edited, and the library can be expanded and fully customized to add categories of information specific to the manufacturing location. A thorough help system illustrated with graphics explains the details of all shape-forming processes and operations. Engineers can print out customized analysis reports for distribution and review.



## DFMA Best Practices

Introducing a new tool—especially a tool as process-oriented as DFMA—requires some cultural adjustment. The companies that have made this transition and benefited most from DFMA have applied most or all of the “best practices” revealed in this section.

They include:

- Early executive management involvement.
- Cross-functional teams
- Clearly defined goals and benchmarks
- Training
- Distribution throughout the enterprise
- Proper utilization of materials and process experts

It is important to note that the barriers to progress and improvement are the same barriers that will slow the adoption of DFMA methods. They include:

- “We’ve always done it this way, so we’ll do it this way now.”
- “I don’t need a tool to tell me how to do my job.”
- “I’m in engineering. Manufacturing people can’t teach me anything.”
- “I’m in manufacturing. Product engineers can’t teach me anything.”
- “I am familiar with these processes and materials, so we will use these processes and materials.”
- “If it doesn’t turn out right the first time, we can always do it over.”

- “I know what I did last time; there’s no need to have a history.”

All of us fall into these traps. It’s human nature to remain in our “comfort zone.” But today’s markets are open, chaotic, and highly competitive. The Internet has made it easy for customers to compare various alternatives; the competition is only a click away. If two PC manufacturers offer basically the same computer, and one manufacturer can deliver that computer in 5 days—and offers an impressive warranty—we all know which manufacturer will get the order.

Top managers are in a unique position; they are able to encourage and guide their employees out of their comfort zone and into a more competitive mode, and to help them work effectively as a team.

This is what happened at Nortel Networks of Ontario, Canada, a provider of communications equipment, software and services, according to an article in *Mechanical Engineering* magazine.<sup>14</sup> Nortel was able to get a product to market in time, but as they did so, the competitor lowered its price on its own, more mature product. Nortel had to quickly redesign the product to be cost-competitive. The product was packaged in a sheet-metal box; each product cost \$276 US to make.

First the engineering team improved the hinged box, which consisted of 53 parts and cost \$78 to make. Most of the parts were fasteners. They replaced the aluminum front cover with plastic, and replaced fasteners with snaps. The redesigned cover consisted of only 17 parts and cost \$26, a savings of \$52. The new cover also took a quarter of the time, 95 seconds to assemble, versus 378 seconds for the original.

Other improvements were made by a cross-functional team at Nortel. Peter Maheux, director of time-to-market implementation for Nortel, observed that "the mechanical engineer pulled in a materials expert and a fabrication expert, and they actually came up with a new cost-reduced plating process that's environmentally friendly. It wasn't even in the project plan. But they put it in because it was a good idea."

In all, the redesign of the OC-3 Express shelf mechanics, performed using DFMA software, cut its total cost to \$136, less than half the original cost of \$276. Nortel expects to save about \$700,000 a year in assembly and manufacturing costs. Nortel used DFMA on another product, a seven-foot, closet-sized bandwidth system for communication carriers that consists of “circuit packs” (modules that function as transmitters, receivers, regenerators, or switches), and “filler packs” (empty modules that take up any extra slots). The design team reduced the cost of a filler pack from \$410 to \$65. The total number of parts was reduced from 59 to 32, and the time to assemble each filler pack was cut by two-thirds, from 15 minutes to five. The entire redesign process lasted 10 months. The annual expected cost saving to Nortel was about \$3.45 million.

According to Maheux, adoption of DFMA methods required a mind-set change at Nortel. “Engineers have to get over a certain fear,” he said. “Let’s say it takes a year to design, develop, and release a product. Usually what happens with the old mind-set is that the engineer wants to get the front end done really quickly—the product definition, the customer requirements, all the engineering—and then get on with the design and fabrication. The change in the model is that the upfront work takes longer now. But the end result, the total end-to-end cycle, is a lot shorter.

“The equation I like is one plus one equals three,” continues Maheux. “One person has an idea, and another person has an idea, and if you teach them how to communicate and team, they come out with a better idea.”

Boothroyd Dewhurst, Inc. (BDI) has helped hundreds of companies install, utilize, and optimize its DFMA tools. BDI executives are well aware of the cultural and educational barriers that must be overcome in order for DFMA to be successfully adopted and for companies to profit from its use. The company provides a rigorous, yet efficient training program for engineers. In addition, the software has been designed to be as “intuitive” as possible.

“Most of the training we do does not focus as much on using the software—which is fairly straightforward because of the way it has been designed and refined over the years,” says Nicholas Dewhurst, executive vice president for BDI and chief DFMA instructor. “Instead, we spend a significant amount of time on the best way to approach designing from a ‘business goal’ perspective. Cost of manufacture, cost of materials, and ease of assembly are the essential ingredients in a competitive design. Engineers who don’t use DFMA are unable to *effectively* factor these considerations into their design; the process is hampered by the need to refer to a variety of sources, which may or may not offer the ability to make ‘apples-to-apples’ comparisons.

“Once they realize that it is possible to answer a few questions and come up with a series of ‘ballpark’ costs for various approaches, they grasp how this tool can streamline their entire design process and open up new avenues of exploration.”

## **Management Considerations and Caveats**

The best tools in the world are only as good as the managers who deploy them throughout their organizations.

It's instructive to look again at Dell, a company that could have easily "rested on its laurels" long ago. Instead, the company's managers, from Michael Dell on down, are "pleased, but never satisfied." It's not enough to win awards for the most serviceable PC. They're still not satisfied. Why not standardize processes and parts across product lines, saving the company millions while making the product easier to assemble and service? Why not remove all the screws from the chassis assembly, while designing in shock absorption for the computer's drives? Why not color-code cables, so even the first-day-on-the-job assembly employee knows exactly which cable goes with which component? These are all out-of-the-box goals that could be explored—and achieved—using DFMA tools and methods.

DFMA has proven itself in hundreds of companies and thousands of products. It has saved its users literally billions of dollars. But where there are significant benefits, there are also significant challenges.

DFMA will *not* be successful if it is not supported by management, because it fundamentally changes the way that a company approaches design and manufacturing, and because its implementation depends on cross-functional integration. Functional managers can advocate and suggest that cross-functional integration take place, but managers must approve and support it in order for it to actually happen.

DFMA, unlike many enterprise systems, does not suffer from technical integration issues. The product works fine as a stand-alone complement to CAD/CAM systems, and it also accepts data from CAD/CAM systems, typically with the click of one button.

Don't assume, however, that data ported from CAD/CAM systems is sufficient to answer all the questions posed by DFMA. Because the software facilitates the incorporation of

manufacturing methods and materials into the early stages of a design, it asks for data that is not traditionally required by CAD/CAM systems. Additional questions must be answered. Which, we might add, is precisely the point. Companies depending exclusively on CAD/CAM systems will not be optimizing their designs for costing or manufacturing.

Engineers who assume that the data included in their CAD/CAM designs will be sufficient for the DFMA analysis will be disappointed. However, once they have experienced the benefits of “thinking through” their design with costs and manufacturing in mind, have seen the results of DFMA analysis on their own designs, and have witnessed the ease with which the design could be produced, they become “DFMA champions” who actively advocate that other technical team members start using the software. This is why BDI has a number of flexible licensing options, and is working on new products that make it even easier for a larger number of engineers to use DFMA tools.

BDI is a company run by engineers, offering products and services for engineers. DFMA software solves a major problem for its users, providing a tool that actually enables engineers to “design it right from the start,” fully considering the cost, profit, and manufacturing aspects of the product as it is being conceived and refined. The issues that keep managers awake at night are considered as the product is being designed. This is, in a real sense, a revolution in how products are engineered and manufactured.

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For more information about DFMA and Boothroyd Dewhurst, Inc., please visit <http://www.dfma.com> or call 800-424-DFMA.

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