Six Sigma for Non Normal Processes: A Case Study

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ASQ CMQ/OE, CSSBB, CQE, CQA
BCSP ASP, CSP, CET
“Quality has to be _______ not controlled.”
___ Phil Crosby

Bio

- Bachelor, Master, & Ph.D. from Arizona State University, USA
- Founder and General Manager, GLC
- Professor of Industrial & Management Systems Engineering.
- KFAS Prize Winner Scientific Production in Engineering Sciences in 2014
- Holds Quality Certifications: ASQ CMQ/OE, CSSBB, CQE, CQA, CSQP
- Holds Safety Certifications: BCSP ASP, CSP, & CET
- Consults and trains in quality, organizational excellence, and safety

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AGENDA

- Quality
- Six Sigma
- Six Sigma Performance
- Case Example: Normal Six Sigma
- Case Study: Non Normal Six Sigma
Quality is ....

Customer ________

Quality Starts and Ends with ... Customer

• Quality starts with identifying
  _____________

• Translating these customer needs into technical features on the products and services

Then

• Producing the products and services according to the specified features, and

• Quality ends with achieving ___________.

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The Three Principles of Quality

- *Customer* Driven
- *Process* focus
- *Variation* focus

The Quality Trilogy & SS

- Quality *Planning* ... Set the __________
- Quality *Control* ... Maintain __________ to standard
- Quality *Improvement* ... Challenge __________ & __________
Strategies of Performance Improvement

- _________ reduction
- _________ reduction

Cycle Time

38 days

Defective

Lean ... Issuing Commercial Licenses
“Six Sigma is a __________ program that when all is said and done, improves your customers’ experience, lowers your costs, and builds better leaders.”

___ Jack Welch, Former CEO of GE

Elements of LSS Project

- Teamwork
- Company-Wide Training (Belts)
- Statistics
- Lean & Quality Tools (Waste & Variation)
- Project Management

To some, what matters is the ___________; to others it is the ___________. In my opinion, it should be ___
LSS & Business

Customer Delight

Right Product/Service Features

Quality of Design

Product/Service Free of Deficiencies

Quality of Conformance

Variation and the Meaning of SS

Good operation ... 27 defects per 10,000 (3 Sigma)

Excellent operation ... 3.4 defects per 1,000,000 (6 Sigma lenient)

Ideal operation ... 2 defects per 1,000,000,000 (6 Sigma strict)
Why LSS Works?

1. __________ results
2. ______ management is involved
3. A __________ approach; DMAIC
4. _____ project completion times 3 to 6 months
5. ______ defined measures of success
6. Infrastructure of ______ individuals; belts
7. Focus on _______ and _______
8. Use of a sound __________ approach

Case Example: Six Sigma Normal

• The standard of a copper cylinder diameter is __________

• The supervisor wanted to check preliminarily on the quality of production; so he examined the diameters of the last 10 produced items (last two decimals).

13 22
16 16
25 19
22 17
16 20
Case Example: Dot Diagram

- The supervisor drew the Dot Diagram for the diameter values as follows:

```
13  22
16  16
25  19
22  17
16  20
```

Measures of Centrality: Mean, Median, Mode

The sample mean ($\bar{x}$) is

a. the middle value in an ordered data. For even data set, the median is the average of the two middle values.

b. the maximum value in a data set.

c. the most widely used measure for central tendency. It is the arithmetic average. It is the sum of all data values divided by the number of data points. It is an estimate of the population mean $\mu$.

d. the most frequently occurring number in the data set. A data set may have more than one mode.
Case Example: Mean & Accuracy

- The mean ($\bar{x}$) = 
- Show the mean on the dot diagram
- Accuracy = $|\text{Mean} - \text{Target}|$
  - $|____ - _____| = ________$
- Mode = ________
- Median = ________

13 22
16 16
25 19
22 17
16 20

Measures of Dispersion

The sample standard deviation $SD (s)$ is

a. the difference between the largest and smallest values in a data set.

b. the most widely used measure for analyzing dispersion. It measures the average deviations from the mean. It estimates the population standard deviation $\sigma$.

c. the standard deviation squared.

d. the standard deviation divided by the mean expressed as a percentage.
**Case Example: SD & Precision**

- The SD \((S)\) = __________
- Show the SD on the dot diagram.
- Precision = SD = __________
- \(S^2 = \) __________
- \(R = \) ______
- \(CV = \) ______

\[ S = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} \]

\[
\begin{align*}
13 & \quad 22 \\
16 & \quad 16 \\
25 & \quad 19 \\
22 & \quad 17 \\
16 & \quad 20 \\
\end{align*}
\]

**Case Example: Current Sigma Performance**

- The process quality is determined by the mean and SD. Process quality improves when:
  - the mean gets _______ to the target
  - the standard deviation _______
- In our example, the Sigma of our process is __________

\[
\begin{align*}
13 & \quad 22 \\
16 & \quad 16 \\
25 & \quad 19 \\
22 & \quad 17 \\
16 & \quad 20 \\
\end{align*}
\]
SS Sigma Level Metrics

- In SS, the process sigma level is calculated for ideal (i.e. no shift) and Motorola (i.e. 1.5σ shift allowance) methods.

- Motorola approximation:
  \[ \text{Sigma Level} = 0.8406 + \sqrt{29.37 - 2.221 \times \ln(ppm)} \]

- What is the sigma level of a process with a yield of 99.9930%?

  \[ = P(\text{defect}) = \quad \]
  \[ = \text{Sigma Level} = \quad \]

<table>
<thead>
<tr>
<th>Sigma Level</th>
<th>ppm (ideal)</th>
<th>ppm (Motorola)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sigma</td>
<td>317,300</td>
<td>697,700</td>
</tr>
<tr>
<td>2 Sigma</td>
<td>45,500</td>
<td>208,700</td>
</tr>
<tr>
<td>3 Sigma</td>
<td>2,700</td>
<td>66,810</td>
</tr>
<tr>
<td>4 Sigma</td>
<td>63</td>
<td>6,210</td>
</tr>
<tr>
<td>5 Sigma</td>
<td>0.057</td>
<td>233</td>
</tr>
<tr>
<td>6 Sigma</td>
<td>0.002</td>
<td>3.4</td>
</tr>
</tbody>
</table>

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Process Accuracy & Precision
Process Accuracy & Precision

Process Improvement Strategies
Case Example: Sigma Performance Improvement

• Assume a six sigma team studied the process of making copper rods over a 4-month period. They were able to improve the extrusion process and the multiple forming dies.

• This lead to reducing the sigma to half.

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Case Example: Sigma Performance Improvement

• The production manager was pleased with the new performance; however, he asked the team to improve further. So, the team – after further analysis – managed to fix the rotating spindle so it doesn’t deviate during the drawing process.

• This lead to moving the process mean closer to the nominal value.
What Sigma is Your Process?

Case Study: Research of SS Performance of Non Normal Processes

**How significant is the assumption of normality when the process is not normal?**

**Is the effort to achieve the six sigma goal of 3.4 ppm for a non-normal process the same as that of a normal?**

**How does a non-normal process affect the 6 Sigma methodology?**

**Research Team**
- Prof. Tariq A. Aldowaisan, Global Lead Consultants
- Prof. Mustapha Nourelfath, Laval University, Canada
- Dr. Jawad Hassan, Kuwait University
Case Study: OFI

Good operation ... 27 defects per 10,000 (3 Sigma)

Excellent operation ... 3.4 defects per 1,000,000 (4.5/6 Sigma)

Ideal operation ... 2 defects per 1,000,000,000 (6 Sigma)

Case Study: RFQ Process

- One-Sided (upper) Specification
- Not-Normal
Case Study: RFQ Process

Case Study: How Significant is the Normality Assumption?
Case Study: Flowcharting RFQ Process

Case Study: The RFQ Milestones

<table>
<thead>
<tr>
<th>RFQ Process Milestones</th>
<th>Non-spare Up to 5K</th>
<th>Non-Spare 5K – 30K</th>
<th>Spare Up to 5K</th>
<th>Spare 5K – 30K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Time to issue RFQ</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2 Time to bids’ closing date</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>3 Time to extended closing date</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>4 Time to evaluate bids</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>5 Time to prepare final recommendations</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6 Time to Award</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Cycle Time Deadline (Days)</td>
<td>38</td>
<td>45</td>
<td>52</td>
<td>59</td>
</tr>
</tbody>
</table>
Case Study: Process Analysis

Case Study: Root Cause Analysis

- Delay due to low value (less than KD.500/-)
- Delay due to missing documents
- Delay due to need for offer review by multiple divisions
- Delay due to many offers/documents for review and finalization
- Delay due to processing RFQ by buyer
- Delay due to no offer received (hence extending closing date)
- Delay due to request for technical clarifications from vendors
- User/CAT engineer delay in providing clarifications
- Delay due to-sales engineer/user in giving final comments
- Delay to price negotiations
- Delay in opening bids (senior/buyer)
- Delay due to many offers/documents for review and finalization
- Delay due to low value (less than KD.500/-)
Case Study: Improvement Methodology

Case Study: Standard & Deadline

Determine CT **standard** using scientific method

Determine CT **deadline** based on CT standard and benchmarks, if available

Determine **performance zones** based on CT standard and deadline

Revise BSC on RFQ Completed on time (%), where SMG is at 99.73% (i.e. 3σ)

Deadline

Zone A

680,000 ppm

Zone B

670,000 ppm

Zone C

47,300 ppm

2700 ppm
Case Study: Research of SS Performance of Non Normal Processes

How significant is the assumption of normality when the process is not normal?

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How does a non-normal process affect the 6 Sigma methodology?

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<td>2. Evaluating Six Sigma failure rate for inverse Gaussian cycle times</td>
<td>International Journal of Production Research (IJPR)</td>
<td>Published 2016</td>
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<tr>
<td>3. Six Sigma for Gamma-Distributed Process Cycle time</td>
<td>International Journal of Quality &amp; Reliability Management (IJQRM)</td>
<td>Accepted 2017</td>
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