Design for Six Sigma

Book 1 of 8 | Week 1

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Introduction to Design for Six Sigma

This week we will discuss several challenges you will face during product and process design as well as identify some basic risks. We will illustrate the DMAIC model and categorize the basic Six Sigma concepts as they apply to product and process design.

Objectives

- Describe several challenges for product and process design
- Illustrate the basic DMAIC model
- Identify basic risks in product and process design
- Categorize the basic Six Sigma concepts as they apply to product and process design

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Assignment Checklist

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Lectures

Course Introduction

Introduction

Hi. I'm Dan Munson, Associate Vice President for Continuous Process Improvement and Master Black Belt for Villanova Universities Lean Six Sigma Programs. I personally congratulate you for choosing Villanova as your source for Design for Six Sigma training.

By now, you're probably aware that Villanova has been rated as one of America's best universities year after year. The Villanova Six Sigma courses started way back in 2003, and they've grown to become a highly respected source of training for individuals and organizations worldwide. Tens of thousands of students have gone through these courses, and a few have taken that next step to earn their certification credentials. This DFSS course is a continuation to the foundation of Lean Six Sigma. If you participated in the Green Belt, the Lean, Black, or Master Black Belt courses, the structure is the same. It's basically three things: it's videos, virtual classes, and a very active discussion board. Remember, the videos can be viewed by streaming video, or you can download these videos – and I recommend you do that for future reference.

Now, for most of you, you probably remember the virtual classes. We have them here just as we have them in the other courses. And the discussion boards – don't forget to take advantage of the discussion boards. Remember, the discussion board is seeded with thought-provoking questions, links to helpful websites, and much more.

Now, here's a layout of the weeks. In Week 1, you're going to get a quick overview of the Six Sigma philosophy. From there, we segue into the introduction to DFSS, and it's going to expand on that popular DMAIC approach you know to a more proactive approach to process improvement that builds quality into the process from inception of the process. This approach is known as DMADV. Week 2 is all about DFSS and how project management ties in. You're going to learn about network diagrams, critical path analysis, Gantt charts. And then from there, you'll get a quick review of some of the Six Sigma tools: things like critical-to-quality trees, balance scorecards, statistical analysis. You're going to get a quick overview of DOE and reliability analysis. All of that in the third week.

Week 4 is the Identify phase. You'll be introduced to project risks, a review of Failure Modes and Effects Analysis, identifying project requirements, SMART objectives, measurement system evaluation, and more. In Week 5, you will be introduced to the Analyze and Design phases, looking at things like conceptual designs, the Pugh matrix, concept generation. You're going to get a couple of lectures on tolerancing, and then we're going to move on to week number six. Now, Week 6 is the Optimize phase. The design included in that week will be robust design, error proofing, capability analysis, the Taguchi model, and some other things that round out that sixth week.

In Week 7, you're going to learn how to verify the data with statistics. Included will be control plans, closing out the project, transferring the project, developing SOP's, and then on to week number eight. Week 8 is all about managing the closed out project. Critical factors for project success that's going to be covered in that Week 8. Project life-cycle tasks are going to be touched on, and you're going to find out why monitoring is so important.

Now, that's a high level overview of the layout of this course. Now it's your turn. Proceed to the next lecture, and let's get started.

Six Sigma Overview

Six Sigma and DFSS Methodologies

Six Sigma and DFSS both focus on reducing defects toward a goal of 3.4 defects per million opportunities. Both methodologies utilize statistics and data analysis. Six Sigma is used when an existing product, process, or service needs to be improved. This is normally when a customer is not satisfied with their product, and it is not meeting their specifications.

DMAIC

Six Sigma uses a methodology called DMAIC which is as follows: define, measure, analyze, improve, and control. Let us go through the DMAIC phase.

D - Define

- The purpose of the define phase is to define the project goals and customer expectations and requirements

M – Measure

- The measure phase is the stage in which current process performances are quantified

A - Analyze

- And then, Analyze phase: the root causes of the flaws or deficiencies in the process are identified

I – Improve

- During the improve phase, defects are eliminated or reduced. Variation is ultimately minimized during the improve phase

C - Control

- And finally, during the control phase, the process performance is measured for sustainability to ensure the old way of doing things does not come back into play

Six Sigma Processes and Measurements

Six Sigma is a very disciplined process that focuses on developing and delivering products and services as seamlessly and consistently as possible. Six Sigma focuses on change and empowerment while ensuring top management support is able to direct and manage the team. DMAIC is used for process improvements, while DFSS is used for designing a new process, a new product, or for re-engineering.

The metric for Six Sigma quality means 3.4 defects in a million opportunities or a process with 99.9997 percent rolled throughput yield, or defect rate. Six Sigma assumes a 1.5 sigma shift in the process mean. This is also called the Motorola shift. Sigma is the standard deviation of a process metric.

The following are the Six Sigma metrics:

SIX SIGMA METRICS

Sigma process	Defects per million opportunities	Rolled throughput yield
1	697,672	30.2328%
2	308,537	69.1463%
3	66,807	93.3193%
4	6,210	99.3790%
5	233	99.97670%
6	3.4	99.99966%

Six Sigma measures defects, which are every result of an opportunity that does not meet customer's expectations. Remember, specifications come from the customer and not the business, so if we do not fall within the upper specification limit (USL) and the lower specification limit (LSL), we are not satisfying the customer. These limits represent the range of variation that the customer is willing to accept.

Purposes of Six Sigma

Six Sigma eliminates causes of mistakes and defects in a process by ultimately reducing the variation. Six Sigma creates solutions by creating a robust process or product that mitigates variation in the customer's product. The customer should always get what they want and what they predict in a product or service that they are used to.

Some systems have variations up to and sometimes exceeding a 10 percent deviation from nominal or the target. Thus, the process must be built to tolerate the variation in the system. This would require

increasing the tolerance in the system while ensuring there is no damage to any components in the system or the system itself.

Six Sigma will reduce variation and waste in a process. It also gives us a competitive advantage. Ultimately, Six Sigma will satisfy customers and achieve organizational goals.

Six Sigma Factors

- Six Sigma emphasizes on the DMAIC (define, measure, analyze, improve, and control) method of problem solving
- Six Sigma uses focused teams which are assigned to well-defined projects that directly impact an organization's bottom line
- Customer satisfaction is the number one factor Six Sigma considers and first pass quality is always sought after
- Six Sigma requires extensive use of statistical methods and tools that ensure data driven results are made rather than just a matter of opinions

Processes for DFSS

There are two major processes for DFSS: there is IDDOV and DMADV. First let us touch on IDDOV.

I - Identify

- The identify stage utilizes a project charter to identify the new design requirement

D – Define

- The define phase is where the customer's needs and requirements are understood; CTQs for the customers are measured at this point in time

D – Develop and Design

- The develop and design phase is where a baseline functional performance is designed for a proposed product concept
- The optimal design performance is optimized
- During this phase, it is important to document and demonstrate that the product design meets or exceeds the customer expectations

O – Optimal

- During the optimize phase, the key focus is ensuring the team understands the customer requirements and their tolerance to performance variation

- To do this, it is necessary to bring the appropriate experts together to engineer a robust solution and reduce the impact of variation.

DFSS enables teams to understand the process standard deviation, determine Six Sigma tolerances, or confirm the customer expectations are actually met.

V – Verify and Validate

- Verify and validate is the phase where we quantitatively verify the system capability of a proposed product concept
- We validate the new product, process, or service to ensure customer requirements are actually met

DMADV Processes

Then there is DMADV. Let us take a look.

D - Define

- First, define – we define the problem and the opportunity a new product, process, or service represents

M – Measure

- Then, we measure – measure the process and gather the data associated with the problem as well as the voice of customer data associated with the opportunity to design a new product, process, or service

A - Analyze

- We then analyze – analyze the data to identify relationships between key variables, generate new product concepts, and select a new product architecture from the various alternatives

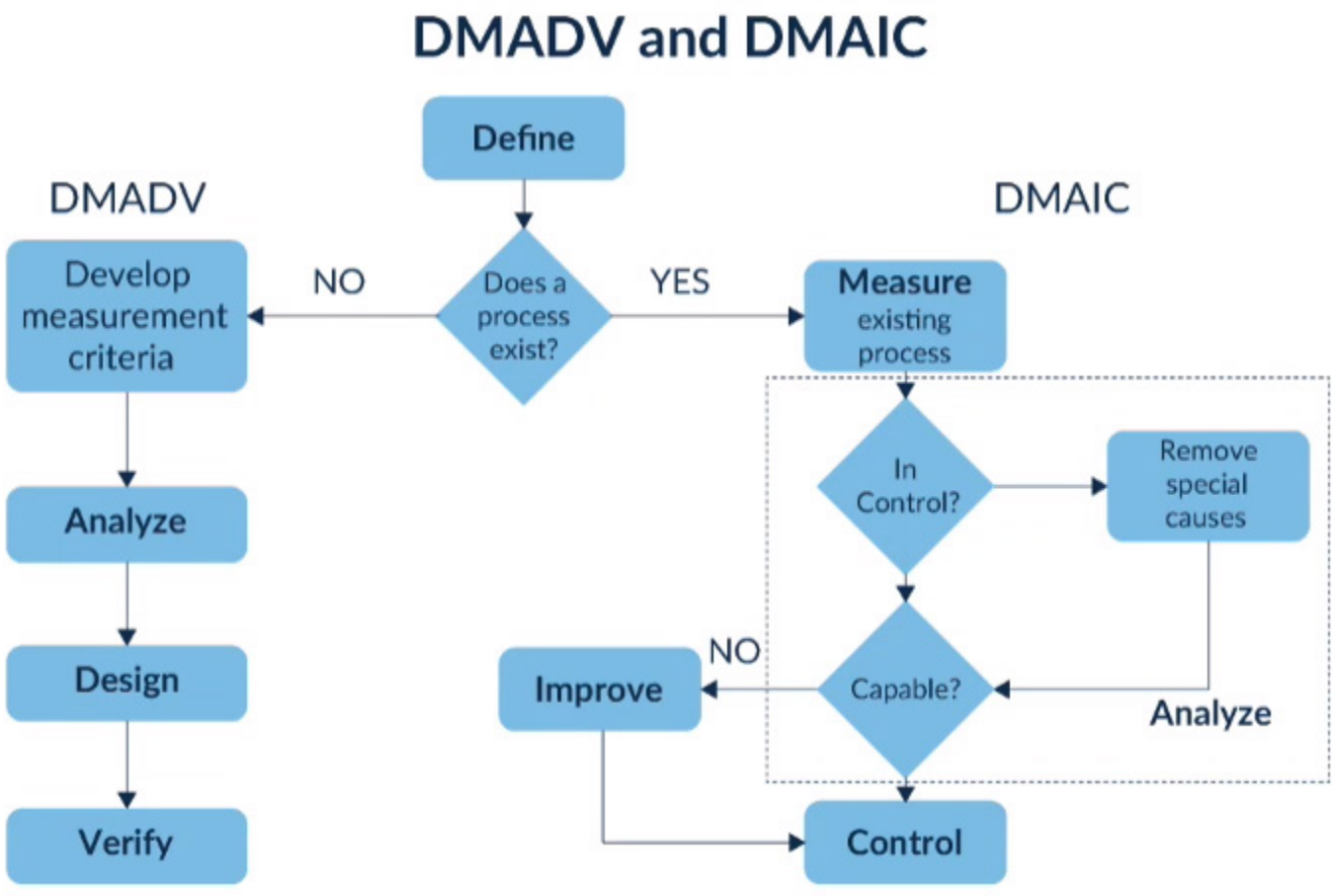
D - Design

- Then there is design – design new detailed product elements and integrate them in order to eliminate the problem and meet the customer requirements

V - Verify

- And verify – we validate the new product, process, or service to ensure the customer requirements are met

A quick view of the demonstration of DMADV and DMAIC is shown to show you which process to use.



Introduction to DFSS

Introduction

DFSS, or Design for Six Sigma, is a roadmap that is meant to assist in developing robust products and services, much like Six Sigma is a method that can improve any process.

Focus is on Customer

DFSS uses a methodology similar to Six Sigma that strongly involves the voice of the customer in order to develop product and service concepts while utilizing data-driven decision making and continuous improvement to create a process to deliver that product or service. Much like Six Sigma, DFSS uses quantitative and qualitative approaches, statistical analysis, and quality tools and methods to optimize products and services to ensure the voice of the customer is heard and delivered.

Improving a Product

Have you ever bought a product and asked yourself why the manufacturer didn't think through the system capabilities? Think about when you are using your smartphone and you see that spinning black wheel, and you can no longer use your phone without a restart. If the company receives enough negative feedback, maybe they will conduct a Six Sigma project to improve the product or service. That's all well and good if the process can be fixed. But what if it can't? What if it just won't deliver that level of service? Or what if you are designing a brand new product or service? That's where DFSS comes in.

The focus of DFSS is to emphasize on the usability, reliability, serviceability, and manufacturability if you are making a physical product, or when creating a product or service. You need to make sure that whatever you do, that product or service meets the needs and requirements of the customer.

TDRs as Tollgates

In a Six Sigma project, you go though "tollgates" that are designed to ensure that you are successful at improving the process. By improved, we mean changing it so that defects are eliminated and the customer is satisfied or even delighted. In DFSS, it is important to have technical design reviews, also known as TDRs. These are tollgates during the design process which will ensure all problems are escalated appropriately while minimizing risks. If there is a potential problem in the process – we don't want to use that process. We want to create a process that is problem-free from the start.

Typically, for example, a business provides, say, a toy robot dinosaur. The process was created on the fly. There were issues. The robot doesn't always sense when it should move. There were defects. The robot doesn't respond sometimes when you press the button. The company could conduct a Six Sigma project and improve the product. That's great, but until it gets fixed, there will be dissatisfied customers, defects and rework, and loss of revenue. Hopefully, they can fix it in time. And even more importantly, hopefully the process can be improved enough to meet the customer's needs.

Eliminating Defects

A big problem with a lot of processes is that they were never designed in a way that would eliminate all of the defects. Six Sigma means 3.4 defects per million opportunities. But often, a process is only able to get to 4.5 Sigma, or 1,300 defects per million opportunities, and usually it's not that good. The reason is the process was initially designed in a way that would prevent it from ever attaining Six Sigma performance, even after many rounds of improvement. The purpose of the DFSS methodology is to design a product, process, or service right the first time. DFSS utilizes the same principles as Six Sigma except that we design a process to be capable of achieving 3.4 defects per million opportunities. The focus is to prevent any design issues at the beginning rather than fixing them later when they have already been experienced by the customer.

DMADV

DFSS embeds the underlying principles of Six Sigma in order to design a process capable of achieving 3.4 defects per million opportunities. The focus is on preventing design flaws from occurring in the first place rather than fixing them later when the customer sees them.

Five Phases – DMADV

DFSS consists of five interconnected phases – define, measure, analyze, design, and verify (DMADV) – that start and end with the customer.

Where DMAIC is used to address a problem, DMADV is used to either create a new process or completely redesign one. You might do this when a process is simply so broken that it cannot be fixed or will not ever attain a high-performance level. You may also do this when innovation needs has provoked a new product or service.

The DMADV phases are utilized in DFSS. Let us go through those phases.

D - Define

D is for define. Define the problem and the opportunity a new product, process, or service represents. The purpose of the define phase in DFSS is to define the problem and the opportunity a new product, process, or service represents. In this phase, the team must identify customers and their product requirements.

A key focus in Define is going to really understand the voice of the customer. Many products and services go wrong right from the beginning because the voice of the customer was never adequately gathered. The company got them “right enough” to be somewhat successful, but then something went wrong. Complaints started piling up, costs from errors were growing, or continual improvement efforts were not helping, or they were not helping anymore.

Continuous improvement was likely not effective because the process was flawed in some fundamental or unchangeable way. An example is the machines would not work on necessary materials. Critical suppliers lacked the speed of service, delivery and technology. And a lack of customer focus applies to both external and internal customers.

Have you ever had a problem with a “next process step” group and the root cause was they were not capable of meeting requirements?

M - Measure

In the measure phase of DFSS, the team determines the baseline for the product, process, or service and gathers the data associated with the problem as well as the voice of the customer data associated with the opportunity to design a new product, process, or service. This is the opportunity to really define solid process metrics out of the gate.

In Six Sigma, we often find that we need to implement metrics for critical steps, and that if they were there, we could have avoided a lot of problems. Effectiveness and efficiency metrics like quantity, quality, cycle time, and cost should be fully deployed throughout the process.

DFSS is going to pay special attention to costs. That is often an area where processes run into problems. They either spend too much on quality, or quality is not possible at the allocated cost.

A – Analyze

In the analyze phase, the team analyzes the data to identify relationships between key variables, generate new product concepts, and select a new product architecture from the various alternatives. In addition, the team develops multiple conceptual designs and performs a statistical analysis of relevant data to assess capability of concepts. This involves the development of scorecards to perform a risk assessment.

Say we are building a robot. We need to understand key parameters from the voice of the customer, such as does the robot need to have a particular width or height? Does the robot need to be packaged in a critical fashion for the customer? Does the robot need to go on a particular path? Taking the analysis from the voice of the customer, several conceptual designs can be made. These conceptual designs are typically drawn out, just by hand.

D – Design

The purpose of the design phase is to determine the new detailed product elements and integrate them in order to eliminate any flaws and ensure customer satisfaction. The new design is an optimized design that will increase robustness and implement mistake proofing.

In addition, tolerance analysis is performed, and transfer functions, such as the Taguchi loss function for predictive capability analysis are developed. At this point in time, statistical process control is put in place in order to review variances. Capability analyses are also performed during this phase.

The purpose of the design phase is to prevent design flaws and mistakes in the next phase of development and manage obstacles during a development phase.

V – Verify

In the final phase, the new product, process, or service is validated to ensure customer requirements are met. Statistical confirmation is performed to verify that the predictions made through the prior phases were actually met.

Control plans, control charts, SOPs, documentation, training, and transition plans are critical to closing out the project.

Conclusion

DFSS puts the focus up-front in the design-engineering process. The key focus is ensuring the team understands the customer requirements and their tolerance to performance variation.

IDDOV

Unlike DMAIC, where there is one and only one method, DFSS actually has many models. DMADV is the most commonly used one, but it is not the only one. I am going to describe a couple of the other versions. They are all very similar, and they all use the same tools.

Another DFSS methodology is called IDDOV which stands for identify, define, develop or design, optimize, verify or validate. This sounds very different, but I think you will see that it is not.

I – Identify

The identify stage utilizes a project charter to identify the new design requirements.

D - Define

The defined phase is where the customers' needs and requirements are understood. Critical-to-quality issues for the customers are measured at this point in time.

D – Design and Develop

The design and develop phase is where a baseline functional performance is designed for a proposed product or service concept. During this phase, it is important to document and demonstrate that the product design meets or exceeds the customer expectations.

O - Optimize

During the optimize phase, the key focus is ensuring the team understands the customer requirements and their tolerance to performance variation. To do this, it is necessary to bring the appropriate experts together to engineer a robust solution and reduce the impact of variation. DFSS tools used in the optimize stage enables teams to understand the process standard deviation, determine Six Sigma tolerances, or confirm the customer expectations are actually met.

V – Verify or Validate

Verify or validate is the phase where we quantitatively verify the system capability of a proposed product concept. We validate the new product, process, or service to ensure customer requirements are met.

IDDOV Differs From Other DFSS Models

So there are a few differences that you can see. The identify stage is new. It really is making an explicit step for creating the charter for a DFSS project. In DMADV, it occurs during the define phase.

The design and develop stages really serve the same purpose as the measure, analyze and design phases. Optimize is a new one. This stage in IDDOV is about making sure you have really got the perfect design from the start. There are no new or different tools used here than in DMADV though. You can still optimize a process in DMADV. Even though the step is not explicitly stated, does not mean you should not do it. It would occur during design in DMADV.

If you use IDDOV, you might place a bit more emphasis on design of experiments in this phase. But you could still use DOE in DMADV as well. The key, as always, is to stay flexible and use the tool that meets your needs. Both methods end up with Validate, which is the bottom line: Does your process actually deliver the expected performance?

A very popular alternative to DMADV is DMADOV. That is simply DMADV with an optimize step included.

Conclusion

There are still other variations, but we are going to focus on the most widely used and flexible, which is DMADV. We can debate the differences, but overall, the tool sets and goals are the same. No matter what, they will all help us achieve Six Sigma performance for your business and your customers.

When to Use DFSS

The Goal of DFSS

The primary goal for DFSS is to identify and correctly translate customer needs to proper design choices and critical-to-quality characteristics. The emphasis is on correctly. By correctly, we mean by creating a process that is effective, efficient, robust, and resilient. Performance is capable, a Six Sigma, or even more. Costs are low, customer satisfaction is high, and we want to do it right the first time.

The Best Time to Use DFSS

Lean practitioners will appreciate that as the third critical point of value add, if it isn't right the first time, it is waste. There isn't any reason that principle shouldn't be applied to creating processes. The best time to use DFSS is before a new product or service ever occurs. DFSS should be used to get it right the first time.

So, if products or processes do not currently exist, or you're introducing new products or services, DFSS should be our go-to approach. A new product or service that results in dissatisfied customers can be worse than no new product or service at all. The real benefit in DFSS is to understand design risks, understand when design trade-off should take place, and understand the next steps to design, while never forgetting the customer, whether they are internal or external.

The other time to use DFSS is when you simply can't get a process from where it is to where you want it to be with DMAIC. There are two situations where or when this could occur. The first is easy: when the process is so damaged and so far from the target level of performance that it is obvious that rebuilding it from the ground up is the way to go. If you start down the DMAIC path, and after Define or Measure, it becomes evident that there are major flaws in the process, that there will be constraints to improving that can't be overcome, or that it will take many, many cycles of improvement to achieve your goal, DFSS is probably the better road to take. It may take longer up front to do a DFSS project, but it will be much faster and result in far better customer and financial performance in the long run.

The other situation is when you hit the 4.5 Sigma wall. The 4.5 Sigma wall is a barrier that actually contributed to the rise of DFSS approaches. Over many years of DMAIC projects, it was found that Six Sigma was often not able to be achieved. The reason for this was that at some level, the process that was originally developed was lacking something critical that couldn't be changed.

When to Move a Project to DFSS

For example, if you build a house made of wood, you can build it quite high, but at some point, you simply can't build another level onto it. The wood is too weak and will collapse under the weight. To get as tall a building as possible, you needed to start the ground floors with stone or steel. Processes are the same. For example, at some point, you may not be able to speed up production without being able to immediately access raw materials. No amount of Six Sigma will make one appear in the ground at the loading dock. You need to build a new factory, one that has an ore mining and processing building as a first process step. Knowing when to move the DFSS with a project that has been making improvements can be difficult. If you have been using Six Sigma tools, though, you should be able to identify when the number of root causes left to eliminate and their contribution to improvement will achieve its maximum level. When you get to the point that eliminating them does not get you to Six Sigma – or whatever level your target is – it is probably time to consider a DFSS project.

What DFSS Emphasizes

DFSS, like Six Sigma, still utilizes management support to plan the design and development. DFSS should examine critical design elements adding peer and expert insight to the creative process. DFSS will emphasize four main elements to ensure there's value add: product design, cost or spend, value chain, and marketing. And much like DMAIC, you will have to pass through a tollgate at the end of each phase and have a sponsors consider those issues before moving on.

A product or process might be too expensive or have insufficient market, or you may lack the capability to meet the customer's needs. You can stop the process from ever starting. If you did start such a process, it would ultimately end up with excessive costs or constant improvement efforts and dissatisfied customers.

DFSS will emphasize the usability, reliability, serviceability, and manufacturability when producing the design. DFSS will focus on optimization of the value for the customer. The Design for Six Sigma methodology will ensure determining the needs of customers and the business and then driving those needs into solutions for the product or service needed. And it will make sure you achieve maximum performance and allow you to achieve Six Sigma levels of performance.

DMAIC vs. DFSS

Introduction

Six Sigma and DFSS. Both focus on reducing defects towards a goal of 3.4 defects per million opportunities. Both methodologies utilize statistics and data mining. Six Sigma is used when an existing product, process, or service needs to be improved. This is normally when a customer is not satisfied with their product, and it is not meeting their specifications.

Design for Six Sigma

DFSS is used when a new product, process, or service does not exist and needs to be developed. DFSS focuses on product and service design where problems are hard to see and less expensive to correct. The purpose of the methodology is to design a product, process, or service right the first time. DFSS is an important part of Six Sigma that mitigates problems in manufacturing and service using data analysis and statistical techniques.

Six Sigma and DFSS

Both approaches utilize the following methodology of Define, Measure, and Analyze. However, Six Sigma improves and controls an existing product or service, whereas as DFSS designs and verifies a new product or service. Both Six Sigma and DFSS aim for 3.4 defects per million opportunities as a target.

Notes