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Authors: Joseph A. De Feo

17.0. CHAPTER PRELIMINARIES

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17.1. High Points of This Chapter

1. Innovation is key to the survival of all organizations. Innovation, like continuous improvement, is the result of a systematic approach, not a haphazard one.
2. Continuous innovation (CI) is different from product development. Continuous innovation must happen in all areas of an organization, from creating products, services, or processes used to meet internal and external customer needs to designing new facilities' or office environments.
3. There have been many improvements in the methods used to design and develop products and services in the past decade. Design for Manufacturing, Design for Assembly, Design for Lean, Design for Environment, and Six Sigma all have become models to meet critical to quality customer needs—and lead to innovative products.
4. Continuous innovation using the steps of Design for Six Sigma or DMADV, as it is often referred to, is similar to the Juran Quality by Design model (see **Chap. 4**, Quality Planning and Design of New Goods and Services) and has become the basis for what we call "continuous innovation of goods, services, and processes."
5. Creating the habit of innovation requires that management create an infrastructure similar to that of continuous improvement. Set goals, select projects, and educate teams to create innovative goods and services—project by project.
6. Continuous innovation using Design for Six Sigma consists of carrying out five steps:
    1. *Define* the goals and objectives for the new good, service, or process.
    2. *Measure* and discover hidden customer needs.
    3. *Analyze* the customer needs and determine the innovative features that will meet those needs.
    4. *Design* by combining the features, thereby creating new products, services, or processes that incorporate the features.
    5. *Verify* that the new innovation meets the customers' and organization's needs.

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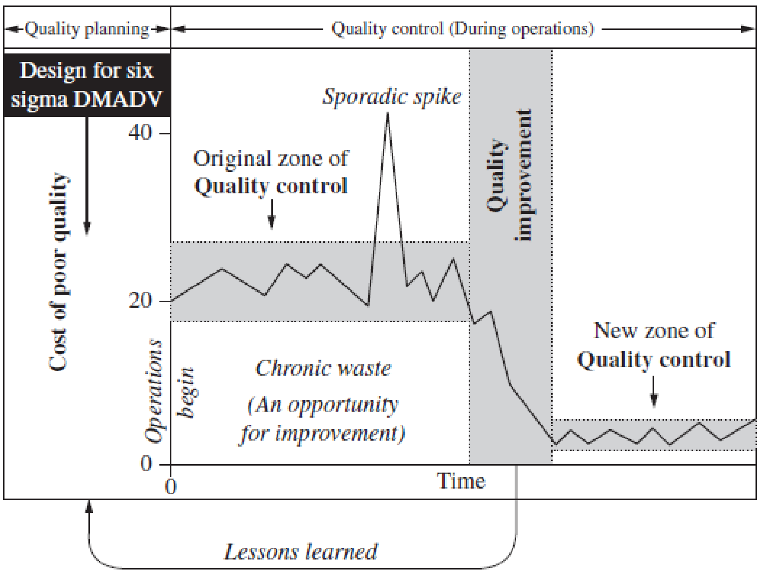
17.2. Continuous Innovation and the Juran Trilogy

We have previously explored the Juran Trilogy as it relates to quality planning. Designing for customer needs always leads to higher-quality products and services as well as innovative outcomes because an effective design process uncovers hidden customer needs. This discovery and the subsequent solving of the problems that kept customer needs hidden lead to innovation (Fig. 17.1). This chapter addresses the use of the define, measure, analyze, design, verify (DMADV) steps above and tools for creating continuous innovation (CI). Adapting the most effective models such as the Quality by Design used by the FDA and Design for Six Sigma (DFSS) model used by many such as GE, Samsung, and Microsoft, organizations can create the *habit of innovation*, which is similar to creating the*habit of improvement*. Deploying a CI program will ensure organization adaptability and sustainability in meeting societal and business needs.

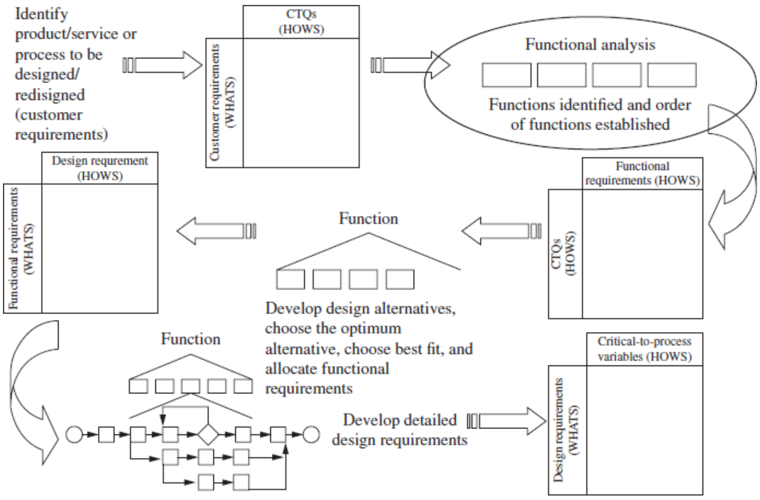
Figure 17.1 *Design for Six Sigma and the Juran Trilogy. (Juran Institute, Inc., Southbury, CT.)*



CI using the Design for Six Sigma model and tools, which arose out of GE Medical's adaptation of the Juran quality planning model described in Chap. 4, Quality Planning and Design of New Goods and Services is a powerful engine available for those who want to truly plan quality into their products, typically goods, rather than services or processes.

Juran referred to the quality planning design steps (Fig. 17.2) as a framework for planning (designing) new products and services (or revisions). These steps apply to both the manufacturing and service sectors and to products for both external and internal customers.

Figure 17.2 *How to design matrices. (Juran Institute, Inc. Used by permission.)*



Planning an effective solution for an improvement project (see Chap.5, Quality Improvement and Breakthrough Performance) may require one or more steps of this quality planning process. Early and Colleti (1999) and Juran (1988) provide extensive discussions of the steps. These quality planning steps must be incorporated with the technological tools for the product being developed. Designing an automobile requires automotive engineering disciplines; designing a path for treating diabetes requires medical disciplines. But both need the tools of quality planning to ensure that customer needs are met.

The road map is presented in greater detail in Fig. 2.4 (in Chap. 2, Developing an Excellence Culture). It is useful, however, to present an overview now to explain briefly the steps (Early and Colleti 1999).

New designs or innovations happen when one discovers hidden customer needs. Some examples include the following:

Abrasive cloth:	Lower internal cost of polishing parts due to better durability of cloth
Automobile:	Less effort in closing door; better "sound" when door closes
Dishwasher:	Greater durability because heavier parts make up the appliance
Electronics:	Simplicity all-in-one device, e.g., iPhone, iPod,
Software:	Understandable owner's manual
Fibers:	Lower number of breaks in processing fibers
Tire valve:	Higher productivity when tire manufacturer uses valve in a vulcanizing operation
Photographic film:	Fewer process adjustments when processing film due to lower variability
Commodity product:	Delivery of orders within 24 hours rather than the 48-hour standard requirement
Home mortgage application:	Decision in shorter time than that of competition

Traditionally, the main activities to capitalize on these insights were executed*sequentially*. For example, the planning department studied customer desires and then presented the results to design; design performed its tasks and handed the results to engineering; engineering created the detailed specifications; and the results were then given to manufacturing. Unfortunately, the sequential approach results in a minimum of communication between the departments as the planning proceeds—each department hands its output "over the wall" to the next department. This lack of communication often leads to problems for the next internal customer department. To prevent this from occurring, activities are organized as a team from the beginning of the project. Thus, for example, manufacturing works *simultaneously* with design and engineering before the detailed specifications are finalized. This approach allows the team to address production issues during the preparation of the specifications.

Creating new products and services contributes to the vitality of an organization. Many organizations have adopted numerous methods to improve the salability of their designs. From the 1980s to the present, there were a number of newly adopted methods based on Juran's Quality by Design to improve product salability. Many continue to pay dividends:

- Design and development phase gates
- Concurrent or Simultaneous Engineering
- Design for Manufacture
- Design for Assembly
- Design for Six Sigma

In this past decade, a number of new methods have popped up. Most recently there have been promising methods such as:

- Design for Environment
- Lean Design
- Sustainable Design

Today, Design for Six Sigma is a systematic methodology to provide the means to attain new services and innovative designs. The steps for designing new products and services that lead to innovation are as follows:

- Discover the customers and their needs
- Gather and research information, and observe the behaviors of these customers
- Generate and then design solutions to meet their needs
- Design the solution and validate that the needs are met
- Transfer the design to operations

Along the way, these steps force people to "think outside the box." They force people to gain new information in a structured and organized way, arriving sometimes at revolutionary means to create new services.

17.2.1. DFSS Works for Goods, Services, and Transactional Processes

The Design for Six Sigma (DFSS) model has been used within new product introduction (NPI) processes for a wide variety of physical goods including electronics, chemicals, sophisticated industrial equipment, transportation equipment, and a plethora of consumer goods. It has also been used successfully to develop high-quality new services in insurance, health care, banking, and public service.

In the design phase of DFSS, a multifunctional team develops both the detailed product design down to the full engineering drawings and the process design for delivering the product, including all equipment, work instructions, work cell organization, etc. The difference between product design and process design is fairly clear when physical goods are produced. It is sometimes less clear for services where the two are intertwined.

Making and acting on the distinction between the design of the service and the design of the process that delivers that service has proved to be very helpful. The *service design* is the flow of activity as experienced by the customer. The service *process design* is the flow of activity required to make the customer experience possible.

For example, the service for paying a customer's insurance claim will have features related to timeliness, ease of use, responsiveness, and transparency. These are what the customer sees, feels, hears, and touches. To deliver that seamless flow of activity to the customer, the production process will include features related to data processing, information access, payment procedures and policies, and interpersonal skills of individuals interacting with the customer during the process. The behind-the-scenes production process is largely invisible to the customer. In fact, when these invisible production processes become visible to the customer, it is usually because they have broken down and failed to deliver the seamless service as designed.

Experience shows that it is a useful division of the work to first design the customer-experienced service and then design the process that makes it possible. Teams that try to design both the service and the process as a single step usually subordinate the customer experience to the exigencies of operations.

17.2.2. An Example of Designing for Services

In an example from the service sector, the quality planning process was applied to re-planning the process of acquiring corporate and commercial credit customers for a major affiliate of a large banking corporation. Here is a summary of the steps in the quality planning process.

1. *Establish the project.* A goal of $43 million of sales revenue from credit customers was set for the year.
2. *Identify the customers.* This step identified 10 internal customer departments and 14 external customer organizations.
3. *Discover customers' needs.* Internal customers had 27 needs; external customers had 34 needs.
4. *Develop the product.* The product had nine product features to meet customers' needs.
5. *Develop the process.* To produce the product features, 13 processes were developed.
6. *Develop process controls and transfer to operations.* Checks and controls were defined for the processes, and the plans were placed in operation.

The revised process achieved the goal on revenue. Also, the cost of acquiring the customers was only one-quarter of the average of other affiliates in the bank. Quality planning generates a large amount of information that must be organized and analyzed systematically. The alignment and linkages of this information are essential for effective quality planning for a product. A useful tool is the quality planning spreadsheet or matrix (basically, a table). **Figure 17.2** shows four spreadsheets corresponding to steps in the quality planning process. Note how the spreadsheets interact and build on one another; they cover both quality planning for the product and quality planning for the process that creates the product. The approach is often called *quality function deployment* (QFD). Thus QFD is a technique for documenting the logic of translating customer needs into product and process characteristics. The use of spreadsheets in the quality planning process unfolds later in this chapter.

These six quality planning steps apply to new or modified products (goods or services) or process in any industry. In the service sector the "product" could be a credit card approval, a mortgage approval, a response system for call centers, or hospital care. Also the product may be a service provided to internal customers. Endres (2000) describes the application of the six quality planning steps at the Aid Association for Lutherans insurance company and the Stanford University Hospital.

17.2.3. CI Requires Understanding Customer Needs and Solving Their Problems

Designing innovative and superior quality services and products requires gaining a clear understanding of the customers' needs and translating those needs into services aimed at meeting them. This information is the driver of most innovation, yet most do not recognize it as such.

Innovation has everything to do with creating something new. In competitive business situations, success often comes to the best innovators. Many organizations have design and development functions that create annual plans to develop new models and new services. Sometimes these functions design the good or service internally to the organization and then look for customers to sell it to. Other innovation comes from solving societal problems. And still other organizations look for customer problems to solve; as a result they create something new, something innovative. It is the latter that we have found to be the most economical and therefore provides the greatest return on its investment.

To create continuous innovation, an organization must design to meet customers' unmet (often hidden) needs. To do this one must:

- Capture the voice of the customers—the potential new customers or existing ones
- Discover hidden customers and needs
- Design solutions to meet those needs
- Use a systematic approach to ensure innovation happens—continuously
- Have tools to capture the information and use it to ensure that the good or service is produced efficiently
- Use multifunctional staff to carry out the systematic process to ensure the good or service can be produced as planned

One can learn about innovation, which means "making something new," by studying innovations and innovative methods from the past.

17.2.4. Polaroid Camera

The conventional photographic process involves exposing light-sensitive material, which in turn must be developed, fixed, and printed and the print developed and fixed, a procedure that can take hours (or days if the processing facility is far from the place where the photograph was taken). In 1947, a remarkable new system of developing and taking pictures was introduced by U.S. physicist Edwin Herbert Land (1909–1991). Land had left Harvard after his freshman year to conduct his own research on the polarization of light. Two years later, he invented a sheet polarization filter that could be used on camera lenses to eliminate reflection and glare. In 1937, Land founded the Polaroid Corporation to manufacture and market his filters, lamps, window shades, and sunglasses. In February 1947, he introduced Polaroid instant film for use in his own Polaroid Land Camera. The Land Camera (U.S. Patent 2,543,181) was first offered for sale on November 26, 1948. Polaroid film processes chemicals in a flat, hermetically sealed compartment attached to the photosensitive paper. A pair of pressure rollers spreads the chemicals uniformly across the paper when exposed, and the completed print is ready a minute later. In 1963, Polaroid introduced Polacolor, a full-color film that could be processed in less than a minute.

17.2.5. Life Savers Candy

In 1912, when candy maker Clarence Crane first marketed Crane's Peppermint Life Savers, life preservers were just beginning to be used on ships—the round kind with a hole in the center for tossing to a passenger who had fallen overboard. But that is not the whole story. Crane had been basically a chocolate maker. Chocolates were hard to sell in summer, however, so he decided to try to make a mint that would boost his summertime sales. At that time most of the mints available came from Europe, and they were square. Crane was buying bottles of flavoring in a drugstore one day when he noticed the druggist using a pill-making machine. It was operated by hand and made round, flat pills. Crane had his idea. The pill-making machines worked fine for his mints, and he was even able to add the life preserver touch by punching a tiny hole in the middle. In 1913, Crane sold the rights to his Life Savers candy to Edward Noble for only $2900. Noble then sold Life Savers in many flavors, including the original peppermint. Clarence Crane may have regretted that decision to sell, for Life Savers earned the new manufacturer many millions of dollars.

17.2.6. iPod

The iPod originated with a business idea dreamed up by Tony Fadell, an independent inventor. Fadell's idea was to take an MP3 player, build a Napster music sales service to complement it, and build a company around it. It resulted in Apple creating the iPod.

17.2.7. Segway

This new means of transportation meant reimagining virtually every piece of conventional wisdom about the last century of transportation, from how it moves, to the fuel it uses, to how you control it. The result is electric transportation that doesn't look, feel, or move like anything that has come before. And of all the conventional wisdom we've left in pieces behind us, none has been shattered more fully than the belief that we must choose between "more" and "less." In 2001, Dean Kamen announced the arrival of the first self-balancing, zero emissions personal transportation vehicle: the Segway Personal Transporter. Founded on the vision to develop highly efficient, zero emissions transportation solutions using dynamic stabilization technology, Segway focused its research and development on creating devices that took up a minimal amount of space, were extremely maneuverable, and could operate on pedestrian sidewalks and pathways. Today, Segway continues to develop safe, unique transportation solutions that address urban congestion and pollution.

17.2.8. Two Types of Innovation

There are two basic types of innovation. The first, type I, does happen, but rarely. Type I is something completely new. And new things under the sun do not occur as often as we think they do. The first automobile and internal combustion engine were certainly new innovations, but even they built on the wheel, cart, and other existing technologies.

Things such as nuclear power, radio, phones, electricity in the home, and manned flight are certainly good examples of something that was pretty close to new under the sun. All the great, really new innovations can often be traced back to a genius, a lucky accident, or both.

We know the names of many of the geniuses—Fermi, Wright, Edison, Benz, and Ford. However, this is not an endless list, and while lucky accidents are good, they are too chancy. Type II innovation presents a better way.

Type II innovation is much more common than type I. This second type of innovation can be reduced to three general approaches:

1. Making something that already exists larger
2. Making something that already exists smaller
3. Combining one thing that exists with something else that exists

The simplicity of type II is profound. It can create dramatic breakthroughs and change the way we live. Most of what we see and consider to be great innovations were derived from the three methods of type II innovations listed.

For example, the mobile phone or PDA in your pocket was once a fair-sized wooden box on the wall. The phone has been made smaller from the original wall model hardwired to the outside world. The phone has also been "combined" with a radio, calculator, computer, TV, and music player. The flat-screen television evolved from a device that was once considered a piece of furniture and that took up more room than an easy chair. Over time, the TV's depth and height have been "made smaller," and its width has been "made larger." Add the appropriate technology, and you have your flat-screen display.

An example is Web-based learning. Web-based learning came about when transparencies were replaced by electronic slides such as PowerPoint. This led to improved quality of presentation graphics, then added animation, placed on the Internet, with voice-over IP, and video, thus delivering Web-based learning.

The "bigger/smaller/combination" approach sounds simple when you look backward. But the trick is doing it in the present, as an innovation for the future. However, it is still much easier than becoming a genius.

The good news is you can get better at type II innovation. As good as we are today, we can also get better with practice.

The next time you are in a serious brainstorming meeting and need an innovation for a new product, service, marketing strategy, or similar task, put up three new header columns, and attack them one at a time.

A header is the place where you will hang your ideas. The three headers are, of course, "make it bigger," "make it smaller," and "combine it with." The "it" is whatever product or service or whatever you are working on. Have fun with it. Remember not to critique or scrub the ideas until after the generation of ideas is done. Most people are surprisingly good at type II innovation. Morph some of the wild ideas into something that is doable. The great innovator Henry Ford said, "If you think you can or can't, you're right."

Innovators are not born that way. If you have your heart set on being the next Thomas Edison, you are probably going a bit too far. But whatever your innovation quotient is now, you can make it better with practice and by using a methodology that causes innovation to happen.

For instance, how many times do we hear "Think outside the box"? That's all well and good, but what box? Few of us recognize that the box is in fact ourselves. Learning to temporarily let go, be foolish for a moment, and be comfortable with ambiguity is necessary for innovation.

Getting beyond our "boxed" selves is a skill that can be learned and improved with technique, practice, and courage. For example, imagining oneself as someone else and seeing everything through his or her eyes can be a great technique.

Arriving at this level of letting go will require a systematic methodology. Many methods have been used in developing simpler and better products. These design processes incorporate early involvement teams.

The teams are composed of a broad spectrum of employees, customers, and suppliers who work together through a systematic process of looking and thinking outside the box to solve problems. The results are significant, and new products can be discovered.

This concept of push innovations (e.g., toys and foods) is a short-term exercise that continues to flood the market with new products. Some are good and last a long time; many are short-lived. If you are trying to innovate to solve a customer or societal problem, the outcome of a purposeful design process often leads to products that benefit society for many years. Drug development is a good example. Aspirin has been around for more than 100 years. New drugs that reduce cholesterol will also be here for decades.

Why do some products last so long and others do not? This answer lies in the methods used to design or create the innovation. Innovation requires a systematic process and set of tools to create customer-focused, need-driven designs.

Designing world-class services and products requires gaining a clear understanding of the customers' needs and translating those needs into services aimed at meeting them. The process goes on to design and optimize the features and then develop and execute the new designs. This process is sometimes referred to as the service development process, the design process, or the DFSS process.

Random, innovative ideas, no matter how clever, will not deliver economic success unless they meet a customer need better than the current method or fulfill a previously unknown or unmet need. The talented design people we have working for our organizations give us excellent designs when we specify who wants it and what it is that they want—the "they" being the customers who make up a market segment.

The problem with most failed new products and services is not poor design. The problem is that the product or service did not have customers waiting and ready for the things that were actually produced. The question is whether there is a way to reliably get around this problem of good design. There are also innovations that are replaced or that evolve quickly. Foods based on fad diets and toys based on television shows come and go. Other innovations, such as the computer, stay for generations. Why do some innovative products and services splash onto the scene and evaporate while others last? The answer often lies in the reason for wanting to create them in the first place.

DFSS was developed to precisely fill this methodological void. DFSS is a rich concept with a well-developed core methodology. The process entails a five-phase service or product development method, and the phases are as follows:

17.2.8.1. Define

In the define phase, top management has to look critically at the business. It would help to revisit the organization's strategic plan. (If you do not have an up-to-date strategic plan, you should get one.) Management provides the design team with specific guidance on the need for the new service or product; management should not, however, design the product. It is okay to provide a high-level concept, but leave the design to the designers.

17.2.8.2. Measure

The measure phase is all about discovering and exploring customers and their needs—especially any unmet needs. This is the heart of DFSS. How do you ask a target audience for what they want in a service or product that does not exist? You cannot, at least not directly. It is best to focus on needs. Again, let the designers design the product, not the customer.

The team then transforms the customers' needs into something more technical. We will call these critical-to-quality characteristics (CTQs). In the CTQs, we transform the needs as articulated by the customer into words and phrases we can measure. The CTQs become the targets for the designers. This step makes it possible to design a product or service that will interest a target group of customers. (Recall that this was the failing of most unsuccessful products or services.)

17.2.8.3. Analyze

In the analyze phase, the designers try several concept designs with potential to meet the CTQs developed in the measure phase. The concepts are now traceable to one or more CTQs, which in turn are traceable to one or more customer needs. The team develops and matches functional requirements of the concept design to the CTQs. The analyze phase is the exciting part for most designers, but the foundation was laid during the define and measure phases.

17.2.8.4. Design

The detail design follows. In the design phase, we take the winning concept design and fill in all the details. When inevitable choices and tradeoffs must be made, we have ready-made selection criteria: the CTQs. The CTQs are like having the customer beside us at every decision point. We will develop and match the functional requirements from analysis to the design requirements of the detail design.

17.2.8.5. Verify

When the team is satisfied with the details of the design, they are ready to verify meeting the business needs given to them by management in the define phase and the customers' needs provided during the measure phase. Complete planning for procurement, production, delivery, advertising, warranty, and other items is also completed during the verify phase.

Innovation can be enhanced. Most innovation will flourish if organizations can develop their own creative talents. Type II innovation is the key—encouraging all employees to think in terms of making something bigger, smaller, or combined with something else. DFSS then helps us to identify customers, learn their needs, and deliver products or services that meet those needs. Innovation cannot be commanded. But innovation can certainly be encouraged and managed to achieve an organization's goals by assigning teams to solve customer problems, by creating new goods and services to solve them.

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17.3. Evolution of Design and Innovation Methods

17.3.1. Quality by Design

Quality by Design was a concept first outlined by Dr. Juran in various publications, most notably *Juran on Quality by Design,* by Dr. Juran and the Juran Institute. It stated that quality must be planned into products, and that most quality crises and problems relate to the way in which quality was planned in the first place. While Quality by Design principles have been used to advance product and process quality in every industry, and particularly the automotive industry, they have most recently been adopted by the U.S. Food and Drug Administration (FDA) as a vehicle for the transformation of how drugs are discovered, developed, and commercially manufactured. The FDA defines Quality by Design as the level of effectiveness of the design function in determining a product's operational requirements (and their incorporation into design requirements) that can be converted into a finished product in a production process. Today Quality by Design has evolved into numerous other methods. Here are some of the most popular:

17.3.1.1. Concurrent Engineering

Concurrent Engineering was a popular new product development process in which all individuals responsible for development and production were involved at the earliest stages of product design. Some 70 to 80 percent of a product's cost is locked in at these early stages of development, when the product's configuration is determined and choices are made for the manufacturing processes and materials from which the product will be made. If a product is to end up cost-competitive, it is absolutely essential that cost be a consideration when these decisions are made.

One of the earliest forms of Design for Quality was the Design for Manufacturing and Assembly (DFMA) from University of Massachusetts Profs. Boothroyd and Dewhurst. They created a methodology and later software technology that help guide design teams through this critical stage of product development with cost information, even before prototype design models are created.

17.3.1.2. Design for Manufacture

Design for Manufacture (DFM) is a systematic approach that allows engineers to anticipate manufacturing costs early in the design process, even when only rough geometries are available on the product being developed. Given the large number of process technologies and materials available, few design engineers have detailed knowledge of all the major shape-forming processes. Consequently, engineers tend to design for manufacturing processes with which they are familiar. DFM methodology encourages individual engineers and concurrent development teams to investigate additional processes and materials and to develop designs that may be more economical to produce. With more information about viable processes and materials, users can quantify manufacturing costs for competing design alternatives and decide which design is best.

DFM provides guidance in the selection of materials and processes and generates piece part and tooling cost estimates at any stage of product design. DFM is a critical component of the DFMA process that provides manufacturing knowledge into the cost reduction analysis of Design for Assembly.

17.3.1.3. Design for Assembly

Design for Assembly (DFA) is a methodology for evaluating part designs and the overall design of an assembly. It is a quantifiable way to identify unnecessary parts in an assembly and to determine assembly times and costs. Using DFA software, product engineers assess the cost contribution of each part and then simplify the product concept through part reduction strategies. These strategies involve incorporating as many features into one part as is economically feasible. The outcome of a DFA-based design is a more elegant product with fewer parts that is both functionally efficient and easy to assemble. The larger benefits of a DFA-based design are reduced part costs, improved quality and reliability, and shorter development cycles.

17.3.1.4. Design for Environment

Meeting the needs of an increasingly eco-conscious marketplace, DFMA allows product designers to conduct an environmental assessment during the concept stage of design, where they can evaluate the impact of material selection as well as account for the end-of-life status of their product.

The analysis prompts designers to select, from the DFMA database, the materials they prefer to use or avoid, then reveals the proportions (by weight) of those materials in the product. It also estimates and designates the proportions of product that go to different end-of-life destinations, including reuse, recycling, landfill and incineration. These measures help manufacturers meet such requirements as the European Union's Restriction of Hazardous Substances (RoHS) regulations.

17.3.1.5. Sustainable Design

Sustainable Design (also called Environmental Design, Environmentally Sustainable Design, Environmentally Conscious Design, etc.) is a method of designing physical goods that comply with the principles of economic, social, and ecological sustainability. The intention of Sustainable Design is to prevent negative environmental impact by identifying potential impacts and applying creative or best practices to prevent or mitigate them. Manifestations of sustainable designs require no nonrenewable resources, impact the environment minimally, and relate people with the natural environment.

17.3.1.6. Design for Six Sigma

The evolution of many lessons learned has led to the development of DFSS. It is focused on creating new or modified designs that are capable of significantly higher levels of performance (approaching Six Sigma). The define, measure, analyze, design, verify (DMADV) sequence is a design methodology applicable to developing new or revised products, services, and processes. Although DFSS implies to design to the lowest level of defects possible, Six Sigma, it is more than that. The steps in DFSS enable one to understand the customers and their needs. DFSS actually focuses on both sides of quality: the right features and the fewest failures.

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17.4. Design for Six Sigma—DMADV Steps

Table 17.1 summarizes the main activities within each of the DMADV steps. These are discussed in more detail in this section. Experience with applying the five DMADV steps has led us to believe that it is useful to define a step to select the project before the team actually begins its DMADV journey.

Table 17.1 *Major Activities in Phases of DFSS*

Define	Measure	Analyze	Design	Verify
Agree to opportunity	Identify customers	Develop alternative designs	Develop detailed designs	Execute manufacturing/ operations verification
Agree to goals	Discover customer needs	Complete functional analysis	Integrate designs	Execute pilot and ramp-up
Agree to scope	Translate needs into CTQs	Select best-fit design	Model predictions of performance	Execute control plan
Establish project plan	Establish design scorecard	Specify functional requirements	Optimize design parameters	Finalize design scorecard
Assign resources		Specify subsystem functional requirements Complete high-level design review Validate with customer Update design scorecard	Develop statistical tolerances Specify process features and detailed operations Design complete control plan Complete design verification test Validate with customer Complete design review Update design scorecard	Transition to operational owners and validate

17.4.1. Select the Opportunity

The select phase in DFSS is more strategic than for quality improvement or DMAIC projects (see **Chap. 15**, Six Sigma: Breakthrough to in-Process Effectiveness). A target for a new product or capability is identified as part of the strategic and annual business planning processes. When a major opportunity is identified, leadership will determine that it is best served with a new design or redesign of something that exists. Typically this means that a new or emerging market has been targeted; it may also mean that customer needs in an existing market are shifting, or that competition has shifted, and a new approach is required.

This type of project selection is different from a DMAIC project in which specific deficiencies or wastes are targeted for an existing product or process. Rarely is an existing product or process so broken that the initial analysis in DMAIC leads to the conclusion that a total redesign is required. A major health insurer reached that conclusion with respect to payment of claims. Instead of multiple improvement projects, it redesigned the entire claims payment service so as to raise customer satisfaction from 75 to 93 percent, improve timeliness by a factor of 10, and reduce costs by more than one-half.

The project opportunity and goal statements are prepared and included in a team charter, which is confirmed by management. Unlike the rather simple and direct goal statements for a DMAIC project, the DMADV goal statement may, in fact, be multiple statements about the market to be served by the new product and the economic returns to be achieved, such as market penetration, growth, and profitability. Management selects the most appropriate team of personnel for the project, ensures that they are properly trained, and assigns the necessary priority. Project progress is monitored to ensure success.

17.4.2. Select: Deliverables

- Make a list of potential projects.
- Calculate the return on investment and contribution to strategic business objective(s) for each potential project.
- Identify potential projects.
- Evaluate projects and select a project.
- Prepare project opportunity statement and a team charter.
- Select and launch team.
- Formal project team leader should be a qualified practitioner or Black Belt.

17.4.3. Select: Questions to Be Answered

1. What new market opportunities do we have?
2. What new emerging customers or customer needs can we go after?
3. What are the likely benefits to be reaped by gaining or increasing that business?
4. Which of our list of opportunities deserves to be tackled first, second, etc.?
5. What formal opportunity statement and goal statement should we assign to each project team?
6. Who should be the project team members and leader (Black Belt) for each project?

17.4.4. Define Phase

A project begins with the define phase when it is officially launched by the management team. It may be necessary for the management team or Champion to work closely with the project design team to refine the design opportunity. This refinement will lead to an accurate scope of the project and will ensure a common understanding of the objectives and deliverables. Experience has shown that projects that fail to deliver the expected results frequently get off track at the start, when the project is being defined.

A key task in the define phase is to create the initial business case that validates the selection rationale and establishes the business justification through reduced product cost, increased sales, or entirely new market opportunities. The initial business casework is conducted under the auspices of the management team, and then it is validated and updated continuously by the design team through the subsequent phases of the design project. The management team selects a black belt to lead the design project. The Champion, who is the management sponsor with vested interest in the success of the design, in conjunction with the Black Belt, is responsible for selecting a cross-functional team that will conduct all the activities to complete the design and carry it into production.

17.4.5. Define: Deliverables

- Initial business case is developed.
- Design strategy and project are established; leaders and team are selected.
- Project charter is drafted, including project opportunity statement and design objectives.
- Team is launched and a list of customers defined: market customers, nonmarket customers—users, regulators, stakeholders etc.—and internal customers.

17.4.6. Define: Questions to Be Answered

1. What are the design goals or objectives of the project?
2. What are the specific goals of the project team?
3. What is the business case that justifies the project?
4. What charter will the team members receive from management empowering them to carry out the project?
5. What will be the project plan?
6. How will the project be managed?
7. Who will be the customers of this project?

17.4.7. Measure Phase

The measure phase in the DMADV sequence is mainly concerned with identifying the key customers, determining what their critical needs are, and developing measurable critical quality (CTQ) requirements necessary for a successfully designed product. An initial assessment of our markets and customer segmentation by various factors is required to identify the key customers. This assessment is often completed by the marketing organization and is then reviewed and verified by the design team. However, it is the design team's responsibility to complete the customer needs analysis and compile the results into a prioritized tabulation of customer needs. The design team transforms the critical customer needs into measurable terms from a design perspective. These translated needs become the measurable CTQs that must be satisfied by the design solution. Competitive benchmarking and creative internal development are two additional sources to generate CTQs. These methods probe into design requirements that are not generally addressed or possibly even known by the customer. The result is a set of CTQs stated in specific technical requirements for design in the voice of the organization that become the measurable goals (specifications) for product performance and ultimate success.

The project team may use several means to set the goals for each CTQ. Some tools include competitive benchmarking, competitive analysis, value analysis, criticality analysis, and stretch objectives for current performance. The result is a combination of customers' stated requirements, and requirements that may not be generally addressed or known by the customer. The measure phase ends with the assessment of the current baseline performance against the enumerated CTQs and performance of risk assessments. To establish these baselines, typical process capability methods and tools are utilized. These include the following:

- Establish the ability of the measurement system to collect accurate data using measurement system analysis (MSA)
- Measure the stability of the current or surrogate process(es) using statistical process control techniques
- Calculate the capability and sigma level of the current or surrogate process(es)
- Evaluate risk by using tools such as design failure mode effects analysis (DFMEA) and process failure mode effects analysis (PFMEA)

Another tool employed by some design project teams is the set of quality function deployment (QFD) matrices (see **Fig. 17.2**). Each matrix lists vertically some objectives to be fulfilled (the "what") and then horizontally the means to fulfill the objectives (the "how"). Within the body of the matrix are indicators for how well each objective is met by the respective means. For example, the first matrix displays how well each of the customer needs is addressed by the specific CTQs. As a group, the matrices are tied together, with the means (how) of one matrix becoming the objectives (what) of the next. In this way the customer needs are tied seamlessly to the CTQs, to the functional requirements, to the design requirements, finally to the process requirements, and ultimately to the control requirements. In this way nothing critical is lost and no extraneous matters are introduced.

The QFD matrix (or simpler version) is meant to highlight the strengths and weaknesses that currently exist. In particular, the weaknesses represent gaps that the design team must shrink or overcome. The demand on the team then is to provide innovative solutions that will economically satisfy customer needs. Keeping this matrix up to date provides a running gap analysis for the team.

17.4.8. Discover Customer Needs

- Plan to collect customer needs from internal customers and external customers.
- Collect list of customers' needs in their language.
- Discover and prioritize customer needs in terms of the customer-perceived benefit.

17.4.9. Translate and Prioritize Customer Needs

- Translate needs and benefits from the voice of the customer (VOC) into voice of the producer as CTQ requirements.
- Establish measurement for all prioritized CTQs, including units of measure, sensor, and validation.
- Establish targets and upper and lower specification limits for all CTQs.
- Establish target permissible defect rate (DPMO, Sigma) for each CTQ.

17.4.10. Establish Baseline and Design Scorecard

Once the prioritized list of CTQs is produced, the design team proceeds to determine the baseline performance of relevant existing product and production process. The current baseline performance is determined in terms of multiple components:

- Measurement systems analysis
- Product capability
- Production process capability
- Risk assessment by using tools such as product FMEA
- Competitive performance

Finally, a design scorecard is created that tracks the design evolution toward a Six Sigma product performance. This tool is used in the attempt to predict what the final product performance and defect levels will be after integration of all the design elements. The design scorecard is updated throughout the project to ensure that objectives are met.

17.4.11. Measure: Deliverables

In summary, the key deliverables that are required to complete the measure phase are

- A prioritized list of customer needs
- A prioritized list of CTQs
- A current baseline performance
- A design scorecard

17.4.12. Measure: Questions to Be Answered

1. What customer needs must the new product meet?
2. What are the critical product and process requirements that will enable the customer needs to be met?
3. How capable is our current product and production process of meeting these requirements?
4. How capable must any new product and production process be to meet these requirements?

17.4.13. Analyze Phase

The main purpose of the analyze phase is to select a high-level design and develop the design requirements that will be the targets for performance of the detailed design. This is sometimes referred to as system-level design versus the subsystem or component design levels.

The design team develops several high-level alternatives that represent different functional solutions to the collective CTQ requirements. A set of evaluation criteria is then developed, against which the design alternatives will be analyzed. The final configuration selected may be a combination of two or more alternatives. As more design information is developed during the course of the project, the design may be revisited and refined.

In developing the high-level design, the team establishes the system's functional architecture. The flow of signals, flow of information, and mechanical linkages indicate the relationship among the subsystems for each design alternative. Hierarchical function diagrams, functional block diagrams, function trees, and signal flow diagrams are commonly used to illustrate these interrelationships. Where possible, models are developed and simulations run to evaluate the overall system functionality.

The requirements for each subsystem are expressed in terms of their functionality and interfaces. The functionality may be expressed as the system transfer function, which would represent the desired behavior of the system or subsystem. Interfaces are described in terms of the input and output requirements and the controls (feedback, feed-forward, automatic controls). These specifications will be provided to the detail design teams in the design phase.

In the analyze phase, DMADV analysis tools enable the design team to assess the performance of each design alternative and to test the differences in performance of the competing design alternatives. The results of these tests lead to the selection of the best-fit design, which is then the basis to move into the next phase, detailed design. These analyses are accomplished using graphical and statistical tools including

- Competitive analysis
- Value analysis
- Criticality analysis
- Fault-tree analysis
- Risk analysis
- Capability analysis
- High-level design matrices from QFD
- TRIZ (teoriya resheniya izobretatelskikh zadach; Russian, literally "theory of the resolution of invention-related tasks")
- Updated design scorecard

One of the significant advances affecting this process is the availability of several statistical analysis tools. These software applications, running on desktops or laptop computers, speed up the number crunching required to perform the preceding analysis. This availability has also made it necessary for individuals who would not normally use these tools to be trained in the use and interpretation of the results.

17.4.14. Analyze: Deliverables

Develop a high-level product or service and process design and detail design requirements.

- Design alternatives
- Functional analysis
- Best alternative selected
- Best-fit analysis
- High-level quantitative design elements
- High-level resource requirements and operating ranges
- High-level design capability analysis and prediction
- Detail design requirements for subsystems/modules
- Key sourcing decisions
- Initial product introduction resources and plans
- Updated design scorecard
- QFD design matrices

17.4.15. Analyze: Questions to Be Answered

1. What design alternatives could be employed in the new product or process service?
2. Which is the "best" alternative?
3. What are the requirements for the detailed design?
4. Has customer feedback been obtained?
5. Does the high-level design pass a business and technical design review?
6. Has the design been validated with customers?

17.4.16. Design Phase

The design phase builds upon the high-level design requirements to deliver a detailed optimized functional design that meets operational manufacturing and service requirements. Detail designs are carried out on the subsystems and eventually integrated into the complete functional system (product). DMADV tools focus on optimizing the detail-level design parameters.

In particular, designed experiments and/or simulations serve several purposes. One purpose is to determine the best set of features (optimum configuration) to employ. Another purpose can be to obtain a mathematical prediction equation that can be used in subsequent modeling and simulations. Experiments are typically designed at differing levels of complexity, from minimal-run screening experiments to multilevel replicated design. Screening experiments typically try to establish which factors influence the system, providing somewhat limited results for modeling. More detailed experiments, including response surface and mixture designs, are conducted to determine system performance more accurately and produce a mathematical equation suitable for prediction and modeling applications. More complex products will often require nonlinear response surface models as well as mixture and multiple-response models.

During the design phase, the design team is also concerned about the processes that must be developed to provide the service or build the product. During the measure phase, the team examines the current capability of the business to deliver the product or service at the expected quality levels (approaching Six Sigma). During the design phase, the team continually updates the design scorecard with the results of designed experiments, benchmarking results, process capability studies, and other studies to track the design performance against the established goals, continuing the gap analysis that runs throughout the project. The product design is also reevaluated against the manufacturing or operational capability. Product designs may be revised as needed to ensure reliable, capable manufacturing and operations.

Part of the design for operations includes the validation of tolerances for each parameter. Designed experiments can contribute to developing these tolerances, and statistical tolerancing can also validate them.

To conclude the design phase requires the goals of the design for performance to be verified through testing of prototype, preproduction models, or initial pilot samples or pilot runs. The design team documents the set of tests, experiments, simulations, and pilot builds required to verify the product/service performance in a design verification test (DVT) plan. Upon completion of the several iterations that occur during the DVT and pilot runs, the design is solidified and the results of testing are summarized. A design review meeting marks the conclusion of the design phase, when the results of the DVT are reviewed. The design scorecard is updated, and each area of the development plan (quality plan, procurement plan, manufacturing plan, etc.) is adjusted as necessary.

17.4.17. Design: Deliverables

- Optimized design parameters (elements)—nominal values that are most robust
- Prediction models
- Optimal tolerances and design settings
- Detailed functional design
- Detailed designs and design drawings
- Detailed design for operations/manufacturing
- Standard operating procedures, standard work, and work instructions
- Reliability/lifetime analysis results
- Design verification test results
- Updated design scorecard

17.4.18. Design: Questions to Be Answered

1. What detailed product design parameters minimize variation in product performance?
2. What tolerances both are practical and ensure performance?
3. How do we ensure optimum product reliability?
4. How do we ensure simplicity and ease of manufacture or operations?
5. What detailed process parameters consistently and predictably minimize production process variation around target values?

17.4.19. Verify Phase

The purpose of the verify phase in the DMADV sequence is to ensure that the new design can be manufactured or service delivered and field supported within the required quality, reliability, and cost parameters. Following DVT, a ramp-up to full-scale production is accomplished via the manufacturing verification test (MVT) or operations verification test (OVT). The objective of this series of tests is to uncover any potential production or support issues or problems. The operations process is typically exercised through one or more pilot runs. During these runs, appropriate process evaluations occur, such as capability analyses and measurement systems analyses. Process controls are verified and adjustments are made to the appropriate standard operating procedures, inspection procedures, process sheets, and other process documentation. These formal documents are handed off to downstream process owners (e.g., manufacturing, logistics, and service). They should outline the required controls and tolerance limits that should be adhered to and maintained by manufacturing and service. These documents come under the stewardship of the company's internal quality systems. One of the considerations of the design team is to ensure that the project documentation will conform to the internal requirements of the quality system.

The design team should ensure that appropriate testing in a service and field support environment is accomplished to uncover potential lifetime or serviceability issues. These tests will vary greatly, depending on the product and industry. These tests may be lengthy and possibly not conclude before production launch. The risks associated with not having completed all tests depend on the effectiveness of earlier testing and the progress of final MVT/OVT tests that are underway. A final design scorecard should be completed, and all key findings should be recorded and archived for future reference. The team should complete a final report that includes a look back at the execution of the project. Identifying and discussing the positive and not-so-positive events and issues will help the team learn from any mistakes made and provide the basis for continuing improvement of the DFSS sequence.

17.4.20. Verify: Deliverables

- Verify product/process performance against project targets
- Pilot build is complete
- Pilot tests are completed and results are analyzed
- All operational and control documentation, procedures, controls, and training are complete
- Scale-up decision(s) are made
- Full-scale processes are built and implemented
- Business results are determined/analyzed
- Processes are transitioned to owners
- DFSS project is closed

17.4.21. Verify: Questions to Be Answered

1. Is the product or process meeting the specifications and requirements?
2. Is the production process "owned" by the business?

Source: Juran's Quality Handbook: The Complete Guide to Performance Excellence, 7th Edition
ISBN: 9781259643613
Authors: Joseph A. De Feo

17.5. Examples of Continuous Innovation Process Using Design for Six Sigma

17.5.1. Example 1: A Design for Six Sigma (DMADV) Project

17.5.2. Project Background

[1]The current process to look up, retrieve, and interpret product engineering information such as component specification drawings and product structures has been in place since 1998. This system is complex and expensive to maintain. From the beginning, this process has had many shortcomings from the point of view of the primary users—the manufacturing plants. These shortcomings cost the company money in lost productivity and high system maintenance costs.

17.5.3. DMADV Process Implementation

With the long history of complaints and a limited customer base, areas of improvement were not difficult to determine. To provide focus for our team, a survey was developed and analyzed to prioritize customer groups and customer needs as well as their performance expectations for the new system. The needs became the customer CTQ items.

We worked with our customers to determine baseline capability against four criteria:

1. Accuracy of information
2. Fast retrieval of information
3. Easy retrieval of information
4. Easy-to-interpret information

From this list we constructed a quality function deployment flow-down matrix to convert the CTQs to product feature alternatives that support customer needs. The current process was mapped at high and then more detailed levels to identify areas of improvement.

A high-level design was prepared, and high-level capability was estimated. Next a more detailed design was developed, simulated, documented, and verified.

17.5.4. Results

- Accuracy level unchanged (Six Sigma capable)
- A 451 percent improvement in average print access/printout time (from 1.5 to 6 sigma)
- 100 percent improvement in virtual viewing/inquiry capability
- 300 percent improvement in drawing line weight differentiation
- Final expected savings: not insignificant

17.5.5. Project Details and Selected Slides

Problem statement: Plant quality and customer service/technical support personnel find that our current system to find and view product component and assembly information is cumbersome to access, interpret, and maintain.

Project definition: The purpose is to provide faster access to product engineering information in a consolidated format using a single user-friendly interface.

Mission statement: The project team will develop a user interface and training system to provide faster single-point access for plant quality managers, engineering, customer service, and technical support to product structures and related component and assembly specifications by July 2004.

The slides shown in Figs. 17.3 through 17.20 highlight the project for each phase: define, measure, analyze, design, and verify.

Figure 17.3 *SIPOC (high-level process map).*

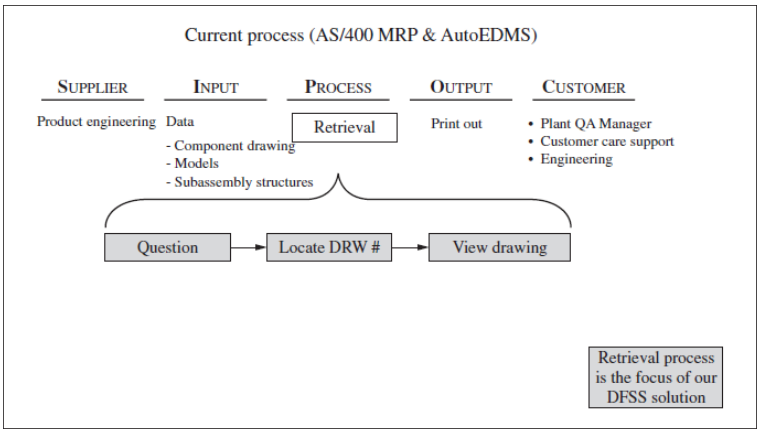


Figure 17.4 *Pareto of customer prioritization.*

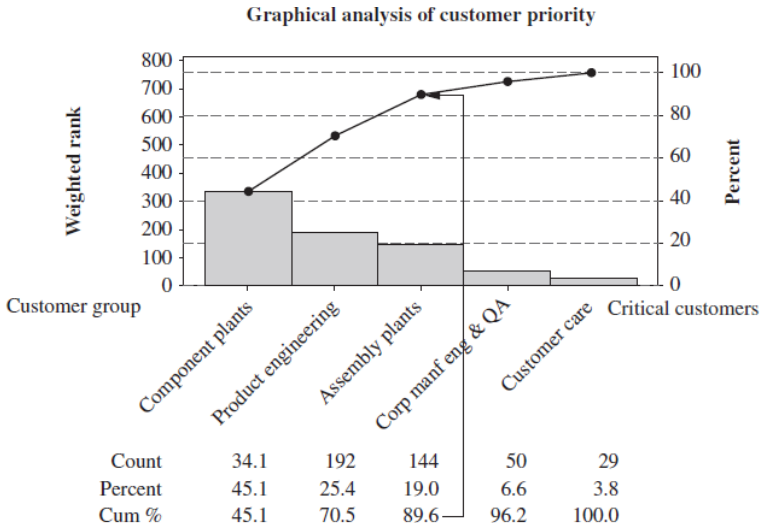


Figure 17.5 *Flow-down customer versus customer needs.*

	Customer weighting	Customer needs (based on survey results)	Accuracy of information	Speed to retrieve	Ease of retrieval	Format
		Need weighting	592	343	275	260
Prioritized customers (based on # users in group & frequency of need)		Association table customer Wt × Need Wt.				
Component plant	341		201,872	116,963	93,775	88,660
Product engineering	192		113,664	65,856	52,800	49,920
Assembly plant	144		85,248	49,392	39,600	37,440
		Totals:	400,784	232,211	186,175	176,020

Figure 17.6 *The vital few CTQs.*

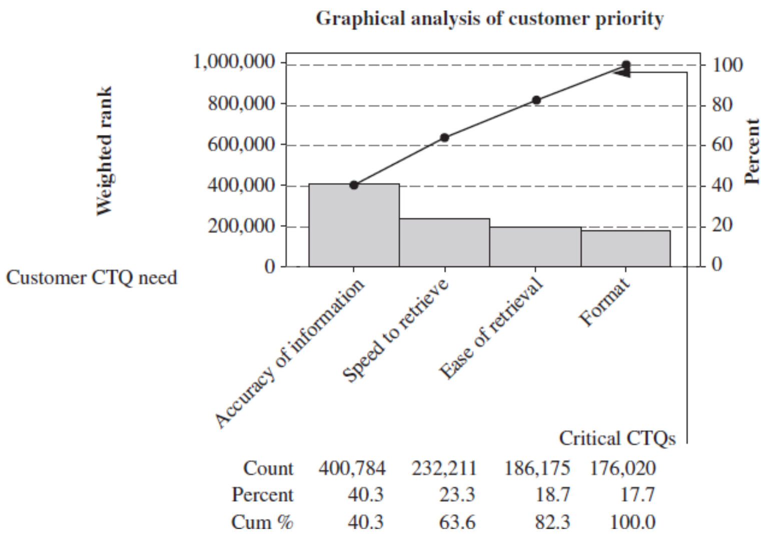


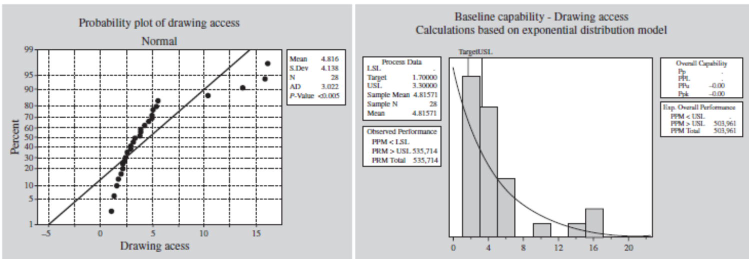
Figure 17.7 *Translation of customer needs into measurable CTQs.*

Need/ Expectation	Priority	Characteristic	Measure/ Sensor	Target	Upper Specification Limit	Allowable Defect Rate
Accuracy of information	400,784	Drawing represents part number correctly	Match: Y or N/ visual	Y	Must match	3.4 DPMO
Fast retrieval of information	232,211	Time to find a component drawing and print	Time/ Stopwatch	1.7 min	+1.6 min	10,700 DPMO
Easy retrieval of information	186,175	Number of user inputs to locate a drawing	Number of inputs/visual	10	+3	3.4 DPMO
Information is easy to interpret (format)	176,020	Different line weights are apparent on drawing	Number of multiple line weights/ visual	3	+1	3.4 DPMO

Figure 17.8 *Baseline CTQ.*

Baseline CTQ Capability Analysis
Drawing Access Spec (combined data from Dim and Non-Dim Lookup)

Normality Test



Alpha: 0.05
Ho: Data are normal
Ha: Data are not normal
P-value: <0.005, therefore reject Ho.
Data are not normal
Conclusion:
Use 1 sample Wilcoxon for data statistical analysis

Conclusion:
Baseline capability based on 500,000 DPMO
is 1.4 sigma

Figure 17.9 *Baseline CTQ.*

Baseline CTQ Capability Analysis
Drawing Access Spec (combined data from Dim and Non-Dim Lookup)

Customer expectations are 1.70 minutes or faster to access and print a drawing, from CTQ survey. Is the current system running at the customers' expectations? This is the primary CTQ on our design scorecard.
See Appendix A for survey data analysis.

Ho = Sample median is equal to 1.70 minutes
Ha = Sample median is not equal to 1.70 minutes
Alpha = 0.05
Wilcoxon Signed Rank Test: Drawing Access

```
Test of median = 1.700 versus median not = 1.700

                        N
                       for  Wilcoxon           Estimated
                   N  Test  Statistic      P      Median
Drawing Access   28    28      393.5   0.000       3.750
```

P-value = .000 < 0.05
Therefore reject Ho
Ha = Sample median is not equal to 1.70 minutes

Ho = Sample median is equal to 1.70 minutes
Ha = Sample median is greater than 1.70 minutes
Alpha = 0.05
Wilcoxon Signed Rank Test: Drawing Access

```
Test of median = 1.700 versus median not > 1.700

                        N
                       for  Wilcoxon           Estimated
                   N  Test  Statistic      P      Median
Drawing Access   28    28      393.5   0.000       3.750
```

P-value = .000 < 0.05
Therefore reject Ho
Ha = Sample median is greater than 1.70 minutes

Conclusion: The current system is not meeting customer expectations

Figure 17.10 *Design scorecard.*

CTQs					
Description	Spec/Target LSL	Spec/Target USL	Current capability	High-level Capability	Feature Capability (From verification testing)
Information is accurate	0 Errors (6 Sigma)		0 Errors (6 Sigma)		
Fast retrieval	0 sec	3.3 min	4.82 min (1.4 Sigma)		
Easy retrieval (mimimal inputs)	8	12	17 (0 Sigma)		
Easy to Interpret format (number) of line weights)	2	4	1 (0 Sigma)		

Figure 17.11 *QFD flow down: CTQs versus functions.*

CTQs	Functions: Retrieve specs by part number	Drawings retrievable by latest revision	Multiple line weights on drawing high print quality	Readily accessible	Attribute information on drawing (species/color etc.)	3D representation of cabinet	Capable of storing legacy data/drawings	
Easy to interpret (format)	□ 2	⊖ 1	■ 3	⊖ 1	■ 3	□ 2	⊖ 1	13
Fast retrieval	■ 3	⊖ 1	⊖ 1	■ 3	⊖ 1	⊖ 1	□ 2	12
Minimal number of inputs from user	■ 3	■ 3	⊖ 1	⊖ 1	⊖ 1	⊖ 1	⊖ 1	11
Information is accurate	■ 3	□ 2	⊖ 1	⊖ 1	⊖ 1	⊖ 1	⊖ 1	10
	11	7	6	6	6	5	5	

KEY	
■ 3	Strong relationship
□ 2	Moderate relationship
⊖ 1	Weak relationship

Figure 17.12 *Easy to interpret function/feature diagram.*

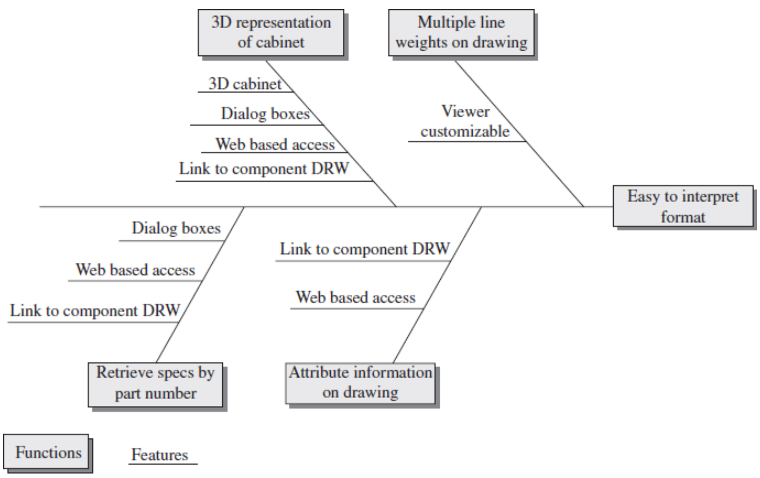


Figure 17.13 *Function/feature diagram, fast retrieval.*

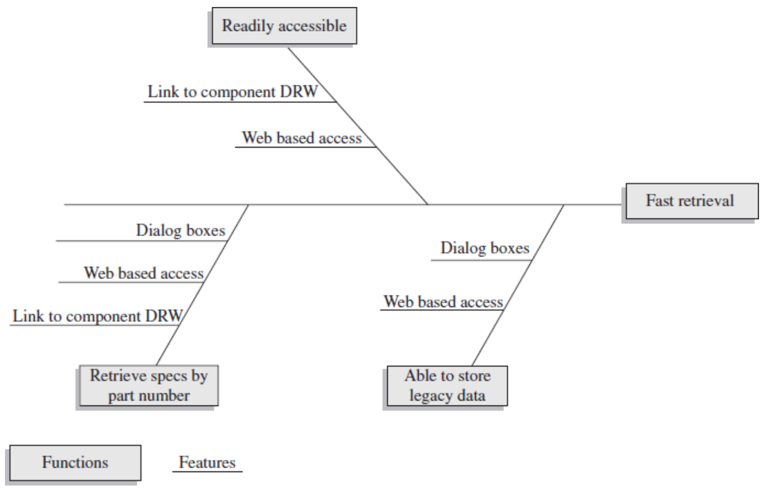


Figure 17.14 *Function/feature diagram, minimum number of user inputs.*

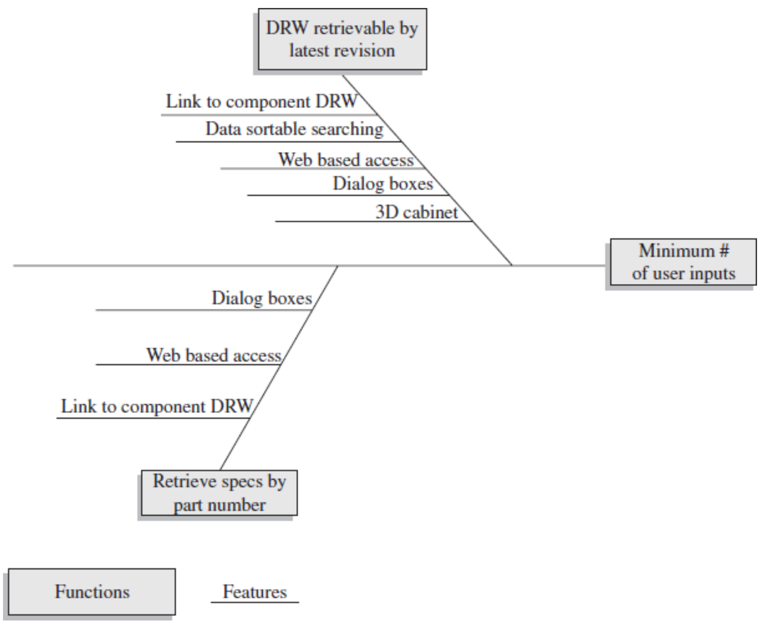


Figure 17.15 *Function/feature diagram, information accurate.*

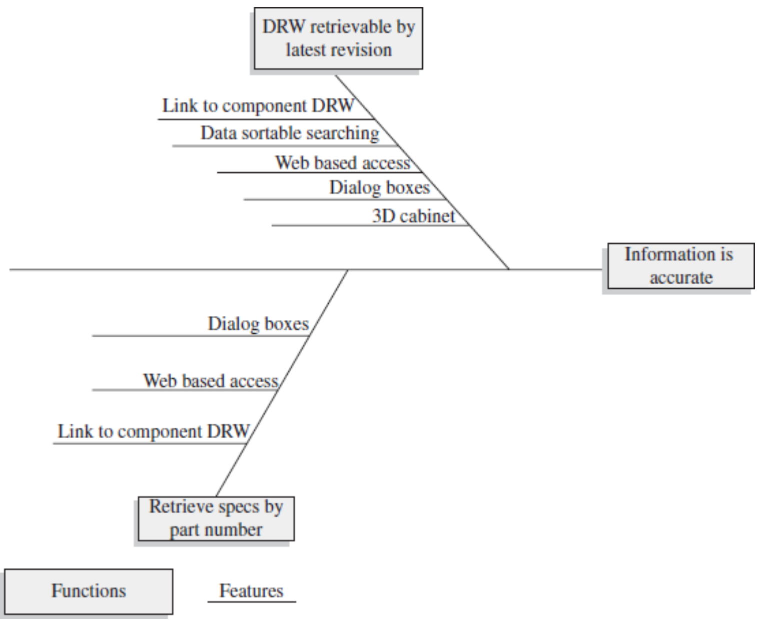


Figure 17.16 *QFD flowdown, functions versus features.*

Functions	Features: Link to component drawings	Web-based access	Dialog boxes	Virtual cab viewing	Data sortable searching	Viewer customization	
Drawings retrievable by latest revision	■ 3	□ 2	□ 2	□ 2	■ 3	⊖ 1	13
3D representation of cabinet	□ 2	□ 2	□ 2	■ 3	⊖ 1	⊖ 1	11
Readily accessible	■ 3	■ 3	⊖ 1	⊖ 1	⊖ 1	⊖ 1	10
Retrieve specs by part number	□ 2	□ 2	■ 3	⊖ 1	⊖ 1	⊖ 1	10
Attribute information on drawing (species/color etc.)	■ 3	□ 2	⊖ 1	⊖ 1	⊖ 1	⊖ 1	9
Capable of storing legacy data/drawings	⊖ 1	□ 2	□ 2	⊖ 1	⊖ 1	⊖ 1	8
Multiple line weights on drawing high print quality	⊖ 1	⊖ 1	⊖ 1	⊖ 1	⊖ 1	■ 3	8
	15	14	12	10	9	9	

KEY	
■ 3	Strong relationship
□ 2	Moderate relationship
⊖ 1	Weak relationship

Figure 17.17 *QFD flowdown, features versus alternatives.*

Features	Alternatives (X's): Use case-based training materials	JSP web page	Browser plug-in	Link from list	Java applet input box	Link from thumbnails	
Web based access	■ 3	■ 3	■ 3	■ 3	■ 3	■ 3	18
Virtual cab viewing	■ 3	□ 2	■ 3	■ 3	⊖ 1	■ 3	15
Link to component drawing	■ 3	■ 3	□ 2	■ 3	■ 3	⊖ 1	15
Dialog boxes	■ 3	■ 3	⊖ 1	⊖ 1	■ 3	⊖ 1	12
Data sortable searching	■ 3	■ 3	⊖ 1	⊖ 1	⊖ 1	⊖ 1	10
Viewer customization	■ 3	⊖ 1	■ 3	⊖ 1	⊖ 1	⊖ 1	10
	18	15	13	12	12	10	

KEY	
■ 3	Strong relationship
□ 2	Moderate relationship
⊖ 1	Weak relationship

Figure 17.18 *Verification CTQ capability analysis.*

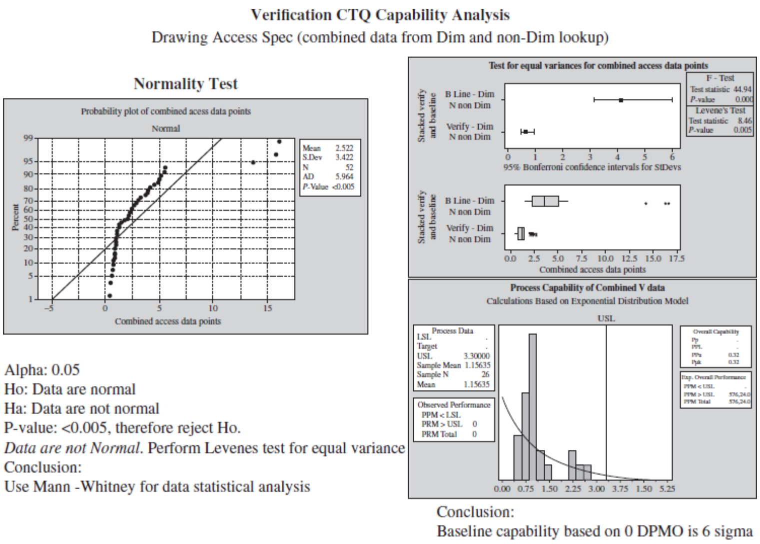


Figure 17.19 *Verification CTQ capability analysis.*

Verification CTQ Capability Analysis

Drawing Access Spec (combined data from Dim and non-Dim lookup)

Customer Expectations are 1.70 minutes or faster to access and print a drawing, from CTQ Survey. Is the new system running at the customers expectations? This is the primary CTQ on our design scorecard.

Ho = Sample median is equal to 1.70 minutes
Ha = Sample median is not equal to 1.70 minutes
Alpha = 0.05

Wilcoxon Signed Rank Test: Combined V data

```
Test of median = 1.700 versus median not = 1.700

                        N
                       for   Wilcoxon            Estimated
                  N   Test  Statistic      P        Median
Combined V data  26     26       53.5  0.002         1.033
```

P value = .002 < 0.05
Therefore reject Ho
Ha = Sample median is not equal to 1.70 minutes

Ho = Sample median is equal to 1.70 minutes
Ha = Sample median is less than 1.70 minutes
Alpha = 0.05

Wilcoxon Signed Rank Test: Combined V data

```
Test of median = 1.700 versus median < 1.700

                        N
                       for   Wilcoxon            Estimated
                  N   Test  Statistic      P        Median
Combined V data  26     26       53.5  0.001         1.033
```

P value = .001 < 0.05
Therefore reject Ho
Ha = Sample median is less than 1.70 minutes

Conclusion: DDL and the design of the user interface will meet customer expectations for drawing access time.

Figure 17.20 *Design scorecard updated and verified.*

CTQs					
Description	Spec/Target LSL	Spec/Target USL	Current capability	High level capability	Feature capability (from verification testing)
Information is accurate	0 Errors (6 Sigma)		0 Errors (6 Sigma)	0 Errors (6 Sigma)	0 Errors (6 Sigma)
Fast retrieval	0 sec	3.3 min	4.82 min (1.4 Sigma)	0.75 min (6 Sigma)	1.07 min (6 Sigma)
Easy retrieval (minimal inputs)	8	12	17 (0 Sigma)	10 (6 Sigma)	10 (6 Sigma)
Easy to interpret format (number of line weights)	2	4	1 (0 Sigma)	3 (6 Sigma)	3 (6 Sigma)

This example depicts well how the DFSS process takes place and can be used by the practitioner as a guide for his or her own projects.

17.5.6. Example 2: A Design for Six Sigma (DMADV) Project

This second project is an example of DFSS applied to a new product development and how that application can result in a more successful product being brought to market because it better meets customer needs. Due to the sensitive competitive nature of such a project, the example has intentionally been made generic for presentation here.

17.5.7. Project Background

The project was chartered to design a new, more competitive consumer medical device. The following sections detail the project background, important business considerations, and the customer characteristics.

17.5.8. Development Goals

Provide an improved consumer device that optimally meets feature and benefit requirements of the product line.

17.5.9. Product Description

The product is a medical device for use by patients with specific conditions that lend themselves to use of self-monitoring systems.

17.5.10. Process(es) within Scope

- Industrial design
- Packaging configuration
- Device color, texture
- Device configuration
- Device ergonomics, ease of use
- Launch schedule

17.5.11. Market Strategy

The current market for this device mirrors the market for the higher-level devices it is used with. However, only 40 to 50 percent of our users of the higher-level device report using this device's current version. Among our competition this device is a much higher source of revenue, and this would imply that they can produce it at a lower cost.

17.5.12. Financial Strategy

Of today's similar devices 98 percent go into kits. Therefore, reducing cost is important.

17.5.13. Technology Strategy

No off-the-shelf original equipment manufacturer devices provide multiple capabilities. However, the project can leverage prior development efforts to implement enhanced capabilities in this design.

17.5.14. Product Strategy

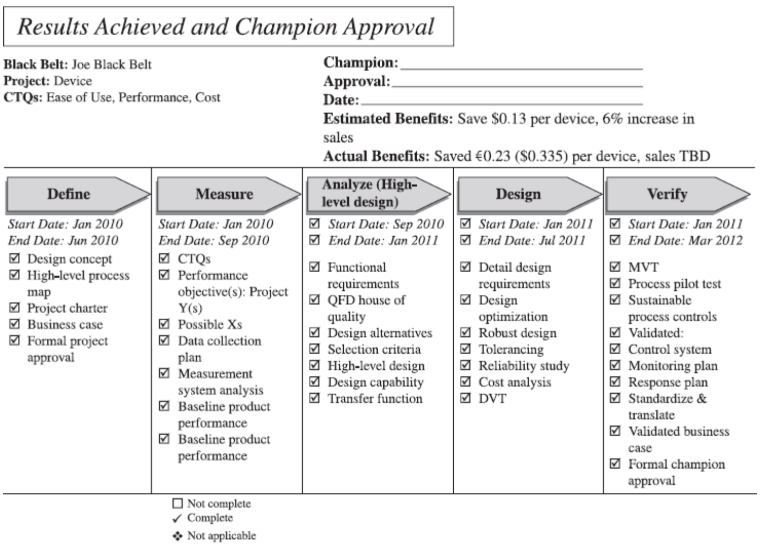
The strategy is to provide a device that maximizes customer acceptance across all major higher-level device platforms.

17.5.15. Design Project Approach

Leverage existing device development, especially internal mechanism with reduced bounce (associated with pain).

Figure 17.21 shows the process the team followed, each step completed, and the associated timing. Also, you can see the actual results of the project as measured by the marketing and financial strategies above. The project in fact exceeded the cost reduction goal of $0.13 per device with the actual reduction of $0.335 per device.

Figure 17.21 *DFSS applied to medical device design.*



It may also be noted fromFig. 17.21 that the total project took a little more than 2 years. Particularly for the application of DFSS to new product design, as in this case, it is common for DMADV projects to take a good bit longer than DMAIC projects.

[1] Adapted from the final report of a Six Sigma design project led by Dave Kinsel at a Juran Institute client; with acknowledgment of thanks.