6σ

An Introduction
by
Dr. Habib Siddiqui, Master Black Belt
Global Six Sigma Process Leader
Rohm and Haas Company
Competitive Realities of Our Time
The Global Business Climate

• Fierce, global competition
• Accelerating pace of change
• New technologies
• Increasing customer demands - performance, quality, price, “solutions, not products,” ...
New **Initiatives** to Meet the Realities

**Cost**
Target Costing, Globalization

**Lower Cost**

**Speed**
e-Engineering, Lean Enterprise, Streamlining SC

**Quicker to Market**

**Quality & Performance**
Six Sigma, Design for Six Sigma, Stage Gate/NPI, Risk Management

**Better Quality**

**Higher Performance**
Six sigma business improvement starts with SIPOC

- Suppliers
- Inputs
- Process
- Outputs
- Customer (Requirements)

Root cause analysis leads to permanent elimination of defects.

Variation in the output from what the customer wants causes defects.

Defects

CCR
The basic Six Sigma premise

- All processes have variability
- All variability has causes
- Typically only a few causes are significant
- To the degree that those causes can be understood - they can be controlled
- Designs must be robust to the effects of the process variation
- This is true for products, processes, services, information transfer, everything . . .

.. is that uncontrolled variation is the enemy

© Habib Siddiqui
What is Six Sigma?

- Six Sigma is a powerful set of statistical and management tools and methodologies that can create dramatic increases in customer satisfaction, productivity and shareholder value for both service and manufacturing companies/organizations.

- It is a disciplined methodology of defining, measuring, analyzing, improving and controlling the quality in every product, process and transaction – with the ultimate goal of virtually eliminating all defects. (Jack Welch, GE)
History of Six Sigma

- Motorola (mid-’80s)
- GE – under Jack Welch (mid-’90s)
- Others doing it:
  - Dow, Witco (now Chemtura), DuPont, Rohm and Haas
  - Ford, GM
  - Johnson & Johnson, Merck (2000-01)
  - Maytag
  - Wal-Mart, Bank of America, Home Depot
  - Allied Signal (now Honeywell), Siemens, Intel
  - 3M, Kodak, Corning, Xerox, Avery-Dennison
  - and many others.
- Average six sigma project saves $250M 😊
Six Sigma: Philosophy

**The Motorola School:** *(Show me the “Defect”)*
Relentless Defect Elimination
- Find and Remove Existing Defects
- Prevent New Defects

**The GE School:** *(Show me the “$$”)*
Relentless Pursuit of Financial Opportunities
- Identify High Impact Projects
- Use Six Sigma Methodology to Optimize the Process
- Visible Bottom Line Impact

© Habib Siddiqui
# Six Sigma: Measurement

<table>
<thead>
<tr>
<th>Sigma Level</th>
<th>% Good</th>
<th>Defective ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>69.15 %</td>
<td>308,537</td>
</tr>
<tr>
<td>3</td>
<td>93.32 %</td>
<td>66,807</td>
</tr>
<tr>
<td>4</td>
<td>99.379 %</td>
<td>6,210</td>
</tr>
<tr>
<td>5</td>
<td>99.9767 %</td>
<td>233</td>
</tr>
<tr>
<td>6</td>
<td>99.99966 %</td>
<td>3.4</td>
</tr>
</tbody>
</table>
How Important is Quality?

If your goal was 99% quality, you'd still have:

- 15 minutes of unsafe drinking water every day
- 2 unsafe plane landings per day at most major airports
- 20,000 pieces of lost mail every hour
- 200,000 wrong drug prescriptions per year
- 5,000 incorrect surgical operations per week

(Ref: Control Engineering, Jan. 1999)
Sigma Levels of Some Activities

Sigma Level

Defects / Million

1000000

100000

10000

1000

100

10

1

1.5 2 2.5 3 3.5 4 4.5 5 5.5 6

Sigma Level

Avg. US Company

Tax Advice at IRS Help Centers

Airline Baggage Handling

Restaurant Bills

Prescription Writing

World-Class Quality Companies

US Airline Fatality Rate

Avg. US Company

Tax Advice at IRS Help Centers

Airline Baggage Handling

Restaurant Bills

Prescription Writing

World-Class Quality Companies

US Airline Fatality Rate
The High Cost of Poor Quality

**Tangible Costs**
- Inspection
- Scrap
- Rework
- Warranties

**Intangible Costs**
- Lost Customers
- Longer Cycles

**Cost of Poor Quality (% of Sales)**

**Enormous opportunity**

---

Avg. US Co. | World-Class Co
---|---
Sigma Level

Avg. US Co.

Enormous opportunity
Six Sigma Methodology “Flavors”

- Six Sigma Process Optimization (DMAIC)
  - Manufacturing process
  - Business/service/transaction process
- Design for Six Sigma (DFSS)
  - new products
  - new processes
  - new services
  - Redesigning an existing product/service to meet entitlement
Six Sigma DMAIC Methodology

Six Sigma is information dependent.

Define what’s important
Measure how we’re doing
Analyze what’s wrong
Improve by fixing what’s wrong
Control to guarantee performance

© Habib Siddiqui
The Six Sigma Filtering Effect

Inexpensively, narrow in on fewer and fewer Variables, Saving more “expensive” tools for when we have fewer Variables

Output $Y = f(x_1, x_2, \ldots, x_n)$

100+ Inputs

- Process Maps
- Capability Study
- Measurement Study
- C& E Matrix

25 - 30

- FMEAs
- Multi-Vari Studies

8 - 10

- Design of Experiments (DOE)

3 - 6

- Control Plans

1 - 3

Critical Input Variables

$ \quad \$
Six Sigma: Conceptual Approach

Practical Problem → Statistical Problem

\[ y = f(x_1, x_2, \ldots, x_k) \]

Practical Solution ← Statistical Solution

© Habib Siddiqui
Design for Six Sigma (DFSS)

(Applicable to R&D/Tech Service)
Cost Of Poor Quality over the product life cycle (from lab to customer)

Most current six sigma effort is here

We ought to do here

R&D/Discovery, Pre-clinical
Pilot plant/Clinical I-III
Production/Commercialization
Customer

Defects are:
Difficult to see/predict
Easy to fix
Costly to fix
May lose customers

We need a paradigm shift in how we do things: from reactive to predictive mode.
How Does R&D Play in the Six Sigma Game?

• R&D focuses on **discovery** or **innovation**, not process improvement
• Defects are not known (or difficult to see) for new, innovative designs
• Most new product quality problems are in **performance** and **reliability**, not **producibility**
Why DFSS?

D-M-A-I-C has been around for over 10 years, but...

» Six Sigma Practices in Manufacturing is Not Enough
» Cannot Produce a Six Sigma Product via Mfg Alone

$\text{Up to 4.5}\sigma \rightarrow \text{Achievable via Mfg Improvements}$

$4.5\sigma \rightarrow 5\sigma \rightarrow \text{Law of Diminishing Returns in Mfg}$

The “5σ Wall”

$5\sigma \rightarrow 6\sigma \rightarrow \text{Requires Product Designed for 6σ, DFSS}$

Customers don’t care about the Mfg Processes

Customers want Product Performance, Reliability & Durability

DFSS is Essential to Achieve Customer Satisfaction
Underlying Truism: Knowing what the customer needs

We don't know what we don't know, we can't act on what we don't know, we won't know until we search, we won't search for what we don't question, we won't question what we don't measure, and hence we just don't know.
Customer Service 101: Know what is “good” to your customer ... (VOC)

Ichiro Ishikawa:

“When I ask the designer what is a good car, what is a good refrigerator and what is a good synthetic fiber, most of them cannot answer. It is obvious they cannot produce good products.

You simply cannot design a good product or service if you do not know what “good” means to the customer.

The designer must create a map that moves the world of customer to the world of the designer”
Customers: how important are they?

- Customer loyalty for strategic partners is very important. Keeping an old customer happy is more fruitful than finding a new one. (It is easy to retain five satisfied customers than to find a new one.)
- One happy customer tells three people, 1 unhappy customer tells 20.
Voice of the Customer

Customer Satisfaction = f(Perception, Expectation)

Level 1: Features and Cost
Level 2: Quality
Level 3: Features, Cost, Quality, Delivery, … Value added

Customer value =

Higher Quality × Better Service

Lower Cost × Less Time

© Habib Siddiqui
Kano Model (a 2-d concept of quality)
And we often do ....

- Insane things.

Insanity (definition):
Continue to do things we have always done and yet expect to get different results.

Six sigma is about doing things the right way
DFSS Overview: Alternative Roadmap

A Specific Product Design Methodology where Customer Requirements Dictate the Critical Parameters and the Variability of the Critical Parameters are Optimized for Predictive Product Performance, Manufacturability, Reliability and Durability.

Define
Customer Requirements Based on Expectations, a.k.a: Voice of the Customer (VOC)

Identify
Critical-To-Quality (CTQ) Parameters, Set Technical Requirements & Quality Targets

Design
Concept Design, Develop Transfer Functions between CTQ’s and Design Spec’s… Y=f(x)

Optimize
Analyze & Optimize for Robust Performance, Predictive Manufacturability, and Reliability

Validate
Test & Validate Predictions, Assess Performance, Initial Capability Studies

© Habib Siddiqui
What’s Different About DFSS?

- Disciplined, comprehensive process
- Line of sight from customer CTQs to all design levels
- Statistical design to understand and reduce variation
- “New” tools: QFD, DOE, Robust Design, DFM, statistical tolerancing, multi-variable optimization, ...
- Quality prediction throughout development
Integrating DFSS with Stage-Gate/ NPI

<table>
<thead>
<tr>
<th>Tollgates</th>
<th>NPI Stages</th>
<th>DFSS Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marketing &amp; Concept Design</td>
<td>1. Business needs, Mkt reqts</td>
</tr>
<tr>
<td>2</td>
<td>Preliminary Design</td>
<td>2. Preliminary product specs</td>
</tr>
<tr>
<td>3</td>
<td>Detailed Design</td>
<td>2. QFD 1: Customer CTQs to tech reqts</td>
</tr>
<tr>
<td>4</td>
<td>Prototype &amp; Test</td>
<td>3. CTQ flowdown, Subsystem reqts &amp; transfer functions</td>
</tr>
<tr>
<td>5</td>
<td>Mfg Preparation</td>
<td>4. Improved transfer fcts: eng analysis &amp; DOE</td>
</tr>
</tbody>
</table>

**Product Specs**
- Business needs
- Mkt reqts
- Alpha drawings
- Rev 1 drawings
- Rev 2 drawings

**CTQs**
- Customer CTQs
- QFD 1: Customer CTQs to tech reqts
- CTQ estimates
- CTQ verification
- CTQ verification

**Systems Eng**
- System concept
- Functional block diagram
- CTQ flowdown
- Subsystem reqts & transfer functions
- Improved transfer fcts: eng analysis & DOE
- CTQ verification
- CTQ verification

**Design for Perf**
- Tech feasibility
- Prelim perf based on
- Prelim perf based on
- Tech feasibility
- Improved perf: eng analysis, DOE
- Improved perf: eng analysis, DOE
- Improved perf: eng analysis, DOE

**Design for Prod**
- Process concept
- Key process capability data
- Key process capability data
- Key process capability data
- Process capability data
- Process capability data
- Process capability data

**Quality Prediction**
- Quality targets
- Initial Z allocations & scorecard: opinion, entitlement
- Initial Z allocations & scorecard: prediction, capability data
- Initial Z allocations & scorecard: prediction, capability data
- Initial Z allocations & scorecard: prediction, capability data
- Initial Z allocations & scorecard: prediction, capability data
- Initial Z allocations & scorecard: prediction, capability data

**DFSS: Technical process - how product is designed**
- Stage-Gate/NPI: Bus/mgt process for new product dev
- Rows: Progressive refinement of DFSS elements
- Columns: Items required for tollgate review

© Habib Siddiqui
Practical Statistics

- The long-range contribution of statistics depends not so much upon getting a lot of statisticians into industry as it does in creating a statistically minded generation of physicists, chemists, engineers, and others who will have a hand in developing and directing the production processes of tomorrow.

  – W. A. Shewhart and W. E. Deming (1939)
Six Sigma ... A simple approach

The right projects
+

The right people
+

The right roadmap and tools
+

The right support
=

The right results
Business Results of Using Six Sigma

Higher yield & productivity
Lower cycle time
Less scrap & rework
Fewer warranties & recalls
Less fire fighting
Lower freight & RM costs
Operating consistency
Customer satisfaction
Inventory reduction
Customer loyalty
Bottom Line: Increase profits & market share

© Habib Siddiqui