Innovation & DFSS (Design for Six Sigma) - An Introduction

September 20, 2012

Presented by Sharon Gregory

ASQ Dinner Presentation & Webinar
Sharon Gregory is the founder and president of Hexagon Solutions and Beyond (HexSAB), established almost twelve years ago. She provides customized Lean Six Sigma training and project consulting services for organizations dedicated to process improvement. She helps her clients implement Lean Six Sigma to achieve business results through training, statistical design and analysis techniques, project management, and team building leadership skills. Her passion for Lean Six Sigma is clearly demonstrated through her enthusiastic, practical, and interactive style. A few of Sharon’s clients include Alstom Power Conversion, American Cap Company, Bombardier, Carnegie Mellon University, Catalyst Connection, JLG Industries, JWF Industries, Kepner-Tregoe, Lake Region Medical, McNeilus Truck/Oshkosh Corp., MEDRAD, Mine Safety Appliances, North Side Foods, Pace Industries and SingTel Optus.

A former high-school mathematics teacher, Sharon has a bachelor’s and master’s degree in mathematics education. She is a Six Sigma Master Black Belt with over 15 years of experience in applying and teaching Lean Six Sigma. As a practitioner for companies including Whirlpool, PPG, and Eaton, she facilitated significant cost saving projects, process improvements, and Six Sigma implementations.

Sharon is just returning to Pittsburgh after a successful two-year project for a large telecommunications company in Australia. In this role, she gained tremendous experience with developing, customizing and delivering all levels of leadership and practitioner Lean Six Sigma training, including Design for Six Sigma for Services, to be suitable for a services industry.

Sharon allocates her time between classroom training, course development, and hands-on project based consulting. She brings to her clients’ executive boardroom and shop-floor, technical and hands-on knowledge in painting, molding, assembly, power distribution, medical devices, telecommunications and other manufacturing and business processes.

Sharon also owns and operates Sigmas Conference and Event Center, a top-notch venue for hosting corporate meetings and trainings and upscale social banquet events.
Presentation Agenda

• Facilitate a “hands-on” design exercise that encourages teams to experience simple but profound lessons in collaboration, innovation and creativity
  - “The Marshmallow Challenge”
• Understand the concept & definition of Design for Six Sigma (DFSS) and the motivation for its use including:
  - Principles, Benefits & Applications
  - Compare “Design for Six Sigma” to “Process Six Sigma”
• Discuss DFSS methodologies
  - Summarize selected DFSS methodologies
    ▪ DMADOV, IDOV, DCCDI, DMEDI
    ▪ **DMADV (Define, Measure, Analyze, Design, Verify)**
      - Describe the DMADV phases
  - Learn differences between DMAIC* & DMADV
    (* DMAIC – Define, Measure, Analyze, Improve, Control)
• Handout references - Roadmaps
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The Marshmallow Challenge

- Objectives
- Supplies
- Instructions
- The Challenge!
Objectives

• The Marshmallow Challenge is a “hands-on” design exercise that encourages teams to experience simple but profound lessons in collaboration, innovation and creativity

  – This challenge has been conducted by tens of thousands of people in every continent, from the CFOs of the Fortune 50 to students at ALL levels. The lessons learned are universal and will set the stage for our Design for Six Sigma (DFSS) introduction!

• In 18 minutes, each team must build the tallest free-standing structure out of 20 sticks of spaghetti, one yard of tape, one yard of string, and one marshmallow. The marshmallow, in whole form, needs to be on top.
Supplies

• Each “Kit” contains the following:
  - 20 sticks of spaghetti
  - 1 yard of masking tape
  - 1 yard of string
  - 1 marshmallow
Instructions

• Build the tallest freestanding structure
  – The winning team is the one that has the tallest structure measured from the table top surface to the top of the marshmallow
    ▪ That means the structure cannot be suspended from a higher structure, like a chair, ceiling or chandelier
• The entire marshmallow must be on top
  – The entire marshmallow needs to be on the top of the structure
    ▪ Cutting or eating part of the marshmallow disqualifies the team
• Use as much or as little of the provided kit
  – Use as many or as few of the 20 spaghetti sticks
  – Use as much or as little of the string or tape
  – Cannot use the container for the kit items as part of the structure
• Teams are free to break the spaghetti and/or to cut up the tape and/or string
• The challenge lasts **EXACTLY 18 minutes**
  – Teams cannot hold on to the structure when the time runs out
    ▪ Those touching or supporting the structure at the end of the exercise will be disqualified
The Winner Is...

- Everyone will be seated for the **Measuring of the Structures**
  - Heights will be recorded on the flipchart
- The team with the highest freestanding structure (made according to the design requirements) will be rewarded with a standing ovation!

Let’s Begin!
Results: Kids Out-Perform Business Students

• Kids do better than business students!
  – On virtually every measure of innovation, kindergarteners create taller and more interesting structures
Prototyping Matters

- The business school students spend a vast amount of time planning, then executing on the plan, with almost no time to fix the design once they put the marshmallow on top.

- The reason kids do better than business school students is kids spend more time playing and prototyping.
  - They naturally start with the marshmallow and stick in the sticks.

![Diagram of prototyping process]

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The Hidden Assumptions of a Project

- The marshmallow is a metaphor for the hidden assumptions of a project
  - The assumption in the Marshmallow Challenge is that marshmallows are light and fluffy and easily supported by the spaghetti sticks
  - However when team’s actually try to build the structure, the marshmallows don’t seem so light!
  - The lesson in the marshmallow challenge is that we need to identify the assumptions in our project:
    - the real customer needs
    - the cost of the product
    - the duration of the service
      - and test them early and often

These are the mechanisms that lead to effective innovation and the motivation for DFSS!
Summary of Lessons Learned - Reference

• Comments from a facilitator of the exercise, Tom Wujec:
  http://www.marshmallowchallenge.com/Welcome.html
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Design for Six Sigma (DFSS)

What does DFSS mean to YOU?
What Is Design for Six Sigma (DFSS)?

- DFSS is a process for
  - Addressing concerns/problems at the product, service and/or process development stage
  - Eliminating errors before they are introduced to the market/customers via products or services
  - Incorporating the Voice of the Customer (VOC) for quality products, services and/or processes

DFSS is a process for designing for the best customer experience!
Key Principles for DFSS Method

• All areas within an organization to simultaneously design the product, service and/or process to minimize future problems

• Design the product, service and/or process to minimize variability in critical to quality characteristics (CTQs) important to customers and maximize customer satisfaction

• Design a process capable of delivering the quantity and quality of products or services desired by customers in a timely fashion

• Include suppliers early in the design process
DFSS Creates Designs That Are

- Based on stakeholder/customer needs and wants
- Resource efficient
- Minimal in complexity
- Capable of generating high yields
- Robust to process variations
- Quick to generate a profit
DFSS Benefits

- Launching projects on time and on budget
- Reaping additional incremental revenues sooner
- Achieving greater market share
- Minimizing problems uncovered at launch
- Improving ability to reduce rework
- Ensuring quality and efficient services through data-driven scorecards
- Differentiating products, services and processes due to a customer focus
Application of DFSS - Examples

- **Product**
  - Design a lighter-weight, more-durable & portable mobile broadband device
  - Design a state-of-the-art meeting room with leading & user friendly technology

- **Service**
  - Design a better benefits package for the employees
  - Design meeting package offerings for corporate clients

- **Process**
  - Design a more cost effective, error-free, faster internet service activation system
  - Design a process to identify obsolete service plans and transition customers from the obsolete plans to ‘new’ plans
  - Design a process to generate error-free, faster quotes to customers inquiring about service offerings
Back to Basics: “Process” Six Sigma

• A management philosophy that focuses on eliminating mistakes and reducing variation from existing processes
  - A “defensive” strategy because it focuses on doing the many things you’re already doing… but doing them better, with fewer mistakes & faster

• A strategic problem solving methodology to improve the customer experience and the business metrics
  - Teaches employees how to improve the way they do business & maintain the new level of performance over time

• Promotes discipline, structure, and a foundation for sound decision making based on simple statistics and project/change management techniques
  - Improves the customer experience which results in increased business benefits

We’ll refer to “Process” Six Sigma as simply “Six Sigma”
The Six Sigma “Wall”

- A company can only get so far by picking “low hanging fruit”
  - Choosing Six Sigma projects to correct the biggest problems that yield the greatest savings and customer satisfaction is a GREAT start!
    - But eventually, tougher issues will need to be tackled
    - As process knowledge is gained from process Six Sigma efforts, focusing on design improvement is a natural next step

Companies wanting to reach the next level of performance and efficiency turn towards DESIGN FOR SIX SIGMA (DFSS) if they didn’t start there!
Which Comes First?

• “Process” Six Sigma (i.e. Six Sigma to improve existing processes) is NOT a prerequisite for DFSS
  
  – It may be easier to be able to quantify direct “savings” from “process” Six Sigma which is why it is often the first approach implemented

    ▪ DFSS may need to take more of a “Leap of Faith” attitude!

DFSS is not a re-packaging of lessons learned in Six Sigma but rather a fundamentally different approach to business
Improve Design or Existing Processes?

- Focus on design!
- Process improvement is often the result of ineffective product/process development
- If the design is correct, process improvement will not need to be the focus!

Six Sigma helps us to learn WHY something is broken and WHERE it is broken to attack the problem at its source instead of simply putting on a band-aid. However, it doesn’t address the original DESIGN of the process (or product); it merely improves on them.
Six Sigma vs. DFSS

• DFSS complements the Six Sigma improvement methodology, but DFSS takes it one step “back”…to learn about the flaws of the product/process during the upstream design stage, NOT the quality control or servicing customers stage

• Six Sigma focuses on improving existing designs for processes, services or products, DFSS concentrates on creating new and better ones!

Instead of “debugging” a process that already exists, DFSS starts from the beginning to design the process to be error-free in the first place!
DFSS Requires a Shift of Focus!

- Traditionally, companies spend only about 5% of their budget on design, yet design typically would determine 70% of the cost of the product or process!
  - 80% of all quality problems are inadvertently designed into the product or process itself!
Focus on Upstream Problem Prevention

• This requires that the time is taken to learn what the customers really want and then use this information to meet the needs of the customers

Products, services and processes need to be designed with the end in mind, which is the CUSTOMER EXPERIENCE!
Importance of DFSS

- Choosing not to invest time in improving the product/process development process would be appropriate only if:
  - You have now and will never have any competition (i.e., you are in a permanent monopoly situation), and
  - Your customers must, out of necessity for all time, continue purchasing your service(s) in sufficient quantity that your company can continue to make adequate profit even in the face of cost inflation
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DFSS Methodology

- A Design for Six Sigma (DFSS) methodology is appropriate when the goal is to design a new process, service or product for Six Sigma quality

- **Apply a DFSS methodology, such as DMADV (explained on the following slide) if**

  1. A product or process or service is not in existence and one needs to be developed OR

  2. The existing product or process or service exists and has been optimized (using DMAIC or other techniques) and still doesn’t meet the level of customer specification or Six Sigma level of quality
DFSS Methodologies

- DMADOV
  - Define, Measure, Analyze, Design, Optimize & Verify
- IDOV
  - Identify, Design, Optimize & Validate
- DCCDI
  - Define, Customer, Concept, Design & Implementation
- DMEDI
  - Define, Measure, Explore, Design & Implement
- DMADV
  - Define, Measure, Analyze, Design & Verify
Summary of the DMADV Methodology

- Define the project objective and scope; develop the business case
- Measure and determine customer needs and translate them into CTQs (critical-to-quality) characteristics
- Analyze the process options/design concepts to meet the customer needs
- Design the process to meet the customer needs & prepare for a pilot
- Verify the design performance through testing and its ability to meet customer needs
DMAI C

**DEFINE the project:**
- Develop a clear definition of the project
- Collect background information on the current process & the customers’ needs/requirements

**MEASURE the current situation:**
- Validate the measurement systems
- Gather data/information on the current situation to provide a clearer focus for the improvement effort

**ANALYZE to identify root causes:**
- Identify the root causes of defects
- Confirm them with data

**IMPROVE**
- Develop, test and implement solutions that address root causes
- Use data to evaluate results for the solutions and the plans used to carry them out

**CONTROL**
- Maintain the gains that have been achieved by standardizing work methods or processes
- Anticipate future improvements and make plans to preserve the lessons learned from this improvement effort

DMADV

**DEFINE the project:**
- Develop a clear definition of the project.
- Develop organizational change plans, risk management plans and project plans

**MEASURE the customer requirements:**
- Collect VOC (Voice of the Customer) data
- Translate the VOC into design requirements (CTQs)
- Identify the most important CTQs
- Develop a phased approach, if needed

**ANALYZE to identify concepts:**
- Generate, evaluate and select the concept that best meets the CTQs within budget & resource restraints

**DESIGN**
- Develop the high-level and detailed design
- Test the design components
- Prepare for pilot and full-scale deployment

**VERIFY design performance:**
- Conduct the pilot, and stress-test and debug the prototype
- Implement the design
- Transition responsibility to the appropriate people in the organization
- Close the team
DMAIC vs. DMADV

DMAIC

Inputs → Process → Outputs

What are the key drivers in the process that can be affected to improve performance relative to the Critical to Quality (CTQ) characteristics?

DMADV

Inputs → Outputs

What are the key drivers in the processes that can be designed to produce the products and services?

What products and services can be designed to satisfy the CTQ's?

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Is the project opportunity a business need?

- Yes:
  - Is it an existing process, product or service?
    - Yes:
      - Does it meet customer needs?
        - Yes: Process Management
        - No: Process Management
    - No: DMADV

- No: Process Management

Is incremental improvement enough?

- No: Process Management
- Yes: DMAIC

Is the solution a new process, product or service?

- No: Improve
- Yes: DMAIC

Improve

Define

Measure

Analyze

Control

Process Management

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DMADV vs. DMAIC High-Level Tools Summary

- **Tool Similarities**
  - Project Charter (though some different components)
  - Thought Map
  - Stakeholder Analysis
  - Measurement System Evaluation (MSE)
  - Control Charts
  - Design of Experiments (DOE)
  - Regression
  - Control plans

- **Tool Differences**
  - Multi-Generational Project Plan (MGPP)
  - Kano Analysis
  - Quality Function Deployment (QFD)
  - Design Scorecard
  - Benchmarking
  - Pugh Matrix
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# DMAIC Tools Summary

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* NOTE: Lean Tools (5S, Visual Mgmt., Standardization, etc.) may be used throughout DMAIC when appropriate!
## DMADV Tools Summary

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**Note:** Manage Change Throughout the Project
A DMAIC Roadmap

**Define**
- Define Voice of Customer.
- Determine/document the critical characteristics of the transaction/service at the final stage (the “BIG Y’s”).
- Identify Scope (In/Out of Frame) and define metrics (Pareto, data collection).
- Baseline the Y’s, the final product/service critical characteristics (Cpk, $\sigma^2$, average, error rate, etc.), through SPC/control charts.
- Establish goals for the final output’s improvement (in line w/business objectives).
- Establish team (this may change over time as more is learned about the process).
- Begin writing project contract (charter) to document project and SIPOC to clarify scope.

**Measure**
- Begin process map; revise contract and VSM if relevant; update thought map.
- Identify/prioritize process steps.
- Establish relationship between in process transaction/service parameters (y’s) and process parameters (x’s).
- Document x’s, y’s and Y’s (process map, C&E, PFMEA).
- Confirm measurement systems (MSE) for “Big Y’s”.
- Baseline the Y’s, the final product/service critical characteristics (Cpk, $\sigma^2$, average, error rate, etc.), through SPC/control charts.
- Begin to formulate hypotheses that will be tested in the Analyze phase.

**Analyze**
- Continue to update thought map. Begin to understand the x’s of interest (those captured on process map, and may have been “filtered” through C&E, PFMEA).
- Determine where the variation is (i.e. where to work) through SPC, ANOVA studies; update thought map.
- Plan DOEs (consult thought & process map) or other appropriate sampling plans to test the hypotheses to determine the CRITICAL x’s (What questions are you trying to answer?)
- Conduct DOE/Gather data for the hypothesis testing.
- Analyze* DOE (or specific data collection or regression) and make recommendations for the next steps which may lead to decision for next DOE and/or further data collection.

**Improve**
- Continue to learn Y = f(x); update thought map.
- Use appropriate Lean improvement tools (5S, visual management, Kaizen) to achieve improvements suggested through the analyses.
- Conduct optimization studies through confirmation data collection.
- Plan & conduct Pilots; Verify changes had impact (ANOVA, control charts, etc.).
- Learn Y = f(x), and make recommendations for improvements through models (regression).
- Ensure models and operating parameters/procedures will be implemented by appropriate people.
- Ensure site process owners recognize their responsibility for process improvement and measurement systems sustainability.

**Control**
- Establish control and capability monitoring schemes through data collection plans; update thought map.
- Formalize control plan; establish procedures (SOP), link to ISO (include reaction plans) or other internal quality mgmt. system.
- Plan & conduct Pilots; Verify changes had impact (ANOVA, control charts, etc.).
- Establish plans to ensure measurement systems are stable; be sure they will be implemented by appropriate people.
- Create & implement training and communication plans.
- Ensure site process owners recognize their responsibility for process improvement and measurement systems sustainability.
- Add project to local “scorecard” (to track savings, improvements, etc.).

**Abbreviations:**
- VSM - Value Stream Mapping
- MSE - Measurement System Evaluation
- Cpk - Capability Index
- $\sigma^2$ - Variation (sigma squared)
- SIPOC - Suppliers, Inputs, Process, Outputs, Customer
- C - Controllable
- N - Noise
- S - Standard procedure
- RACI - Responsible, Accountable, Consulted, Informed
- C&E - Cause and Effect
- PFMEA - Potential Failure Mode and Effects Analysis
- SPC - Statistical Process Control
- 5S - Standardize, Sort, Set in Order, Shine, Sustain
- ANOVA - Analysis of Variance
- DOE - Design of Experiments
- SOP - Standard Operating Procedure
- ISO - International Organization for Standards
- 5S - Standardize, Sort, Set in Order, Shine, Sustain

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*Practically, Graphically, Analytically

Continuously improve!
**A DMADV Roadmap**

<table>
<thead>
<tr>
<th>Define</th>
<th>Measure</th>
<th>Analyze</th>
<th>Design</th>
<th>Verify</th>
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<tbody>
<tr>
<td>1. <strong>Project team developed</strong>&lt;br&gt;2. Business case created&lt;br&gt;3. Project objective &amp; scope defined&lt;br&gt;4. Multi-Generational Project Plan (MGPP) started&lt;br&gt;5. Project plan initiated&lt;br&gt;6. Document control system established&lt;br&gt;7. Risk reduction plan commenced</td>
<td>1. Prioritized list of CTQs and CTPs (Critical to Process)&lt;br&gt;2. Risk management plan&lt;br&gt;3. Requirements for each CTQs and CTPs; Validation of their measurement processes&lt;br&gt;4. Design scorecard initiated&lt;br&gt;5. IP, patents &amp; trademarks understood&lt;br&gt;6. Thought Map &amp; MGPP updated</td>
<td>1. High-level design concepts for each CTQ and high-level CTP are generated &amp; prioritized&lt;br&gt;2. Best parts of the prioritized design concepts are combined to create a few best-design concepts for study &amp; risk assessment&lt;br&gt;3. Best design concept selected&lt;br&gt;4. Thought Map &amp; MGPP updated</td>
<td>1. A detailed design is constructed&lt;br&gt;2. CTPs have operational definitions&lt;br&gt;3. Measurement systems are validated and documented for CTPs&lt;br&gt;4. Baseline CTP capabilities are established&lt;br&gt;5. Pilot planned to verify the detail design with control considerations&lt;br&gt;6. Thought Map &amp; MGPP updated</td>
<td>1. “Prototype” created &amp; tested (i.e. pilot)&lt;br&gt;2. Design reviews conducted and documented with the design scorecard&lt;br&gt;3. Feasibility to move forward to full-scale implementation is determined&lt;br&gt;4. Full-scale process/service is implemented &amp; verified through data&lt;br&gt;5. Control plan instituted&lt;br&gt;6. Thought Map &amp; MGPP updated</td>
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**Key Deliverables**

**Define**
1. Project team developed
2. Business case created
3. Project objective & scope defined
4. Multi-Generational Project Plan (MGPP) started
5. Project plan initiated
6. Document control system established
7. Risk reduction plan commenced

**Measure**
1. Prioritized list of CTQs and CTPs (Critical to Process)
2. Risk management plan
3. Requirements for each CTQs and CTPs; Validation of their measurement processes
4. Design scorecard initiated
5. IP, patents & trademarks understood
6. Thought Map & MGPP updated

**Analyze**
1. High-level design concepts for each CTQ and high-level CTP are generated & prioritized
2. Best parts of the prioritized design concepts are combined to create a few best-design concepts for study & risk assessment
3. Best design concept selected
4. Thought Map & MGPP updated

**Design**
1. A detailed design is constructed
2. CTPs have operational definitions
3. Measurement systems are validated and documented for CTPs
4. Baseline CTP capabilities are established
5. Pilot planned to verify the detail design with control considerations
6. Thought Map & MGPP updated

**Verify**
1. “Prototype” created & tested (i.e. pilot)
2. Design reviews conducted and documented with the design scorecard
3. Feasibility to move forward to full-scale implementation is determined
4. Full-scale process/service is implemented & verified through data
5. Control plan instituted
6. Thought Map & MGPP updated

**Key Tools**

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*Review throughout!
Presentation Agenda

• Facilitate a “hands-on” design exercise that encourages teams to experience simple but profound lessons in collaboration, innovation and creativity
  – “The Marshmallow Challenge”
• Understand the concept & definition of Design for Six Sigma (DFSS) and the motivation for its use including:
  – Principles, Benefits & Applications
  – Compare “Design for Six Sigma” to “Process Six Sigma”
• Discuss DFSS methodologies
  – Summarize selected DFSS methodologies
    ▪ DMADOV, IDOV, DCCDI, DMEDI
    ▪ **DMADV (Define, Measure, Analyze, Design, Verify)**
      – Describe the DMADV phases
  – Learn differences between DMAIC* & DMADV
    (* DMAIC – Define, Measure, Analyze, Improve, Control)
• Handout references - Roadmaps