Learn Six Sigma

A Lean Six Sigma Green Belt Training Guide

Featuring Examples Using Minitab v.18

Lean Sigma Corporation™

Michael Parker

LEARN SIX SIGMA
USING MINITAB V.18

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FEATURING EXAMPLES FROM MINITAB V.18

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0.0 INTRODUCTION

This book has been written to explain the topics of Lean Six Sigma and provide step by step instructions on how perform key statistical analysis techniques using Minitab. The content of this book has been updated to include instructions using Minitab version 18.

This book will provide the reader with all the necessary knowledge and techniques to become an effective Lean Six Sigma practitioner. For those who have already achieved certification this book is an excellent reference manual as well as companion for all who pass on the virtues of Lean Six Sigma.


Another valuable component to this publication is the use of numerous step by step analysis instructions for the reader to learn exactly how to perform and interpret statistical analysis techniques using Minitab. Anywhere throughout this book where you see the image of a chart on a clipboard followed by the words “Data file:” will be a place where the reader will need the necessary data file to accurately follow the exercise. This data file can be downloaded from your account in your Study Six Sigma portal.

1.0 DEFINE PHASE

1.1 SIX SIGMA OVERVIEW

1.1.1 *WHAT IS SIX SIGMA?*

In statistics, *sigma* (σ) refers to standard deviation, which is a measure of variation. You will come to learn that variation is the enemy of any quality process; it makes it much more difficult to meet a customer's expectation for a product or service. We need to understand, manage, and minimize process variation.

Six Sigma is an aspiration or goal of process performance. A Six Sigma goal is for a process average to operate approximately 6σ away from the customer's high and low specification limits. A process whose average is about 6σ away from the customer's high and low specification limits has abundant room to "float" before approaching the customer's specification limits.

Most people think of Six Sigma as a disciplined, data-driven approach to eliminating defects and solving business problems. If you break down the term, Six Sigma, the two words describe a measure of quality that strives for near perfection.

A Six Sigma process only yields 3.4 defects for every 1 million opportunities! In other words, 99.9997% of the products are defect-free, but some processes require more quality and some require less.

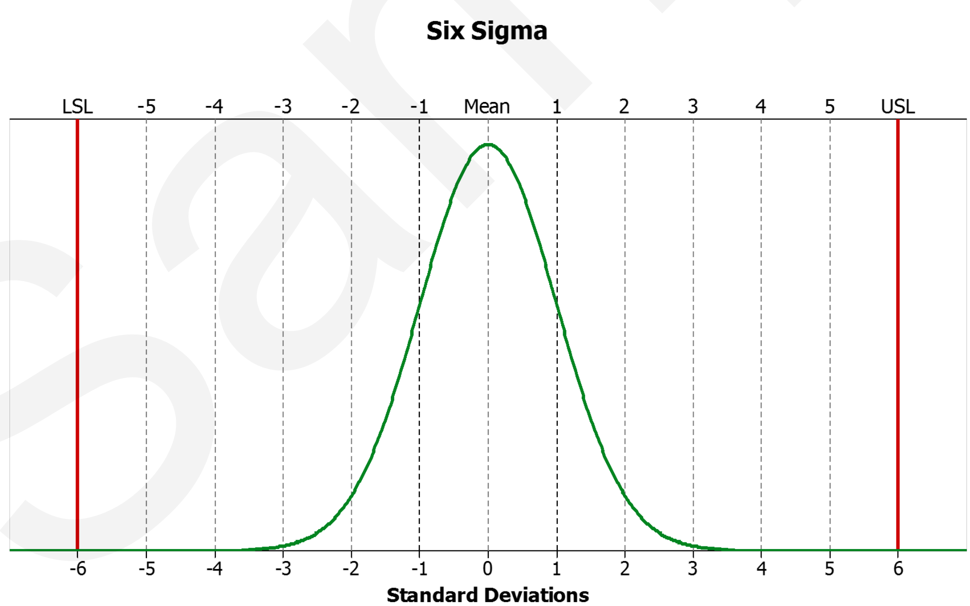

Fig. 1.1 Six Sigma Process with mean 6 standard deviations away from either specification limit.

The more variation that can be reduced in the process (by narrowing the distribution), the more easily the customer's expectations can be met.

It is important to note that a Six Sigma level of quality does not come without cost, so one must consider what level of quality is needed or acceptable and how much can be spent on resources to remove the variation.

What is Six Sigma: Sigma Level

Sigma level measures how many sigma there are between your process average and the nearest customer specification. Let us assume that your customer's upper and lower specifications limits (USL and LSL) were narrower than the width of your process spread. The USL and LSL below stay about one standard deviation away from the process average. Therefore, this process operates at *one sigma*.

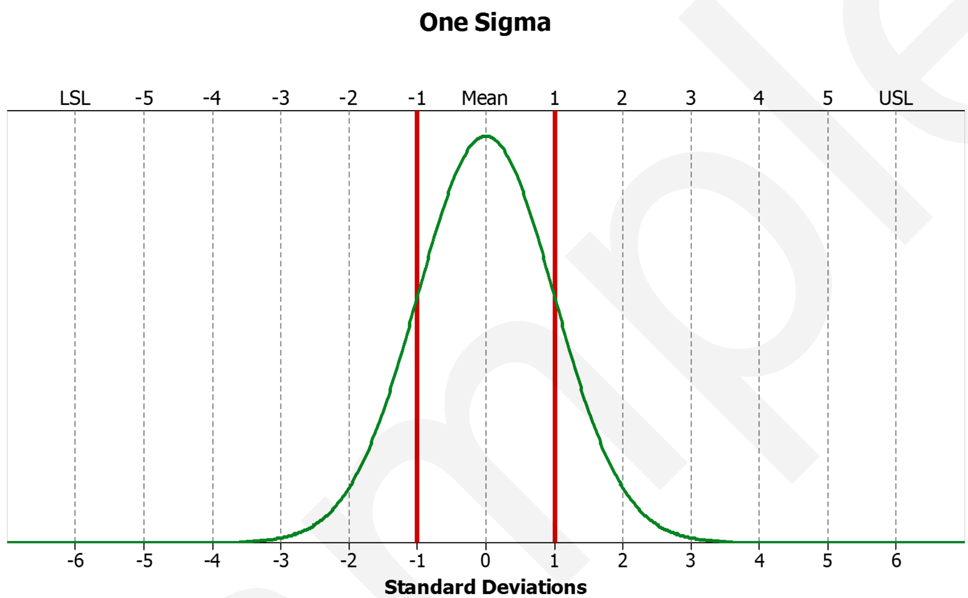

Fig. 1.2 Process operating at 1 sigma with mean one standard deviation away from closest spec limit.

In Fig. 1.1, the LSL and USL were at six standard deviations from the mean. Would that process be more or less forgiving than the one shown in Fig. 1.2?

Answer: *This* process is much less forgiving. It is a one sigma process because the USL and LSL are only one standard deviation from the mean. The area under the blue curve to the left of the LSL and to the right of the USL represents *process defects*.

A process operating at one sigma has a defect rate of approximately 70%. This means that the process will generate defect-free products only 30% of the time, so for every three units that are good, seven are defective. Obviously, a one sigma process is not desirable anywhere because its implications are high customer claims, high process waste, lost reputation, and many others.

What about processes with more than one sigma level? A higher sigma level means a lower defect rate. Let us look at the defect rates of processes at different sigma levels.

Table 1.1 shows each sigma level's corresponding defect rate and DPMO (defects per million opportunities). The higher the sigma level, the lower the defective rate and DPMO. The table shows how dramatically the quality can improve when moving from a one sigma process, to two-sigma, to three, and so on. Next, we will look at how this concept applies to some everyday processes.

Sigma Level	Defect Rate	DPMO
1	69.76%	697612
2	30.87%	308770
3	6.68%	66810
4	0.62%	6209
5	0.023%	232
6	0.00034%	3.4

Table 1.1 Sigma level, Defect Rate and DPMO

Let us look at processes operating at three-sigma, which has a defect rate of approximately 7%. What would happen if processes operated at three-sigma? According to http://www.qualityamerica.com:

- Virtually no modern computer would function.
- 10,800,000 health care claims would be mishandled each year.
- 18,900 US savings bonds would be lost every month.
- 54,000 checks would be lost each night by a single large bank.
- 4,050 invoices would be sent out incorrectly each month by a modest-sized telecommunications company.
- 540,000 erroneous call details would be recorded each day from a regional telecommunications company.
- 270 million erroneous credit card transactions would be recorded each year in the United States.

Just imagine what a three-sigma process would look like in the tech industry, in health care, in banking. Can you apply this concept to a process that you relate to? What if processes operated with 1% defect rate? There would be:

- 20,000 lost articles of mail per hr. (Implementing Six Sigma – Forest W. Breyfogle III).
- Unsafe drinking water almost 15 minutes per day.
- 5,000 incorrect surgical operations per week.
- Short or long landings at most major airports each day.
- 200,000 wrong drug prescriptions each year.
- No electricity for almost seven hours per month.

Even at a 1% defect rate, some processes would be unacceptable to you and many others. Would you drink the water in a community where the local water treatment facility operates at a 1% defect rate? Would you go to a surgeon with a 1% defect rate?

So, what is Six Sigma? Sigma is the measure of quality, and Six is the *goal*.

What is Six Sigma: The Methodology

Six Sigma itself is the *goal*, not the method. To achieve Six Sigma, you need to improve your process performance by:

- Minimizing the process variation so that your process has enough room to fluctuate within customer's spec limits.
- Shifting your process average so that it is centered between your customer's spec limits.

Accomplishing these two process improvements, along with stabilization and control (the ability to maintain the process improvements or level of quality over time), you can achieve Six Sigma. This way, the process becomes more capable of meeting the specification limits that are set by the customer.

The methodology prescribed to achieve Six Sigma is called DMAIC. DMAIC is a systematic and rigorous methodology that can be applied to *any* process in order to achieve Six Sigma. It consists of five phases of a project:

1. **D**efine
2. **M**easure
3. **A**nalyze
4. **I**mprove
5. **C**ontrol

You will be heavily exposed to many concepts, tools, and examples of the DMAIC methodology through this training. The goal of this training is to teach you how to apply DMAIC and leverage the many concepts and tools within it. At the completion of the curriculum, you will become capable of applying the DMAIC methodology to improve the performance of *any* process.

1.1.2 Six Sigma History

The Six Sigma terminology was originally adopted by Bill Smith at Motorola in the late 1980s as a quality management methodology. As the "Father of Six Sigma," Bill forged the path for Six Sigma through Motorola's CEO Bob Galvin who strongly supported Bill's passion and efforts.

Bill Smith originally approached Bob Galvin with what he referred to as the "theory of latent defect." The core principle of the theory is that *variation* in manufacturing processes is the main driver for *defects*, and eliminating variation will help eliminate defects. In turn, it will eliminate the wastes associated with defects, saving money and increasing customer satisfaction. The threshold agreed to by Motorola was 3.4 defects per million opportunities. Does it sound familiar?

Starting from the late 1980s, Motorola extensively applied Six Sigma as a process management discipline throughout the company, leveraging Motorola University. In 1988, Motorola was recognized with the prestigious Malcolm Baldrige National Quality Award for its achievements in quality improvement.

Six Sigma has been widely adopted by companies as an efficient way of improving the business performance since General Electric implemented the methodology under the leadership of Jack Welch in the 1990s. As GE connected Six Sigma results to its executive compensation and published the financial benefits of Six Sigma implementation in their annual report, Six Sigma became a highly sought-after discipline of quality. Companies across many industries followed suit. In some cases GE taught companies how to deploy the methodology, and in many cases experts from GE and other pioneer companies were heavily recruited to companies that were new to methodology.

Most Six Sigma programs cover the aspects, tools, and topics of Lean or Lean Manufacturing. The two, work hand in hand, benefitting each other. Six Sigma focuses on minimizing process variability, shifting the process average, and delivering within customer's specification limits. Lean focuses on eliminating waste and increasing efficiency.

While the term Lean was coined in the 1990s, the methodology is mainly based on the concepts of the Toyota Production System, which was developed by Taiichi Ohno, Shigeo Shingo, and Eiji Toyoda at Toyota between 1948 and 1975.

Lean and its popularity began to form and gain significant traction in the mid-1960s with the Toyota initiative TPS or Toyota Production System, originally known as the "just-in-time production system." The concepts and methodology of Lean, however, were fundamentally applied much earlier by both Ford and Boeing in the early 1900s.

The DMAIC methodology is essentially an ordered collection of concepts and tools that were not unique to Six Sigma. The concepts and tools are leveraged in a way that leads down a problem-solving path.

Despite the criticism and immaturity of Six Sigma in many aspects, its history continues to be written with every company and organization striving to improve its business performance. The track record for many of these companies after implementing Six Sigma, speaks for itself.

1.1.3 Six Sigma Approach

Six Sigma Approach: Y = f(x)

The Six Sigma approach to problem solving uses a transfer function. A *transfer function* is a mathematical expression of the relationship between the inputs and outputs of a system. The relational transfer function that is used by all Six Sigma practitioners is:

$$Y = f(x)$$

The symbol Y refers to the measure or output of a process. Y is usually your primary metric, the measure of process performance that you are trying to improve. The expression f(x) means function of x, where x's are factors or inputs that affect the Y. Combined, the Y = f(x) statement reads "Y is a function of x," in simple terms, "My process performance is dependent on certain x's."

The objective in a Six Sigma project is to identify the critical x's that have the most influence on the output (Y) and adjust them so that the Y improves. It is important to keep in mind this concept throughout the DMAIC process. The system (or process) outputs (Y's) are a function of the inputs (x).

Example
Let us look at a simple example of a pizza delivery company that desires to meet customer expectations of on-time delivery.

Measure = on-time pizza deliveries
Y = percent of on-time deliveries

f(x) would be the x's or factors that heavily influence timely deliveries

x1: might be traffic
x2: might be the number of deliveries per driver dispatch
x3: might be the accuracy of directions provided to the driver
x4: might be the reliability of the delivery vehicle

The statement Y = f(x) in this example will refer to the proven x's determined through the steps of a Six Sigma project. Most would agree that an important requirement of pizza delivery is to be fast or on-time. In this example, let us consider factors that might cause variation in Y (percent of on-time deliveries). In the DMAIC process, the goal is to determine which inputs (x's) are the main drivers for the variation in Y.

With this approach, all potential x's are evaluated throughout the DMAIC methodology. The x's should be narrowed down until the vital few x's that significantly influence on-time pizza deliveries are identified.

This approach to problem solving will take you through the process of determining all potential x's that *might* influence on-time deliveries and then determining through measurements and analysis which x's *do* influence on-time deliveries. Those significant x's become the ones used in the Y = f(x) equation.

The Y = f(x) equation is a very powerful concept and requires the ability to measure your output and quantify your inputs. Measuring process inputs and outputs is crucial to effectively determining the significant influences to any process.

1.1.4 Six Sigma Methodology

Six Sigma is a data-driven methodology for solving problems, improving, and optimizing business problems. Six Sigma follows a methodology that is conceptually rooted in the principles of a five-phase project. Each phase has a specific purpose and specific tools and techniques that aid in achieving the phase objectives.

The five phases of DMAIC are:

1. **D**efine
2. **M**easure
3. **A**nalyze
4. **I**mprove
5. **C**ontrol

The goals of the five phases are:

1. **D**EFINE—To define what the project is setting out to do and scope the effort
2. **M**EASURE—To establish a baseline for the process, ensure the measurement system is reliable, and identify all possible root causes for a problem
3. **A**NALYZE—To narrow down all possible root causes to the critical few that are the primary drivers of the problem
4. **I**MPROVE—To develop the improvements for the process
5. **C**ONTROL—To implement the fix and a control plan to ensure the improvements are sustained over time

In terms of the transfer function, the five phases mean:

1. **D**EFINE—Understand the project Y's and how to measure them
2. **M**EASURE—Prioritize potential x's and measure x's and Y's
3. **A**NALYZE —Test x–Y relationships and verify/quantify important x's
4. **I**MPROVE—Implement solutions to improve Y's and address important x's
5. **C**ONTROL—Monitor important x's and the Y's over time

Six Sigma Methodology: Define Phase

The goal of the *Define* phase is to establish a solid foundation and business case for a Six Sigma project. Define is arguably the most important aspect of any Six Sigma project. It sets the foundation for the project and, if it is not done well and properly thought, it is very easy for a project to go off-track.

All successful projects start with a current state challenge or problem that can be articulated in a quantifiable manner—without a baseline and a goal, it is very difficult to keep boundaries around the project. But it is not enough to just know the problem, you must quantify it and also determine the goal. Without knowing how much improvement is needed or desired, it can be very difficult to control the scope of the project.

Once problems and goals are identified and quantified, the rest of the Define phase will be about valuation, team, scope, project planning, timeline, stakeholders, Voice of the Customer, and Voice of the Business.

Define Phase Tools and Deliverables
1. *Project charter*, which establishes the:

- Business Case
- Problem Statement
- Project Objective
- Project Scope
- Project Timeline
- Project Team

The project charter is essentially a contract formed between a project team, the champion, and the stakeholders. It defines what the project is going to do, why they are going to do it, when it will be done, and by whom. It includes the business case, problem statement, project objective, scope, timeline, and team.

2. *Stakeholder Assessment*

Stakeholder assessment involves the following:

- High-Level Pareto Chart Analysis
- High-Level Process Map
- Voice of the Customer/ Voice of the Business and Critical to Quality Requirements Identified and Defined
- Financial Assessment

A stakeholder assessment is done to understand where there are gaps in stakeholder support and develop strategies to overcome them. High-level Pareto chart and process maps, along with Voice of the Customer, Voice of the Business, and Critical to Quality Requirements also help to develop the scope and put some guardrails around the process.

Six Sigma Methodology: Measure Phase

The goal of the *Measure* phase is to gather baseline information about the process (process performance, inputs, measurements, customer expectations etc.). This phase is necessary to determine if the measurement systems are reliable, if the process is stable, and how capable the process is of meeting the customer's specifications.

Throughout the Measure phase you will seek to achieve a few important objectives:

- Gather All Possible x's
- Assess Measurement System and Data Collection Requirements
- Validate Assumptions
- Validate Improvement Goals
- Determine Cost of Poor Quality
- Refine Process Understanding

- Determine Process Stability
- Determine Process Capability

Measure Phase Tools and Deliverables
The tools and deliverables for this phase are:

- Process Maps, SIPOC, Value Stream Maps—To visualize a process
- Failure Modes and Effects Analysis—To identify possible process failure modes and prioritize them
- Cause-and-Effect Diagram—To brainstorm possible root causes for defects
- XY Matrix—To prioritize possible root causes for defects
- Six Sigma Statistics
- Basic Statistics and Descriptive Statistics—To understand more about your process data
- Measurement Systems Analysis—To establish repeatability, reproducibility, linearity, accuracy, and stability
- Variable and/or Attribute Gage R&R
- Gage Linearity and Accuracy or Stability
- Basic Control Charts—To assess process stability
- Process Capability and Sigma Levels—To assess and quantify a process' ability to meet customer specification limits
- Data Collection Plan—To ensure that when data is collected, it is done properly

Six Sigma Methodology: Analyze Phase

The *Analyze* phase is all about establishing verified drivers. In the DMAIC methodology, the Analyze phase uses statistics and higher-order analytics to discover relationships between process performance and process inputs. In other words, this phase is where the potential root causes are narrowed down to the *critical* root causes.

Statistical tools are used to determine whether there are relationships between process performance and the potential root causes. Where the strong relationships are discovered, these become the foundation for the solution to improve the process.

Ultimately, the Analyze phase establishes a reliable hypothesis for improvement solutions. During the Analyze phase, one needs to:

- Establish the Transfer Function Y = f(x)
- Validate the List of Critical x's and Impacts
- Create a Beta Improvement Plan (e.g., pilot plan)

Analyze Phase Tools and Deliverables
The Analyze phase is about proving and validating critical x's using the appropriate and necessary analysis techniques. The tools that help to formulate a hypothesis about how much improvement can be expected in the Y, given a change in the x include:

- Hypothesis Testing (e.g., t-tests, Chi-Square)
- Parametric and Non-Parametric
- Regression (Simple Linear Regression, Multiple Linear Regression)—To establish quantitative and predictive relationships between the x's and Y's

The Analyze phase is also about establishing a set of solution hypotheses to be tested and further validated in the Improve phase.

Six Sigma Methodology: Improve Phase

The goal of the *Improve* phase is make the improvement. Improve is about designing, testing, and implementing your solution. To this point, you have defined the problem and objective of the project, brainstormed possible x's, analyzed and verified critical x's. Now it's time to make it real! During the Improve phase, the following are necessary:

- Statistically Proven Results from Active Study/Pilot
- Improvement/Implementation Plan
- Updated Stakeholder Assessment
- Revised Business Case with Return on Investment
- Risk Assessment/Updated Failure Modes and Effects Analysis
- New Process Capability and Sigma

Methodologies for the Improve phase include:

- Experiments and planned studies
- Pilots or tests designed to validate relationships and determine how much change in an input is needed to induce the desired result in the output
- Implementation plan to stimulate thoughts and planning for any necessary communications, training, and preparations to implement the process improvement

Improve Phase Tools and Deliverables
The tools and deliverables of this phase are:

- Any appropriate tool from previous phases
    - An updated stakeholder assessment to ensure the right support exists to make the process change
    - An updated business case to justify the change
    - An updated Failure Modes and Effects Analysis to ensure the solution is robust and proper control points are identified
    - A revisited process capability and sigma level to quantify how well the improved process will perform against customer specifications
- Design of Experiment: Full Factorial and Fractional Factorial
- Pilot or Planned Study using Hypothesis Testing and Valid Measurement Systems
- Implementation Plan

6.0 Index