

## SSMI's Operational Guidelines for Lean Six Sigma Projects



### Abstract

*Lean Six Sigma projects are identified, planned, executed, reviewed and verified to achieve a predetermined benefit for the sponsoring organization and its customers. To this end, a Lean Six Sigma project must first be properly chartered and initialized. Next, it must flow smoothly through each step of the DMAIC problem solving process. This means that a project must pass through the Define, Measure, Analyze, Improve and Control (DMAIC) phases of improvement in order to realize a comprehensive, lasting solution. In short, Lean Six Sigma projects are formal investigations guided by the hand of scientific knowledge, not a collection of loosely organized ad-hoc activities with an indeterminate outcome or a "let's see what falls out" type of focus. Where Lean Six Sigma projects are concerned, success is the result of a thoughtfully designed outcome, not a chance or circumstantial set of events. This is what makes Lean Six Sigma projects so effective and efficient. Given this, it is easy to understand why Lean Six Sigma projects must be carefully planned, resourced, managed and judiciously reviewed. Naturally, upon completion of such a project, the accounting function must verify its derived benefits and then management must officially sanction its closure.*

### Introduction

In today's world, corporations are questing for top line growth and constantly seek to reduce their total cost structure. The business leaders of such organizations want to increase capability and capacity without capital investment.

They also know that customer satisfaction must be continually monitored and improved. At the same time, they recognize the need to enhance investor

relations. And the interconnected list of imperatives continues in a seemingly endless way.

Some of these business professionals have not been exposed to the huge gains made by companies such as General Electric, Honeywell, Sony, Ford Motor Company, and DuPont, just to mention a few. As many now know, these fine organizations found the "magic formula" in the chemistry of Lean Six Sigma. They discovered the power of highly focused, benefit-centric lean sigma projects.

Since its inception in the 80's as a quality initiative at Motorola, Six Sigma has evolved into a world-class business management system. Over time, Six Sigma has been intelligently blended with many of the best practices commonly associated with Lean Manufacturing.

Thus, Lean Six Sigma provides a viable means for industrial and commercial organizations (through focused projects) to reach the control function of the business and positively alter the genetic code of its leadership.

The combination of Lean Six Sigma thinking and the DMAIC problem solving methodology offers the capacity and capability to rewire all of the critical processes of a business - in every corner and in everything it does.

Thus, Lean Six Sigma forces an organization to reexamine the way in which it gets the work done and not simply modify or augment the existing system to realize some marginally acceptable level of improvement.

While the practice of Lean Methods targets process efficiency (i.e., waste reduction), Six Sigma targets process effectiveness (i.e., variation reduction). Taken together, the duo represents the proverbial one-two punch for waste and variation. Of course, this translates to an improvement in overall process efficacy.

Owing to this, Lean Six Sigma is more than a simple quality improvement or cost reduction initiative - it is a system of management that produces quantum change in everything it decides to focus on.

It's a way to identify, execute and manage many simultaneous improvement projects that are linked to a common set of unified business objectives. Of course, when such projects are deployed and implemented, their collective power suddenly and dramatically blips the radar screen of business.

In this sense, Lean Six Sigma is a strategic and tactical system for managing the total business enterprise. From this perspective, it is easy to see why Lean Six Sigma projects are so widely used to create business process improvements. In other words, the practice of Lean Six Sigma enables a business enterprise to breakthrough to new levels of performance. Figure 1.0 presents a few of the many reasons for deploying and implementing Lean Sigma Projects.



Compliance Failures	High Cost-of-Quality
Customer Complaints	High Cycle Time
Low Customer Satisfaction	High Error Rates
Low Employee Satisfaction	High Defect Rate
High Employee Turnover	High Inventory Cost
Late Supplier Deliveries	High Labor Cost
Poor Supplier Quality	High Material Cost
Shareholder Dissatisfaction	High Overhead Cost
Deficient Process Capability	High Warranty Cost
Deficient Process Capacity	High Service Calls
Excessive Headcount	Insufficient Profit
Excessive Change Notices	Schedule Overruns
Cost Overruns	Late Deliveries
Delivery Speed	Poor Financials
Poor Field Performance	Poor Growth
Poor Margins	Low Sales
Poor Product Yield	Poor Revenues

Figure 1.0. Typical Business Reasons for Deploying and Implementing Lean Sigma Projects

## Project Benefits

A recent iSixSigma Magazine benchmarking study found that the median value of Black Belts projects is US\$188,000. That figure represents the "hard savings" delivered per project, regardless of industry or company size. Companies with revenue of more than US\$1.0 billion reported median results of US\$335,000, whereas companies with revenue of less than US\$100 million experienced median results of US\$117,000.

The range of results was similar when segmented by the number of employees in an organization (i.e., less than 1,000, 1,000 to 10,000 and greater than 10,000). Fewer companies track the "soft" financial savings (no direct impact to a company's financial statement), but for those that do, the median value of soft savings was US\$107,500.

Michael Cyger, publisher and founder of iSixSigma Magazine and iSixSigma.com, said, "This study validates that companies of all sizes can reap significant financial benefits from Six Sigma. Enormous positive results from Six Sigma at companies like GE, Motorola, Allied Signal and DuPont are well documented. Now we have the data across all company sizes (by both revenue and employee count) and industry, and it's significant enough that CEOs cannot afford to ignore Six Sigma. It would be a disservice to their shareholders and customers."

"Given that most Black Belts complete at least three Lean Six Sigma projects per year," Cyger continued, "the cumulative benefit of all projects is over US\$500,000 per Black Belt per year -- just measuring the 'hard' savings that can be directly tied to the company's top and/or bottom lines on the financial statement."

Erin Ducceschi, editor of iSixSigma Magazine, also indicated that, "Significant financial results can be achieved at any stage of a Six Sigma initiative. There is no statistical difference in financial benefits based on the number of years a company has been using Six Sigma, meaning that a return on a company's investment can be achieved within a short timeframe."

Of interest, the benchmarking data was gathered from the iSixSigma.com readership from October 7 through 15, 2004. Of the 819 individuals who responded, 48.7% were Black Belts. All data reported was for the 12-month period prior to the survey.

Source: RIDGEFIELD, CT, Feb. 15, 2005 (MARKET WIRE via COMTEX)

## Project Deployment Guidelines

Lean Six Sigma projects take on different faces in different organizations. Naturally, the overall goal of such improvement projects is to enhance some form of customer satisfaction or business performance. Thus, within the same enterprise, some projects will be focused on industrial processes while others will concentrate their efforts on commercial processes and activities.

**Enterprise Linkages:** Almost without saying, such improvement projects must be linked to the highest levels of strategy in the enterprise and be in direct support of specific business-centric objectives. Of course, all such improvement projects must be agreed upon by both business and operational leadership. After this, the project must be “chartered” by the project Champion and then executed by an X-Belt (i.e., Black Belt or Green Belt).

**Business Level Focus:** At the business level, projects should be selected based on the strategic goals and direction of the larger enterprise (e.g. corporation). Black Belt and Green Belt projects should be aimed at improving such things as customer satisfaction, cost, capacity, and top-end growth.

**Operations Level Focus:** At the operations level, Lean Six Sigma projects obviously will have a greater and more immediate impact at the local level than they will have at the enterprise level. However, localized projects should still link to the overall strategic goals and direction and directly involve the local leadership.

**Process Level Focus:** Projects at this level should focus on key operational and technical problems that are process-centric. In addition, the focus (i.e., improvement objectives) must be ultimately connected to the strategic goals and objectives of the parent enterprise, but done so through the operational objectives. Naturally, this ensures hierarchical linkage, thereby creating synergistic improvements that can be meaningfully classified and subsequently “pooled” or otherwise aggregated to the enterprise level.

**Deployment Strategy:** Project selection can rely on a “top-down” or “bottom-up” approach. The top-down approach considers a company’s major business issues and objectives and then assigns a Senior Champion. Following this, a Lean Six Sigma Project Champion identifies high-potential projects and then assigns an X-Belt to identify the corresponding processes and critical-to-quality characteristics, develop process baselines, and create specific improvement plans. This is the favored approach and the best way to align localized business needs with enterprise-level goals.

The bottom-up approach often results in projects being selected by local department-level managers under pressure to make budget reductions, resolve specific quality problems, or improve process flow and efficiency. These projects should be considered “targets of opportunity,” and don’t always integrate well with the company’s strategic business goals. In other

words, such projects are difficult to unify or otherwise synergize toward a common goal.

For example, managers may be asked to identify specific areas of waste, part-shortage problems, supplier quality issues, or unclear or impractical engineering requirements, and then a Black Belt is assigned to solve a specific problem. With this approach, it is easy for the operations-level focus to become diffused and disjointed in relationship to the higher strategic aims and directions of the parent business.

**Resource Allocation:** During deployment planning, an organization should consider how it will allocate resources between the two types of approaches. While the top-down approach has structural and managerial appeal, the bottom-up approach can ensure that key opportunities at lower levels of the organization are not lost. Usually, the optimal approach is a rational combination of the two.

**Project Focus:** At the process level, Lean Six Sigma projects should focus on those processes and critical-to-quality characteristics that offer the greatest financial and customer-satisfaction leverage. Each project should address at least one element of the organization’s key business objectives, and be properly planned. It is the Champion’s responsibility to gain the executive leadership’s support so that roadblocks are cleared and projects are successfully aligned and completed.

## Project Benefit Guidelines

There is no substitute for the experience of on-the-job application. This is also true in the world of Lean Six Sigma. In this context, it can be said that an application project is the point where the proverbial rubber of training meets the road of reality, so to speak.

Through application projects, a Lean Six Sigma X-Belt (i.e., Black Belt or Green Belt) can demonstrate the value of his or her skills while concurrently ferreting out added value for the sponsoring organization, as well as themselves.

A valid application project must return some form of tangible, measurable and verifiable benefit for the X-Belt’s employer or sponsoring organization. Of course, such a benefit must be substantial and meaningful to the sponsoring organization. By convention, the Champion takes ownership for assessing the viability of potential projects.

It is up to the Champion to determine if a potential project has the right scope and depth for a particular Green Belt or Black Belt and whether or not it can return bottom-line, measurable and verifiable benefits. Of course, this could mean that the Master Black Belt might need to be involved (to some extent) in order to reliably determine whether or not a project is technically feasible and viable.

In this context, cost-avoidance activities do not usually qualify as valid X-Belt projects. Generally speaking, only those activities that can deliver “hard” value to the bottom line should be considered as viable Lean Six Sigma projects. This means that only quantifiable problems should be considered project viable and placed in the pool of assignable X-Belt projects.

Of course, this would naturally imply that each potential X-Belt project must be properly scaled or otherwise “sized” so that it has enough scope and depth to require application of the full DMAIC process, but yet narrow enough so that it can be done in a relatively short period of time (2 to 4 months).

Obviously, when “jumbo sized” projects are assigned to a single Black Belt, the outcome is usually unfavorable. Worse yet is the case where large projects are unwittingly assigned to a worker-level team led by a Green Belt.

As would be expected, lower ranked X-Belt projects have far less returns, but are usually smaller in scope and shallower in depth. For example, a Green Belt project should be scaled so that it can be completed in 4 to 8 weeks. While the returns of a Green Belt project are normally less than that of a Black Belt, they are greater in number.

Thus, for a typical large scale enterprise or mid-sized business, the total project impact of the Green Belt cadre is often greater than that reported by the Black Belt population of the same organization.

In general, Lean Six Sigma projects should be focused on persistent or chronic problems; the type of problems that have previously defied solution. Thus, a Lean Six Sigma organization is not focused on the types of problems that can be solved through “common sense.” However, they are focused on problematic issues and business goals that require some form of “extraordinary sense” to resolve.

This super-ordinate need represents a class of problems that require a data-centric, science-based mindset, like that offered by the discipline of Lean Six Sigma. This means that the typical

Lean Six Sigma X-Belt project is more substantive and involved than a Just-Do-It (JDI) project or Kaizen event.

This also means that the expected project outcome and application methodology must be adequately mapped (i.e., planned) prior to execution, yet flexible enough in its design to take advantage of opportunities along the path, but not at the sacrifice of its super-ordinate business goals.

## Project Selection Guidelines

**Project Identification:** Lean Six Sigma application projects must focus on business value, plain and simple. A valid on-the-job project must yield some form of tangible value for the sponsoring organization.

For example, hard cost savings, yield improvement, defect reduction, cycle time reduction, inventory reduction, headcount reduction, increased customer satisfaction, and so on. Of course, all such value-based improvements can and should be translated into the language of business – money and time.

**Project Returns:** Any true improvement, no matter how large or small, must be viable, visible and verifiable in terms of money. After all, money is what business is all about.

If a Lean Six Sigma practitioner cannot translate his or her efforts and outcomes into some form of economic benefit, then one would have to necessarily question the true value of that practitioner’s contribution. If this vital monetary translation cannot be made, it would be doubtful that the “improvement” was truly tangible or real.

Owing to this line of business-minded reasoning, Lean Six Sigma projects have traditionally been focused on high-impact value-centric problems and issues that are financially traceable and verifiable.

More specifically, Lean Six Sigma projects must be concerned with creating measurable value for both the customer and provider – in every aspect of the business relationship.

**Project Responsibilities:** As would be expected, the X-Belt must take responsibility for learning the Lean Six Sigma tools and methods. On the flip side of things, the Champion must take responsibility for identifying, selecting, assigning, reviewing, approving and closing Lean Six Sigma projects. Only when these two conditions are realized and judiciously blended will mutual success prevail.

**Project Scale:** Naturally, a live on-the-job Lean Six Sigma project must have the right scope and depth for a Black Belt or Green Belt. Only those projects that are capable of delivering hard benefits should be considered. In other words, a Lean Six Sigma project should only be declared, activated and executed if it meets certain predefined decision criteria.

**Project Criteria:** The general criteria for selecting a Lean Six Sigma project are as follows:

- 1) *The project has the proper mix of scope, depth and timing;*
- 2) *The project necessitates using the DMAIC improvement process to realize its projected benefits; and*
- 3) *The targeted performance characteristics and forecasted benefits can be clearly defined and are rationally measurable.*

Generally speaking, a project can usually be considered “viable” and “feasible” when these three criteria can be reasonably satisfied (in both spirit and intent). Only then should that project be assigned to a qualified Lean Six Sigma practitioner, such as a Proficiency Certified Black Belt or Green Belt. Figure 2.0 graphically illustrates an example project selection tool.

Rating Scale	Selection Criteria
1 Disagree	Project is connected to a business need
2 Disagree	Project will benefit the customer
3 Disagree	Project represents clear value to the organization
4 Disagree	Project is within X-Belt's line-of-sight
5 Disagree	Project benefits are fully measurable
6 Disagree	Project benefits can be immediately verified
7 Disagree	Project is based on a product or process characteristic
8 Disagree	Performance characteristic can be reliably measured
9 Disagree	Performance measurements are readily available
10 Disagree	Performance measurements can be economically obtained
11 Disagree	Performance improvements can be sustained
12 Disagree	Performance will be reviewed by management
13 Disagree	Performance will be recognized by management
14 Disagree	Process can be clearly defined and mapped
15 Disagree	Process can be readily adjusted
16 Disagree	Process can be economically adjusted
17 Disagree	Process does not cross organizational boundaries
18 Disagree	Process does not depend on external influences
19 Disagree	Process owner will support the project
20 Disagree	Process knowledge is available to the X-Belt

Figure 2.0. Graphical Illustration of a Lean Six Sigma Project Selection Tool

## Project Charter Guidelines

The project charter is often drafted by the Project Champion or Master Black Belt and then refined by the Black Belt or Green Belt, as the case may be. Naturally, the charter must be approved by the leadership team. It is not uncommon for the charter to be revised several times as the focus

and locus of the project is better understood and data becomes available. Figure 3.0 provides the typical elements that often comprise a Lean Six Sigma project charter.

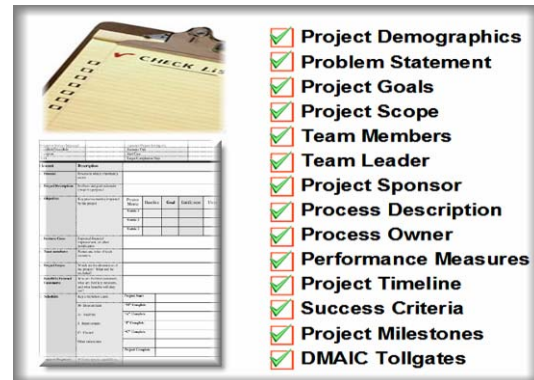


Figure 3.0. The Typical Elements of a Lean Six Sigma Project Charter

At the onset of the *Measure Phase*, the original charter might need to be refined or otherwise modified to account for new knowledge about the problem or process under investigation. In other words, it may be necessary to amend the general scope or depth of work to accomplish the intended aims. In addition, a clear process definition is essential. This helps the X-Belt see where the work will focus and what needs to be accomplished.

Generally speaking, the scope and depth of a Black Belt Lean Six Sigma project should be clear and attainable in a four to six month period; otherwise, the project should be reclassified and elevated to a higher level (i.e., Master Black Belt or team of Black Belts). Furthermore, close attention should also be paid to the selection of process metrics. Such measures focus the X-Belt on the aspects of process performance that must be improved. Moreover, the process metrics are often used to calculate the financial impact of the project.

The baseline, goal, and entitlement values associated with each of the key process metrics is also important to document, as well as the overall business impact of the project. In general, the project team should be small and not have more than four to six members (identified by name within in the charter). Yet another key element of the charter is the work schedule. It is very important to employ and use well accepted project management methods and practices.

## Project Execution Guidelines

**Project Activation:** By conventional practice, a Proficiency Certified Black Belt (or Green Belt) must have completed at least one live Lean Six Sigma DMAIC project as a part of his or her professional development. Of course, such projects are primarily intended to reinforce certain aspects of the X-Belt's training program, but at the same time, the project must also provide one or more benefits. In this context, the training project is very similar to post-training projects.

Regardless of the project's nature, the scope and depth of a Lean Six Sigma project should always be consistent with the X-Belt's rank. Furthermore, it is recommended that the X-Belt prepare a Lean Six Sigma project charter, receive management approval and then execute the project in accordance to the defined plan. In this manner, the overall system of improvement remains measurable, manageable, and accountable.

**Project Charter:** Generally speaking, a project charter is the cornerstone of successful execution. More to the point, approval of a charter signals the activation of a Lean Six Sigma project.

Once a project charter has been created and sanctioned by the sponsoring organization, the key elements of execution must then be identified, prioritized, and committed to a timeline. In this sense, the project charter is a management tool and should be carefully and judiciously prepared.

This is not a simple "check the box" kind of activity – it is the first point where project responsibility and accountability are formally declared; therefore, judicious attention must be given to its formulation and use. Because of this, it's often recommended that a formal project management system is employed that will allow for reporting and archiving of past projects, pooling potential projects and the systematic execution and tracking of active projects. An example of such a system's project charter feature is shown in figure 3.1.

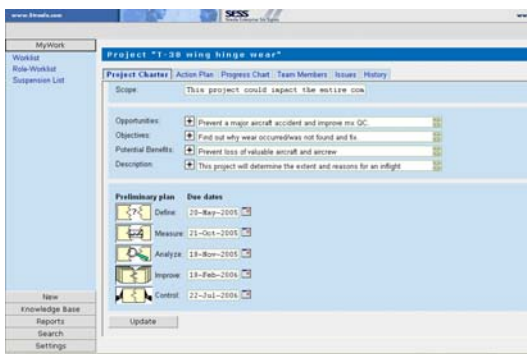


Figure 3.1. Streale Enterprise Project Charter Feature

**Project Execution:** Holistically speaking, each Lean Six Sigma project will follow the DMAIC improvement strategy to realize its aims. The planning and execution of this strategy can involve up to 15 independent milestones that are usually interrelated in a progressive and interactive manner. The milestones activities are progressively listed in Figure 4.0.

	Focus	Phase	Milestone Activity	Aim
DMAIC Strategy	Problem	Define	Identify Problematic Output	CTQ
			Review Output History	CTQ
			Describe Output Process	CTQ
		Measure	Evaluate Process Efficiency	CTQ
			Qualify Measurement System	CTQ
			Establish Output Capability	CTQ
	Solution	Analyze	Diagnose Output Variation	CTQ
			Identify Possible Causes	CTP
		Improve	Isolate Critical Factors	CTP
			Examine Factor Effects	CTP
			Optimize Factor Settings	CTP
		Control	Prescribe Factor Tolerances	CTP
			Verify Solution Repeatability	CTP
			Assure Process Stability	CTP
			Monitor Output Capability	CTQ

Figure 4.0. The Progressive Milestone Activities Associated with the DMAIC Improvement Strategy

**Project Reviews:** It is firmly suggested that the X-Belt's sponsoring organization manage their Lean Six Sigma projects through a formalized set of management tollgates. A tollgate is simply a set of success criteria that must be fully satisfied before a project is allowed to continue on the next scheduled phase of execution. Normally, a management tollgate review will coincide with the completion of each phase of the DMAIC improvement process. However, in some cases, it may be necessary to incorporate In-Phase reviews (i.e., management and technical) so as to ensure adequate oversight and governance.

In this case, the presiding Master Black Belt would assume responsibility for the planned technical reviews, while the Champion (and perhaps process owner) would have responsibility for the planned management reviews. It is also recommended that one or more of the organization's executive management team join in on the management reviews. This should be done periodically so as to provide senior leadership visibility and encouragement.

**Project Tollgates:** As many are aware, tollgates ensure the timely and proper planning, approval, execution, review, verification, and closure of Lean Six Sigma projects. Naturally, the X-Belt's sponsoring organization would seek to establish the success criteria associated with each tollgate – before the fact. Prevailing business needs, management philosophy, operational requirements and organizational policies can often influence the identification and adoption of certain success criteria.

As one might expect, such criteria will vary from organization-to-organization, depending on a host of business variables and constraining circumstances. Owing to the business-centric nature of such criteria, only the sponsoring organization's management can definitively say what constitutes project success. Thus, the management would be concerned with the *Quality of Business*, not the *Business of Quality*.

## Project Closure Guidelines

**Project Conclusion:** After an X-Belt has successfully completed a Lean Six Sigma DMAIC project, that project must pass through a final management review before it can be officially closed. In other words, the project activities and resulting benefits must be validated before it is formally closed.

Of course, the criteria for closure will vary organization-to-organization, but will normally revolve around satisfying one or more of the following needs: a) sustainable benefits; b) accounting verification; c) management approval; and d) technical validity, not necessarily in this order of priority. Generally speaking, a project can only be closed once the X-Belt's sponsoring organization has officially declared that the success criteria have been reasonably satisfied.

**Project Documentation:** For purposes of organizational leadership, the sponsoring organization should want to provide the X-Belt with some type of document that confirms the successful completion and closure of a Lean Six Sigma project. Such a document can take the form of a formal letter, internal memorandum, or official certificate.

**Personal Recognition:** Generally speaking, a project completion document does not reveal specific details about the project (in the interests of business confidentiality), but does acknowledge the X-Belt's contribution and accomplishments. Needless to say, such "artifacts of success" are quite important to the individual X-Belt.

Almost without saying, such credentials can greatly facilitate management's efforts to provide

meaningful recognition, job motivation and can even serve to support employee retention. They are also meaningful for the sponsoring organization when used to facilitate annual personnel reviews.

**Authenticating Agent:** Most normally, a successful project can only be authenticated or otherwise formally certified by a recognized member of the sponsoring organization's management team. For example, such an individual might be the X-Belt's immediate manager, the related process owner, or one of the organization's senior Lean Six Sigma leaders (e.g., Champion or Master Black Belt). Only at this point can the X-Belt legitimately declare a successful project – in a verifiable way.

It should go without saying that an external consultancy or professional institution is not meaningfully positioned to authenticate, validate or otherwise certify the successful closure of an X-Belt project – for a wide array of business reasons. Such tasks are incumbent upon the sponsoring organization. Essentially, these matters are of a business nature and should only be decided by the management of that enterprise.

## Project Life-Cycle

The deployment and implementation of Lean Six Sigma improvement projects is at the center of business breakthrough. Such improvement projects are used to address a wide array of business needs, objectives and problems.

Typically, projects are deployed through a 10 step management process, as illustrated below (see the row variables associated with Figure 5.0). In this context, the 10 steps represent the "depth" of deployment.

The "scope" of implementation is represented by the DMAIC process (see the column variable associated with Figure 4.0). Thus, the table provided in Figure 4.0 holistically constitutes an operations level project deployment and implementation framework.

Use of this table involves three steps. First, select a particular DMAIC step (column variable). Second, select a project deployment step (row variable). Third, locate the row-column intersect.

For example, the assignment and chartering of Lean Six Sigma projects only occurs during the "Define" phase of the DMAIC process. Figure 5.0 also indicates that each phase of the DMAIC process must be planned, executed and reviewed independently, while validation and closure occurs during the "Control" phase of a project.

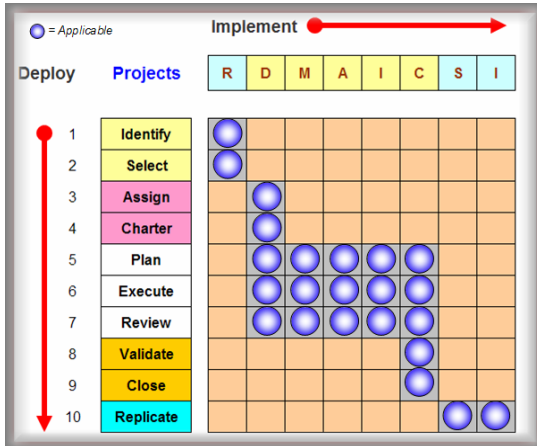


Figure 5.0 Lean Six Sigma Project Deployment and Implementation Guide

## Project Case Study

**Case Facts:** The following discussion is related to a Black Belt project and represents how “low-hanging fruit” can be gathered using the DMAIC improvement strategy.

Our story takes place within General Electric’s Plastics Division. GE Plastics, by applying the DMAIC process to over 3,000 projects, saved \$137 million in 1997. One of these projects took place in Polymerland, a division within GE Plastics (an organization that distributes thermoplastic resins). Polymerland ships plastic products to a variety of customers, including manufacturers of computers, CD-ROM’s compact discs, digital videodiscs, and automobiles.

Polymerland employees had already pulled together a Black Belt team to focus on a suspected problem. The team was in the midst of the Define phase of what they called their “Damage-Free Delivery Project” when one of their largest and most lucrative customers came to their sales force and said, “Look, we are ready to take our business elsewhere. Too many of the products you are sending us have been contaminated.”

The customer was frustrated by the fact that it was constantly receiving damaged products, and that it then had to use its own time and manpower to ship the defective product back to Polymerland for replacement. Between January 1, 1997, and June 30, 1997, Polymerland delivered 275,501,855 pounds of product to its customers.

During this period, 176,381 pounds of product was contaminated – meaning that the packaging had been damaged during shipping – and thus a damaged product was delivered to the customer. This resulted in a damage-free reported sigma of

4.72 and a DPMO (Defects Per Million Opportunities) of 640.

Realizing that one unhappy customer probably meant there were many more who were not voicing their unhappiness, and that lost customers meant lost sales, employees at Polymerland told the customer that they were aware of the problem and that they were pulling out every stop to find a solution.

**Measure Phase:** Polymerland’s Black Belt team decided to take a closer look at each of their ten warehouses from which the product was shipped, in an attempt to determine where the damages were occurring. Of the ten warehouses, two warehouses (Maumee and Piedmont) produced the highest number of defects.

The Black Belt team calculated that, between the 10 warehouse locations, the 50 different product lines, the 14 different types of packaging used, and the 100 transportation carriers used, there were nearly 700,000 combinations of variations that could be the source of the problem.

**Analyze Phase:** Black Belt team focused on the Maumee and Piedmont warehouses. They found that 95 percent of the damaged boxes had two punctures at the base of one side of the box, causing the product to leak. The Black Belts also found that 87 percent of the damage occurred when the boxes were moved by forklift onto stacks or into trucks.

It didn’t take long for the Black Belt team to decide that there was a strong correlation between the number of boxes damaged in-house – as opposed to being damaged during shipping – and the number of damaged products received by customers.

The team also discovered a relationship between how the product was packaged and the type of damage done. Bags were more likely to be damaged if they were scraped across the floor, whereas boxes were more likely to be damaged when being handled by a forklift operator.

Why, they asked, were the boxes handled by forklifts damaged while the bags were not? The answer turned out to be fairly simple. The forks on the forklift protruded six to nine inches out from under the box, so that as the fork was fully inserted under the box being retrieved, the box behind it was punctured. But if this was the case, why was the Brampton, Ontario, warehouse able to operate at Lean Six Sigma using the same forklift?

Several answers were offered, but the most tenable seemed to be the drivers' experience and the control they wielded over the forklift operation. When a box was lifted, the forks were tilted back for load stabilization. But if the driver did not lower the fork tilt, the protruding fork, instead of sliding under the first box, would puncture the second box as the first box was placed next to it. Because drivers could not see over the lift, they were forced to blindly place the boxes onto the pallets.

**Improve Phase:** Now that the problem had been thoroughly analyzed, the Black Belt team was ready to begin the Improve phase. There were several possible solutions to this problem. More-experienced forklift operators could be hired into the Maumee and Piedmont plants at a significant cost to the company, assuming it was possible to find forklift operators with nearly twenty years of experience. A second option was more extensive training for the forklift operators in the Maumee and Piedmont warehouses – another expensive solution without a guaranteed outcome.

In the end, however, the team decided to install shorter forks, eliminating the fork protrusion altogether. In December 1997, the Piedmont plant replaced the forty-two inch forks with thirty-six inch forks at a relatively nominal cost of \$350 per forklift truck. Within a short period of time, thirty-six inch forks had replaced the forty-two inch forks not only at the Piedmont warehouse but at the Maumee warehouse and other warehouses as well.

**Control Phase:** Now the Black Belt team was ready to move into the final phase, the Control phase, where steps are implemented to make sure the process stays fixed. GE has a mandate that before any Lean Six Sigma project is completed it must pass through data points.

A data point shows intervals and can reflect how often an event occurs within a given time period. A data point might be weight, inches, the number of hospital deaths that fall within a specific time period, and so on.

In Polymerland's case, a data point was a period of time, anywhere from two weeks to two months, during which Black Belts must show beyond a doubt that their projects have a workable and permanent solution.

Source: Harry and Schroeder. *Lean Six Sigma*. Doubleday (2000)

## DMAIC Improvement Process

Lean Six Sigma derives its power from the DMAIC application strategy – Define, Measure, Analyze, Improve, and Control. Figure 6.0 illustrates the DMAIC methodology and its phase-wise milestones. Through this strategy, it is possible to improve almost anything because we reduce the problem to its deterministic root. In other words, we apply the fundamental principle that says:  $Y = f(X)$ .

Phase	Goal	Milestones			
		1	2	3	
1	Define	Establish Focus	Identify Problematic Output	Review Output History	Describe Output Process
2	Measure	Create Baseline	Evaluate Process Efficiency	Quality Measurement System	Establish Output Capability
3	Analyze	Discover Causes	Diagnose Output Variation	Identify Possible Causes	Isolate Critical Factors
4	Improve	Devise Solution	Examine Factor Effects	Optimize Factor Settings	Prescribe Factor Tolerances
5	Control	Sustain Benefits	Verify Solution Repeatability	Assure Process Stability	Monitor Output Capability

Figure 6.0. The DMAIC Goals and Related Milestone Activities

Of course, this is to say that “Y” is the outcome and “X” represents all of the essential inputs, and “f” is the ways and means (process) by which the critical inputs ( Xs ) are transformed into an output ( Y ).

So, for any given problem-centric situation, we must define, measure, and analyze the critical “Y” (i.e., the CTQ) and then improve and control the critical Xs (i.e., the CTP's).

Naturally, the DMAIC milestones described in Figure 6.0 represents the progressive steps that must often be planned and sequentially executed in order to ultimately solve the problem under investigation. Figure 7.0 illustrates the possible decision outcomes associated with each milestone.

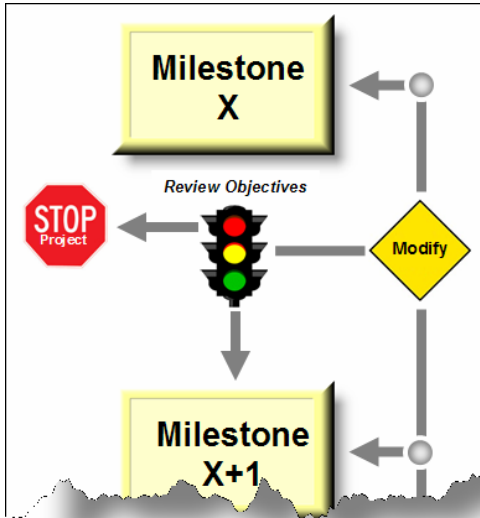


Figure 7.0. Execution Map Associated With Each of the DMAIC Milestone Activities

Appendix A offers the tollgate criteria and application guidelines commonly linked to each DMAIC milestone. Appendix B provides the specific activities (and guidelines) that must often be progressively planned and executed in order to successfully realize the aims of each DMAIC milestone (as specified in Appendix A). Appendices C1 and C2 provide additional case studies that further illustrate application of the DMAIC improvement strategy. Appendix D is a more detailed illustration of Figure 7.0

## Summary

In essence, Six Sigma is driven by a divide-and-conquer strategy that is focused on the idea of “effectiveness,” whereas Lean Practices support the concept “efficiency,” driven by the philosophy of continuous improvement. Owing to this, Lean Six Sigma projects are rolled out in accordance to a well defined process, not according to a vague notion of improving everything we do forever, followed up by a sporadic and disconnected set of actions. Rather, the practice of Lean Six Sigma divides the proverbial “pie of business” improvement into several comprehensible compartments. In turn, these islands of improvement opportunity are portioned into “application projects.” By design, these projects collectively form a vertical focus through all levels of the business enterprise.

By this point in time, it should be fairly clear why many noted industry (and governmental) leaders have taken up Lean Six Sigma: It is an enabler that allows an executive to reach the “control function” of an enterprise through highly focused, data-centric projects. The collective power of such projects unites management (and the workforce) in a pragmatic way. Lean Six Sigma indirectly forces everyone to synchronously raise their company above the limitations commonly associated with schizophrenic, disconnected, fire-fighting types of improvement activities.

Through a circumspect pattern of interrogation and action, the application of Lean Six Sigma arranges the alphabet soup of improvement initiatives (i.e., the various acronyms associated with corporate programs) into coherent words, sentences and paragraphs, so to speak. In doing so, Lean Six Sigma takes the idea of quality to a more execute-able level that is more closely aligned with the aims of business. It elevates quality to the boardroom, demanding the kind of executive attention and action that cascades to the lowest reaches of an enterprise.

## Appendix A

### DMAIC Phase Descriptions and Progressive Milestones: Common Tollgates and Guidelines

#### Phase 1: DEFINE

**General Overview:** During this phase of the DMAIC process, the critical performance variables (Ys) of a product, service, transaction, event, or activity are identified and defined. In addition, the related performance specifications (requirements) associated with each Y must be defined or otherwise established. This means that the critical-to-quality characteristics (CTQs) of a deliverable must be made known, as well as their respective performance expectations. In this manner, the “ought” condition of each essential Y is thoroughly defined and documented.

#### Phase Review Tollgates:

- ✓ The business case fully justified formal project chartering
- ✓ The project success criteria were defined and approved
- ✓ The project closure criteria were defined and approved
- ✓ The project charter reflected sufficient accountability
- ✓ The project charter adequately defined the driving business symptom
- ✓ The project team was properly formed and organized
- ✓ The project team members were allocated sufficient work time
- ✓ The project was provided all necessary leadership
- ✓ The project was sponsored by a business executive
- ✓ The project execution plan was accountable and time bounded
- ✓ The project team was allocated sufficient resources
- ✓ The project work activities were adequately defined and sequenced
- ✓ The project activities and findings were well documented
- ✓ The business symptom was linked to a key deliverable
- ✓ The CTQs for each key deliverable were identified
- ✓ The performance requirements for each CTQ were defined
- ✓ The existing work process for each CTQ was well documented
- ✓ The vital lessons-learned were sufficiently documented and well presented
- ✓ The project achieved its phase milestones on-time and within budget
- ✓ The phase outcomes and project performance justified further continuance

#### Milestone 1.1: Identify Problematic Output

**Activity Description:** This milestone is related to the selection of a product or service (i.e., deliverable) that must be improved. This means choosing a deliverable that is connected to a defined business issue or symptom. For example, a product or service that is experiencing a field quality problem. Of course, this type of problem could induce such symptoms as customer dissatisfaction, excessive warranty costs, or some other form of business risk. Naturally, the selected product or service represents the focus of a Lean Six Sigma project.

#### Application Guidelines:

- ✓ The selected deliverable must be connected to business issue
- ✓ The business issue (symptom) must be visible to stakeholders
- ✓ The business issue (symptom) must be measurable and time bounded
- ✓ The deliverable’s performance requirements must be known
- ✓ The deliverable’s performance data must be reliable and accessible

## Milestone 1.2: Review Output History

**Activity Description:** This milestone is related to understanding how the deliverable's performance history factors into the current problem. The intent is to review (i.e., explore) all of the historical connections between the selected deliverable (i.e., process output) and the driving business issue (i.e., symptom). For example, it might be desirable to analytically correlate or otherwise relate the deliverable's historical performance data to the business metric of interest (e.g., product capability vs. warranty cost). In this way, the driving need for chartering a formal Lean Six Sigma project can be reinforced if not more fully validated (before continuing the planning and execution process).

### Application Guidelines:

- ✓ Examine correlations between the deliverable and business symptoms
- ✓ Uncover patterns (trends and cycles) of poor performance over time
- ✓ Discover patterns (trends and cycles) of superior performance over time
- ✓ Determine if performance expectations have been altered over time
- ✓ Evaluate the impact of any design changes related to the deliverable

## Milestone 1.3: Describe Output Process

**Activity Description:** This milestone is related to defining the ways and means by which the deliverable is created. The intent is to provide a description (e.g., map) of the underlying process (i.e., work flow) that creates the selected deliverable. In this way, the specific process steps, touch-points and actions (that yields a unit of product or service) can be visually documented for subsequent evaluation and analysis. Often, the act of mapping the work flow (or value stream) can surface insights into the problem's nature or its system-of-causation, thereby concluding the Lean Six Sigma project.

### Execution Guidelines:

- ✓ Visually document the deliverable's existing work flow or value stream
- ✓ Include all value-added and nonvalue-added Milestones in the process
- ✓ Use collaborative efforts to create, review and approve the process map
- ✓ Annotate the process Milestones with supporting information and data
- ✓ Employ standard flow chart and mapping symbols

## Phase 2: MEASURE

**General Overview:** During this phase of the DMAIC process, each CTQ is measured so as to establish a performance baseline. In this manner, the "is" condition can be made known and then contrasted to the "ought" condition. Of course, the difference between the "is" and "ought" condition of any given CTQ constitutes a performance gap, or "value gap" as some would say. At all times, it must be remembered, "we cannot improve what we do not measure."

### Phase Review Tollgates:

- ✓ The process capability assessment plan (CAP) was complete and thorough
- ✓ The process efficiency metrics were sufficient and adequately assessed
- ✓ The process was evaluated for viable cost reduction opportunities
- ✓ The process was sufficiently evaluated for complexity reduction opportunities
- ✓ The process work flow was adequately documented and traceable
- ✓ The process work flow was evaluated for improvement opportunity
- ✓ The CTQ data availability study (DAS) was complete and thorough
- ✓ The CTQ measurement system was properly assessed and qualified
- ✓ The short-term CTQ capability metrics were identified and reported
- ✓ The long-term CTQ capability metrics were identified and reported
- ✓ The CTQ capability gaps were fully identified and meaningfully reported
- ✓ The business implications of each capability gap were assessed and reported
- ✓ The process capability metrics were translated into quality metrics

- ✓ The quality metrics were related to the process efficiency metrics
- ✓ The process efficiency metrics were related to key business objectives
- ✓ The customer's best interests (VOC) were sufficiently assessed
- ✓ The provider's best interests (VOP) were sufficiently assessed
- ✓ The vital lessons-learned were sufficiently documented and well presented
- ✓ The project achieved its phase milestones on-time and within budget
- ✓ The phase outcomes and project performance justified further continuance

## Milestone 2.1: Evaluate Process Efficiency

**Activity Description:** This milestone is related to understanding how efficiently the current process actually operates. The intent is to examine the relative efficiency associated with the deliverable's underlying process or work flow. This means that, once a process has been thoroughly documented (i.e., mapped), it is often desirable to evaluate or otherwise examine such things as complexity, cycle-time, operating costs and so on. By way of such an examination, it is often possible to establish a linkage between process efficiency and effectiveness (i.e., the connection between product or service quality and process efficiency).

### Execution Guidelines:

- ✓ Establish the actual operating costs of the process
- ✓ Examine the actual cycle-time of the process
- ✓ Investigate the actual productivity of the process
- ✓ Correlate process efficiency metrics to product quality metrics
- ✓ Perform gap analyses for selected process efficiency metrics

## Milestone 2.2: Qualify Measurement System

**Activity Description:** This milestone is related to understanding how effective the measurement system actually is. The intent is to ensure that the system of measurement provides values (i.e., measurements) that are statistically representative of the characteristic (i.e., CTQ) being investigated. In other words, such studies are intended to verify that the measurement system is capable of providing unbiased results and minimum variation. Of course, such objectives must be satisfied prior to the continuance of a Lean Six Sigma project.

### Execution Guidelines:

- ✓ Ensure that the measurement system is statistically repeatable
- ✓ Demonstrate the measurement system is statistically reproducible
- ✓ Verify that the measurement system provides accurate results
- ✓ Confirm that the measurement system exhibits linearity
- ✓ Assure that the measurement system provides stable results

## Milestone 2.3: Establish Output Capability

**Activity Description:** This milestone is related to understanding how effective the process actually is. The intent is to statistically determine the performance capability of each product or service CTQ that is selected for subsequent improvement. In this manner, the primary improvement planning and execution activities can be better focused. For example, a capability analysis that reveals a long-term problem with process centering would necessarily imply a set of improvement actions that would likely be quite different from those of a problem that was related to short-term process spread.

### Execution Guidelines:

- ✓ Select primary indices of capability (metrics) based on reporting needs
- ✓ Develop a valid sampling plan prior to executing the capability study
- ✓ Estimate short-term capability using accepted quality practices
- ✓ Estimate long-term capability using accepted quality practices
- ✓ Examine the business consequences related to the capability findings

## Phase 3: ANALYZE

**General Overview:** During this phase of the DMAIC process, the focus is on analyzing the performance gaps related to each selected CTQ. Of course, the intent of this phase is to separate where the problem “is” and “is not.” To do this, we must look for patterns of poor performance, as well as patterns of good performance. Such patterns can provide great insight into how the improvement effort should be continued and guided. In addition, we must also consider any key differences or associations within and among the CTQ’s.

### Phase Review Tollgates:

- ✓ The process capability diagnostic plan (CDP) was complete and technically sound
- ✓ The primary sources (families) of CTQ variation were identified and evaluated
- ✓ The analytical and operational assumptions were assessed for compliance
- ✓ The estimates of short-term CTQ capability were free of assignable causes
- ✓ The short-term CTQ capability was assessed for possible autocorrelations
- ✓ The long-term CTQ capability was assessed for possible autocorrelations
- ✓ The sustainability of short-term CTQ capability was adequately evaluated
- ✓ The sustainability of long-term CTQ capability was adequately evaluated
- ✓ The CTQ design specifications were evaluated for possible modification
- ✓ The CTP brainstorming process focused on the primary source of CTQ variation
- ✓ The list of potential causes (CTPs) was properly and sufficiently developed
- ✓ The potential causes (CTPs) were prioritized in terms of their contributory power
- ✓ The CTP variable confirmation plan (VCP) was complete and technically sound
- ✓ The top suspect variables were thoroughly tested for contributory power
- ✓ The vital few CTPs were identified and rank ordered in terms of power
- ✓ The essential phase conclusions were rational and supported by the data
- ✓ The vital lessons-learned were sufficiently documented and well presented
- ✓ The phase best-practices were identified and adequately documented
- ✓ The project achieved its phase milestones on-time and within budget
- ✓ The phase outcomes and project performance justified further continuance

### Milestone 3.1: Diagnose Output Variation

**Activity Description:** This milestone is related to identifying the major family of variation associated with the CTQ of interest. The intent is to isolate the major categories of variation that underpins the current process capability. This means the observed CTQ variations must be classified (i.e., decomposed into logical categories). For example, the major source of variation might be within-group and not group-to-group or temporal in nature (i.e., occur over time). Of course, this would point to a certain subset of causative variables. Thus, subsequent improvement efforts would be better focused.

#### Execution Guidelines:

- ✓ Determine the extent to which capability is influenced by centering
- ✓ Determine the extent to which capability is influenced by spread
- ✓ Explore the influence of centering and spread on output quality
- ✓ Isolate the source (category) of variation that leverages capability
- ✓ Examine autocorrelations to uncover nonrandom patterns and trends

### Milestone 3.2: Identify Possible Causes

**Activity Description:** This milestone is related to identifying the process variables that are suspect causes of insufficient capability. The intent is to identify possible causes (i.e., agents) that could induce or otherwise cause process capability to change (positively or negatively). Of course, such causes are frequently identified and prioritized through the application of structured brainstorming methods. Naturally, these methods rely heavily on collaboration; therefore, participants must be quite familiar with the related product or service, as well as the associated process. Historical sources of data and information are often used to supplement and guide the related activities

**Execution Guidelines:**

- ✓ Identify and evaluate all relevant sources of data and information
- ✓ Focus brainstorming efforts on the major source (category) of variation
- ✓ Employ a rational method for prioritizing all of the potential causes
- ✓ Classify the potential causes by centering and spread influence
- ✓ Determine if the suspect variables can be easily manipulated

**Milestone 3.3: Isolate Critical Factors**

**Activity Description:** This milestone is related to confirming the relative influence of each suspect cause (i.e., process variable). The intent is to determine the extent to which the suspect variables can independently exert undue influence on the CTQ capability (positively or negatively). In other words, the objective is to isolate improvement leverage by exploring the effects of competing variable settings among the array of suspect variables (i.e., contrasting different operating conditions). The goal is to estimate the direction and magnitude of effect associated with each of the suspect variables.

**Execution Guidelines:**

- ✓ Discover the magnitude of effect associated with each suspect variable
- ✓ Establish the direction of effect associated with each suspect variable
- ✓ Evaluate the risk that any variable effect is due to sampling error
- ✓ Ensure the testing assumptions are reasonably satisfied
- ✓ Assure analytical conclusions are fully supported by the data

**Phase 4: IMPROVE**

**General Overview:** During this phase of the DMAIC process, we seek to improve the capability gap of each CTQ by close examination and improvement of the critical process Xs. Such Xs are also called critical-to-process variables (i.e., CTPs). Once identified, the CTPs must be set to their most optimal operating conditions. Of course, the overall intent of this phase is to discover the “vital few” CTP relationships that drives the performance of each selected CTQ. Hence, the goal is isolate process leverage by uncovering the CTP relationships and settings that exert undue positive (and negative) influences on the CTQ capability gaps. Thus, a solution is identified, examined and rationally tested.

**Phase Review Tollgates:**

- ✓ The process capability improvement plan (CIP) was complete and thorough
- ✓ The CIP made provisions for the possibility of process redesign
- ✓ The CIP made provisions for the possibility of product redesign
- ✓ The statistical effects of each CTP were appropriately evaluated and reported
- ✓ The practical effects of each CTP were appropriately evaluated and reported
- ✓ The selected CTPs were each assigned an optimal nominal specification
- ✓ The selected CTPs were each assigned an optimal performance tolerance
- ✓ The recommended CTQ capability gap solutions were subjected to pilot testing
- ✓ The recommended CTQ capability gap solutions were evaluated for robustness
- ✓ The recommended CTQ capability gap solutions were evaluated for feasibility
- ✓ The recommended CTQ capability gap solutions were evaluated for sustainability
- ✓ The essential phase conclusions were rational and fully supported by the data
- ✓ The solution implementation plan (SIP) was documented and well organized
- ✓ The SIP included provisions for a pilot implementation of the proposed solutions
- ✓ The SIP included a cost-benefit analysis and time bounded milestones
- ✓ The vital lessons-learned were sufficiently documented and well presented
- ✓ The phase best-practices were identified and adequately documented
- ✓ The project achieved its phase milestones on-time and within budget
- ✓ The phase outcomes and project performance justified further continuance

## Milestone 4.1: Examine Factor Effects

**Activity Description:** This milestone is related to understanding how each CTP can directionally influence the CTQ capability. The intent is to explore and assess all of the key effects associated with the CTPs that are known to exert undue influence on the CTQ capability. This means that the independent and interactive effects (that surface during the course of testing and evaluation) must be statistically examined and validated in terms of direction and magnitude. In addition, the practical and statistical conclusions must be rendered with a known degree of decision confidence.

### Execution Guidelines:

- ✓ Develop a test strategy that conforms to accepted quality practices
- ✓ Ensure an appropriate sample size prior to executing the test strategy
- ✓ Graphically examine the effect of each CTP prior to statistical analysis
- ✓ Determine the statistical and practical significance of each effect
- ✓ Assure the analytical conclusions are fully supported by the data

## Milestone 4.2: Optimize Factor Settings

**Activity Description:** This milestone is related to establishing the ideal process center for each CTP. The intent is to prescribe a nominal operating condition (i.e., target value) for each CTP. Of course, only those CTPs that exerts an undue influence on the CTQ capability should be considered for optimization. The larger intent is to discover those input settings that allows substantial variations in each CTP, yet maximizes the overall CTQ capability and operating efficiency. This action makes the CTQ capability impervious to variations in the CTPs, as well as other process variables (i.e., robustness). Thus, the overall capability and producibility of the CTQ can be significantly enhanced.

### Execution Guidelines:

- ✓ Evaluate the usefulness of interactions to facilitate robustness
- ✓ Evaluate the usefulness of nonlinearities to facilitate robustness
- ✓ Isolate the CTP conditions that maximizes CTQ performance
- ✓ Evaluate the selected CTP conditions in terms of process efficiency
- ✓ Assure the analytical conclusions are fully supported by the data

## Milestone 4.3: Prescribe Factor Tolerances

**Activity Description:** This milestone is related to tolerancing the CTPs. The intent is to prescribe operating specifications (i.e., upper and lower boundary limits) for each of the critical process variables that exert undue influence on the CTQ capability. The larger intent is to specify a robust targeting condition and corresponding tolerances for each CTP. This means that the process center and spread of the CTQ will not be appreciably disturbed by the short-term or long-term variations in the CTP. In other words, the performance capability of the selected CTQ (or any other CTQ) will not be negatively impacted by CTP variations in process centering and spread (or any other potentially disturbing low-grade nonrandom process event).

### Execution Guidelines:

- ✓ Establish a nominal performance specification (target) for each CTP
- ✓ Establish tolerances for all nominal specifications
- ✓ Post the performance specifications in an appropriate location
- ✓ Develop a statistical tolerancing model to assess producibility
- ✓ Perform tolerance simulations or worst-case analysis as needed

## Phase 5: CONTROL

**General Overview:** During this phase of the DMAIC process, we seek to control the optimal settings of each CTP. In this manner, the performance condition of each CTQ can be made stable over time and "robust" to normal nonrandom low-grade errors in process centering. When the settings of each CTP are truly optimal, the CTQ will be naturally "robust" or otherwise "impervious" to a limited range of variations in the corresponding CTPs.

### Phase Review Tollgates:

- ✓ The process capability control plan (CCP) was complete and documented
- ✓ The CCP is based on a defined data-driven closed-loop feedback control strategy
- ✓ The CCP included well defined set of CTQ monitoring guidelines and procedures
- ✓ The CCP included well defined set of CTP control guidelines and procedures
- ✓ The CCP included guidelines and procedures for CTQ capability assessment
- ✓ The CCP included meaningful documentation of the optimal process work flow
- ✓ The CCP included guidelines and procedures for evaluating process efficiency
- ✓ The CCP included guidelines for the periodic review of process design
- ✓ The CCP included a defined set of audit criteria for assuring on-going compliance
- ✓ The CCP included a time bounded transition plan for the process owner
- ✓ The impact of process improvements on existing business systems was evaluated
- ✓ The impact of process improvements on existing business metrics was evaluated
- ✓ The vital lessons-learned were sufficiently documented and well presented
- ✓ The phase best-practices were identified and adequately documented
- ✓ The project achieved its phase milestones on-time and within budget
- ✓ The primary project benefits were validated and approved by Phase Review
- ✓ The original project closure criteria were sufficiently satisfied and approved
- ✓ The customer related benefits were communicated to the appropriate personnel
- ✓ The project team members were acknowledged for their successful participation
- ✓ The project team members were rewarded for their successful participation

### Milestone 5.1: Verify Solution Repeatability

**Activity Description:** This milestone is related to assuring the solution's on-going effectiveness. The intent is to empirically verify that the solution can be replicated, thereby validating its effectiveness at resolving the original problem and related business issue or operational symptom. To this end, it is often necessary to demonstrate the solution's short-term viability and long-term feasibility to sustain improvements related to the CTQ capability. This means the solution must resolve the underpinning problem and keep it from reoccurring over time.

#### Execution Guidelines:

- ✓ Implement the proposed solution on a trial basis
- ✓ Conduct periodic reviews to assess the solution's vitality
- ✓ Execute limited post-mortem tests to evaluate solution effectiveness
- ✓ Execute limited post-mortem tests to assure solution stability over time
- ✓ Evaluate the solution's operational feasibility and efficiency

### Milestone 5.2: Assure Process Stability

**Activity Description:** This milestone is related to assuring on-going process stability for each CTP. The intent is to implement a robust closed-loop feedback control system that will effectively and efficiently restrict the random and nonrandom variations associated with process operation. In turn, this ensures that the CTQ capability will remain relatively constant and predictable over time. Once the process has been stabilized, the practice of continuous improvement can be more effectively and efficiently implemented, thereby further enhancing process performance over time.

**Execution Guidelines:**

- ✓ Develop a process control plan to enable the voice-of-the-process
- ✓ Track the performance of each CTP using standard SPC methods
- ✓ Use appropriate control limits that are properly computed and plotted
- ✓ Make process adjustment decisions based on statistical data
- ✓ Detect and eliminate assignable (special) causes as they occur

**Milestone 5.3: Monitor Output Capability**

**Activity Description:** This milestone is related to monitoring the deliverable's performance (i.e., CTQ capability) over time. The larger aim is to detect, react to and eliminate the occurrence of nonrandom variations (i.e., assignable or special causes) that could result in some form of unacceptable business risk or loss. This means that the deliverable's performance capability must be periodically reviewed and evaluated for compliance to standards (with a known degree of statistical confidence).

**Execution Guidelines:**

- ✓ Develop a product control plan to enable the voice-of-the-customer
- ✓ Track the performance of each CTQ using standard SPC methods
- ✓ Use appropriate control limits that are properly computed and plotted
- ✓ Make process adjustment decisions based on statistical data
- ✓ Detect and eliminate assignable (special) causes as they occur

## Appendix B

### DMAIC Milestone Activities: Common Planning and Execution Guidelines

**Milestone Activity Descriptions:** For each progressive milestone related to the DMAIC process (see figure 5.0), it is essential to systematically plan the key activities that must be sequentially executed in order to ensure success. More specifically, the improvement team leader is well advised to consider the following planning and execution activities (and related guidelines) in order to facilitate the successful realization of each DMAIC milestone.

- 1.0 Plan Focus:** Establish one or more execution objectives to guide the investigation
- 2.0 Plan Metrics:** Specify the performance metrics and variables that underpins each objective
- 3.0 Plan Tools:** Select analytical tools to examine variable effects and relationships
- 4.0 Plan Sampling:** Employ valid sampling methods that ensures proper representations
- 5.0 Plan Resources:** Provide for the human and economic resources essential to success
- 6.0 Execute Plans:** Implement the execution plans in a responsible and accountable manner
- 7.0 Execute Solutions:** Devise and test solutions that fully satisfy the phase objectives
- 8.0 Execute Closure:** Bring about a verifiable and accountable conclusion to the phase

**Milestone Activity Guidelines:** Of particular interest, each activity is defined by a set of sequential application guidelines (see below). Owing to the fact that every project is unique, it may not be necessary to adopt all of the activities or related guidelines. Nonetheless, the full range of activities and guidelines should be evaluated in the interest of thoroughness. As the old saying goes: “poor planning makes for poor performance.” Therefore, the team leader’s time is well spent evaluating each of the project activities and application guidelines.

#### 1.0 Plan Focus – Guidelines:

- 1.1 Define Phase Objectives
- 1.2 Establish Phase Boundaries
- 1.3 Examine Phase Assumptions
- 1.4 Conduct Management Review
- 1.5 Make Progress Decision

#### 2.0 Plan Metrics – Guidelines:

- 2.1 Specify Performance Variables
- 2.2 Identify Measurement Scale
- 2.3 Define Performance Expectations
- 2.4 Select Performance Metric
- 2.5 Document Measurement Strategy
- 2.6 Conduct Technical Review
- 2.7 Make Progress Decision

#### 3.0 Plan Tools – Guidelines:

- 3.1 Establish Analytical Objectives
- 3.2 Assess Analytical Constraints
- 3.3 Select Analytical Methods
- 3.4 Examine Analytical Assumptions
- 3.5 Document Analytical Plan
- 3.6 Conduct Technical Review
- 3.7 Make Progress Decision

#### **4.0 Plan Sampling – Guidelines:**

- 4.1 Identify Sampling Requirements
- 4.2 Determine Sample Size
- 4.3 Devise Tracking System
- 4.4 Develop Recording System
- 4.5 Document Sampling Plan
- 4.6 Conduct Technical Review
- 4.7 Make Progress Decision

#### **5.0 Plan Resources – Guidelines:**

- 5.1 Develop Resource Plan
- 5.2 Establish Execution Timeline
- 5.3 Conduct Management Review
- 5.4 Make Progress Decision

#### **6.0 Execute Plans – Guidelines:**

- 6.1 Implement Resource Plan
- 6.2 Implement Sampling Plan
- 6.3 Implement Analytical Plan

#### **7.0 Execute Solutions – Guidelines:**

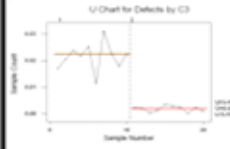
- 7.1 Draw Analytical Conclusions
- 7.2 Develop Phase Recommendations
- 7.3 Conduct Technical Review
- 7.4 Make Progress Decision

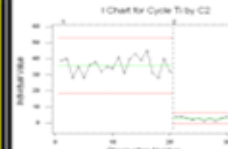
#### **8.0 Execute Closure – Guidelines:**

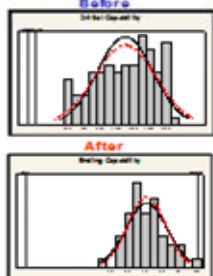
- 8.1 Prepare Phase Report
- 8.2 Conduct Tollgate Review
- 8.3 Make Progress Decision

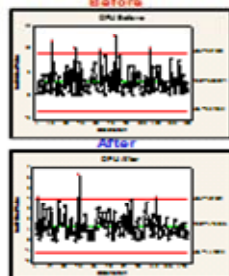
## Appendix C1

### Additional DMAIC Case Studies

Black Belt Project Wave Soldering	
<b>Problem</b> Excessive cost to comply with wave solder specification	<b>Performance</b> 
<b>Tools Used</b> MSA Control Charts DOE Regression	<b>Benefits</b> \$375,000 touch-up and repair ops eliminated Eliminated DOD audit rejects Certification

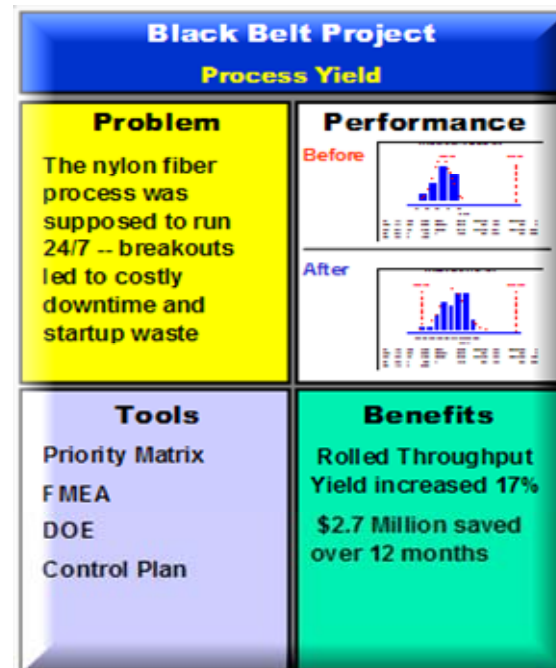
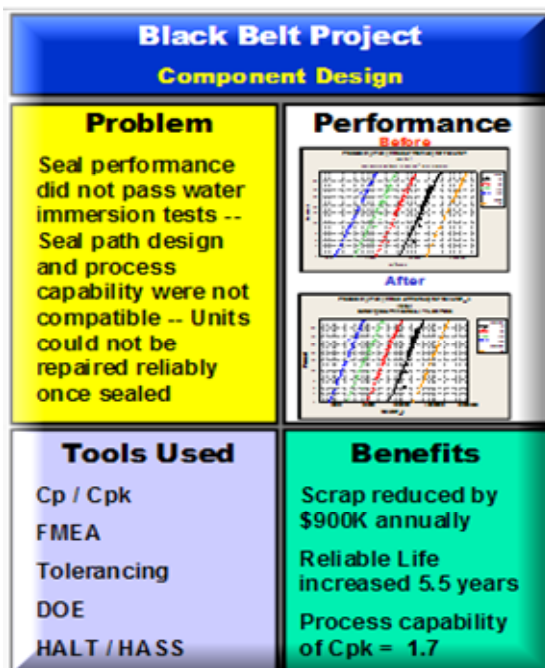
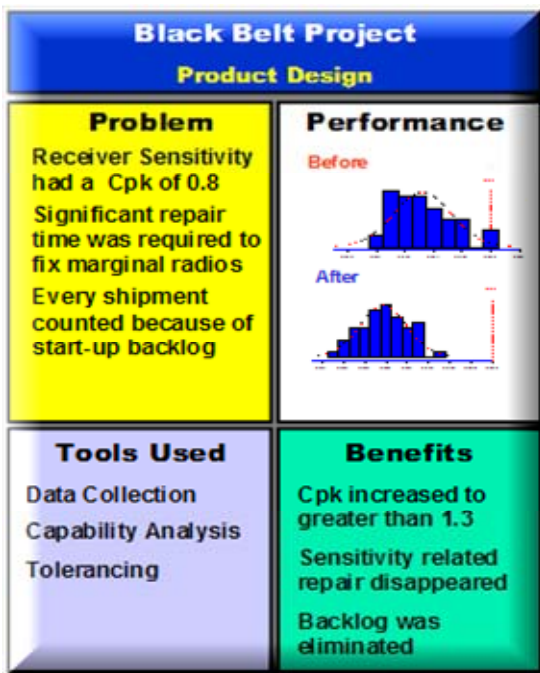
Black Belt Project Accounting Cycle Time	
<b>Problem</b> Challenged to reduce Accounting Cycle time from >30 days average to <7 days average to support Lean and JIT goals	<b>Performance</b> 
<b>Tools Used</b> VOC capture Process Mapping Process QFD Control Charts B vs. C testing	<b>Benefits</b> Accounting Cycle time reduced to <3 days average

Black Belt Project New Product Introduction	
<b>Problem</b> Solder defects were over 1500 ppm New product introduction critical Product could not be repaired Critical customer	<b>Performance</b> 
<b>Tools Used</b> Measurements Failure Modes Experiments Response Surface	<b>Benefits</b> Defect levels reduced <100 ppm & Scrap reduction of over \$500K Reduced test time from 3 min < 30 sec

Black Belt Project Customer Service	
<b>Problem</b> Pricing and product code errors in Customer Service -- \$750K in excess inventory -- Unrealized margin of \$225K	<b>Performance</b> 
<b>Tools Used</b> Process Mapping Data collection FMEA B vs. C Test Control Charts	<b>Benefits</b> Pricing Error reduced 48% Reduced inventory by 35% \$150K benefit

## Appendix C2

### Additional DMAIC Case Studies



## Appendix D

### DMAIC Milestone Roadmap

