GLASS WASTE AND VARIATION REDUCTION
BY APPLYING R-DMAIC-SI APPROACH

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Glass Waste and Variation Reduction by Applying R-DMAIC-SI Approach

Presented By:
Nadeem Alam
(Consulting Engineer-PIQC)

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2 What is RDMAICSI?
3 Why Six Sigma Way?
4 Six Sigma Phases - Implementation
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### Project Goals

**Improve PPM Level**

- **Goals**
  - To Reduce Wastage By Lowering Customer Returns
  - To Reduce Variation in the Glass Bottle (Weight)

### Case Study

<table>
<thead>
<tr>
<th>VARIATION</th>
<th>Indicator</th>
<th>Baseline</th>
<th>Target</th>
<th>Entitlement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range - Weight</td>
<td>Above 1.5</td>
<td>Less than 1.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>SD - Weight</td>
<td>Above 1</td>
<td>Less than 1</td>
<td>Less than 1</td>
</tr>
<tr>
<td></td>
<td>Cpk - Weight</td>
<td>1.28</td>
<td>Maintain more than 1</td>
<td>1.33</td>
</tr>
</tbody>
</table>

**WASTAGE**

- Customer Returns (PPM)
  - Baseline: 10,000
  - Target: 0
  - Entitlement: 0
2  What is RDMAICSLI?

R - Recognize
Get recognition from the Executive Management

D - Define
Set the goals, scope and the identification of issues that need improvement

M - Measure
Measure current situation and identify problem areas

A - Analyze
Analyze root causes and confirm those causes using appropriate tools

I - Improve
Implement solution that address root causes identified during the analyze phase

C - Control
Evaluate and monitor the results of the previous phase

S - Standardize
Standardize the improved situation using appropriate document

I - Integrate
Integrate the approach with other systems and identify other improvement opportunity

3  Why Six Sigma Way?

External Thrust

Internal Improvements

Competitive Edge

Business Success (Pande, 2000)

- Cost Reductions
- Defect Reductions
- Cycle-time Reductions
- Market Share Growth

- Improved Productivity
- Improved Customer Relations
- Improved Product
- Cultural Change
Six Sigma Phases - Recognize

- E-Proposal of Six Sigma Project
- Six Sigma Project Team
- Action Plan for Training
- Will the management recognize and support the initiative?
- Has the team been defined?
- Do they have enough awareness on statistical tools?
- Formal Project Approval
- Project Team Formation
- Trained Team Members
Six Sigma Phases - Define

- Voice Of Customer (VOC)
- Critical-to-Quality (CTQ)
- Project Charter
- Project Title
- Problem Identification
- Problem Statement
- Baseline, Target & Entitlement

Define Phase

---

Six Sigma Phases - Define

**Tools**

- Customer Audit Report
- Project Charter
- Quality Function Deployment - QFD
- What is important to the customer?
- How can we translate VOC into our language (CTQs)?
- What are the problem and project goals?
- How does it relate to the business case?
- What is the scope, baseline, target, start and finish timeline?

**Output**

- Defined Project Scope, Goals and Plan
- Identified CTQ
- Defined Measurement Metrics
Six Sigma Phases - Define

<table>
<thead>
<tr>
<th>Customer Needs (WHAT)</th>
<th>Design Considerations (HOW)</th>
<th>Internal Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Material Composition</td>
<td>0.3</td>
</tr>
<tr>
<td>Color</td>
<td>Model Dimensions</td>
<td>0.3</td>
</tr>
<tr>
<td>Threads</td>
<td>Environmental Temperature</td>
<td>0.3</td>
</tr>
<tr>
<td>Attribute Defects</td>
<td>Product Temperature</td>
<td>0.3</td>
</tr>
<tr>
<td>Bottle Dimension</td>
<td>Manufacturing Process</td>
<td>0.3</td>
</tr>
<tr>
<td>Bottle Diameter</td>
<td>Design</td>
<td>0.3</td>
</tr>
<tr>
<td>Bottle Strength</td>
<td>Standard Deviation</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Ratings: High, Medium, Low

Target Values

- Capacity: 6
- Color: 4
- Threads: 6
- Attribute Defects: 3
- Bottle Dimension: 4
- Glass Distribution: 4
- Bottle Strength: 6

Unit: (gm), (%), (mm), (°C), (°C)

Six Sigma Phases - Measure

- Process Mapping
- Dimensional Measurement
- Reproducibility & Reproducibility
- Glass Weight - Mean
- Glass Weight - Variation
- Process Capability Index
- PPM Level

MEASURE PHASE
Six Sigma Phases - Measure

**Tools**
- Process Flow Chart
- GRR
- Glass Weight (Mean, Std. Dev., Range)
- Measure Cpk and PPM

**Justification**
- Which process needs attention?
- Is the data discrete or continuous?
- Is the ability to measure data good enough? What are the sources of variation?
- What are the existing capability and rejection level?

**Output**
- Identified Key Process - Forming
- Verified measurement system
- Measured existing performance

Glass Manufacturing Processes

1. Batch Preparation of Raw Materials
2. Melting in a Furnace
3. Glass Forming
4. Annealing
Six Sigma Phases - Measure

GRR Study at G2-II

<table>
<thead>
<tr>
<th>Gage name:</th>
<th>Electronic Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of study:</td>
<td>May 9, 05</td>
</tr>
</tbody>
</table>

**Components of Variation**

- Percent
  - Gage:
  - Repeatability:
  - Repeatability:
  - Part to Part

**Measurement by Part**

- Part 1: 50
- Part 2: 55
- Part 3: 60
- Part 4: 65

**Measurement by Operator**

- Operator A: 50
- Operator B: 55
- Operator C: 60

**Xbar Chart by Operator**

- Sample Mean
  - Operator A: 50.0
  - Operator B: 55.0
  - Operator C: 60.0

**Operator * Part Interaction**

- Interaction

---

Six Sigma Phases - Measure

**Glass Weight - Mean**

**Time Series Plot of Xbar-1 (Apr 05-May 05, 2005)**

- xbar-1: 100.83
- Mean for the month is found to be 102.83 gms.
Six Sigma Phases - Measure

Glass Weight-Range

Time Series Plot of R-2 (Jul 5 - Aug 2)

Range for the month is found to be 1.4 gms

Glass Weight-Standard Deviation

Time Series Plot of SD-1 (Apr 5 - May 5, 2005)

Some data points are crossing one-sigma level
Six Sigma Phases - Measure

Glass Weight-Range

Time Series Plot of R-2 (Jul 5 - Aug 2)

Range for the month is found to be 1.4 gms

Six Sigma Phases - Measure

Glass Weight-Standard Deviation

Time Series Plot of SD-1 (Apr 5 - May 5, 2005)

Some data points are crossing one-sigma level
Six Sigma Phases - Measure

Glass Weight Cpk

Time Series Plot of Cpk-2 (Jul 5 - Aug 2)

For the year 2004-05, PPM level is 10,000

In this case, only the reduction in process variation can make the process capable.

Six Sigma Phases - Analyze

- Analysis of Graphs
- ANOVA for variation
- Cause and Effect Diagram
- Why-Why Analysis

- What are the trends of graphs?
- Which is the biggest source of variation?
- Which KPIVs affect KPOV?
- What is the root cause?

- Identified root cause and KPIVs
- Identified biggest source of variation
- Analyzed graphs for improvement
Six Sigma Phases - Analyze

Two-Way ANOVA Table With Interaction (GRR Study)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
<td>9</td>
<td>388.622</td>
<td>43.1802</td>
<td>2057.41</td>
<td>0.000</td>
</tr>
<tr>
<td>Operator</td>
<td>2</td>
<td>0.067</td>
<td>0.0333</td>
<td>1.50</td>
<td>0.232</td>
</tr>
<tr>
<td>Part * Operator</td>
<td>18</td>
<td>0.378</td>
<td>0.0210</td>
<td>0.94</td>
<td>0.532 (P&gt;0.25)</td>
</tr>
<tr>
<td>Repeatability</td>
<td>60</td>
<td>1.333</td>
<td>0.0222</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>390.400</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Two-Way ANOVA Table Without Interaction (GRR Study)

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
<td>9</td>
<td>388.622</td>
<td>43.1802</td>
<td>1968.35</td>
<td>0.000 (P&lt;0.05)</td>
</tr>
<tr>
<td>Operator</td>
<td>2</td>
<td>0.067</td>
<td>0.0333</td>
<td>1.52</td>
<td>0.225</td>
</tr>
<tr>
<td>Repeatability</td>
<td>78</td>
<td>1.711</td>
<td>0.0219</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>390.400</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Six Sigma Phases - Analyze**

<table>
<thead>
<tr>
<th>Source</th>
<th>% Contribution</th>
<th>(%Study Var.)</th>
<th>(% Tolerance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gage R&amp;R</td>
<td>0.46</td>
<td>6.81</td>
<td>22.41</td>
</tr>
<tr>
<td>Repeatability</td>
<td>0.46</td>
<td>6.75</td>
<td>22.22</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>0.01</td>
<td>0.89</td>
<td>2.92</td>
</tr>
<tr>
<td>Operator</td>
<td>0.01</td>
<td>0.89</td>
<td>2.92</td>
</tr>
<tr>
<td>Part-To-Part</td>
<td>99.54</td>
<td>90.77</td>
<td>328.47</td>
</tr>
<tr>
<td>Total Variation</td>
<td>100.00</td>
<td>100.00</td>
<td>329.24</td>
</tr>
</tbody>
</table>

Number of Distinct Categories = 20

*From AIAG Acceptance Guidelines*

- % Contribution should not be >= 9%
- % Study Variation should not be >= 30%
- % Tolerance should not be >= 30%
- Number of Distinct Categories should not be <= 5
Six Sigma Phases - Analyze

<table>
<thead>
<tr>
<th>Why</th>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Why some values have Cpk less than 1?</td>
<td>Because of the large process standard deviation and mean</td>
</tr>
<tr>
<td>2</td>
<td>Why process mean values cannot be at target</td>
<td>Because of the mould wear, it is inevitable to keep the process mean at one point. For this particular project (120 ml bottle) the life of the mould is 7.5 million parts production. After attaining this line, mould is not capable to produce good parts. Hence, drift cannot be controlled. This results in lowering Cpk values with the passage of time. However, process variation can be controlled to maintain Cpk more than 1.</td>
</tr>
<tr>
<td>3</td>
<td>Why all the range values are above one and</td>
<td>In all the three shifts, technicians set the process parameters by hit n trial to get the desired bottle capacity, irrespective of the weight. That's why the variation exists in weight. There isn't any defined level of the parameters so that the variation could be minimized.</td>
</tr>
<tr>
<td></td>
<td>some standard deviation values are also not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>within one sigma?</td>
<td></td>
</tr>
</tbody>
</table>

Case Study

Cause and Effect Diagram

- Measurements: Calibration, HSA Study, Trained Inspector
- Material: Cubist Washing, Composition, Density, Contamination
- Personnel: Competence, Training, Attitude, Sluggish, Motivation

Factors: Manual Control, Maintenance, Tool Tear, Tool Wear

Cause Weight

Environment: Temperature, Humidity

Methods: Reference Standard, Parameters Setting, Operator Instructions

Machines: Calibration, HSA Study, Trained Inspector

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Six Sigma Phases - Improve

Evolutionary Operation (EVOP)
- Data collection
- Results analysis
- Optimal setting

What should be the strategy for improvement?
- Which KPIVs have significant affect on KPOV?
- How to set up KPIVs to optimize process?

Optimal factor-level combination
- Reduced variation
- Improved capability

EVOP Implementation Steps

6. Define Reference Standard
5. Identify and Confirm Optimal Setting
4. Results Analysis for Further Progression
3. Gather Data
2. Identify Process KPIVs / KPOV
1. Identify Practical Problem
Six Sigma Phases - Improve

1. Identify Practical Problem
   How to set up the machine to minimize variation in the process?

2. Identify KPOV / KPIVs
   Output: Bottle Glass Weight (mg)
   Inputs: Front Temperature (°C) and Rear Temperature (°C)

Six Sigma Phases - Improve

3. Gather Data
   Designed EVOP data sheet

4. Results Analysis (further progression)
   Table 1: Factors and Levels
   Table 2: Phase 1, Cycles (1 to 2)
   Table 3: Phase 1, Cycles (1 to 3)
### Six Sigma Phases - Improve

**Case Study**

#### Table 1

<table>
<thead>
<tr>
<th>Factor</th>
<th>High (+)</th>
<th>Low (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Front Temperature (C)</td>
<td>11.25</td>
<td>11.11</td>
</tr>
<tr>
<td>B - Rear Temperature (C)</td>
<td>12.55</td>
<td>12.45</td>
</tr>
</tbody>
</table>

#### Table 2

<table>
<thead>
<tr>
<th>Run</th>
<th>A</th>
<th>B</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>-1</td>
<td>+1</td>
<td>105</td>
<td>105</td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>+1</td>
<td>-1</td>
<td>105</td>
<td>105</td>
<td>105.5</td>
<td>0.767</td>
</tr>
<tr>
<td>4</td>
<td>-1</td>
<td>+1</td>
<td>107</td>
<td>105</td>
<td>105</td>
<td>1.414</td>
</tr>
</tbody>
</table>

#### Table 3

<table>
<thead>
<tr>
<th>Run</th>
<th>A</th>
<th>B</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>104.33</td>
<td>0.577</td>
</tr>
<tr>
<td>2</td>
<td>-1</td>
<td>-1</td>
<td>105</td>
<td>105</td>
<td>105</td>
<td>104.66</td>
<td>0.577</td>
</tr>
<tr>
<td>3</td>
<td>+1</td>
<td>-1</td>
<td>106</td>
<td>105</td>
<td>105</td>
<td>105.33</td>
<td>0.577</td>
</tr>
<tr>
<td>4</td>
<td>+1</td>
<td>-1</td>
<td>107</td>
<td>105</td>
<td>105</td>
<td>105.65</td>
<td>1.155</td>
</tr>
</tbody>
</table>
Six Sigma Phases - Improve

5. Optimal Settings

- A = 1118 °C (Front Temperature)
- B = 1245 °C (Rear Temperature)

6. Reference Standard

Control Plan
S P C

Six Sigma Phases - Control

- Statistical Process Control
- Measure of Location
- Measure of Variation
- Capability Monitoring
- How to control the gains?
- How to monitor variations?
- How to monitor capability?
- How to monitor location?
- SPC Graphs
- Status of Process Control
- Capability Values
Six Sigma Phases - Standardize

- Control Plan
  - Control Parameter
  - Tolerance
  - Method of Control

- How will gains be maintained?
- How can we standardize KPIVs?
- Are all the shifts following the same methodology?

- Improved Control Plan
- Reference Line for the Operators
- Harmonization among Shifts

Six Sigma Phases - Integrate

- Flat Glass Section & Other Parameters
  - Glass Thickness
  - Bottle Diameter
  - Bottle Height

- Have any similar process been identified?
- Have any other critical characteristic been identified?
- Have the opportunities been communicated?

- Other Opportunities for Improvement
- Dissemination of the Concept
- Company-wide Application
5 Conclusion

From this Project, Observed Tangible Benefits:

✓ An estimated saving per annum is more than one-million rupees (i.e. Rs.1,265,232/-)
✓ Targets for the variation reduction (range and standard deviation) have been achieved
✓ PPM went down to zero since no returns have been observed during three months (study period)

From this Project, Observed Intangible Benefits:

✓ Improved Customer Satisfaction
✓ Improved Monitoring
✓ Improved data analysis tools applications
✓ Structured Problem Solving Approach
✓ Six Sigma Awareness

6 Recommendations

Key factors for a six sigma project:

s Support and approval of executive management
s Major importance to the organization
s Link to the business priorities
s Reasonable scope
s SMART Quantitative measure of success

Impediments to the project:

s Team not trained or involved
s Team too large
s Project scope too large
s No clear measure of success
s BB and team not given time to the project
s Objectives not important to the organization