LECTURE

10 Quality improvement methods – Six Sigma

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LECTURE 10 - OVERVIEW

Quality improvement methods – Six Sigma and its tools

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WHAT IS SIX SIGMA

Six Sigma

- set of tools and methods for process improvement
- Developed in 1986 in Motorola
- First used in large scale in General Electric in 1995
- Used in many industry fields

KEY CONCEPTS OF SIX SIGMA

Critical to Quality: Attributes most important to the customer

Defect: Failing to deliver what the customer wants

Process Capability: What your process can deliver

Variation: What the customer sees and feels

Stable Operations: Ensuring consistent, predictable processes to improve what the customer sees and feels

Design for Six Sigma: Designing to meet customer needs and process capability

SIX SIGMA ACTIVITIES

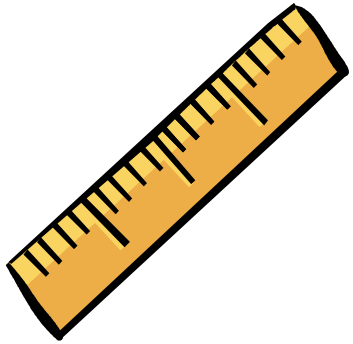
- Continuous efforts to achieve stable and predictable process results (i.e., reduce process variations)
- Measuring, analyzing, improvement and control of both business processes and manufacture
- Continuously improving quality
- Support of the top-level management is crutial!

KEA IDEA

You cannot manage what you cannot control.

You cannot control what you cannot measure.

You cannot measure what you cannot define.



SIX SIGMA TYPICAL ASPECTS

- focus on achieving **measurable** and **quantifiable** financial returns
- emphasis on strong and passionate management leadership and support
- commitment to making decisions on the basis of verifiable data and statistical methods

SIX SIGMA HISTORY AND USAGE

registered service mark and trademark of Motorola Inc.

Developed in Motorola during 1980s

An important factor in the spread of Six Sigma was GE's 1998 announcement of $350 million in savings thanks to Six Sigma

In late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives

In 2006 Motorola reported over US$17 billion in savings from Six Sigma in total

Well-known six sigma applications:

- Honeywell
- General Electric

Mostly finds application in large organizations

but can be used in any type of organization – is rather set of tools

COMBINATION WITH OTHER METHODOLOGIES

In 2000s combination with Lean manufacturing principles

⇒ methodology named Lean Six Sigma

- lean manufacturing – process flow and waste issues
- Six Sigma – focus on variation and design

serves as a foundation for innovation throughout the organization

- manufacturing,
- software development,
- sales,
- service delivery
- ...

Used e.g. in IBM, Sandia National Laboratories

LEAN PRODUCTION

Lean manufacturing, **lean enterprise**, or **lean production**, often simply, "**Lean**," is a production practice that

- considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination
- "value" is defined as any action or process that a customer would be willing to pay for.

LEAN SIX SIGMA

Synergized concept of Lean and Six Sigma

- results in
  - the elimination of the seven kinds of wastes (classified as TIMWOOD - Transportation, Inventory, Motion, Waiting, Overproduction, Over-Processing, and Defects,)

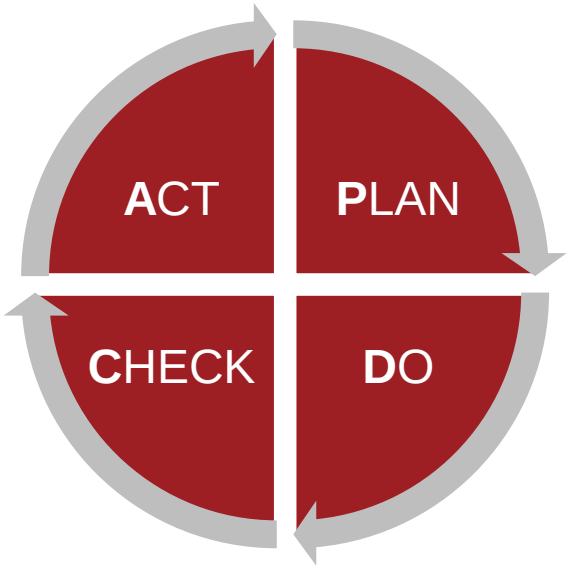
  (sometimes TIMWOODS – Staff)
  - provision of goods and service at a rate of 3.4 defects per million opportunities (DPMO)

First published in the book titled "Lean Six Sigma: Combining Six Sigma with Lean Speed" by Michael George in 2002

- Lean Six Sigma utilises the DMAIC (define-measure-analyse-improve-control) phases similar to that of Six Sigma
- DMAIC toolkit of Lean Six Sigma comprises all the Lean and Six Sigma tools

BASICS OF SIX SIGMA

inspired by Deming's Plan-Do-Check-Act Cycle.



BASICS OF SIX SIGMA

methodologies DMAIC and DMADV.

DMAIC

- used for projects aimed at improving an existing business process

DMADV

- used for projects aimed at creating new product or process designs

DMAIC PROJECT METHODOLOGY

- **Define** the problem and the project goals
- **Measure** key aspects of the current process and collect relevant data.
- **Analyze** the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- **Improve** or optimize the current process based upon data analysis using techniques such as design of experiments,
- **Control** the future state process to ensure that any deviations from target are corrected before they result in defects.

Recognize step may be added at the beginning – to recognize the right problem → RDMAIC methodology.

DMADV

DMADV methodology – design method for six sigma

- **Define** design goals consistent with customer demands and the enterprise strategy
- **Measure** and identify characteristics Critical To Quality (CTQs), product capabilities, production process capability, and risks
- **Analyze** the design alternatives, create a high-level design and evaluate design capability to select the best design
- **Design** details, optimize the design, and plan for design verification
- **Verify** the design, set up pilot runs, implement the production process and hand it over to the process owner(s)

REASONS FOR SIX SIGMA INTRODUCTION

Six Sigma professionalizes quality management

Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department.

Six Sigma adopts a

- ranking terminology
- define a hierarchy (and career path) that cuts across all business functions.

SIX SIGMA CERTIFICATION

Goal to verifying individuals' command of the Six Sigma methods at the relevant skill level

no standard certification body, different certification services are offered by various quality associations and other providers

- Yellow Belt
- Green Belt,
- Black Belt
- Master Black Belt
- Champion

http://www.sixsigmadaily.com/certification/six-sigma-training-belt-levels

SIX SIGMA DETAILS (WHY “SIX SIGMA“?)

- The term "Six Sigma" comes from statistics
- Known as capability studies process
- Measure the number of standard deviations between the process mean and the nearest specification limit in sigma units
- Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification.
- Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO)

SIX SIGMA PRINCIPLE

Based on the normal distribution

σ (sigma) marks the dispersion – the distance between the mean μ, and the curve's inflection point

greater this distance, the greater is the spread of values

The upper and lower specification limits (USL and LSL) are at a distance of 6σ from the mean

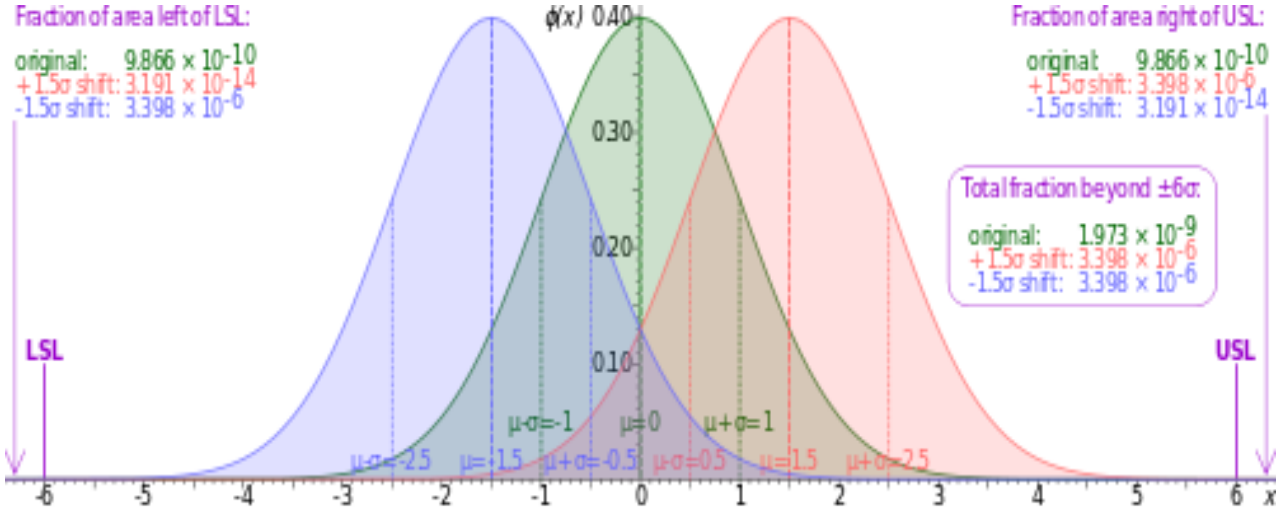
As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification

SIX SIGMA PRINCIPLE

In the normal distribution values lying 6σ from the mean are extremely unlikely

Even if the mean were to move right or left by 1.5σ in the future (1.5 sigma shift, coloured red and blue), there is still a good safety cushion

→ Six Sigma aims to have processes where the mean is at least 6σ away from the nearest specification limit.



en.wikipedia.org/wiki/Six_Sigma /

REASONS FOR 1,5 SIGMA SHIFT

In the long terms processes do not perform without changes

→ number of sigmas that will fit between the process mean and the nearest specification limit may drop

→1.5 sigma shift introduced (empirically-based)

Assumtion:

process that fits 6 sigma between the mean and the nearest specification limit in a short-term study will in the long term fit only 4.5 sigma

- process mean can move
- long-term standard deviation can grow

SIX SIGMA GENERAL DEFINITION

Widely accepted definition of a six sigma process:

process that produces 3.4 defective parts per million opportunities (DPMO)

(based on the normal distribution - 3.4 parts per million are beyond a point that is 4.5 standard deviations above or below the mean)

→ in fact 3.4 DPMO of a six sigma process corresponds to 4.5 sigma, namely 6 sigma minus the 1.5-sigma shift introduced to account for long-term variation

This allows for the fact that special causes may result in a deterioration in process performance over time, and is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation

SIX SIGMA ADVANTAGES

- Publicly available
- Lots of tools to choose form
- Does not need complete implementation – one can choose what is userful
- Contains both measuring and implementation tools

SIX SIGMA DISADVANTAGES

- Is said that in fact it brings nothing new
- Over-reliance on methods and tools
- Reliance on significance testing and use of multiple regression techniques → common statistical error and mistakes can be introduced
- Many tools, methods – lack of unified documentation
- Principle of 6 sigma (1,5 sigma) shift is not useful for all processes

MANAGEMENT TOOLS AND METHODS USED IN SIX SIGMA

- 5 Whys
- Analysis of variance
- ANOVA Gauge R&R
- Axiomatic design
- Business Process Mapping
- Cause & effects diagram (also known as fishbone or Ishikawa diagram)
- Check sheet
- Chi-squared test of independence and fits
- Control chart
- Correlation
- Cost-benefit analysis
- CTQ tree
- Design of experiments
- Failure mode and effects analysis (FMEA)
- General linear model
- Histograms

MANAGEMENT TOOLS AND METHODS USED IN SIX SIGMA

- Pareto analysis
- Pareto chart
- Pick chart
- Process capability
- Quality Function Deployment (QFD)
- Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
- Regression analysis
- Rolled throughput yield
- Root cause analysis
- Run charts
- Scatter diagram
- SIPOC analysis (Suppliers, Inputs, Process, Outputs, Customers)
- Stratification
- Taguchi methods
- Taguchi Loss Function
- TRIZ

SIX SIGMA TOOLS

Pareto chart

To perform root cause analysis

Pareto rule is also known as 80/20 rule since it states that 80% of the problems are caused by 20% of the causes or issues

Used to visually identify the most occurring defects, most important factors or the most common problems.

These “Most Important” factors are also known as “**The vital few**“.

SIX SIGMA TOOLS

Pareto chart - example

Evaluation of the frequency of occurence (y axis) – on the right side cumulative frequency

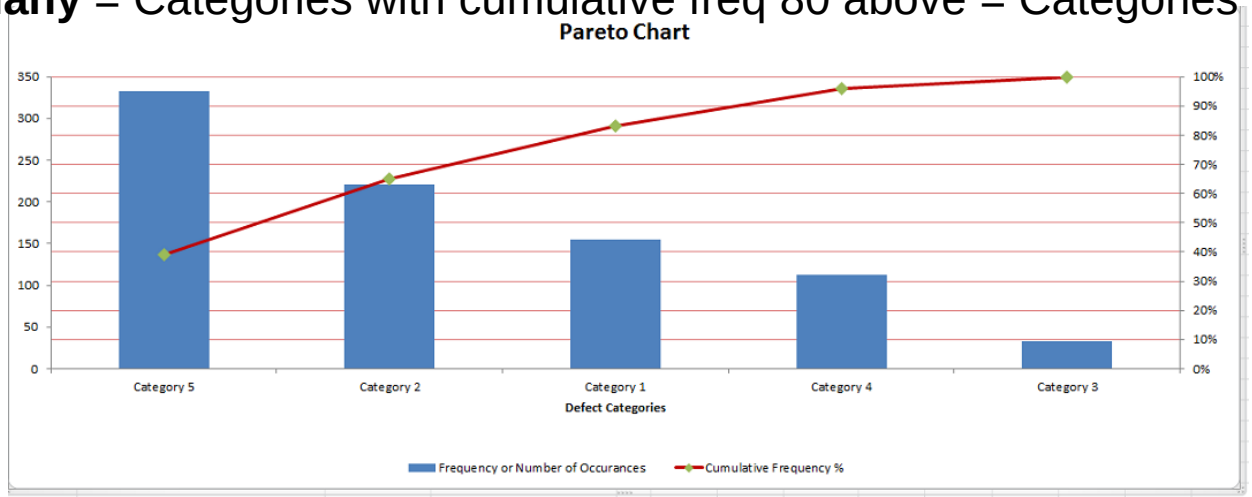
Looking for the point where the cumulative line graph crosses 80%

Categories to the left of that point are **“vital few”** - most significant factors

Remaining categories (or factors) are called **“Useful Many” -** less significant

For this example Vital Few = cumulative freq 80 below = Categories 5,2,1

Useful Many = Categories with cumulative freq 80 above = Categories 3,4



http://sixsigmatutorial.com/sigma-pareto-analysis-pareto-chart-download-free-template-microsoft-excel/104/#more-104/

SIX SIGMA TOOLS

Pareto chart summary

- helps finding which issues are causing most problems
- used in root cause analysis
- decision making tool
- do not contain data such as detail data analysis and costs of failure
- results in finding the efforts where it will have the most impact
- decide the order in which the issues will be addressed

SIX SIGMA TOOLS

Statistical Process Control Charts; SPC

Requires regular recording of data on process performance (e.g. hourly, daily)

Goal

- compare the performance now against past performance
- define if the data is within the statistically expected range.

If the data is beyond what is expected or a statistically unusual trend is observed then it could indicate that the process is out of control and that some form of special cause is present.

Able to identify when things are changing

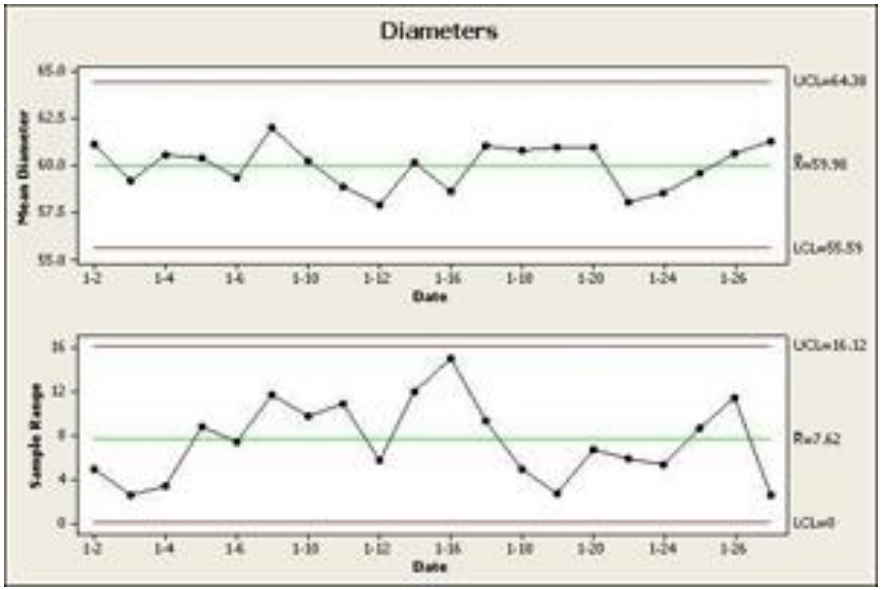
→ often possible to prevent the creation of defective materials, rather than rely on inspection to remove defects – able to locate the problem before it starts to expresses itself

SIX SIGMA TOOLS

Statistical Process Control Charts; SPC - example

Monitoring the variation if it is stable and can be predicted over time

tool for continuous Business Improvement

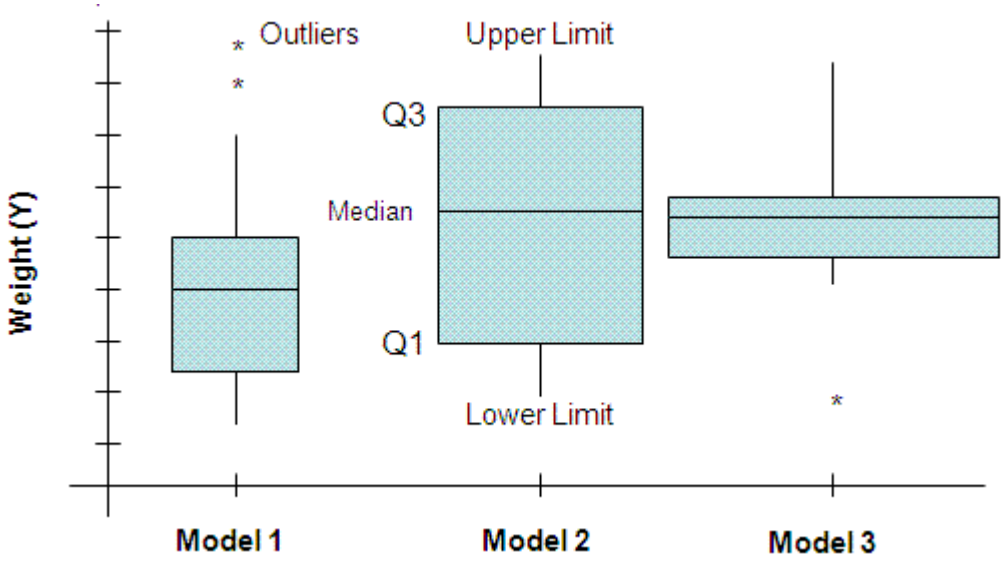


http://www.processexcellencenetwork.com/six-sigma-quality/articles/statistical-process-control-the-alpha-and-omega/

SIX SIGMA TOOLS

Box-plot analysis

- graphical summaries depicting distributions
- Showing median, quartils



http://www.six-sigma-material.com/Box-Plot.html

SIX SIGMA TOOLS

Box-plot analysis - explanation

1) center point (line) in the boxes. - median (M or Q2)

2) The bottom of the box – first quartile (Q1)

3) The top of the box – third quartile (Q3)

4) The whisker extend up to the highest value of upper limit and down to the lowest value of the lower limit.

5) The lowest point of the lower whisker is called the lower limit. Lower limit value equals Q1 – 1.5 * (Q3-Q1)

6) The highest point of the upper whisker is the called the upper limit. The upper limit value equals Q3 + 1.5 * (Q3-Q1).

7) Outliers are points that fall outside the limit

8) Width of the box plot indicates the size of the sample taken

SIX SIGMA TOOLS

Quality function deployment matrix (QFD)

Used in Six Sigma DMAIC

used in the Define stage

- Collect customer's requirements/desires as specified by the customers in their own words
- Prioritize these desires
- Translate them into engineering/process requirements
- Establish targets to meet the requirements.

QFD is also termed as:

- Voice of the Customer
- House of Quality
- Customer-Driven Engineering
- Matrix Product Planning

SIX SIGMA TOOLS

Quality function deployment matrix (QFD)

- customer driven product or service planning process
- methodology for translating customer requirements into company requirements at each stage
- QFD matrix is a tool to translate CCRs (Critical To Customers) into CTQs (Critical to Quality).

QFD collects the voice of the customer (VOC) in their own language and incorporates this VOC into the companies cross-functional team's project management of the integrated development process. The QFD process establishes customer objectives and measures and records them on a series of matrices

SIX SIGMA TOOLS

Quality function deployment matrix (QFD) - example

		Hows or CTQs internal to the company/process/engineering->								
Customer Needs or CCRs or Whats	**Importance to Customer**	Time On Hold <------	Feedback Score ------>	How 3 <------	How 4 ------>	How 5 ------>	How 6 <------	How 7 ------>	How 8 ------>	How 9 <------
Need Quick Response from Helpdesk	5	5	2	3	3	1	1	3	5	2
Want satisfactory result from Helpdesk	3		5			4	2		1	
What 3	2	5		1	2			4		1
What 4	1		1			1	5			5
What 5		2	2	4	1	3		2		1
What 6	3				2	4	2			4
What 7		1	1	1				2	2	5
What 8	3		3		2		1		1	2
What 9	1	2	4	2	1		1	2	5	
What 10	2	1	4	1	3	1	4			1
Score		**39**	**47**	**21**	**38**	**32**	**34**	**25**	**36**	**37**
Current Avg Value of CTQ		2.5	3.1	2 da	3	6	0	1	2	7

http://sixsigmatutorial.com/what-is-six-sigma-quality-function-deployment-qfd-download-free-excel-qfd-template/50/

SIX SIGMA TOOLS

Quality function deployment matrix (QFD) – summary

- Create a list of customer requirements/desires (**Whats**) by
  - Asking the customer, e.g.“What are the important features of The Product”
  - Capturing the customer’s own words or “**Voice of the Customer”** or **VOC**
  - Categorizing the **Whats** into groups/buckets if needed.
- Prioritize the above collected Whats on a scale of 1-5, with 5 being the most important
- The CCRs (Whats) are listed vertically in the first column and all related CTQs (Hows) are listed horizontally across the top
- Score each CTQ (Hows) on how strongly it correlates to each CCR – can be either positively correlated or negatively correlated (5 - strong correlation, 1 - weak correlation, 0- no correlation
- Multiply the importance rating for the CCR by the correlation score for each CTQ.
- Sum the scores vertically for each CTQ
- The highest scores are the highest priority Six Sigma project objectives

SIX SIGMA TOOLS

Taguchi Loss Function

explains that until a component is manufactured in the nominal size, it incurred a certain amount of loss to the manufacturer even though it has been manufactured within specified tolerance limit. The loss incurred by the component is zero in its nominal size and gradually increase as it deviates from the nominal size.

Graphical Representations

The parabolic curve , minimum loss is for the target values, the loss increases even within the process limits

Fig.1.1- Taguchi Loss Function

http://www.brighthubpm.com/six-sigma/46604-concept-and-example-of-the-taguchi-loss-function/#imgn_0

SIX SIGMA TOOLS

Critical to Quality tree

to decompose broad customer requirements into more easily quantified requirements

CTQs are derived from customer needs.

CTQs (Critical to Quality) are the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer

http://www.mindtools.com/pages/article/ctq-trees.htm

SIX SIGMA TOOLS

Critical to Quality tree

Step 1: Identify Critical Needs

You first need to identify the critical needs that your product has to meet. Do a CTQ Tree for every need that you identify. During this first step, you're essentially asking, "What is critical for this product or service?“

Step 2: Identify Quality Drivers

Next, you need to identify the specific quality drivers that have to be in place to meet the needs that you identified in the previous step.

Step 3: Identify Performance Requirements

Finally, you need to identify the minimum performance requirements that you must satisfy for each quality driver, in order to actually provide a quality product.

Once you've completed a CTQ Tree for each critical need, you'll have a list of measurable requirements that you must meet to deliver a high quality product.

SIX SIGMA IN JOKES

Source:
http://search.dilbert.com

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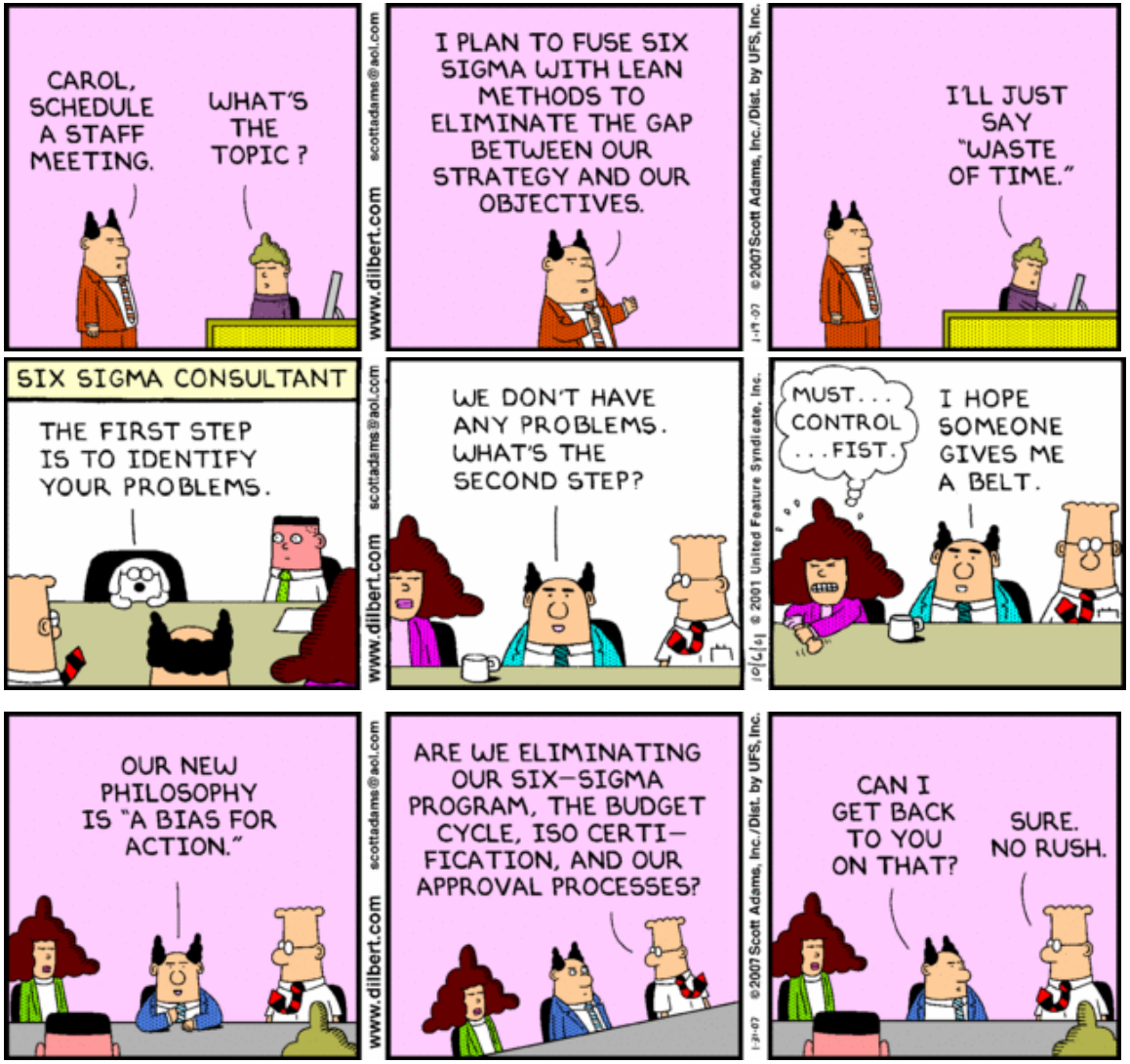

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