SIX SIGMA

The Breakthrough Management Strategy
Revolutionizing the World's Top Corporations

By Mikel Harry Ph.D and Richard Schroeder

(Random House, Doubleday 2000)

Preface: What is Six Sigma?

(1) Quality programs are reactive, focusing on detecting and correcting *defects*.
(2) 6Sigma proactively *re-creates processes* so defects/errors will not occur at all.

How does Six Sigma work? Organizations need to measure what they claim to value.

(1) We don't know what we don't know
(2) We won't know until we measure
(3) We measure what we value ... and what we don't measure, we don't value

6Sigma is a process of asking questions that lead to tangible, quantifiable answers that ultimately produce profitable results.

CHAPTER #1: Why Six Sigma?

6Sigma improves *profitability*, although better quality and efficiency are immediate by-products.

Observed results:

(1) 1σ per year improvement to 4.7σ
  (a) If already at 4σ, a company should achieve 4.7σ in one year.
  (b) 4.7σ can be achieved without large capital outlay.
(2) Improvement from 4.7σ to 5σ will take 1 year.
  (a) The closer to 6σ, the harder to achieve greater improvement
  (b) At 4.8σ, companies hit-the-wall requiring DFSS (covered later)
(3) Improvement from 5σ to 5.1σ will take another year

Companies typically operate at a 3-to-4σ level:

(1) Companies focus on *process quality* ... customers focus on *product* or *service quality*.
(2) With 6Sigma, a defect is *anything* that blocks or prohibits a process.
(3) 6σ is a performance target applying to critical-to-quality (CTQ) items, not the total product.

Airlines deliver passengers safely at 0.5 failures per million, better than 6Sigma. However, their *baggage* operations are in the 3.5-to-4σ range.

Cost of quality:

σ-level	defects/million	cost of quality
2	308,537 (non-competitive)	not applicable
3	66,807	25-40% of sales
4	6,210	15-25% of sales
5	233	5-15% of sales

CHAPTER #2: The Yellow Brick Road

6Sigma is the *philosophy* of 3.4 defects per million (the Land of Oz). Breakthrough Strategy is the *means to achieve* that goal (The Yellow Brick Road).

Breakthrough Strategy is data-gathering and statistical analysis, pinpointing sources of error and ways of eliminating them.

(1) Statistics separate common sense from extraordinary reasoning.

(2) Statistics is a microscope that makes invisible things visible.

Four core phases in applying Breakthrough Strategy to achieve 6Sigma results:
(1) Measure: data collection and reporting
(2) Analyze: statistical methods and tools to ñexplainò defects
(3) Improve: ñDesign for Six Sigmaò process
(4) Control: continuous monitoring, no problem reoccurrences

CHAPTER #3: Being Cheap is Better

Every defect is an economic detractor for the producer and the customer.

5 Cost-of-Quality categories:
(1) Failure in the field: service problems, warranty claims
(2) Internal failure: labor + material associated with rework and scrapped parts
(3) Appraisal and inspection: labor + material + equipment to catch defects before shipping
(4) Improving poor quality: training programs and equipment to control quality
(5) Opportunity costs: without resources tied-up in fixing defects, production could be greater

Some organizations believe that the costs of going beyond 3-or-4ů through defect reduction (more and more expensive quality control) will exceed the benefits of reducing poor quality. Wrong. 6Sigma performance levels dramatically reduce appraisal and prevention costs.

We don't try to *inspect* our way to 6Sigma.
Rather, we eliminate defects at the root source.
Abandon minor adjustments and consider entirely new ways of doing business.

The cost-of-quality attributable to poor design is difficult to estimate, but we know it is very large.

(1) Numerous studies show that 70% of a productôs total cost is due to its design.

(2) Management consultants put the estimate at 80%

The higher the quality designed-in to a product, the lower its cost.
Reducing testing and rework increases profitability greatly.

GENERAL ELECTRIC: In the 20 years of Jack Welchôs reign as CEO and Chairman, General Electric grew from $12 Billion to almost $300 Billion. Prior to 6Sigma, he was a self-proclaimed cynic when it came to quality programs ... feeling they were *heavy on slogans and light on results*.

(1) Training in GEôs 6Sigma program takes precedence over *every* other GE training program. In March 1997, Welch sent out an Email directing that *everyone* interested in senior management positions must complete Green or Black Belt training by 1 July 1998.

(2) Welch says ñ6Sigma means fixing processes so they are nearly perfect ... and then controlling them so they stay fixed.ò The objective of all 6Sigma programs is the elimination of variance.

CHAPTER #4: Benchmarking ... Who's the Best?

A 4.2ů company can lead a pack of 3.8ů companies ... if itôs happy with being just ñgood enoughò.

Benchmarking lets companies define what ñworld classò really is and assess their current performance relative to the BEST.

(1) Companies should always know their strongest competitors ... on process-by-process basis.
(2) Answer what it means to be ñbestò, and what it takes to get there. It can bring to light questions and insights that lead to breakthrough.
(3) Not a one-time event ... it is a continuous process.
(4) Not blindly incorporating someone elseôs business practices based on hearsay or speculation.
(5) Can be accomplished through literature searches, computer searches, articles and technical papers ... site visits and interviews, too.

(a) *Internal benchmarking*: comparing common processes within single company
(b) *Competitive benchmarking*: comparing directly with competitors
(c) *Functional benchmarking*: focuses on the process itself, regardless of industry
(d) *Quantitative benchmarking*: seeks to establish two things:
- determines yield or defect rate
- determines the number of opportunities for defects

Example: Dissimilar products made using the same process

Product A ... 85% final yield, 600 opportunities for defects (high complexity).
Avg yield per defect opportunity = (0.85)**(1/600) = 99.97% (or about 3.5ů)
meaning: (1) 15% of the units produced contain one or more defects, or
(2) A product with 600 defect opportunities, at 3.5ů, produces one defect for every 1.2 units produced.

Product B ... 96.8% final yield, 48 opportunities for defect (low complexity)
Avg yield per defect opportunity = (0.968)**(1/48) = 99.97% (or about 3.5ů)

6Sigma creates a level field for benchmarking, regardless of a product's complexity.

CHAPTER #5: Changing What Companies Measure

Measure what you are speaking about. When you can express it in numbers, you *know* something about it. When you cannot, your knowledge is unsatisfactory.

Breakthrough language:
Without ñtalkingò data, products and services are mute and companies are deaf.

Without measurement, there is no *control*.

If we assume there is a relationship between an outcome (Y) and a potential cause (X), we must collect and analyze data to prove our hypothesis. *If we want to change an outcome, we need to focus on the X, not the Y.*

(1) 4ů companies focus on the final product or service (Y). For example, ñHave we met our financial targets?ò. Answer ... yes, but the *reasons* are not explored.

(2) 6ů companies focus on the processes that generate the problem ... the X variables.

As the organization examines and corrects the *processes* (Xs) that create the product or service, the need to inspect and test the outcomes (Ys) diminishes.

Critical-to-Quality Characteristics (CTQs): Organizations must determine what is critical to their customerôs satisfaction, then define how to measure and report them. CTQ measurements must be correlated to key process variables and so they can improve the process.

CHAPTER #6: Unmasking the Hidden Factory

Poor-quality companies spend a huge amount of time and money detecting and correcting mistakes.

Hidden factory: The time, space and resources taken up by companies unwittingly by ad hoc systems set up to correct errors.

> *Example*: Mary in Dept A returns a defective part to Jane in Dept B, before it is noticed by management. Are they acting responsibly? No, they are masking a bad process.

First-time yield: # units that pass inspection, compared to the total # units inspected (output divided by input) at a certain point in the process. This metric is *flawed* ... it can gravely mislead and deceive. It ignores *multiple defects in the same unit*. Final yield is similar, but after the last step in the process. It sometimes ignores defects entirely:

Example: A process produces ten coffee cups. The operator sees that 5 are defective, so he recycles that material and sends the 5 good ones to the inspection point. Yield = 100% at the inspection point. The rework is not captured in any cost structure. This is a ñhidden factoryò.

Three fundamental metrics can expose even the smallest inefficiencies: They are based on *defects* produced, whereas other traditional measurements are based on # units produced.

(1) **Throughput Yield (TY)** vs First-time yield (FTY): Likelihood of ñdoing all things rightò *at a given point in the process.* TY is defect-sensitive and measures how well companies process quality. FTY is unit-sensitive and measures how well companies process units.

Example: In a 5-step process, 100 units have just passed through step #3. Each unit has 20 opportunities for defect (CTQs). At step #3, we observed 5 defects in the 100 units.
Defects/unit = 5/100 = 5%

5 of every 100 units created at step #3 will contain one or more defects
Throughput yield = 95% (95 of 100 will pass step #3 with zero defects)
* with FTY, if all five defects were in one unit, FTY = 99%

Defects/opportunity = (Defects/unit) / (opportunities/unit) = 0.05/20 = 0.0025
Defects-per-million-opportunities = 2,500, or about 4.3ů capability

(2) **Rolled Throughput Yield (RTY)** vs Final Yield (FY): Likelihood of ñdoing all things rightò *across the entire process*. RTY is based on the total number of defect opportunities produced, and FY is based on the total number of units produced.

Correlations: Interestingly, there is no correlation between FTY and FY ... they are independent measures (FTY is not used to calculate FY). But there is a direct correlation between, because both TY and RTY are calculated based on defects-per-opportunity data. Both TY and RTY are dependent on quality information, not production volume.

Example: Same 5-step process. TYs for each step = 98%, 93%, 95%, 98% and 94%.
RTY = (.98)x(.93)x(.95(x(.98)x(.94) = 0.7976 = probability of passing a unit through all five steps defect-free.

(3) **Normalized Yield (NY)**: Average throughput yield at any given step in the process.

Example: 10-step process, and RTY is 36.8%.
NY = *k*th root of TRY, where *k* is the # steps in the process
= (0.368)**(-10) = 0.9051

Additional calculations: A certain process has an RTY = 70%. How many units must be input to produce one defect-free output?

Assuming defects are repairable: 1 + (1 - RTY) = 1 + (1 - .7) = 1.3
Assuming defectives are scrapped: 1/(RTY) = 1.43

Effectiveness focuses on *results*. Efficiency focuses on *activity*.
Effectiveness is turning the right crank. Efficiency is turning the crank right.
Companies, like people, can do the wrong things with great efficiency.

CHAPTER #7: Breakthrough Strategy

The Breakthrough Strategy affects different organizational levels like multiple gears moving in synchronicity but at different speeds.

Organizational levels:
(1) *Business* level ... executives use 6ů to improve market share, profitability and ensure long-term viability.
(2) *Operations* level ... managers use 6ů to improve yield, eliminate hidden factories and reduce costs of labor and material.
(3) *Process* level ... Black Belts use 6ů to reduce defects and variation, improving profitability and customer satisfaction.

Components and categories:
(1) Identification category ... Recognize and Define components
(2) Characterization category ... Measure and Analyze components
(3) Optimization category ... Improve and Control components
(4) Institutionalization category ... Standardize and Integrate components

		Business level	Operations level	Process level
Identify	**Recognize**	true states of your business	links to key business systems	functional problems
	Define	plans for improvement	6Sigma projects	processes linked to problems
Characterize	**Measure**	systems supporting plans	performance of 6Sigma projects	capability of each process
	Analyze	gaps in benchmarks	performance WRT to goals	data for trends and patterns
Optimize	**Improve**	system elements	6Sigma project management	key process characteristics
	Control	characteristics critical to value	inputs to project management	most influential variables
Institutionalize	**Standardize**	ñbest in classò systems	ñbest in classò practices	best methods and processes
	Integrate	best systems into strategy	6ů practices into policies	processes into design cycle

CHAPTER #8: Measuring Performance on the Sigma Scale

Most defects are persistent, tenacious and covert, making them hard to identify and correct. They do not raise alarms. They are often factored-in as ñcost of doing businessò.

All processes vary around their target *mean*. Over time, the variance increases due to ñprocess-centering errorò.

(1) Research has shown that 4ů processes drift about 1.5ů over time.
(2) So when a company claims 6ů processes, they really mean:
    (a) the short-term sigma capability of their processes is 6ů
    (b) the long-term performance is 4.5ů due to process-centering errors

Example: A builder designs a garage with standard width and depth, and he draws a line exactly down the center of the parking area. If the car parked exactly over the line every time, there is always enough room to get in and out comfortably. But the builder knows the driver will rarely park exactly in the center, so he takes into account ñdriver errorò , or process-centering error.

VARIATION: There are three primary sources of variation:
(1) Inadequate design margins ... tolerances and permissible ranges
(2) Unstable parts and materials ... provided by vendors and suppliers
(3) Insufficient process capability ... canôt meet CTQs demanded by customers

Design for Six Sigma (DFSS): Product quality is directly tied to an organizationôs ability to take a design concept from development on through production with minimal variation. DFSS is intended to create designs that are:

(a) resource efficient
(b) capable of very high yields regardless of complexity or volume
(c) impervious (or ñrobustò) to process variations

Although design typically represents the smallest actual cost element in products, it leverages the largest cost *impact*. Incremental improvements in design can have huge impacts on total costs.

GENERAL ELECTRIC: In 1995, GE decided to design a new CAT-scanner using 6Sigma methodology. The X-Ray tubes cost $59K and lasted 3 months. The new tubes cost $85K, but:

(1) they came with a *one-year* warranty.
(2) full-body scans that once took 3 minutes now take *20 seconds*
(3) equipment takes *less time to cool* from the end of one scan to the start of another

At GE, Chairman and CEO Jack Welch said ñSix Sigma is now part of the genetic code of our future leadershipò.

CHAPTER #9: Implementation and Deployment

Reducing defects not only improves reliability, it reduces cycle-time and increases capacity.

Six Sigma is not a grassroots initiative. It will not ñbubble upò to the surface.

Six Sigma roles and responsibilities:
(1) Executive Management ... inspire, own, fund and drive the initiative. *It is not enough for senior management to attend a 6Sigma training session and then assign Black Belts to projects*.
(2) Senior Champion* ... permanent corporate-level position, reporting to President, responsible for day-to-day corporate-level management of 6Sigma.
(3) Deployment Champion* ... permanent (strategic) business unit-level position, reporting to Senior Champion, may become collateral duty as deployment progresses.
(4) Project Champion ... 2-year (tactical) business unit-level position, ñtrail bossesò and responsible to guide Black Belts.
(5) Deployment Master Black Belt ... the ñJohnny Appleseedsò of 6Sigma, spreading the seeds, while Master Black Belts water the seeds, and Black Belts harvest the fruit.
(6) Master Black Belts ... 2-year assignment. If Black Belts are where the rubber-meets-the-road, Project Master Black Belts are where the tire-meets-the-rim.
(7) Black Belts ... 2-year technical position, 6Sigma expert, responsible for execution
(8) Green Belts ... part-time assistants, extending reach of Black Belts, may take on mini-projects

* positions to receive intensive training and certification in the Breakthrough Strategy

Postponing implementing major systems until processes are 4σ or better will result in:
(1) time to implement these systems reduced 50%
(2) cost of implementation reduced 60%.

Compensation: CEOs and executive-level should have 30% of their incentive compensation tied to 6Sigma. Black Belts should be compensated for their achievements. Leaders not achieving their targets must be penalized. Only the best should be tapped for 6Sigma leadership positions.

Suppliers/Vendors: Perennial problem. However, 5-or-6ů products *can* be created out of 4ů components. Not every part is critical ... open the bandwidth for those. Only key suppliers need to be 6Sigma-trained. Often, just realizing you are measuring his performance is enough to encourage a supplier to correct his problems.

Choosing a consultant: This is much like selecting a surgeon for open-heart surgery ... most can use a scalpel, but some are significantly more skilled than others. Implementing and deploying 6Sigma is much more than training Black Belts.

CHAPTER #10: The Six Sigma Players

6Sigma quality is built around the customer. Customers are why companies implement 6Sigma Breakthrough Strategies.

Comparison of Roles:

	Qualifications:	Training:	# Employees trained:
CHAMPIONS	Senior Execs, VPs with familiarity with statistics	1 week	1 per business group or manufacturing site
MASTER BLACK BELTS	Managers with technical degrees, familiar with Statistics	Two 1-week sessions	1 per 30 Black Belts
BLACK BELTS	Technicians with 5 or more years experience, basic statistics	Four 1-week sessions with assigned project	1 per 100 employees
GREEN BERETS	Support backgrounds, familiarity with selected problem, basic statistics	Two 3-day sessions with assigned project	1 per 20 employees

CHAPTER #11: Six Sigma Black Belts

Project leaders trained in statistical problem solving.

What do Black Belts do?

(1) Stimulate management thinking, challenge conventional wisdom.
(2) Take responsibility for achieving higher financial targets.
(3) Should complete 4-6 projects annually, saving nearly $1M in direct costs
(4) It will take 2-3 projects for a Black Belt to truly become adept
(5) Requires a risk-taker with good leadership skills
(6) Usually a 2-year tour of duty

How are Black Belts selected?

(1) Good candidates *might* be managers who understand the potential of 6ů and are frustrated by past management practices.

(2) Need 1 BB per 100 employees in industrial sectors, 1 per 50 in commercial sectors. It is unlikely that a large company will be able to find enough BBs on the outside to hire. Train them internally.

(3) Expect positive financial results by the end of the second year.

ALLIED SIGNAL: First corporation to implement the Breakthrough Strategy. They had tried quality initiatives with mixed results.

Lessons learned:

(1) Top Leadership must *own* 6Sigma. Not a flavor-of-the-month initiative.

(a) All managers needed to understand 6Sigma

(b) Employees stopped reacting emotionally to problems, started looking at data

(c) Master BBs were promoted to VPs, autocrats were booted out

(2) Training is an ongoing process: It never ends. There are always new faces.

(3) BB retention: Early on, 50% of Allied Signalôs BBs were absorbed back into their organization within 6 months, long before their training had produced results. They began *requiring* 24 months on the job.

(4) Supplier capability is critical: Traditionally, you used as many suppliers as possible to hold down costs. Under 6ů, use as few as possible ... all trained in the Breakthrough Strategy.

(5) No such thing as Operator Error: *Processes* fail, not people. This concept opens the floodgates for the exchange of more information.

(6) Focus on bottom-line improvement: BBs find ways for the company to save money. Management is responsible to act on those opportunities.

(7) Initiative overload: Customer-satisfaction and Continuous-improvement are good, but you canôt ignore end results ... you have to make the numbers.

CHAPTER #12: Six Sigma and the Service Industry

Nearly 80% of the US workforce is employed in the Service industry. In manufacturing, 90% are doing service work.

Substitute the word ñtransactionò for the traditional manufacturing idea of ñpartsò.

Cycle time + Customer satisfaction: It is important to determine the level of service quality.

Reliability + Consistency: Critical-to-Quality (CTQ) characteristics in service transactions.

Example: Delinquent accounts-receivable at Foxboro, costing the company over $7M/yr and operating at about a 2ů-level. Analysis found the following root causes:

(1) Purchase orders not verified against sales receipts.

(2) None (or late) hard-copy confirmation of verbal orders

(3) Inadequate monitoring of company billing

(4) Payments terms not established during quotation process

Delinquency costs were reduced to $2.45M. One BB and 9 team members took 3 months to begin returning financial results to the bottom line.

CHAPTER #13: Project Selection Guidelines

The overall goal of *any* 6Sigma project is to raise customer satisfaction and profitability.

Big picture:
(1) Someone must be accountable for the project (ñownò it)
(2) Someone must be responsible to execute it
(3) Selection of projects is based on company Strategic Goals and direction
    (a) *Top-down*: Major business issues, assigned a Senior Champion
    (b) *Bottom-up*: Production managers under pressure to make budget reductions

Selection criteria categories:
(1) Low Yield Rate: Lower-than-expected production, slower-than-planned-for line speeds
(2) Cost of poor quality: inspection requirements, scrap, rework, etc.
(3) Under-capacity: Not enough facilities, tools, employees, etc.
(4) Customer satisfaction: Data available from surveys
(5) Internal performance: defects from ñhidden factoriesò

Prioritizing 6Sigma projects: Should be based on these factors
(1) Value to the business: Want significant impact on performance and profitability
(2) Resources required: Costs must be offset by gains in profitability and market share

CHAPTER #14: Psychology of Six Sigma

Employee motivation is a complex science. People need recognition for their successes.

Black Belts need:
(1) Financial compensation: Reward mechanisms send powerful messages, telling employees what management thinks is important.
(2) Promise of promotion: 6Sigma leaders should move into the ñbig jobsò (but not all high-performers want management positions)
(3) Written and verbal recognition: *How* recognition is given is as important as *what* recognition is given.

Failure: Most CEOs see mistakes as tools for personal growth.

Tom Watson (IBM's founder) wanted to see a young executive who had just lost IBM over $10M in an unsuccessful project. The exec expected to be fired. Watson's response was: "You've got to be kidding. We have just spent over $10M educating you!"

CHAPTER #15: Preparing an Organization for Six Sigma

Superstitious dance: Embracing ñsolutionsò that have no bearing on the problem. Persistent problems never go away until the root cause is found and corrected.

Many employees associate their *last behavior* with a result. Bad information and wrong metrics cultivate and perpetuate many superstitious dances.

Results change cultures (not the other way around!): People need to see how their values and behaviors impact their jobs and the organization. Employees flourish when they know they are creating goods and services of incomparable value. In the end, *an organization's sigma-level is an indicator of how strong it's values are.*

Business measurements drive *values*.
Values determine *how people work*.
How people work determines *profitability*.

Change: Employees have understandable and rational fears about change. Change is a balancing act ... with favorable outcomes on the right, unfavorable outcomes on the left. The role of leadership is to move the balance point without knocking employees off the high wire.

History vs future:

(1) *Quality* programs use metrics to focus on the past, like steering a boat by looking at its wake. They allow mistakes to be corrected, but they donôt prevent mistakes from recurring.

(2) *6Sigma* programs are a predictive strategy ... companies drive themselves into the future. It takes 3-5 years for even the most progressive company to get 6Sigma fully entrenched.