

# Reducing Defects By Designing For Manufacturability

The intense competition in today's marketplace has raised customers' expectations to unprecedented levels. An almost flawless product delivered in a timely manner is a company's goal in a game where the object is to make the product better, faster and cheaper than the competition can. Therefore, many companies search diligently for real-life solutions to deal with the negative effects of process variation in manufacturing as it applies to total manufacturing costs. The **phenomenon of variation**, that is the deviation from the perfect target, is a significant contributor to high production costs and lower than expected customer approval. Additionally, studies have shown that reducing cycle time within the manufacturing process also lessens the **opportunity** for error.

Better training in the theory of variation phenomenon along with its effects on the designed-in sources of variations can help engineers do a better job of eliminating the root cause for many production defects while the product is in the design phase. If this training is successful, the end result is more control over manufacturing costs, reduced production cycle time and better customer acceptance. In short, a new goal emerges: make a better product with higher customer satisfaction at lower costs to the manufacturer.

"Companies **often** recognize that they are having problems with the quality of their products based upon their own measurements. They might also sense that their customers are not satisfied with product quality, but they are not exactly sure how to approach solving these problems," remarked Peter Davis, a Motorola University Senior Applications Consultant.

Motorola, a world leader and recipient of the prestigious U.S. Government's Malcolm Baldrige National Quality Award in 1988, through its education and training arm, Motorola University (MU) has developed methodologies called Design for Manufacturability (DFM) and Cycle Time Reduction (CTR). These methodologies focus on designing quality into a product in the initial development stage and/or during the engineering design phase while reducing the time it takes for the entire cycle to be completed.

DFM's philosophy aims at reducing the defects that occur during manufacturing which in turn lowers the total product costs. With an exceptionally designed product, there will be fewer returns, less warranty service, less rework, a shorter production cycle time and less of a need for inspections. CTR's methodology aims at reducing the cycle time (the time it takes from start to finish) for every process within an organization. Motorola has found that the best way to do this is to eliminate unnecessary and non-value added work. The final judgment on what is valuable is asked not of the

staff, but of the customer. By reducing cycle time, it is possible to make impressive improvements in cost, efficiency and quality.

“We were having trouble detecting defects in our manufacturing process. What we needed was to identify the defects throughout the entire process,” states Kim Hamner, manager of manufacturing operations for the Budd Company, an automotive supplier for GM, Chrysler and Ford. “Otherwise, the ‘latent defect’ is just being passed on to the customer. The problem must be solved at the point of creation.” *Latent defects*, which result in early life failure, are not detectable by normal tests or inspections, but are controlled in the manufacturing process.

Typically, the first step in avoiding defective products is understanding the connection between engineering design decisions and the resulting capability of the design to be manufactured efficiently with no defects. “Most companies can start eliminating the root cause of product defects by employing a Pareto analysis (named for the Italian economist who developed the 80/20 rule) on all the defects found during manufacturing of the product under scrutiny,” comments Davis. Simple errors can be identified and eliminated before the more intense investigation of the complex elements occurring in the production stages of the product are attacked. Correcting simple things like:

incorrectly written specifications;

knowing exact specifications wanted by the customer or client and eliminating those specifications NOT desired;

telling the outside supplier exactly what you want in his components;

getting delivery of correctly manufactured components on time;

correcting bad basic instructions anywhere in the process for producing the product;

specifying what each person in the process should be doing and when that person should be doing it;

establishing the proper training of personnel who will be producing product.

“Examining these simple, up-front, steps can easily eliminate 30-35% or more of the root cause for defects in any product or function,” adds Davis. DFM teaches that it is not enough just to find the problems, but it is more important to the overall product’s success rate to eliminate these problems before the product leaves the plant. Focus on the defects of the product not on how great the product is; greatness is a marketing issue not a manufacturing one.

Years ago many industries adopted a ‘zero defect’ policy. However, this policy was not totally successful because it placed most of the burden for perfect products on the production line.

This pressure of never making mistakes coupled with the company's goal of getting as much product to the streets fast as possible was in a reality a losing situation. Davis remembers a case in point of manufacturing life at a previous employer: "We could never afford to do it right the first time, but, we could afford to do it right the 2nd or 3rd time." DFM tackles the whole product, not just the individual elements like the design, the materials or just the production.

Davis relates a Motorola case history while teaching DFM to companies. "Motorola learned the hard way about the positive effects of DFM when they saw its own products coming back on the US market at prices far lower than when Motorola had made the same product. 'They couldn't be making a profit on these' was echoed throughout Motorola. Motorola personnel found that the new company was using the same number of people, the same equipment and the same type of factory for producing the same product – nothing seem to have changed. However, the real difference was that the company had analyzed the final product, up front, found where the defects were and corrected them. So, fewer products were returned for repairs or refunds. It became apparent to all involved that handling the returns, credits, and repairs added significantly to the true cost of the original product." Hence, improving the product's design and creating it to satisfy the customers' true needs, at the front end, actually cost the company less in the long run. In addition, since customers' satisfaction for the product rose because fewer products were returned, more product was actually sold." That is what DFM teaches: reducing defects at the beginning of the process – in the design phase – reduces ALL costs through returns and warranty repairs.

DFM methods, which is part of Motorola's well-known Six-Sigma philosophy have saved the Corporation billions of dollars in reduced manufacturing costs while simultaneously increasing quality by orders of magnitude. "Some believe that Six Sigma is too much to strive for and that Three or Four Sigma quality, which is over 99% error free, is good enough. But with complex electronic products, this is not true. If each circuit is only Three Sigma and you multiply that by a hundred circuits in one piece of equipment, the error rate soars. When you realize this, you realize that Six-Sigma is not overkill," stated Doug Rinker, manager of product software design at Sundstrand, an Illinois based Fortune 500 Company.

The quest to reach Six-Sigma can be accomplished through several routes depending where the company's weaknesses lie. CTR is another methodology within the Six-Sigma framework that is implemented to improve quality. By reducing process cycle time, the product and the company will benefit with cost savings and production efficiency. CTR also empowers employees at all levels to be personally responsible for product and customer satisfaction.

**CTR's strength is working with the people who are actually involved in the process.**  
**Leigh Dyson , Quality Development Manager for ALCOA in Western Australia, the largest alumina**

(raw material) and aluminum producer in the world, supports this, saying, “traditionally, changes were sent down from the top, by professionals and experts from both inside and outside the company. This did not allow employee ownership. Now that team members are part of the solution, they take pride in their work. CTR also gives everyone a view of the big picture. I’ve found that many times, people only know what is happening at their part of the process - not what is upstream or downstream of them.”

The unique perspective achieved by involving employees who work in the “trenches” but are not necessarily trained in problem-solving results in solutions that save time and money. One of the great strengths of this tool is the involvement of the “hands-on” employees. It takes the existing process and uses creative solutions to cut out issues and streamline the process.

The key to Cycle Time Reduction is determining which steps in your process add value in the eyes of the customer. Using a customer driven approach changes both perspective and solutions.

Focusing on the customer does not mean adding or deleting steps that you think might be important to your customers. This research led to Cross Functional Process Mapping (CFPM) to reduce total Cycle Time. This mapping process is done by a cross functional team made up of employees from every department involved in the process.

The first step is the “As is” map which details every step and identifies all of the issues in the current process. The “As is” map documents every step in the process as it is currently done. Unlike re-engineering, as defined by Michael Hammer, which tries to start over from scratch, Cycle-Time Reduction builds on past successes and strengthens or deletes weaker parts of the process. It is the involvement of the empowered employees not the consultants that makes the difference.

After the “As is” mapping, employees go back to their departments to mull over the issues and find out if others in the department have additional issues. About a month later the original team and the facilitators return for a “Should be” mapping session. “Should be” is the level of performance that could be expected given today’s investment in people, capital and facilities. It often approaches best in class without the addition of new people or capital expenditures.

Three days are spent on detailing each step in the improved version of the process. During this mapping session, a list of action items is created which define what needs to be changed in order to move from the “As is” state to the “Should be” vision.

The Action Item Owner forms the sub-teams which complete the action items. A list of any “stoppers” is also created. “Stoppers” are the items that the team thinks might prevent them

**from implementing the full “Should be” action items. All stoppers become the senior management’s action items.**

**There are four types of team members. The project champion provides resources and removes barriers. A team leader is chosen to organize and conduct the meetings and to ensure that information exchange occurs. Team Members and Action Item Owners complete assigned tasks. The smaller sub-teams mainly consist of employees not on the original team. This helps gain wider employee support of the new process.**

**Action items are prioritized to ensure that they are completed in the most effective manner. Upon completion of all action items, the company will have achieved their “Should be” vision.**

**Inherent in CTR/CFPM is a corporate culture change. Everyone must play a part in working towards solutions and everyone has an active role. While this is an excellent tool on a project by project basis, it should also become an important part of every employees’ problem-solving tool kit.**

“With these powerful tools, we are now able to develop a plan to permanently correct the problem,” noted the Budd Company’s Hamner. According to MU’s Davis, measuring defects is no easy task. “Yields are not a very good measuring tool when you are striving for world class quality. Many companies fall into the trap of thinking that yields around 99% cannot be improved. Motorola’s initial product quality goal was 3.4 defects per million (a Six Sigma Quality Level). That is better than a 99.99966% yield.”

“DFM can really make a difference in terms of quality. This ultimately results in the company adopting this process in other areas,” said Paul Baits, manager of electronic test equipment for Sundstrand, an Illinois-based Fortune 500 company that specializes in aerospace and industrial products. Along the way, DFM debunks a lot of myths that surround product design and production: designs with less variability and more manufacturing robustness have to cost more; production returns can be avoided with more testing regardless of the basic defect rate; and acceptance test tolerances should be as tight as the design allows to guard against incorrect parts.

Using DFM, a product has a superior design margin. The greater the design margin, the lower the total number of defects per unit. In other words, if a product’s original design enables it to be dropped 4 feet without damage, then redesigning the product so it can be dropped 8 feet unharmed adds a greater defect margin. “With this improvement in the ‘robust design’, the product’s tolerance has doubled, and the likelihood of problems is reduced by half,” remarked Hamner. Therefore, a ‘robust design’ has resulted in the ability to produce a product that is higher in quality and reliability at a lower price.

Many companies are uneasy about both the quality of their products and the extent of customer's loyalty to them. Some of the possible problems are flaws in product design or the inability to meet volume and cost goals because of rejects and reworks. Even after these companies realize they need assistance in defining and solving these problems, they are still uncertain about whom to consult or where to find the help they desperately need. Selecting the right consultant from among many options is a daunting task.

What attracts many to the DFM and CTR methodologies are their simplicity. There are no complicated formulas or trendy catch phrases. "The class used simple examples you can interpret. Since the examples are fundamental you can understand immediately what is important. No plugging in the numbers," Sundstrand's Baits commented. "There are no buzzwords. Everything is in plain English and you don't need a secret decoder ring to understand what they are saying." You don't have to be a statistician either to understand the DFM concept. DFM examples are clear and to the point and can be as simple as counting how many times a letter may appear on a piece of paper. **In this exercise**, after the entire class has completed the project, trainers tally the numbers and show the results. The number of mistakes demonstrates why inspection and testing sometimes are just not enough. Through examples and projects as simple as this one, engineers see the importance of catching defects in the design process.

The case studies used in the DFM course provide a clear beginning and end. In the Space Tower exercise, the class divides into teams that represent small start-up companies competing against each other for a design and development contract for a Space Tower. This exercise focuses on the designing and manufacturing cycles. During the design phase, the team must develop a product proposal, complete a block diagram, fill out a Bill of Materials and produce and test a prototype. Then the teams move on to the manufacturing phase where they actual build a "Space Tower" from different shaped blocks. This timed exercise figures points or profits by how well the team did in different categories. The exercise demonstrates the importance of asking questions and gathering information during the initial design process.

Once the concept is understood, it can be used over and over again to redesign an old product or to help with future products. "We initially used DFM to reduce defects on our car hoods. Our initial project was to reduce the amount of dirt specs that were getting into the primer. So far, we have reduced this problem by roughly 75% and we plan to improve on that percentage. After our first success, we used this knowledge in other areas of the Budd Company," said Hamner.

Within the Six-Sigma structure, methodologies such as DFM and CTR ultimately teach that with improved cooperation between engineering and manufacturing functions during all stages of

product development, and if all departments will become more sensitive to the issues surrounding daily tasks, products can be designed that have significantly improved quality and customer acceptance.

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