WEEK 7

LEAN AND SIX SIGMA CONCEPTS

TCM 545/645 – Project Control Systems
Dr. Richard Gebken

Outline for Week 7

2

- **Six Sigma**
  - Basics and history
  - What is 6 Sigma
  - 5 Process for Six Sigma – DMAICL
- **Lean Principles**
  - Basics and history
  - 7 Types of Waste
  - Value stream mapping
  - Other Lean terminology and tools

3 Six Sigma and Statistical Modeling

Basics of Six Sigma (6σ)

4

- **6σ** is an outgrowth of **TQM** (Total Quality Management)
- Started in the mid-1980's at Motorola, the purpose of Six Sigma is to developing and delivering **near-perfect products and services consistently**
  - Bill Smith and Mikel Harry are the pioneers at Motorola
    - The first team at Motorola were Karate students (hence the adopted terms of Black Belts, Green Belts, etc.)
  - Motorola initiated 6σ for process improvement and reduced defects to negligible levels
  - Motorola initiated the project when the company was not doing well with Customer Satisfaction levels
- In 1995, GE initiated 6σ under Jack Welch
  - It was at GE that 6σ was used to improve the entire Business System
- Today, 6σ is a more that just reducing defects, **it is a continuous improvement process, with a focus on change empowerment, seamless training of resources and consistent top management support**

What is Six Sigma?

5

- **Six Sigma thinking**: All processes can be Defined, Measured, Analyzed, Improved, and Controlled (5 phases of Six Sigma). Any process has inputs (x), and delivers outputs (y). Controlling inputs will control output.
- **Six Sigma as set of tools**: 6σ incorporates many qualitative and quantitative tools to drive improvements
  - Examples include: Control Charts, FMEA, Process Mapping, SIPOC, Hypothesis-testing, T-testing, etc.
- **The metric of 6σ**: Six Sigma quality means 3.4 defects in 1 million opportunities or a process with 99.99966% Rolled Throughput Yield.
  - Assumes a 1.5 sigma shift in the process mean.
- **Sigma (σ)**: It is the standard deviation of a process metric

What is Six Sigma? (continued)

6

Sigma Process (σ)	Defects per million opportunities	Rolled Throughput Yield
1	697,672	30.2328%
2	308,537	69.1463%
3	66,807	93.3193%
4	6,210	99.3790%
5	233	99.97670%
6	3.4	99.99966%

- **Opportunity**: Every chance for a process to deliver an output that is either "Right" or "Wrong", as per customer's specifications. In other words, an opportunity is every possible chance of making an error. Six Sigma projects are, at a lot of times, referred to as opportunities.
- **Defect**: Every result of an opportunity that does not meet customer's specifications i.e. not falling within Upper Specification Limit (USL) and Lower Specification Limit (LSL).
- **Specification limits**: Limits set by a customer always and not by the business. These limits represent the range of variation the customer can tolerate/accept.

5 Process for Six Sigma - DMAIC

7

- **Define:** Define the problem statement and plan the improvement initiative
- **Measure:** Collect data from the process and understand current quality levels/operational performance levels
- **Analyze:** Study the business process and the data generated to understand the root causes of the problem resulting in variations in the process
- **Improve:** Identify possible improvement actions, prioritize them, test the improvements, finalize the improvement action plan
- **Control:** Full scale implementation of improvement action plan, setup controls to monitor the system so that gains are sustained
- DMAIC is the key for process improvements

Statistical Background to Six Sigma An Example

8

- Assume a machine produces the following number of bottle caps per minute (over a period of 30 minutes)
  - 27,11,13,12,13,12,11,12,9,12,12,13,12,12,13,12,12,12,11,10,12,12,12,11,12,13,12,12,12,12
- The Mean (μ) is the sum of all the data points / Total number of data points
  - (27+11+13+12+13+12+11+12+9+12+12+13+12+12+13+12+12+12+11+10+12+12+12+11+12+13+12+12+12) / 30 = 12.4
- The standard deviation (σ) is calculated by :
  - Subtract mean from each data points and square $[(27-12.4)^2, (11-12.4)^2, (13-12.4)^2, \ldots]$, then
  - Adding those numbers and dividing by the total no. of data points = 8.1
  - Calculate the square root of the value found in above step = $\sqrt{(8.1)} = 2.8 = \sigma$
- The acceptable limits set by the production manager (the customer for the machine) is between 0 bottle caps per minute (LSL), and 25 bottle caps per minute (USL)
  - This means that out of all 30 data points mentioned above, one data point (27) falls outside customer specification
- Calculate ZU (Z-Upper) and ZL (Z-Lower)
  - ZU = (USL – μ)/ (σ) = (25 – 12.4) / (2.8) = 4.5
  - ZL = (μ - LSL)/ (σ) = (12.4 - 0) / (2.8)= 4.3
  - Process Sigma levels = Minimum of ZU and ZL = 4.3, thus the machine is at 4.3 Sigma levels.
- This could be thought of as an improvement opportunity for the production manager, if he wishes to improve process efficiency to 6 Sigma levels.

Why Do Six Sigma?

9

- It eliminates causes of mistakes and defects in a process
  - Elimination of mistakes is subject to successful implementation of **POKA YOKE** or **MISTAKE PROOFING** and other preventive techniques
    - Sometimes the solution is creating a robust process or product that mitigates the impact of a variable input or output on a customer's experience.
    - For example, many electrical utility systems have voltage variability up to and sometimes exceeding a 10% deviation from nominal. Thus, most electrical products are built to tolerate the variability, drawing more amperage without damage to any components or the unit itself.
- It reduces variation and waste in a process
- It helps gain competitive advantage and transform companies into world leader in their respective fields
- Ultimately, it satisfies customers and achieve organizational goals

What are the Key Components of Implementing Six Sigma

10

- **Management Strategy:** An environment where management supports Six Sigma as a business strategy and not as a stand-alone approach or a program to satisfy some public relations need
- **DMAIC:** Emphasis on the DMAIC (Define-Measure-Analyze-Improve-Control) method of problem solving
- **Focused Teams:** Teams are assigned to well-defined projects that directly impact organization's bottom line, with customer satisfaction and increased quality being by-products
- **Use of Statistical Methods:** Six Sigma requires extensive use of statistical methods

11

Lean Principles for Project Control

History of Lean

12

- Lean was originally developed in the manufacturing environment
  - Thus it is commonly referred to as **Lean Manufacturing**
- The origins of lean concepts can be traced back 1000's of years; however, Henry Ford spoke about Lean principles, which **Taiichi Ohno** later adopted at Toyota
- Toyota developed and greatly improved Ford's principles into what was known as the **Toyota Production System** (TPS)
- TPS became one of the key driving points for Lean Manufacturing
  - A term popularized by James Womack in the 1980s

What is LEAN?

13

- Lean talks of doing away with **Muda**, **Mura**, and **Muri**.
  - Muda = Waste
  - Mura = Unevenness
  - Muri = Overburden
- 7 types of Muda or waste are:
  - **Overproduction**: Producing more than is required. Example: customer needed 10 products and you delivered 12
  - **Inventory**: In simple words, stock. Inventory includes finished goods, semi-finished goods, raw materials, supplies kept in waiting, and some of the work in progress
  - **Defects/Repairs/Rejects**: Anything deemed unusable by the customer and any effort to make it usable to the original customer or a new customer.
  - **Motion**: A waste due to poor ergonomics of workplace
  - **Overprocessing**: Extra operation on a product or service to remove some unneeded attribute or feature. Example: customer needed a bottle and you delivered a bottle with extra plastic casing
  - **Waiting**: When the part waits for processing, or the operator waits for work
  - **Transport**: When the product moves unnecessarily in the process, without adding value. Example: product is finished yet it travels 10 kilometers to warehouse before it gets shipped to the customer.

Why Use LEAN?

14

- LEAN helps in reducing/eliminating wastes and reducing non-value added (NVA) activities from a process
- In doing so, LEAN increases continuous flow in the process, as opposed to stop-flow and unbalanced production
- Before starting with a Six Sigma project, it is important to check the WASTE status of the process
- If Wastes and NVAs exist, eliminate or reduce them first, and then apply Six Sigma

Example

An operation might have many defects in the welding operations. An operator observes that he is sometimes welding rusty components together. It might be worthwhile to figure out ways to reduce inventory and the waiting (storage) time that causes the steel to rust (i.e., oxidize excessively) before figuring out other solutions to deal with rust (like using an oil coating which might create other welding problems or require a cleaning process).

LEAN Concepts

15

- **Value Chain**: It is a chain of activities in a business system. Forming a value chain at business system level is more appropriate than forming it at any process level
- **Flow**: It is essential that products/services move through the business system in continuous flow. Any stopping or reduction in flow is a non-value adding activity and hence a waste
- **Pull**: Instead of making products/services based on an estimated sales forecast, the business system makes products/services as the customer requires it. Benefits of a pull process are:
  - Decrease in cycle time
  - Finished inventory is reduced
  - Work in progress is reduced
  - Stable price
  - Smooth flow of the process
- **Perfection**: It is the complete elimination of muda/waste so that all activities along a value chain add value
- **Push** --- It is a type of process, which works exactly the opposite of a Pull process. In the Push process, forecasting of demand is the first step, which moves on to the production line and the parts produced are stocked in anticipation of customer demand.

Value Stream Mapping

16

- It is a visualization tool to map the path and identify all activities involved in the product/service
- All activities related to a product/service are mapped using flowcharts
- Helps in identifying and eliminating/reducing non-value added activities
  - Any activity that does not add any value to the product as perceived by the customer is a non-value added activity
- Value added activities
  - Activities in the making of a product which adds value to the customer using the final product
  - Customer would be willing to pay for those activities
- Every activity of a Value Stream Map can be classified into:
  - It adds value as perceived by the customer. Example: actual production process
  - It adds no value, but is required by the process. Such activities can be termed as non-value adding activities, but you cannot eliminate them from the process as they are necessary Example: regulatory audits, like ISO and financial audits
  - It adds no value, and can be eliminated

Lean Terminology & Techniques

Techniques	Description
Kaizen	Kaizen, or continuous improvement, is the building block of all Lean production methods. Kaizen philosophy implies that all, incremental changes routinely applied and sustained over a long period result in significant improvements
Poka Yoke	Aka Mistake Proofing - It is good to do it right the first time; it is even better to make it impossible to do it wrong the first time. POKA YOKE talks about automated mistake detection and fix
5S	A framework to create and maintain your workplace- Sort, Set-in-order, Shine, Standardize, Sustain
Just in Time (JIT)	A manufacturing philosophy which leads to "Producing the necessary units, in the necessary quantities at the necessary time with the required quality"
Kanban	Literally means signboard in Japanese. Kanban utilizes visual display cards to signal movement of material between steps of a product process
Jidoka	Means "automation with human touch." It is an automated inspection function in production line and stops the process as soon as a defect is encountered. The process does not start until root cause of the defect has been eliminated
Takt time	Takt time is the maximum time in which the customer demand needs to be met. For example, if the customer needs 100 products, and the company has 420 minutes of available production time, TAKT Time = Time Available/Demand. In this case, the company has a maximum of 4.2 minutes per product. This would be the target for the production line
Heijunka	Means Production Leveling/Smoothing. It is a technique to reduce waste which occurs due to fluctuating customer demand

17