Six-Sigma: The Best Way to Demonstrate Technological Leadership and Corporate Excellence

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Abstracts

The term 'Six-Sigma' is a reference to a particular goal of reducing defects to near zero. Statistically speaking, the concept of Six-Sigma broadly implies the processes involved in a system that are working nearly perfectly, delivering only 3.4 defects per million opportunities (DPMO). 'Six Sigma' principle–based management is to be able to measure the extent and nature of defects in a process fairly accurately and systematically find the way-outs to eliminate them. A more rational approach to determine the Sigma level would be to calculate how many defects occur compared to the number of opportunities in the product or service. Design for Six-Sigma (DFSS) involves a business process focused mainly on improving profitability. When properly applied, DFSS generates the right kind and mix of products and services at right time at right cost. Using Six-Sigma, organizations can significantly improve their core processes together with core competency, which, in turn, will improve their product and service delivery. To be consistent, and deliver quality product and services is what ultimately translates into organizational credibility. It also facilitates its transformation to strategic partners at every step with the customer - thus enhancing long-term value in a sustainable manner.

The paper highlights some of the cardinal features and characteristics of six-sigma with focus on its basic ingredients, Tools for measurement of optimization, process design/ redesign. Complemented by illustrative case studies in electronics, energy, power, automobiles, software ,chemicals, defense and healthcare sector.

(Key words: Six-Sigma applications, DFSS, Benchmarking, Corporate leadership & excellence)

Six-Sigma originated as a quality improvement methodology in manufacturing. Using Six-Sigma, organizations can significantly improve their core processes, which, in turn will improve their product and service delivery. Consistent, quality product and service is what ultimately buys organizational credibility. It also facilitates its transformation to strategic partner at every step with the customers enhancing value over a period of time.

Statistical modeling and analysis is the core element of world class Quality process management. It is a fundamental tenant of Six-Sigma and is a regular part

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of management in the world's top organizations. The ability to understand business inputs, internal attributes, outputs, customers, and partners through meaningful and usable statistical analysis enables organizations to reach the highest levels of effectiveness and efficiency. Effective quantification of business processes provides major benefits in terms of: (i) The ability to predict the Quality of outputs, (ii) The ability to quickly identify "real" root causes, (iii) The ability to identify issues before they become problems, (iv) The ability to identify special cases, (v) The ability to improve processes and their outputs.

From simple percentages to complex regression modeling of multiple processes, Six-Sigma helps organizations define and implement analysis systems that deliver meaningful and useable information. These statistical methods are implemented to meet several key criteria such as: (i) Appropriate Level of Complexity; (ii) Actionable Information; (iii) Systemic Data Collection and Reporting; (iv) Horizontal and Vertical Relationships identified and reported upon.

What is Six-Sigma?

Six-Sigma is a set of practices originally developed by Motorola. A defect is defined as nonconformity of a product or service to its specifications. While the particulars of the methodology were originally formulated by Bill Smith at Motorola in 1986, Six-Sigma was used for six decades of quality improvement methodologies such as quality control, TQM, and Zero- Defects. Like its predecessors, Six Sigma asserts the following: [2, 3]

- Continuous efforts to reduce variation in process outputs is key to business success
- Manufacturing and business processes can be measured, analyzed, improved and controlled
- Succeeding at achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management

Six-Sigma Methodology

Six-sigma methodology was formulated to processes and reduce the failure at all levels of production which can help in reduction of failure. The challenge needed in depth and accurate study and analysis of various processes used, and understanding the root-cause of failures in order to minimize the defects and increase profit.

Johnson & Johnson determined that the DMAIC cycle, with the addition of 'innovative' could provide a strategy framework on which Organization process can be built up. The CEOs of corporations made Six-Sigma a top priority. They established Six-Sigma as the Management framework by which their organizations would run. Employees were encouraged to take Six-Sigma Champion, Black Belt and Green-Belt trainings. They were expected to produce results based on Six-Sigma projects 12.

Six-sigma uses process data and analytical techniques in order to find out various process variables. Once the process variables are obtained, they help in developing the exact understanding of various processes. This understanding/data is then used to improve the processes and help in reducing defects/losses in other areas of the organization.

Due to the simplicity, Six-sigma methodology is very easy to implement and integrate into any organization. The six-sigma methodology operates on the following main steps:

- **Define:** In this step, the team responsible for six sigma methodology implementation in the organization collectively defines various goals and sub-goals. Define step emphasizes on customer satisfaction, identification of root causes of any identified defect, improvement and establishment of infrastructure in order to help achieve the defined goals and sub-goals.

- **Measure:** This step involves activities such as preparing various metrics based on the data available in hand, more data collection activities, basic data packets creation or sampling etc.

- **Analyze:** This step involves analysis of defects using 'Cause & Effect' and other diagrams, study of possible modes of failure i.e. root cause analysis etc. in order to prepare various charts to improve process and control & monitor the process improvement activities. This step can help in establishing the facts about processes currently being utilized in terms of there effectiveness, contribution to six sigma methodology success, defect rates and at what extent these processes help in achieving the organization level success etc. and can help in achieving various goals.

- **Improve:** This step involves utilization of data collection, metrics and analysis done during the Define, Measure and Analysis steps. Improvised techniques are brought into action and applied to process improvement model. The team working on six sigma methodology application to the organization also may experiment various techniques to help in process improvement.

- **Control:** In this step, all the techniques being utilized for process improvement are monitored and adherence to procedural methodology is assured. Various charts based on the techniques being utilized against time frame are used to help keep a check on the successful execution of six-sigma methodology.

It's very important to understand the six sigma methodology and its application for any industry/ organization. Six sigma methodologies not only emphasizes on reduction of defects i.e. only 3.4 per million, it also gives a significant importance to customer satisfaction and customer voice.
There are currently three types of expertise levels in six- sigma implementation: Green Belt, Black Belt Practitioner and Black Belt (Master). The degree of expertise and skill sets increases from Green Belt to Black Belt (Master). Cost of six-sigma methodology implementation in an organization depends on the organizational needs; it varies based on deployment and utilization of the six sigma trained resources in various projects or on organization level.

Design for Six-Sigma

Design for Six-Sigma (DFSS)[14] involves a business process focused on improving profitability. When properly applied, DFSS generates the right kind and mix of products and services at right time at right cost. A well-documented, well understood and useful product development process is fundamental to a successful DFSS Programme. Hence, DFSS is known and widely acknowledged to be a rigorous approach to designing products, services, and/ or processes to reduce delivery time, development cost, increase effectiveness and better satisfying ability for the customers. Design for Six-Sigma (DFSS) is a highly disciplined approach to embedding the principles of Six-Sigma as early as possible in the design and development process. When problems are not discovered, until well into the product life cycle, the costs to make changes, not to mention intangible costs, such as customer dissatisfaction, are considerable.

Design for Six-Sigma (DFSS) is a separate and emerging business-process management methodology related to traditional Six Sigma. While the tools and order used in Six-Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is process *generation* in contrast with process *improvement*.

DMADV, Define – Measure – Analyze – Design – Verify, is sometimes synonymously referred to as DFSS. The traditional DMAIC implies: Define – Measure – Analyze – Improve – Control. Six-Sigma process, as it is usually practiced, which is focused on evolutionary and continuous improvement manufacturing or service process development, usually occurs after initial system or product design and development have been largely completed. DMAIC Six-Sigma as practiced is usually consumed with solving existing manufacturing or service process problems and removal of the defects and variation associated with defects. On the other hand, DFSS (or DMADV) strives to generate a new process where none existed, or where an existing process is deemed to be inadequate and in need of replacement. DFSS aims to create a process with the end in mind of optimally building the efficiencies of Six-Sigma methodology into the process before implementation; traditional Six-Sigma seeks for continuous improvement *after* a process already exists.

The DFSS for Software Engineering is essentially a non superficial modification of "classical DFSS" since the character and nature of software is different from other fields of engineering. The methodology describes the detailed process for successfully applying DFSS methods and tools throughout the Software Product Design, covering the overall Software Development life cycle: Requirements, Architecture, Design, Implementation, Integration, Verification and Validation. The methodology explains how to build predictive statistical models for software reliability, robustness and shows how simulation and analysis techniques can be combined with structural design and architecture methods to effectively produce software and information systems at Six-Sigma levels.

DFSS in Software Engineering acts as a glue to blend the classical modelling techniques of software engineering *such as* OOD ERD with statistical, predictive models and simulation techniques. The methodology provides Software Engineers with practical tools for measuring and predicting the quality attributes of the software product and also enables them to include software in system reliability models. It Introduces techniques and measurements from different stages of the life cycle: Requirements, Design, Implementation, Verification and Validation [15].

DMAIC

Basic methodology consists of the following five steps:

- *Define* the process improvement goals that are consistent with customer demands and enterprise strategy.
- *Measure* the current process and collect relevant data for future comparison.
- *Analyze* to verify relationship and causality of factors. Determine what the relationship is, and attempt to ensure that all factors have been considered.
- *Improve* or optimize the process based upon the analysis using techniques like Design of Experiments.
- *Control* to ensure that any variances are corrected before they result in defects. Set up pilot runs to establish process capability, transition to production and thereafter continuously measure the process and institute control mechanisms.

DMADV

Basic methodology consists of the following five steps:

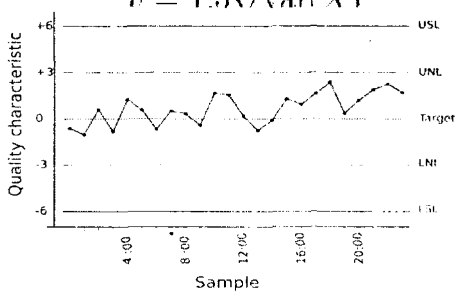
- *Define* the goals of the design activity that are consistent with customer demands and enterprise strategy.
- *Measure* and identify CTQs (critical to qualities), product capabilities, production process capability, and risk assessments.
- *Analyze* to develop and design alternatives, create high-level design and evaluate design capability to select the best design.
- *Design* details, optimize the design, and plan for design verification. This phase may require simulations.
- *Verify* the design, set up pilot runs, implement production process and handover to process owners.

Some people have used DMAICR (Realize). Others contend that focusing on the financial gains realized through Six-Sigma is counter-productive and that said financial gains are simply byproducts of a good process improvement.

The ±1.5 Sigma Drift:

The ±1.5ó drift is the drift of a process mean, which is assumed to occur in all processes [16]. If a product is manufactured to a target of 100 mm using a process capable of delivering ó = 1 mm performance, over time a ±1.5ó drift may cause the long term process mean to range from 98.5 to 101.5 mm. This could be of significance to customers.

$$\nu = 1.5\sqrt{\mathrm{var}(X)}$$



A run -chart, depicting a +1.5ó drift in a 6ó process. USL and LSL are the upper and lower specification limits and UNL and LNL is the upper and lower natural tolerance limits.

Harry then took this a step further. Supposing that there is a process in which 5 samples are taken every half hour and plotted on a control chart, Harry considered the "instantaneous" initial 5 samples as being "short term" (Harry's n=5) and the samples throughout the day as being "long term" (Harry's g=50 points). Due to the random variation in the first 5 points, the mean of the initial sample is different from the overall mean. Harry derived a relationship between the short term and long term capability, using the equation above, to produce a capability shift or "Z shift" of 1.5. Over time, the original meaning of "short term" and "long term" has been changed to result in "long term" drifting means. Harry has clung tenaciously to the "1.5" but over the years, its derivation has been modified. In a recent note from Harry, "We employed the value of 1.5 since no other empirical information was available at the time of reporting." In other words, 1.5 has now become an empirical rather than theoretical value. Harry further softened this by stating "... the 1.5 constant would not be needed as an approximation". Interestingly, 1.5ó is exactly one half of the commonly accepted natural tolerance limits of 3ó.

Despite this, industry is resigned to the belief that it is impossible to keep processes on target and that process means will inevitably drift by ±1.5ó. In other words, if a process has a target value of 0.0, specification limits at 6ó, and natural tolerance limits of ±3ó, over the long term the mean may drift to +1.5 (or -1.5).In truth, any process where the mean changes by 1.5ó, or any other statistically significant amount, is not in statistical control. Such a change can often be detected by a trend on a control chart. A process that is not in control is not predictable. It may begin to produce defects, no matter where specification limits have been set.

Defects & the Sigma level

One significant feature of Six-Sigma is that it translates the messiness of variation into a clear black-or-white measure of success: either a product or service meets customer requirement or it doesn't. Anything that falls below the customer's expectation level is called a 'defect'. A more rational approach to determine the Sigma level is to calculate how many defects occur compared to the number of opportunities there are in the product or service for things to go wrong: viz. Defects per Million Opportunities (DPMO). The Table presented below illustrates the relationship between the Sigma values as are relative to % Accuracy corresponding to the Defects per Million Operations.

Range of Six Sigma Quality

σ	% Accuracy	Defects per Million Opportunities
1	30.85	691,500
2	69.15	308,500
3	93.32	66,800
4	99.38	6,210
5	99.977	233
6	99.9997	3.4
7	99.999998	0.020

Six Basic Ingredients of Six-Sigma

'Six-Sigma Way' introduces the following six critical ingredients that are generally needed to achieve significant Six-Sigma capability within an organization: (i) Genuine focus on customer, (ii) Data and Fact – driven Management, (iii) Process Focus, Management and Improvement, (iv) Proactive Management, (v) Boundary-less Collaboration, (v) Drive for perfection, Tolerance of Failure. To operationalize 'Six-Sigma' ways effectively the ideal thing to do is to form Six-Sigma teams to address specific business issues and improve processes, products and services. In fact, Six-Sigma ideas need to become a way of life for a professionally managed organization, as by applying these ideas, an organization become dynamic, profitable with unparalleled efficiency and customer loyalty.

Six-Sigma Implementation

To operationalize Six-Sigma Design, there are seven critical functions and roles that need to be identified, organized and developed. There are: (i) Formation of Leadership group or Council, (ii) Identification/ Nomination of Sponsors and Champions, (iii) Deployment of Implementation Leader, (iv) Six-Sigma Coach (Master Black Belt), (v) Team/Project Leader (Black Belt), (vi) Team member, (vii) Process owner. Scoping Six-Sigma Projects entail first clearly defining its opportunity. In this exercise, the team refines its problems statement and goal, identifies customers served along with their requirements and writing plan as to how to complete the project (i.e. Process Map). In the implementation schedule, Process map gives way to measuring performance, as a transitional step. There are two important components of performance measurement of activities based on Six-Sigma principle: (i) Plan and Measure performance against customer requirements; (ii) Develop baseline defect measures and identify improvement opportunities.

Implementation roles

Six- Sigma identifies several key roles for its successful implementation.

- *Executive Leadership* includes CEO and other key top management team members. They are responsible for setting up a vision for Six-Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
- *Champions* are responsible for the Six-Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from the upper management. Champions also act as mentors to Black Belts. At GE this level of certification is now called "Quality Leader".
- *Master Black Belts*, identified by champions, act as in-house expert coaches for the organization on Six-Sigma. They devote 100% of their time to Six-Sigma. They assist champions and guide Black Belts and Green Belts. Apart from the usual rigor of statistics, their time is spent on ensuring integrated deployment of Six-Sigma across various functions and departments.
- *Experts* This level of skill is used primarily within Aerospace and Defense Business Sectors. Experts work across company boundaries, improving services, processes, and products for their suppliers, their entire campuses, and for their customers. Raytheon Incorporated was one of the first companies to introduce Experts to their organizations. At Raytheon, Experts work not only across multiple sites, but across business divisions, incorporating lessons learned throughout the company.
- *Black Belts* operate under Master Black Belts to apply Six-Sigma methodology to specific projects. They devote 100% of their time to Six-Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six-Sigma.
- *Green Belts* are the employees who take up Six-Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts and support them in achieving the overall results.
- *Yellow Belts* are employees who have been trained in Six-Sigma techniques as part of a corporate-wide initiative, but have not completed a Six-Sigma project and are not expected to actively engage in quality improvement activities.

Benchmarking for Six-Sigma

- Lean cannot bring a process under statistical control.
- Six-Sigma alone cannot dramatically improve process speed or reduce investment capital.

Guideline for Successful Implementation

For effective and successful implementation of Six-Sigma, manager should ensure the following to minimize possible problems that may be encountered:

- Commitment from the leaders and top management
- All leaders should be trained to be champions
- Six Sigma planning must be included in the operation plan
- Selection of right master belt and black belt
- Return on training investment at least 20 times the amount invested
- Start the movement at the bottom/shop-floor level so as to train people who are directly responsible for the process
- Create a Certification process
- Develop a process for experienced practitioners to mentor new candidates after training
- Validate financial return of projects
- Do not allow Six-Sigma to be classified as

the responsibility of the quality manager

- Create an infrastructure for the Six-Sigma initiative and assign roles and responsibilities throughout the organization

Successful implementation of Six-Sigma Designs also entails leading the Six-Sigma Project Team through 5 distinct stages of implementation viz. (i) The Define stage (ii) The Measuring Process Performance stage (iii) Analyzing Data and Investigating Cause stage (iv) Improving the Process stage (v) Control and Process management stage. In short, these stages are called DMAIC (Define, Measure, Analyze, Improve, and Control).

Six-Sigma Process Redesign

Like Product Life Cycle (PLC), Six-Sigma Design may also suffer the Law of diminishing return in post-maturity phase of DMAIC Projects on account of a few main causes of pains, costs and defects in a process or product. The following issues confronted by Six-Sigma Team may even prompt a process of rethinking leading to redesign of the project:

- Gap between real customer requirement and current performance is so wide that 'fix it' solution won't do
- Number of critical factor/causes that combine to drag the process down is so large that it is prudent to replace the whole process with a new one (e.g. Business Process Reengineering)
- Customers demand greater flexibility needing team's improved process innovations and new technologies to compete with the competitors.
- Need for enhanced risk-taking capability

The best way to address the above circumstantial requirement and redesign a broad framework for DMAIC is to go through the following logical steps for the Six-Sigma Process Redesign:

Step 1: Define the Design/Redesign Goal, Scope and Requirements
Step 2: Measure to Establish Baseline Performance
Step 3: Analyze the Critical Elements to trigger Process Design
Step 4: Improve –Designing and Implementing the New Process
Step 5: Control the New Process

Building Six-Sigma Excellence:

A Case of General Electric

General Electric's Six-Sigma program originated in a meeting between CEO Jack Welch and former vice-chairman Lawrence Bossidy- now CEO of Allied Signal. Welch invited Bossidy to speak to GE executives on Six-Sigma in May 1995. By October 1995, Six-Sigma was company policy. Best Practices, LLC originally studied GE's implementation of Six-Sigma in 1997; two years after CEO Jack Welch designed his company's program, now a global benchmark standard. Allied Signal analysts recently revisited the financial and cultural implications of the program to produce "Building Six-Sigma Excellence: A Case Study of General Electric." The updated and expanded report provides detailed descriptions of how problem-solving skills and techniques mastered at General Electric can boost the impact and efficiency of all business activities. The power of this research study is the comprehensive yet concise profile of successful practices at several top GE business units, including GE Capital, GE Appliances, GE Plastics, and GE Medical Systems as well as in-depth information highlighting Six-Sigma innovation at Motorola and Allied Signal. The Six-Sigma methodology has become more deeply ingrained in GE's corporate culture than any other company. Throughout the development and deployment of the program, GE has benchmarked the Six-Sigma methodology from other companies, including Motorola and AlliedSignal, to ensure that the process is implemented for maximum benefit[24].

At the General Electric, implementation of Six-Sigma Programme resulted in the following pattern of return on investment over the years:

- In 1996, costs of $200 million and returns of $150 million
- In 1997, costs of $400 million and return of $600 million
- In 1998, cost of $400 million and return of more than $ 1 billion

Six -Sigma: A Case study of Motorola in Road mapping

Motorola is widely considered the pioneer of road-mapping. The company initially began using roadmaps in the 1980's to forecast market requirements, predict the availability of key technologies and plan product development accordingly. During the 80s and early 90s, roadmaps were popularized by former Motorola CEO, Robert Galvin, and he is widely quoted in speeches crediting Motorola's success in the marketplace to their technology road-mapping process.

Today, this pioneer uses Alignent's software solutions as their single, company-wide system for all road-mapping information. With Alignent, Motorola's disciplined road-mapping process is now highly collaborative, easy to build upon year-over-year, and tightly connects all business units across the worldwide company.

Motorola, a global communications leader and Fortune 100 company, has long relied on strategic roadmaps to identify new technology and market opportunities. After decades of road-mapping, the company found itself with a "problem of riches" by 2001— Motorola now needed a better way to track and organize the tens of thousands of product roadmap documents distributed across the enterprise. Roadmaps were fueling the company's strategy and innovation practices, but the physical documents were becoming cumbersome to manage.

As Motorola evaluated its evolving road-mapping needs, the company's leaders determined that they not only needed a single system to manage enterprise-wide road-mapping information, they also needed a system that could accomplish six key requirements[26]:

1. Improve innovation planning and collaboration across distributed business units
2. Forecast emerging technologies, products and markets, including monitoring external and internal innovation factors
3. Capitalize on strategic planning data instead of re-planning from ground zero each year
4. Identify instances where the company could increase technology re-use, inserting platform technology into the new product development process to leverage time and resources
5. Minimize duplicative product planning efforts in departmental silos across the globe
6. Implement strategic planning software that incorporates road-mapping best practices into the tool, providing a central repository where roadmaps can be accessed and stored

Motorola explored various options that could scale and support long-range global innovation planning efforts. After an extensive search, Motorola selected Alignent as its road-mapping partner. "With Vision Strategist, we can create multi-dimensional views of roadmaps that set our expectations for the minimum set of information needed to make better decisions," said Tony Piecz, Manager of Planning Solutions at Motorola. The team at Motorola was also impressed with the software's ability to provide visibility into future plans and critical relationships over time. Executives valued the ability to exchange real-time planning information, and receiving automatic updates and alerts when roadmaps changed. Motorola has now deployed Alignent's software in more than nine countries around the world. The company has reported savings of more than $100 million by consolidating strategic planning projects across various business units. Planning teams continuously update roadmaps to reflect changes in markets, customer needs and competitive activity. Individuals across business units collaborate via online strategy meetings where they give and receive feedback on strategic product plans and roadmaps.

Six- Sigma: Designing for Quality & Excellence by Siemens

The task of the Quality Systems Group at Siemens Westinghouse Power Corp. (SWPC) has been reported to be quite challenging in the Power generation industries: It endeavored to systematically implement a supplier-facing standardized product- and process qualification process for gas turbine blades. The new process, still under testing, helped to considerably reduce PPQ cycle time, eliminated or minimized product failure points downstream, reduced scrap and improved first-time yield. In the highly complex and demanding power-generation industry, business success depends on effective collaboration with suppliers to ensure superior, reliable and efficient designs; rapid planning to production cycle time; and containment of development and manufacturing costs. For SWPC, the main business objective was to improve economic performance while achieving customer satisfaction and strategic supplier relationships through standardized processes and consistent methodologies.

Headquartered in Orlando, Florida, SWPC is the regional business entity in the Americas for Siemens Power Generation's global fossil power generation business, which has an installed fleet of more than 600,000 megawatts worldwide. Siemens Power Generation offers a full spectrum of products and services, throughout the entire power plant life-cycle, including gas and steam turbines, electric generators, process control and power management systems, and fuel cells for the distributed generation market. With about 250 multi-tier suppliers across the globe providing components for gas turbines, the supplier quality management function plays a vital role in the sourcing process. Gas turbine blades have one of the most complex sourcing processes, involving upto five unique sourcing steps.[28]

1) Investment casting
2) Root machining
3) Cooling hole drilling (electrical discharge machining and electro-chemical machining)
4) Diffusion and ceramic coatings
5) Airflow testing and moment weight

The process of designing a turbine blade is inherently complex, involving precise and unique product characteristics, such as high-strength and high-temperature alloys, thermal barrier coating, and complex cooling to withstand extreme turbine operating temperatures and tight dimensional tolerances. Meeting the stringent requirements of the design intent and close to zero tolerance for failures requires the skills of many design, manufacturing and quality professionals across various organizations. This eventually made the design and qualification process for gas turbine blades highly collaborative and complex.

After reviewing the data collected during the measurement phase of the study and comparing them with the goals of a closed-loop PPQ process, it was apparent that the existing PPQ process failed to map these goals. The Six-Sigma study also identified a direct link between the up-front effort put into process development and qualification as well as the nonconformance costs. Among other improvements, the study demonstrated that a standardized, closed-loop PPQ process with consistent methodologies would improve first-time yield, thereby reducing or eliminating rework cycles and scrap. Furthermore, the Six-Sigma study concluded that a system leveraging the Internet would drive the PPQ process in a way that steers suppliers to focus on up-front process development as opposed to the current practice of creating a basic process and modifying it after full production has begun.

Applying Six Sigma Methodology to DCC's Energy-Saving Projects:

The Dow Chemical Company is a leading science and technology company that provides innovative chemical, plastic, and agricultural products and services to many essential consumer markets. With annual sales of $27 billion, Dow serves customers in more than 170 countries and a wide range of markets that are vital to human progress, including food, transportation, health and medicine, personal and home care, and building and construction, among others. Committed to the principles of Sustainable Development, Dow and its approximately 50,000 employees seek to balance economic, environmental, and social responsibilities. In 1998 Dow chose to implement Six-Sigma methodology to accelerate the company's rate of improvement in quality and productivity. A trial of Six-Sigma in two of Dow's global businesses convinced management that the value proposition was well worth the effort, and in September 1999 the company launched a corporate-wide program to incorporate the Six-Sigma methodology into all of its businesses and functions. The company's 1999 annual report stated that by the end of 2003, Dow expected its Six-Sigma implementation to deliver revenue growth, cost reductions, and asset utilization totaling $1.5 billion in earnings before interest and taxes (EBIT). At the close of 2002, Dow achieved its $1.5 billion cumulative financial goal—a full year ahead of schedule.

Dow began its implementation of Six-Sigma in 1999. In each subsequent year, Dow has continued its Six-Sigma commitment with renewed vigor. Through our implementation of Six-Sigma, Dow has gained increasing value while equipping employees with critical problem-solving skills and a mindset for reducing variation and defect.

Since the implementation of Six-Sigma as a Company-wide discipline, Six Sigma projects of Dow Chemicals have contributed to Company's economic results in the form of productivity gains, opportunity growth, and cost savings. At Dow, Six Sigma goes beyond dollars and manufacturing efficiency improvements. In 2003, the tools and methodology of Six-Sigma were put to work on more than 300 projects related to Environment, Health, and Safety (EH&S) activities[29]. These projects were primarily focused on 2005 EH&S goals and productivity targets. DCC's Six Sigma project focused on improving water treatment at a major manufacturing complex. In the end, this project delivered effective, efficient wastewater treatment and managed to save Dow approximately $3 million.

DCC is also applying the company's Six-Sigma mindset to improve company's social performance – because DCC view employee dissatisfaction and shortcomings in community relations as defects in our operations, the same as waste generation or shortfalls in plant productivity.

The Advanced Defense Technology Company Mind-Manager to facilitate Lean Six-Sigma process-improvement events

The Advanced Defense Technology Company (ADTC) MindManager- a Fortune-500 defense technology company is a world leader in building extremely complex defense systems - everything from missiles to fighter aircraft. But when the company needs to improve the mission-critical business processes behind its products, it finds there's no substitute for visually mapping information. The company's Lean Six-Sigma facilitators use Mindjet® MindManager® to map information collected during Lean Six-Sigma process-improvement events.

"Lean Six Sigma initiates structured change into the environment," says one of the company's leading Lean Six Sigma event facilitators. "Change is very frightening to most people, and inevitably generates resistance. Mapping helps address the challenges of changing an environment, because employees are able to focus better with the visual representation of that change." Capturing the way things are the facilitator uses MindManager to facilitate week-long Lean Six-Sigma events that bring together up to ten people from across many functional areas involved in a business process. The events have addressed hardware design, software development, networking and telecommunications, and horizontal integration. This leading defense technology company uses MindManager to create visual representations of current, ideal and future state characteristics. Team members are able to quickly grasp the current and future state characteristics, issues and process improvements related to those characteristics, and to work together to devise ways to improve mission-critical business processes in developing Defence Technology [30].

Six-Sigma in Healthcare

Healthcare companies of various types are using six-sigma projects as change management tools to improve the business. The healthcare industry and hospitals in particular, are ripe for a set of improvement tools such as six-sigma. In some healthcare institutions, it has become imperative to reduce costs and provide better and more value added services all at the same time. And the time frame to get this done was "yesterday". Six-sigma is one initiative helping these companies combat this margin squeeze. For example, if a provider performed six ultrasounds per day, it may now be necessary to provide sixteen or more.

Six-sigma tools include statistical analysis, both simple and complex. They include tools such as regression analysis, ANOVA (analysis of variance), FMEA (failure mode and effects analysis), cause and effects matrix, voice of the customer, design of experiments, control charts, hypothesis tests, comparison of means and standard deviations, CT trees, and many others.

As an example of how a tool is used, suppose a hospital chain is trying to find a way to increase the number of tests performed per day, such as X-rays.

Six-sigma tools can be used to help analyze each technician's results and times, and determine the most effective methods. The end solution might be a combined lean six sigma solution. For example, the analysis might show two technicians with the most output, highest quality and samples from the same population. Deeper analysis may show that scheduling improvements and pricing effects the backlog. The result might be a new price and standardized procedures to enable 16 tests to be performed per day in each unit. If eight hospitals averaged four tests per technician, and it is improved to sixteen tests per day, the additional contribution gained by the system is huge.

Maximizing revenue per bed in a hospital is important. The system must provide excellent care, but providing a bed without providing any other services is not maximizing resources. It is therefore critical to find the optimum balance to fill every bed with the most rapid turnover of services while providing the best care possible.

There are hundreds of ways six-sigma and lean six-sigma can be used to improve the business in healthcare companies. They could be as simple as reducing the wasted motion for nurse's aides or as complex as finding the best combination of drugs to treat cancer[31]. In children undergoing surgical intervention, performance improvement principles can improve the handoff process and decrease the delay of time-sensitive therapies [32].

As identified in Phase 1 of this study—the "Define," "Measure," and "Analyze" steps of the Six-Sigma framework—communication errors frequently occurred during the postoperative handoff communication process (mean 5.6; median 5.0 errors per handoff event). These most commonly involved information pertaining to a patient's medical history or current surgical intervention (87 percent of communication errors). Furthermore, the handoff process was found to be negatively affected by the following three factors: (1) clinicians involved in a patient's recent care did not consistently participate; (2) the handoff content and method were poorly standardized; and (3) interruptions or distractions were frequently present during handoff events. (4) Because of this initial evaluation, the "Improvement" step focused on a standardizing the communication process. This standardization centered on establishing a team handoff model and modifying the environment in which the handoffs occurred.[33]

To educate the multidisciplinary health care providers caring for children's heart disease in structured communication techniques, the staff underwent "team training" through the TeamSTEPPS™ curriculum. This program, developed by the Agency for Healthcare Research and Quality (AHRQ) in collaboration with the Department of Defense, is an evidence-based curriculum focused on improving patient outcomes by developing communication and other teamwork skills among health care professionals [34].

Statistical Software for Six-Sigma

Advanced statistical software such as Minitab (http://www.minitab.com/) or Statgraphics (http://statgraphics.com), are very useful if not essential for gathering, categorizing, evaluating, and analyzing the data collected throughout a Six-Sigma project. Both Minitab and Statgraphics are powerful full standalone statistical process control software applications for performing statistical analysis. Both are highly recommended for Six Sigma use as they are tools that can help you utilize one of Six Sigma's biggest advantages: the ability to make better decisions based upon data. They will work with the DMAIC Define-Measure-Analyze-Improve-Control methodology and Lean Six-Sigma.

Both Minitab and Statgraphics are designed to support the Six-Sigma philosophy offering a range of tools for graphical analyses, collecting powerful statistics, quality analyses with potential for a range of custom designed uses.

- Statistical Process Control Charts
- Analysis of Variance and Regression Analysis
- Design of Experiments
- Factorial and Matrix Plots
- Relationships between variables
- Life Data Analysis and Reliability
- Process Capability Analysis
- Hypothesis Testing
- Correlation and regression
- Time Series Analysis and Forecasting
- Measurement Systems Analysis

- Regression Analysis
- Multi-variation analysis
- ANOVA tools and techniques
- Six-Sigma Quality Assessment

Both applications provide you with nearly real time statistical data, enabling you to respond quickly to prevent further defects. Statistical evaluation of the data identifies key areas to focus process improvement efforts on, which can have an adverse effect on product quality if not controlled.

However, while it is easy to purchase a statistical software application, it is harder to use it effectively. It is *smart* analysis of the data that create real change. All too often, Six-Sigma/DMAIC teams collect and load data into Minitab or Statgraphics only to find them overwhelmed by the prospect of where to start and how to use their new tool to successfully analyze their data that comes up with, not just any answers, but meaningful and useful answers. As a result, Six Sigma/DMAIC projects often fall far short of the productivity expectations associated with statistical software. Training in use of Minitab is often offered integrated with Six Sigma training. Minitab training will focus on solving practical problems with Minitab. This includes learning the practical aspects of major statistical tools like Control Charts, Capability Analysis, Regression Analysis, and ANOVA. There is a strong emphasis on learning how to get data into Minitab, learning how to manipulate data once in Minitab and learning how to display graphically major findings from the data. Proper training will teach you how to drive Minitab like a pro and thus bring greater statistical power to your Six Sigma projects (http://www.buzzle.com/editorials/4-3-2006-92630.asp) [37].

Conclusions

Scores of Six-Sigma consulting companies are now in existence, promising to improve an organization's bottom-line. Expectations frequently fall short, however, because the so-called expert consultants do not fully understand or put into practice the true Six-Sigma methodology in the right perspective and/ or operational frame.

"Six-Sigma remains a vital force for identifying and addressing the inefficiencies in business operations that lead to outrageous levels of defects and extraordinarily wasteful operating costs," says Greg Brue- the man who Six- Sigma'd GE, Motorola, Allied Signal and more than 75 leading corporations. "But to gain the benefit of Six-Sigma, one need to know who to select to lead one's company's deployment." According to the findings of Greg Brue, Six-Sigma is today's most honoured and effective quality initiative.[38]

Yet to achieve optimal results from such an initiative, companies must fast master the building blocks of Six-Sigma. Design for Six-Sigma (DFSS) shows decision makers at all levels how to implement and improve the DFSS tools and techniques from earliest design through final production of virtually any product, service or process. Design for Six-Sigma (DFSS) involves a business process focused mainly on improving profitability. When properly applied, DFSS generates the right kind and mix of products and services at right time at right cost. Using Six-Sigma, organizations can significantly improve their core processes together with core competency, which, in turn, will improve their product and service delivery. To be consistent, and deliver quality product and services is what ultimately translates into organizational credibility. It also facilitates its transformation to strategic partners at every step with the customer - thus enhancing long-term value in a sustainable manner.

Six-Sigma principles and methodologies also show us how to join today's quality leaders by incorporating DFSS to each step of new product or service development programme for maximum impact and return on Six-Sigma Investment. This point has been effectively exemplified through citing some of the illustrative case studies in this paper covering manufacturing, non-manufacturing sector, electronics, telecom, automotive, defense technology, chemicals, energy and healthcare sector. The scope of Six-Sigma applications can be synergistically extrapolated to other important segments of the National economy needing creation of critical infrastructure such as Aviation, Port and shipping, hospitality, tourism, mining & minerals, Space research, Oil & Natural gas, Energy & Power etc. Integrating Six-Sigma with Business Process Management, Business Process Reengineering and Business Process Innovations will take the Six-Sigma approach a long way to achieve corporate leadership and excellence.

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