LEAN SIX SIGMA

Achieve major cost, inventory and lead time reductions in less than a year

6σ

Combining Six Sigma Quality with Lean Production Speed

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Lean Six Sigma

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This booklet contains a preview of Section I of *Lean Six Sigma*. It is printed with permission from McGraw-Hill. The full version of the book will be published in Spring 2002.

Preface

In 1996, General Electric CEO Jack Welch praised Six Sigma as "the most important initiative GE has ever undertaken." Yet despite widespread success with Six Sigma, two years later Welch articulated one shortfall:

> *"We have tended to use all our energy and Six Sigma science to move the mean [delivery time] to… 12 days. The problem is, as has been said, 'the mean never happens,' and the customer is still seeing variances in when the deliveries actually occur—a heroic 4-day delivery time on one order, with an awful 20-day delay on another, and no real consistency…* ***variation is evil****."*

Welch's statement was prompted by a growing awareness that **time** is nearly as important an improvement metric as is **quality**—and that reducing process lead times and variation in the amount of time it takes to complete a process has just as much potential for improving a company's performance as does reducing variation in quality.

Sometimes we regard our customers are like the man who has one foot in the fire and the other in a block of ice: On average, he should be comfortable! But obviously the range of temperatures is intolerable—just as unpredictable delivery time is to our customers.

Most of the methods and tools associated with Six Sigma do not focus on time; they are concerned with identifying and eliminating *defects*. Any savings in time that result from Six Sigma projects are often a byproduct of defect reduction and of the general problem solving methodology. That's why in GE's 2000 Annual Report (dated February 2001), Jack Welch announced a additional goal for GE: reducing the variation in lead-time (which he refers to as "span"):

> *"Today we have a Company doing its very best to fix its face on customers by focusing Six Sigma on their needs. Key to this focus is a concept called* ***'span,'*** *which is a measurement of operational reliability for meeting a customer request. It is*

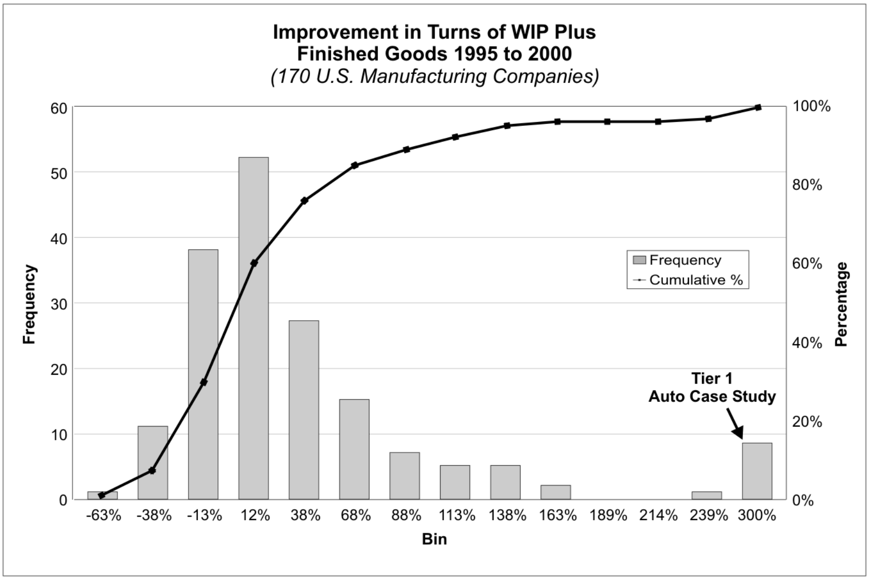
> *the time window around the Customer Requested Delivery Date in which delivery will happen."*

Welch positioned the focus on span as an *addition to* not a replacement for Six Sigma. *Quickly* and *reliably* reducing process lead time—which also reduces overhead cost and inventory—is the province of an entirely different set of principles and validated tools known as Lean methods. Use of Lean tools turbocharges the rate of reduction of lead time and manufacturing overhead and quality cost. Welch has thus provided yet another key insight to improve corporate performance (and we wish him well in his post-GE endeavors): *"The generation that is going off the stage has deserved well of mankind for the struggles it has made*."[1]

How are companies other than GE faring with continuous improvement initiatives? Data on the impact of continuous improvement programs like Six Sigma in service industries is not well defined by financial improvement. However, the December 2000 issue of *Industry Week* included a survey of manufacturing companies that scored themselves against World Class performance metrics. Over half the firms had not achieved 98% on-time delivery, and three-quarters had not been able to reduce manufacturing lead time by even 20% over the last five years. Scrap and rework costs exceeded 1% of sales for 77% of the respondents. These rates of improvement, even by self-evaluation, are quite slow—which is surprising since subjective self-evaluations could be expected to err on the favorable side!

While such surveys are provocative, anyone dedicated to improvement knows that we need to look at objective data. Since my interest is rooted in driving "hard" financial results from improvements in process quality and lead times, I looked into ways that I could get data on World Class metrics from a company's financial statements. Internal quality levels are not reported by most companies; however, you *can* calculate the average delivery time by dividing WIP and Finished Goods Inventory data from the financial footnotes in corporate 10K reports by the cost of goods sold. Digging through the footnotes is a painstaking process, but I had my staff do it for a sample of 170 manufacturing companies for the years 1995 and 2000. We then calculated the percent improvement since 1995 and compared it to the *Industry Week* survey.

Figure i-1: Histogram of Percent Improvement in Lead Time (170 companies)



As you can see, average lead time has shown very little improvement. For about half the firms, lead time performance has in fact *declined* over the five-year period. As we will later see, if process speed has declined, generally so has process quality.

On the positive side, a significant number of companies achieved more that a 100%—and several a 300%—increase in WIP and Finished Goods turns. In "statistics-speak," data that departs from a normal distribution like this generally indicates that there are two populations: those who effectively apply Lean Six Sigma principles and those who don't. I suggest you do the calculation to benchmark your firm against your leading competitors.

These results show that the *Industry Week* survey was valid to the extent it could be tested, and we must conclude that the principal population of companies are in fact improving at a very slow average rate. But take special note of the improvement shown by the Tier 1 Auto supplier, a former division of United Technologies Automotive, at the far right in Figure i-1. This 300% improvement rate was achieved in less than two years, and we will use the case study to show how a company can improve at a very rapid rate if *both* Lean and Six Sigma tools are employed.

The Synergy of Lean and Six Sigma

Why are companies improving at such a slow rate, even when there is such a huge emphasis on improvement techniques like Six Sigma and Lean? What can they learn from GE or the Tier One Auto supplier case study? Six Sigma does not directly address process speed and so the lack of improvement in lead time in companies applying Six Sigma methods alone is understandable. These companies also generally achieve only modest improvement in WIP and Finished Goods inventory turns.

But Lean methods alone aren't the answer either: Many of the firms who have shown little improvement in inventory turns have in fact attempted to apply Lean methods. It appears that, while many of people at these companies understand Lean, they just aren't effective in implementing it across the corporation at a rapid rate. The companies achieves some remarkable successes… but only in small areas. The data shows that improvement across the corporation as a whole remains slow without the Six Sigma cultural infrastructure.

An executive whose company is making rapid progress *now* said they started with Six Sigma… then spent several months trying to reduce lead time, only to realize they were reinventing Lean! In other words, no matter where you start—with Lean or with Six Sigma—you'll be driven to invent or learn the other half of the equation if you want to achieve high quality, high speed, and low cost. When a company uses both Lean and Six Sigma simultaneously, dramatic improvements across the corporation are achieved much more rapidly, and indeed we will prove that this combination is in fact a pre-requisite for rapid rates of improvement.

So what is Lean Six Sigma?

- ***Lean Six Sigma is a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital.***

The fusion of Lean and Six Sigma is required because:

- ***Lean cannot bring a process under statistical control***

- ***Six Sigma alone cannot dramatically improve process speed or reduce invested capital***

The Purpose of This Book

The purpose of the book is to show that the combination of Lean and Six Sigma—when focused on the highest value projects, and supported by the right performance improvement infrastructure—can produce remarkable results and is the most powerful engine available today for sustained value creation. We will provide case studies to illustrate how these results are achieved.

Some people have described Lean Six Sigma as "doing quality quickly," which may seem counter-intuitive at first. Intuition tells us that the faster we go, the more mistakes we make. If that were the case, trying to speed up a process would only result in lower quality. But Lean Six Sigma works not by speeding up the workers or the machines, but by *reducing unneeded wait time* between value-add steps. As James Womack has pointed out "The most basic problem is that Lean flow thinking is counter-intuitive."[2]

This book closes that intuition gap with knowledge, both experiential and quantitative, and shows how Lean and Six Sigma methods complement and reinforce each other. It also provides a detailed roadmap of implementation so you can start seeing significant returns in less than a year.

Is Lean Six Sigma only suited for the factory? Absolutely not. Lean Six Sigma concepts are extremely powerful in improving the quality and speed of all types of "transactional" processes, including sales and marketing, quotations/pricing/order processing, product development, hotel check-in, mortgage applications, financial/administrative, and human resources. Transactional processes must also be improved in manufacturing companies, as they are enablers of the manufacturing process itself. In fact many companies are finding that there is tremendous value-creation opportunity in attacking these processes simply because they have been overlooked in the past.

This book will provide insight into the application of Lean Six Sigma to both the manufacturing operations and to the less-data-rich service and "transactional" processes.

Part I describes the **Lean Six Sigma "value proposition"**: how it is that combining Lean and Six Sigma provides unprecedented potential for improving shareholder value.

Part II discusses the **Lean Six Sigma Process**—how to prepare your organization for Lean Six Sigma, and the steps for implementation.

Part III is devoted to **leveraging Lean Six Sigma** by extending its reach both within and beyond your corporate boundaries.

As you'll see in Part I, unlike other improvement methodologies, Lean Six Sigma is clearly tied to shareholder value creation—an endeavor that must be led by the CEO or COO. Lean Six Sigma therefore demands strong leadership by its very nature. Companies that allow each division to "go its own way" will not achieve the results that are possible when unified leadership focuses all the parts of the organization on the same priorities.

Looking for a Competitive Edge?

The fact that most companies are improving at a very slow rate can be a great competitive advantage to your company *if you find a way to exploit the opportunity.* This book lays out a strategy you can use to capitalize on the slowness of your competitors. These methods are already being used and widely endorsed by companies such as Caterpillar GE, Honeywell, International Truck, ITT Industries, NCR, Northrop-Grumman, Lockheed-Martin, Rockwell, Raytheon, and many others. Should you decide that Lean Six Sigma is the most appropriate improvement process for your corporation, you will be in the best of company!

End Notes

1. Thomas Jefferson, *Letters*, June 18, 1799
2. *Lean Thinking* by James Womack and Daniel Jones, pg. 23.

PART I

The Lean Six Sigma Value Proposition

Chapter 1

Lean Six Sigma: Creating Breakthrough Profit Performance

Put yourself in the place of the CEO of a Tier 1 auto supplier (a former division of United Technologies Automotive[1]) whose business was barely earning its cost of capital in a really tough market. First and foremost, you've got to re-gain your Ford Q1 quality rating to remain in the game. You have been shipping brake hose fittings that are failing, a customer's Critical To Quality issue, which is creating containment costs for you and your customers. You have been notified that if you don't correct this problem, you will lose your largest customer. Marketing has told you that Ford wants to be able to order any of 168 products with only a two- to three-day lead time to support their own Lean initiative. To achieve such capability, your company will have to dramatically improve your currently abysmal on-time delivery performance You also have to **reduce cost** by at least 5% per year to generate a superior Return on Invested Capital (ROIC) and keep up with price reductions demanded by the market.

This firm clearly needed to improve quality and delivery time at a very rapid rate. How does Lean Six Sigma deliver results so much faster than either Lean or Six Sigma? Here's the first clue:

"It's hard to be aggressive when you don't know who to hit"

– Vince Lombardi

The Tier 1 supplier profited from this lesson from the most famous coach of the Green Bay Packers, who once scolded a lineman for not memorizing the Play Book.

The first step was to attack the customer's Critical To Quality issue of defective brake hoses. They then had to confront demanding goals: to reduce lead time from 12 days to 2-3 days, and improve cost. The "who to hit" question facing this CEO was **what specific improvements should be executed and in what order** to achieve these goals? This question is the key breakthrough of Lean Six Sigma that was not, and could not, be understood by those who separately advocated only Lean or only Six Sigma.

The Principle of Lean Six Sigma

> ***The activities that cause the customer's Critical To Quality issues and create the longest Time Delays in any process offer the greatest opportunity for improvement in Cost, Quality, Capital, and Lead time.***

Always solve or contain the external quality problems that affect the customer first. The internal quality problems will manifest themselves in the time delay they cause. What does quality have to do with time delay? They aren't quite two sides of the same coin, but quality and time share a close relationship: The surprising fact is that 10% scrap can slow down a factory by 40% (something we'll get into in more detail later in this book). What does slow process velocity have to do with quality? Faster velocity multiplies the speed with which quality tools reduce defects.

The questions that Lean Six Sigma can uniquely answer, which neither Six Sigma or Lean alone can, are:

- To which process steps should we first apply Lean Six Sigma tools…
- In what order, and to what degree…
- To get the biggest cost, quality and lead time improvements quickly?

It is the synergy of Lean and Six Sigma together that allows companies to reduce Manufacturing Overhead and Quality Cost by 20% and inventory by 50% in less than two years.

The Roadmap to Higher Shareholder Value

It has been my experience that the slow rate of corporate improvement (see the Preface) is not due to lack of knowledge of Six Sigma or Lean. Rather, the fault lies in making the transition from theory to implementation. Managers need a step-by-step, unambiguous roadmap of improvement that leads to predictable results. This roadmap provides the self confidence, punch and power necessary for action and is the principal subject of this book.

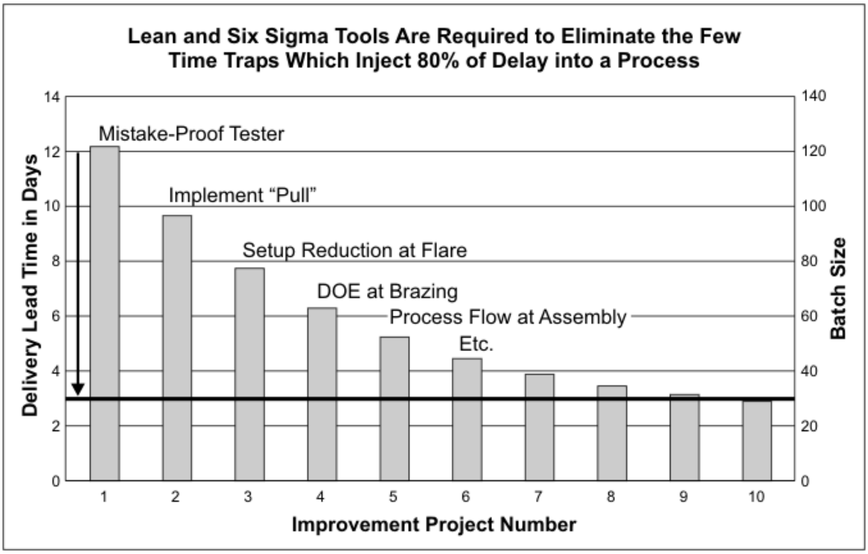
The Tier 1 auto supplier provides a case study of the speed of results that can be achieved when management has a Lean Six Sigma roadmap. As described above, the company needed to decide where to focus their energies to dramatically reduce process lead time and defects. The first step was to apply a Six Sigma tool known as Mistake Proofing to the "testers," which made it impossible for a defective part to be shipped to the customer. Thus defective parts could at least be contained and would no longer by shipped to the customer.

The next challenge was to determine which workstations ("steps in the process") were injecting the longest time delay into the process, so those delays could be eliminated using Lean and Six Sigma tools. Time delays can be determined by spreadsheet calculations for simple processes as will be described in Chapters 3 and 12. For complex processes, the determination can be made by loading MRP data into supply chain acceleration software.[2] Here, MRP data was used to calculate the delay caused by each of 100 workstations.

The output from these calculations (Figure 1-1) shows the reduction of delay time that would result by applying Lean Six Sigma tools on the highest priority sources of delay. How do you identify the priorities? In this case, just 10 workstations out of the 100 created nearly 80% of the delay in the total process lead time, and these 10 are referred to as ***Time Traps***. This small number of actual troublemakers reinforces the well-known Pareto principle that the majority of problems (often 80% or more) come from a "vital few" causes (20% or less of the potential sources). Experience shows that this is true of *any* factory or process where the amount of value-added time (as judged by the customer) is less than 5% of the total process lead time.

The *Top 10 Time Traps* in Figure 1-1 are listed in descending priority of how much time delay they inject into the process. The first bar shows the original 12 days delivery time. Each subsequent bar shows what the new lead time would be if the company made the specific improvement to the process at a given workstation.

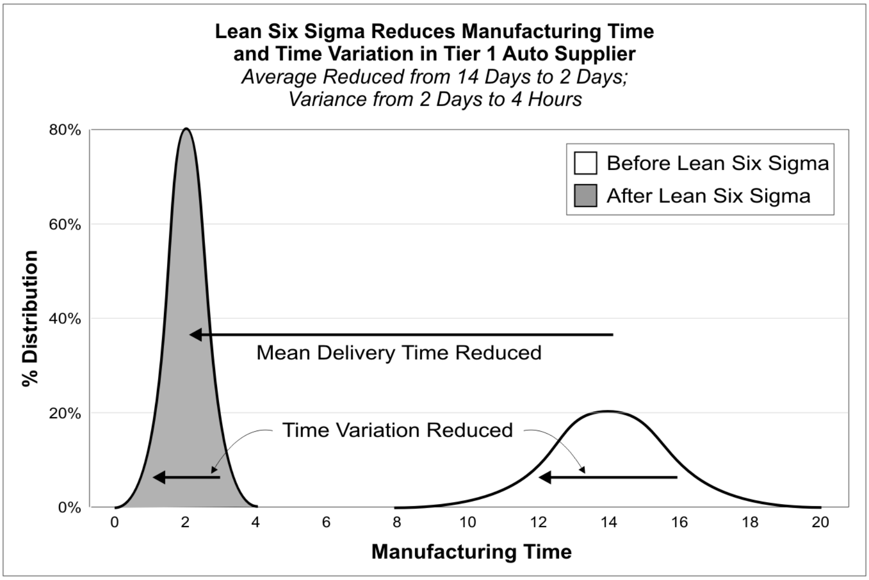
Figure 1-1: The Top 10 Time Traps



You see that Time Trap analysis identifies improvements like "Mistake Proof the Tester" (a Six Sigma tool) and "Setup Reduction at Flare" (a Lean tool) and "DOE" (a Six Sigma tool). The lesson was clear to this company: to meet their goal of improving quality and reducing lead time from its current 12+ days down to 2 to 3 days—in under a year—they would need to combine Six Sigma tools (such as reducing variation and eliminating *process defects*) with Lean tools (how to increase *process speed*).

How well did the combination of Lean Six Sigma work? Look at Figure 1-2.

Figure 1-2: Tier 1 Supplier Results from Lean Six Sigma



As you can see, the variation in delivery time ("span," in Jack Welch's term) was dramatically reduced. Moreover, the variation in process speed fell in direct proportion to the average speed increase. Using both Lean and Six Sigma, the company achieved Six Sigma quality levels (3.4 Defects per Million Opportunities) on parameters that were Critical To Quality (CTQ) to Ford, and allowed them to regain their Q1 rating.

Within two years, the shorter delivery time and improved quality led to a doubling of operating margin and revenue because the company kept winning substantial market share from their slower competitors. In that same time period, the company:

- Reduced Manufacturing lead time from 11 days to 3 days
- Increased WIP Inventory turns from 23 to 67 per year
- Reduced Manufacturing Overhead and Quality cost by 22%
- Increased Gross Profit Margin from 12% to 19.6%
- Increased Operating Margins from 5.4% to 13.8%
- Increased ROIC from 10% to 33%

- Attained Six Sigma quality levels on CTQ parameters

Conclusion: Rapid Improvement Requires *Both Lean and Six Sigma*

The lessons illustrated by the Tier 1 auto supplier have been borne out time and again in company after company. They are what led to the definition of Lean Six Sigma presented in the Preface:

Lean Six Sigma is a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital.

The fusion of Lean and Six Sigma are required because:

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

To make dramatic improvement in cost, quality and responsiveness, a company must eliminate customer Critical to Quality issues and delays due to Time Traps using both Lean and Six Sigma tools. Otherwise, it will make the slow progress of the majority of companies which was described in the preface.

Figure 1-1 reflects improvement specific to that company; the number and type of Time Traps will vary by industry and by situation. A similar analysis of a consumer products company determined that they could reduce Finished Goods Inventory from $500 million to $300 million just by implementing a Lean tool known as “Pull systems.” Given the uncertain lending situation for corporate borrowers, reducing the Revolver debt by $200 million dollars can be very important. This is confirmed by Warren Buffett’s homey wisdom:

> *“Neither a short term borrower nor a long term lender be.”*
>
> Berkshire Hathaway Annual Report,1979

As you will soon see, knowing your Time Traps opens up a whole new universe of corporate performance.

The Lean Six Sigma Secret

The amazing gains achieved by companies like this Tier 1 supplier arise from a key Lean Six Sigma insight:

> ***Most material in a manufacturing process spends 95% of its time waiting….. waiting for someone to add value to it or waiting in finished goods inventory…. By reducing this wait time by 80%, Manufacturing Overhead and Quality cost can be reduced by 20%, in addition to the benefits of proportionally faster delivery and lower inventories.***

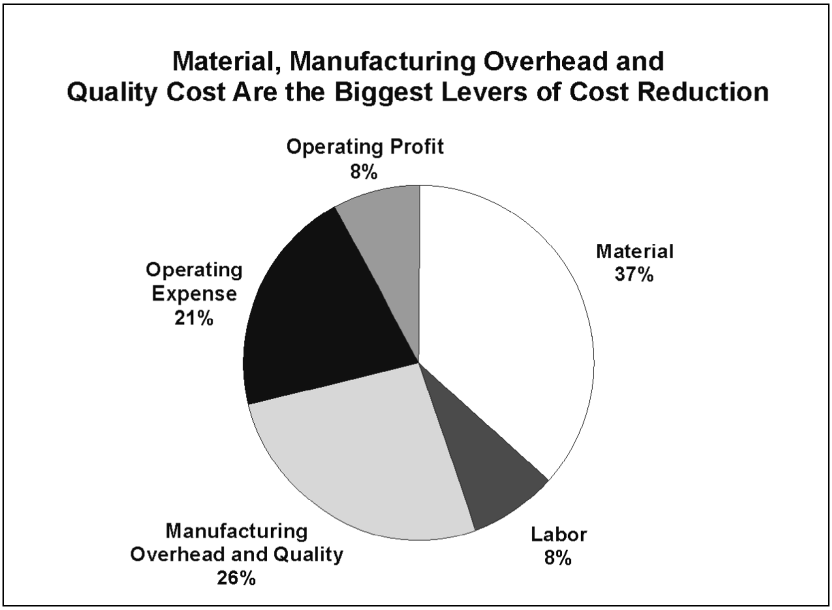
This insight holds true for all processes, not just manufacturing.

One of the reasons cost is reduced by lead time reduction is that ***slow processes are expensive processes.*** Slow moving inventory must be moved, counted, stored, retrieved, moved again, and may be damaged or become obsolete. Slow moving finished goods must be sold at "promotional prices" at a loss of margin. Expediters and stockroom personnel must deal with these problems. If a quality problem erupts, a large amount of inventory is in jeopardy of scrap and rework. A larger plant and more equipment and people must be used for a given capacity. These costs are often called the ***Hidden Factory***.

The Hidden Factory consumes resources and people and produces nothing of value to the customer. Its costs are hidden within Manufacturing Overhead and Cost of Poor Quality (COPQ), which are typically 2 to 4 times that of Direct Labor and are *caused* by long process lead times and variability. Attacking these costs through *lead time* reduction offers enormous *cost reduction* leverage. Additionally, faster lead times quite often generate revenue growth, as customers do more business with the faster, more responsive supplier.

Just how important is Manufacturing Overhead and COPQ? The pie chart in Figure 1-3 shows the distribution of costs as a percentage of revenues for the top 1000 US manufacturing companies.

Figure 1-3: The Cost Levers



If there is strong management support, a company can reduce manufacturing overhead and quality costs by 20% by the end of the first or second year. Increasing Operating Margin by 4–7% of Revenue in less than 2 years is a reasonable target for most companies. Lean Six Sigma directly attacks these costs more effectively than any previous improvement methodology because it comprehends both quality and speed.

The distribution within the pie will differ with industry. For a manufacturer of high tech electronic equipment, Manufacturing Overhead and Labor amounted to only 12% of revenue. Why would such a company be interested in Lean Six Sigma? One wanted to reduce delivery time from 10 days to 2 days, which yielded a revenue growth of 15%. They also had a very large Cost of Poor Quality problem.

However, don't think that Lean Six Sigma attacks only Manufacturing Overhead and COPQ. As stated above, Lean Six Sigma can be used to improve velocity in *any* processes, be it product development, order entry, fulfillment, design changes, customer service—thereby creating value in *all* sections of the pie.

The Lean Six Sigma Value Proposition

Ask yourself these questions:

- Do "customer value-added" activities consume less than 5% of my total process time?
- What competitive advantage would I have if I could deliver in 50%-80% less time?
- What financial benefit would result from a 20% reduction in Manufacturing Overhead and Quality cost?
- What cash infusion/debt reduction would result from a 50%-80% reduction in WIP and Finished Goods inventory?
- What revenue growth would result from reducing delivery time and time-to-market?

Gains in all of these areas are part of the Lean Six Sigma value proposition: the many ways in which use of Lean Six Sigma can contribute to improved shareholder value. They are not only possible but probable using Lean Six Sigma. Table 1-1, for example, shows benefits seen by the Tier 1 auto supplier.

Table 1-1: Operational and Economic Benefits of Lean Six Sigma Seen by the Tier 1 Supplier

Operating Margin	From 5.4% to 13.8%
Capital Turnover	From 2.8 to 3.7
ROIC	From 10% to 33%
Enterprise Value	Increased 225%
EBITDA	Increased 300%
Economic Profit = ROIC% - WACC%	From -2 % to 21%
Manufacturing Lead Time	From 12 Days to 2 Days
Work-In-Process Inventory Turns	From 14 to 100 Turns Per Year
On-Time Delivery	From 80% to > 99.7%
Quality Performance (External CTQ)	From 3σ to 6σ

As this company learned, Lean Six Sigma was the ideal tool for increasing shareholder value. It increases Operating Profit and decreases Inventory and Capex, thus increasing the numerator and decreasing the denominator. In the Tier 1 Auto supplier, Lean Six Sigma efforts increased ROIC from 10% to 33%.

These results can be generalized even further based on typical gains made to the cost levers shown in the previous pie chart (Figure 1-3), as shown in Table 1-2.

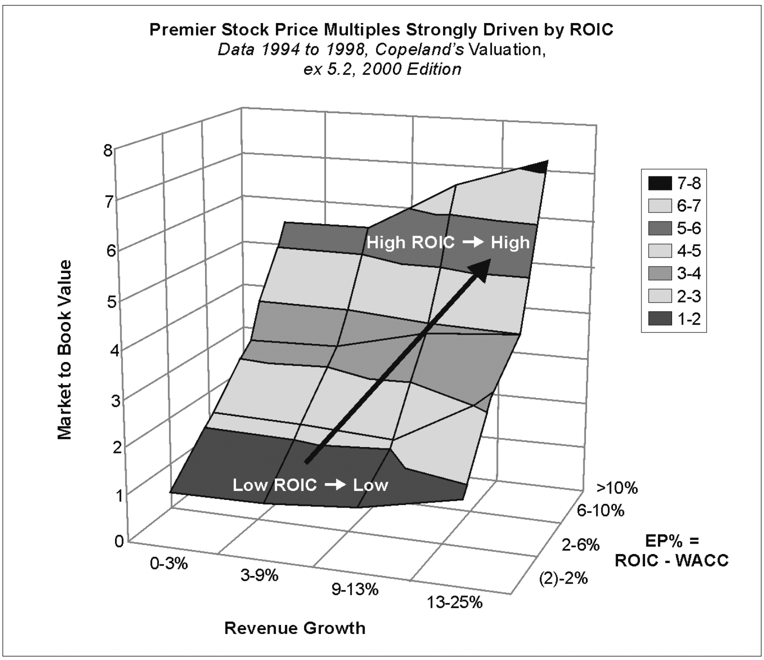
Table 1-2: Lean Six Sigma Value Proposition

	% of Revenue		% Cost
	Current	**Future**	**Reduction**
Revenue	100%	100.0%	
Direct Costs			
Material	30%	28.5%	5%
Labor	10%	10.0%	0%
Overhead + Quality	25%	20.0%	20%
Cost of Goods Sold	65%	58.5%	12%
Gross Profit	35%	41.5%	
G&A	10%	10.0%	0%
Marketing	10%	10.0%	0%
Interest			
Other	5%	**5.0%**	0%
Operating Profit	**10%**	**16.5%**	

The percentages in Table 1-2 are based on an assumption of *no increase in revenue,* but in fact many companies do increase sales. After all, becoming the best supplier in your industry in terms of quality, delivery, and innovation generally conveys increase in market share!

These kinds of gains have a direct impact on one of the key drivers of shareholder value for corporations—**Return on Invested Capital (ROIC).** One of the pillars of Lean Six Sigma is understanding the connection between shareholder value creation and specific improvements in the business. To build this connection, a value creation "line of sight" is established between projects and the key drivers of value creation—ROIC and revenue growth. This connection is supported by empirical stock market data compiled[3] on the top 340 US companies (with permission of McKinsey and Company). The premium multiple the stock market pays above book value (ratio of Market to Book value) was plotted versus revenue growth and Economic Profit (defined as Return On Invested Capital% minus Weighted Average Cost of Capital%), which in turn contributes to an increase in shareholder value as shown in Figure 1-4.

Figure 1-4: The Empirical Link between ROIC, Growth and Stock Price: "The Value Mountain"



You will notice that ROIC—the ratio of profit to invested capital—is the strongest driver of high stock market multiples of book value (indicated by the steep rise as ROIC increases). Revenue Growth is a strong second.

The relationship between ROIC and Revenue growth can be rolled up into one number: **Net Present Value (NPV)**[4]. Throughout this book you'll see NPV used to help select *priority* projects, because a high NPV indicates the likelihood that improvement will contribute to shareholder value. NPV can be applied at many levels: to overall value streams (the sets of activities that transform a customer opportunity into a delivered outcome) or to individual projects. In the Tier 1 Auto example, all products were produced in the same value stream (the production of brake hoses). When a company possesses multiple product lines or markets, it must select which value stream to improve first, and one of the best indicators is NPV. In fact, we recommend you select value streams for improvement based on the potential increase in Net Present Value, confident that these projects will make the greatest contribution to shareholder value.

But are we putting too much emphasis on financial metrics at the expense of customer value? Not at all! The Voice of the Customer is represented within the value creation that leads to increased revenue retention and growth rates of the company.

So how does Lean Six Sigma deliver on its value proposition? The essential elements of the Lean Six Sigma process (the implementation roadmap is discussed in Part II in detail) provide the framework:

1. Increasing Shareholder value requires higher ROIC and growth, both of which roll up into one number: Net Present Value (NPV).
2. Value streams for improvement should be selected based on potential increase in NPV.
3. Once a value stream has been selected, customers' Critical to Quality issues and the *Time Traps* (less than 20% of the activities) should yield project ideas.
4. Projects are selected based on the highest rates of return (the benefit-to-effort ratio)
5. The projects are then attacked using the Lean Six Sigma improvement tools

Lean Six Sigma and MRP

One reason why Lean Six Sigma can deliver results faster is that it uses data stored in MRP systems to locate Time Traps and define what kind of improvement is necessary. This gives "eyes" to the improvement process. Many who advocated Lean or Six Sigma separately were somewhat aloof about MRP systems. ERP systems have been criticized by some advocates of Lean because they claim it "pushes" un-needed material into the line creating congestion and poor flow. Lean Six Sigma makes use of the ERP "order point" to trigger releases from the Pull System (Chapter 15) to prevent congestion. Thus MRP systems are enablers of Lean Six Sigma, which in turn creates a significant return on investment on these systems.

The Power is in the Total Process

Though each piece of the Lean Six Sigma process can add value to your organization, the real gains will come from seeing the methods as a complete process that helps you determine and implement clear direction from the Board room to the frontline office or factory floor.

Earlier in the chapter, we showed that slow processes are expensive processes. As it turns out, slow processes are generally low-quality processes as well. In fact, **Time** and **Quality** are intimately linked, just as Lean and Six Sigma are inextricably linked as partners in cost reduction, lead time and quality improvement. A firm that does only one will be driven to the other, or will simply fail to make rapid progress since it will have to effectively invent the other process on the fly.

Why do you need Lean Six Sigma? Superior speed, quality and cost are the engines driving productivity and sustained competitive advantage. Because of its speed in reducing process lead times, quality defects, cost, and invested capital, Lean Six Sigma provides common direction from the organizational leaders to managers and employees.

Understanding the Lean Six Sigma value proposition is a prerequisite for understanding what Lean Six Sigma really is and how to use it to its greatest advantage. As you'll see in the next three chapters, there are essential cultural structures—such as true management engagement—and tools that are necessary for effective implementation. When these pieces are in place, Lean Six Sigma's relentless pursuit of product quality and process speed leads to corporate success, and personal success for the people that contribute to that journey. In a recent conference, Lockheed-Martin summed up current thinking in the title of their presentation:

"It's not Lean or Six Sigma, it's not Lean then Six Sigma, it's Lean and Six Sigma."

To learn more

- Chapter 2 provides an overview of what Six Sigma contributes to the picture; Chapter 3 does the same for Lean methods
- Chapter 4 shows how the elements of Six Sigma and Lean create a competitive weapon
- Part II goes into implementation details that were beyond the scope of this overview

End Notes

1. The Tier One Auto supplier referred to was a former division of United Technologies Automotive, renamed Preferred Technical Group. The financial results cited are from the S1 Registration statement.
2. With permission from www.profisight.com, protected by U.S. Patent *5,195,041, and 5,351,195*
3. *Valuation: Measuring and Managing the Value of Companies*, Copeland, Koller, and Murrin, 2000.
4. *Takeovers, Restructuring, and Corporate Governance*, J. Fred Weston et al., p. 198.

Chapter 2

Six Sigma: The Power of Culture

Andrew Carnegie

"Quality is the most important factor in business"

"Our hard driving of the 'Lucy' furnace exceeded our most sanguine expectations and the then unprecedented output of 100 tons per day equaled that of a weeks production - an output the world had never heard of before."

"I can make steel cheaper than any of you. The market is mine when I want to take it."

Andrew Carnegie understood the importance of quality and the elimination of variation as a competitive weapon. A few years after he had hired a German chemist, Dr. Fricke, he remarked:

> *"Nine-Tenths of the* ***uncertainties*** *of pig-iron making were dispelled under the burning sun of his chemical knowledge… What fools we had been! But then there was this consolation: we were not as great fools as our competitors, who said they could not afford to hire a chemist.… We had almost the entire monopoly of scientific management."*

Carnegie's costs were always lowest, his quality highest… which was responsible for him becoming the richest man in the world. One of the critical lessons you learn from Carnegie was his personal *engagement* in the quality and manufacturing process, and his personal selection of managers who would transform his goals into *action through continuous improvement and innovation.* In a very real sense, the Six

Sigma culture and infrastructure is the embodiment of these principles in a form that any company can implement. Carnegie's tombstone simply reads:

"Here lies a man wise enough to hire men more clever than himself"

The essential difference between Six Sigma and all other prior initiatives is in the culture. Six Sigma was the first initiative which demanded the engagement of the CEO and P&L managers. It was the first to require them to commit 1% of the workforce to receive four weeks of training and their subsequent full-time commitment to improvement projects as Black Belts. Finally, Six Sigma was also the first to tie specific gains to quality improvements, asserting that each Black Belt should be able to contribute between $250,000 to $1,000,000 of increased operating profit per year.

Thus Six Sigma was the first improvement initiative that tied a level of investment to a clear profit return, the language a CEO can understand.

Anyone who has worked within a Six Sigma-driven organization knows Six Sigma isn't just an "improvement methodology." It is…

- A **System** of management to achieve lasting business leadership and top performance applied to benefit the business and its customers, associates, and shareholders
- A **Measure** to define the capability of any process
- A **Goal** for improvement that reaches near-perfection

The Sigma Level numbers often associated with Six Sigma represents the capability of a core business process, as measured in "defects per million opportunities":

Sigma Level	Defects per Million Opportunity	Yield
6	3.4	99.9997%
5	233	99.977%
4	6,210	99.379%
3	66,807	93.32%
2	308,537	69.2%
1	690,000	31%

The "per million opportunities" aspect of the Six Sigma metric is critical because it allows you to compare the capability of widely different processes. The Sigma metric makes sure that simpler processes, which have fewer steps and fewer chances for something to go wrong, aren't given an advantage over more complex processes. (Having 20 errors in a four-step process is a higher *rate* of defects that having 50 errors in a forty-step process.)

The source of defects is almost always linked to *variation* in some form: variation in materials, procedures, process conditions, etc. (As you'll see, Lean Six Sigma expands the scope of variation to include *time*: missed deadlines, variability in lead times, and so on.) That's why the fundamental thesis of Six Sigma is that *variation is evil* because a high level of variation means customers will not get what they want—with all that that implies for retention, marketing efficiency and revenue growth.

The system needed to achieve Six Sigma creates a culture characterized by:

- **Customer centricity:** The knowledge of what the customer values most is the start of value stream analysis.
- **Financial results:** No project or effort is undertaken unless there is evidence indicating how much shareholder value will be created. The goal is for each Black Belt to deliver an average of $500,000 of improved operating profit per year.
- **Management engagement:** The CEO, Executives and Managers are *engaged* in Six Sigma. They have designated responsibilities for overseeing and guiding Six Sigma projects to make sure those projects stay focused on organizational priorities.
- **Resource commitment:** A significant number, typically 1% to 3% of the organization's staff is devoted to Six Sigma efforts full-time; and other employees are expected to participate regularly on projects.
- **Execution infrastructure:** The hierarchy of specific roles (such as Black Belts and Master Black Belts) provides ways to integrate Six Sigma projects into the "real work" of the organization and sustain the rate of improvement.

Let's expand on each of these important characteristics.

Critical Success Factors for Six Sigma

Customer Centricity

The Six Sigma culture is **customer-centric**; its goal is to delight customers. The quality of a product or service is measured from the customer's perspective, by its contribution to their success. This customer focus comes through the Six Sigma drivers:

- **Voice of the Customer:** What the customer says that they want
- **Requirements:** Voice of the Customer input that is translated into specific, measurable elements
- **Critical to Quality (CTQ):** Requirements that are most important to customers
- **Defect:** Failing to deliver to a customer's CTQ
- **Design for Six Sigma:** Designing products and processes based on customer requirements

The gaps between what customers desire and what you can currently deliver are the areas where significant value can be created for both supplier and customer. Thus Six Sigma is focused on addressing these gaps, increasing operating profit, and becoming part of the DNA by which a company operates.

Six Sigma provides the discipline to help companies go beyond an anecdotal understanding of customer wants and needs to specific requirements-driven process metrics. This changes behavior from firefighting to disciplined improvement based on customer satisfaction.

Every defect in a process not only reduces quality but creates a time delay, generates an additional cost, and produces an associated loss of operating profit. The actual cost of defects is of course dependent on the process. Here's an example: For the Tier 1 auto supplier described in Chapter 1, the cost of a brake hose "leaker" was not only the cost of rework, but also the cost of Q1 status at Ford, the potential loss of revenue, and the cost of potential product liabilities. These leakers were a Critical to Quality defect (when compared to other defects that affected the product's appearance only and were of no importance given the position of the product in the car). Therefore, the benefit of improving quality to prevent leakers both dictated the choice of the value stream where the company should focus its improvement resources, and went far beyond the savings from less rework and scrap.

This example demonstrates why the goal of Six Sigma is to uncover as many defects as possible—especially those that are Critical to Quality: In the words of the founder of Toyota, "Every defect is a treasure" *if* the company can uncover its cause and work to prevent it *across the corporation*. This customer-centric culture is appropriate in an economy of intense global competition where the customer is supreme and has a multitude of alternatives to fulfill their needs.

Financial Results

At the heart of Six Sigma is a focus on financial results that reflects lessons learned the hard way. Total Quality Management (TQM), the principal quality initiative that immediately preceded Six Sigma, often positioned the need to solve quality problems as a moral imperative. With most TQM programs, there was no clear way of prioritizing which quality projects should receive the highest priority; an almost religious fervor caused projects to be carried out regardless of cost to the corporation or value to the customer. TQM was often led by people who had a modest understanding of the drivers of shareholder value, and tended to invent their own metrics.

All that changed with Six Sigma where financial performance is paramount… and putting a new spin on an old saying:

"It's tough to teach a new *dog* old *tricks"*

– Warren Buffet, Berkshire Hathaway

This is not meant in criticism of the hard working quality professionals who strove to the utmost of their ability to make TQM work. The CEO was seldom involved, and to the P&L managers, TQM was regarded as ancillary to making money, and a Cross that management had to bear in the full knowledge that *"this too shall pass."*

In TQM's defense, it had complete success in the few cases in which it anticipated the culture of Six Sigma, i.e., customer centricity, financial results, management engagement, resource commitment, and execution infrastructure. In fact, the quality tools of Six Sigma and TQM are nearly identical. But while TQM has probably gotten a bum rap to some extent, a CEO can afford no patience with ineffective initiatives—which TQM efforts too often were.

Six Sigma speaks the language of the CEO. That's why Six Sigma is quite explicit about financial benefits expected from each and every effort. Black Belts and Champions are expected to contribute between $250,000 and $1,000,000 of incremental operating profit each year (and/or capital reduction times the cost of capital).

These expectations tie Six Sigma to the financial goals of the company as no other improvement process has before it. There are some up front costs: a lot of time and expense occurs during the training and startup phase. But a well-designed Lean Six Sigma process more than pays its costs during the first year of implementation.

Management Engagement

Back when TQM was the buzzword of the day, I well remember an incident at one of the greatest companies in America with revenue of over $15 Billion. The CEO, a truly outstanding executive, brought in the widely respected Dr. W. Edwards Deming, certainly a prime mover in the Quality movement, for a two-day session to train all the senior executives. The CEO told his executives he was totally committed to the process, expected their complete attention and support in the on-going program. He further insisted that every manager watch the 16-hour videotape of Dr. Deming's lecture, and introduced Dr. Deming. The CEO then immediately departed the meeting. A senior manager who attended that meeting told me that "commitment flew out the window" with him. People made fun of Dr. Deming's acerbic style, and signed the clipboard log as having "watched" the videos when they had actually only scanned the outside of their cases.

This CEO no doubt properly felt that he had *endorsed* TQM, and was probably surprised when nothing happened as a result of Dr. Deming's lectures. Given the hindsight of 15 years of experience, we can all now agree that endorsement is inadequate.

In contrast, one of the brightest applications of TQM occurred at Iomega in 1992. The company has had many ups and downs and operates in a very tough environment. In 1991 they were in a "down" period and under great cost pressure. It then took about 16 days to produce their Bernoulli Box mass storage device. The President, Fred

Wenninger, was an advocate of TQM and Lean, which he had applied at Hewlett Packard. He was actively *engaged* in the process and assigned about 20 people full time, and supported the training of 250 other employees. In less than nine months, the lead time had dropped from 16 days to less than 3 days. The company's overhead and quality cost fell dramatically, margins rose and the company's stock price nearly doubled. This approach was really a precursor of what we now know as the Six Sigma culture: an infrastructure needed for success anchored by strong management involvement. In fact the word *engaged* management is due to Fred.

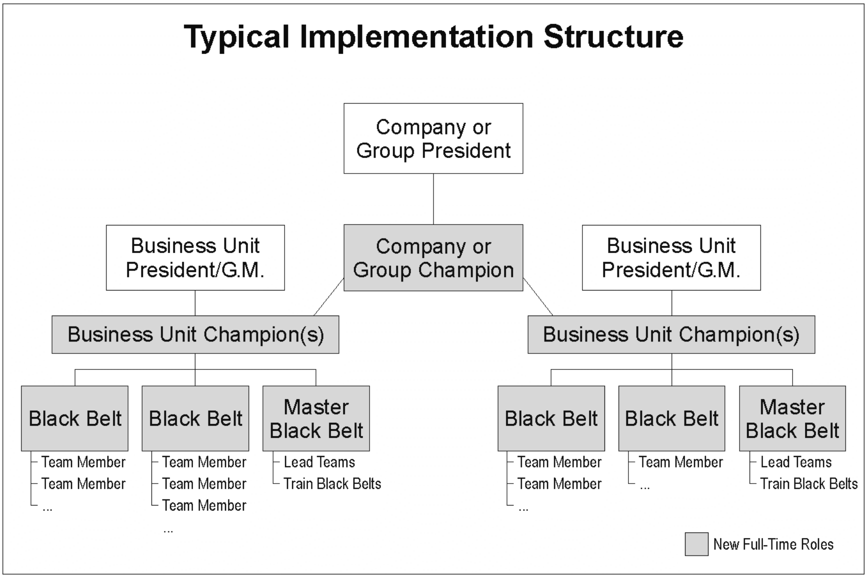
As noted, the problem with the first company was that TQM offered very little of interest to a CEO; there were seldom explicit financial results that could be linked to a CEO's annual or strategic goals. Many TQM efforts were implemented on blind faith that "things would get better" if quality improved. The problem was not the people, it was the process.

Six Sigma has changed all this with its emphasis on financial results that make it clear what executives will gain and have gained through their continued involvement. As with TQM, however, the results are self-evident: the biggest gains have been made in companies where executives are an integral part of Six Sigma deployment and vice versa.

The Six Sigma Infrastructure

Six Sigma possesses an infrastructure that effectively translates the CEO's agenda into a customer-centric set of projects chosen to maximize shareholder value, and provides effective management and monitoring of results versus plan (see Figure 2-1).

Figure 2-1: Six Sigma Infrastructure

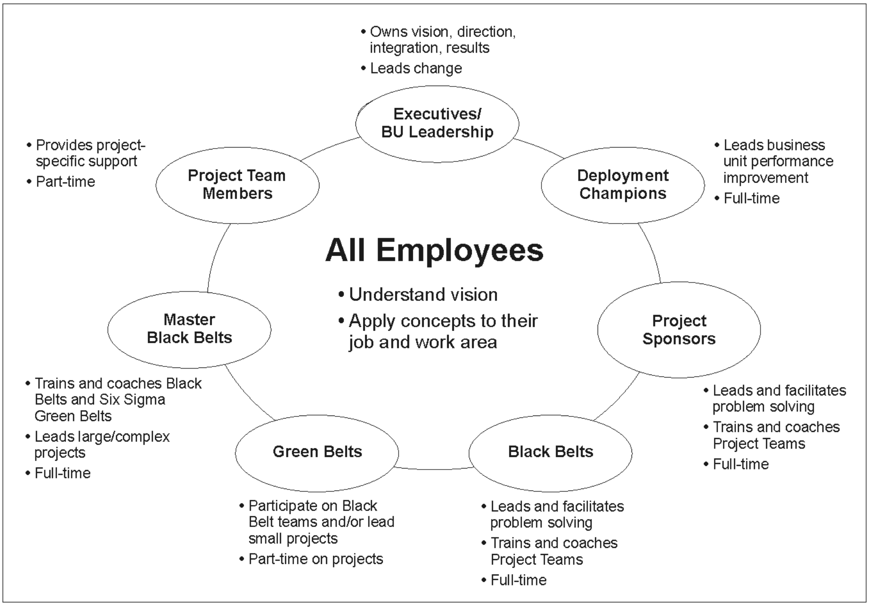


Starting at the top…

- The Corporate Champions are armed with the CEO and P&L manager's agenda for financial performance and shareholder value increase.
- These strategic goals are translated to an operational agenda by the Business Unit Champions (sometimes called Deployment Champions) who report to the P&L managers. These unit Champions are trained in the methods of identifying key value streams and prioritizing projects based on Net Present Value (their potential contribution to shareholder value). The P&L manager has the ultimate authority for value stream identification and project selection, since his or her commitment to the process is essential for success.
- The customer Critical To Quality issues and the Time Traps within the key value stream are developed into projects and then prioritized. These projects (to execute cost reductions, quality improvements, etc.) are then executed by the Black Belts who have been trained in the tools and team leadership skills of Lean Six Sigma.

- Project Sponsors (who are or report to the P&L manager) own the process that is to be improved by a specific project. They have the specific authority to implement improvements and have ultimate long-term accountability for ensuring that the improvements and financial benefits stick.
- Champions are assigned full time to improvement activities, the Green Belts who support Black Belt projects are generally part time, and have received less training. (See Figure 2-2 for a description of these roles.)

Figure 2-2: Performance Improvement Roles



You can also track the linkages in the reverse direction. Starting from the front line, the Black Belts and others can propose project ideas to their Champion and Business Unit manager. These ideas are transmitted to the Business Unit Champion (often via a web-based tracking tool), who reports to the Business Unit GM. The Business Unit GM and controller review the projects with the Champion and provide required financial data and verify savings potential. These projects are then ready to be prioritized against other known projects to ensure that those with the highest returns are executed next.

Resource Commitment

Typical full time commitment of personnel to Six Sigma efforts is roughly 1% of the company's population, though I've seen situations where it reached 3% because there were sufficient opportunities for achieving significant gains. But far more important than the *number* of people is the *quality* of the commitment. Six Sigma requires that Champions and Black Belts be selected based on their potential of becoming the future leaders of the corporation. This makes managers, who have got to get out their billings, often say, "How am I going to get my designs out if I give up my best engineers and program managers?"

The simple answer is that you need to make sure the projects selected are of high priority to the organization and its customers—then it's not a question of giving up anything, but rather devoting current resources to the highest priorities based on their potential to contribute to shareholder value. Those projects always get a lot more effort than is currently the case, whereas lower value projects may be delayed. Ultimately, the Champion will present the opportunities to his P&L manager for approval.

One of the benefits of selecting the future leaders as Black Belts and Champions is that they will receive an exemplary experience in every facet of business management and effective use of resources. They will develop a customer centric process, rather than departmental view of the business. Further, the potential for fast track advancement based on a few years success as a Black Belt works to retain this intellectual capital of the corporation.

Predicting Team Success, Preventing Team Failure

The success of Six Sigma is ultimately dependent on the ability of teams to execute projects effectively. It might be thought that the assembly of many brilliant individuals would be a satisfactory approach, but that perspective has been proven false time and time again. We will discuss one of the most momentous examples of this insight in Chapter 10 when we compare the American and the German Atomic Bomb development efforts.

Even the Six Sigma culture can't overcome poor team composition. Although Team design and leadership skills were not discussed in the early books on the subject, firms have been driven in this direction to attain results. We now have a number of different psychological models which point in the same direction and provide insight into the prediction of team success and failure. One area of common agreement is that it is possible to get much better results from a team if each member is playing his or her "preferred role," and if there is a balance of these essential roles on a team. Inexpensive software is available which facilitates relatively simple testing, making it possible to determine an individual's preferred role, both in his eyes and those of his peers (see Table 2-1).

A team which does not have a balance of the roles depicted in Table 2-1 can be predicted to fail. For example:

- A team of Shapers can become a "killing field" of powerful personalities.
- A team dominated by Monitor –Evaluators can succumb to "paralysis by analysis."

(Note that the existence of nine key roles does not mean a Six Sigma team has to have nine members. Research in this area has shown that most individuals have strength in two to four of the roles, so the right combination of 4+ people can usually provide a balanced team.)

After a team has been evaluated, it is possible to develop corrective actions which will make that team effective. A team with a lot of Shapers will need to appoint a Coordinator as the Chairman with decision powers. There are no bad preferred roles, just preferences that need to be comprehended to make the Lean Six Sigma teams effective.

To draw the best out of the team, Master Black Belts and Black Belts must hone individual leadership skills, such as the ability to balance inquiry and advocacy in the pursuit of superior results from teams. Organizations experienced in the implementation of Six Sigma programs, such as ITT Industries, Starwood Hotels, and GE, have recognized the importance of team and individual leadership skills in the Six Sigma process and include training in this area as a basic requirement. In addition to understanding how to structure a team, Black Belts must learn the basics of team problem solving and facilitation skills so that they may be effective change agents.

Table 2-1: Nine Team Roles

Role	***Team-Role Contribution***	***Allowable Weaknesses***
Thinking Team Roles		
Plant *(creative)*	Creative, imaginative, unorthodox. Solves difficult problems.	Ignores details. Too preoccupied to communicate effectively.
Monitor Evaluator *(objective)*	Sober, strategic and discerning. Sees all options. Judges accurately.	Lacks drive and ability to inspire others. Overly critical.
Specialist *(knowledgeable)*	Single-minded, self-starting, dedicated. Provides knowledge and skills in rare supply.	Contributes only a narrow front. Dwells on technicalities. Overlooks the “big picture.”
Doing Team Roles		
Shaper *(hard driving)*	Challenging, dynamic, thrives on pressure. Has the drive and courage to overcome obstacles.	Can provoke others. Hurts people’s feelings.
Implementer *(organizing)*	Disciplined, reliable, conservative and efficient. Turns ideas into practical actions.	Somewhat inflexible. Slow to respond to new possibilities.
Completer *(meticulous)*	Painstaking, conscientious, anxious. Searches out errors and omission. Delivers on time.	Inclined to worry unduly. Reluctant to delegate. Can be a nit-picker.
People Team Roles		
Team Worker *(diplomatic)*	Cooperative, mild, perceptive and diplomatic. Listens, builds, averts friction, calms the waters.	Indecisive in crunch situations. Can be easily influenced.
Resource Investigator *(outgoing)*	Extrovert, enthusiastic, communicative. Explores opportunities. Develops contacts.	Overoptimistic. Loses interest once initial enthusiasm has passed.
Coordinator *(motivator)*	Mature, confident, a good chairperson. Clarifies goals, promotes decision-making, delegates well.	Can be seen a manipulative. Delegates personal work.
Strength of contribution in any one of the roles is commonly associated with particular weaknesses. These are called allowable weaknesses. Executives, Managers and indeed everyone are seldom strong in all nine team roles.		

The Six Sigma Process and Improvement Tools

You may be surprised that it's taken this long in the discussion of Six Sigma before the quality improvement tools were mentioned. That's because more organizations fail from a lack of creating the right culture and infrastructure than from using the wrong tools! Some companies think Lean and Six Sigma is just a bag of tools and have attempted to implement Six Sigma by sending off people to Black Belt training and failing to make any of the substantive cultural changes described above. These programs end as just another "program of the month" failure. If you don't have the other elements discussed above—management engagement, a strong infrastructure, and so on—any effort put into improvement methods and tools will just be a waste of time.

So the key lesson as you're reading through this section is not to get lost in the statistical weeds or the improvement tools. Important as these are, the source of power is first and foremost in the culture.

Still, the improvement process and tools associated with Six Sigma are incredibly powerful. Motorola recognized that there was a pattern to improvement (and use of data and process tools) that could naturally be divided into the five phases of problem solving, usually referred by the acronym DMAIC (da-may-ick), which stands for Define-Measure-Analyze-Improve-Control. The DMAIC steps are shown in Table 2-2 and described below. You will notice that at each of the DMAIC phases, tools associated with both Lean and Six Sigma are included:

- The purpose of the **Define** phase is to clarify the goals and value of a project. Teams and Champions use those tools necessary to assess the magnitude of the value opportunity in a given value stream, the resources required, and a design of the problem-solving process.
- Assuming that the project is approved by the Champion, the team proceeds to the **Measure** phase in which they gather data on the problem. Here, they primarily use data collection tools, process mapping, Pareto analysis, run charts, etc. (Teams working on non-manufacturing processes are often surprised at how much they gain by completing the Measure phase, because their processes have never been mapped, nor studied with data.)

- In the **Analyze** phase, the team examines their data and process maps to characterize the nature and extent of the defect. The tools help them pinpoint the time traps and define the tools in priority order. This detailed knowledge about the problem lays the groundwork for finding improvements (in the next phase) that will address the underlying causes of the problem.
- The **Improve** phase applies a powerful tool set to eliminate defects in both quality and process velocity (lead time and on time delivery).
- When the process has achieved the required quality level, the tools of the **Control** phase are employed to lock in the benefits. Some of these Control tools, such as Mistake Proofing (known as “pokayoke” in Japanese), create a monitoring, gauging, and feedback system to instantly detect and correct trends—and to shut down the process if necessary. Mistake Proofing makes it impossible for the process to create defects.

Becoming familiar with the DMAIC process and knowing how and when to use data and process tools are critical skills for successful Six Sigma teams—and adding in the Lean tools makes the skill set even more robust. Do not assume that your employees have this knowledge; a brief glance at the tool set (Table 2-2) should convince you that this is a rich set of tools that could be very perplexing to a newly minted Black Belt. Most people will need training in the basic tools; in-depth comprehension of some of the complex tools (e.g., Design of Experiments, Time Trap determination of process delays, Pull System design, etc.) can be obtained by enrichment courses for Black Belts or Master Black Belts.

Table 2-2: Lean Six Sigma Toolset

Define	1. Establish Team Charter 2. Identify Sponsor and Team Resources 3. Administer Pre-Work	• Project ID Tools • Project Definition Form • NPV/IRR/DCF Analysis	• PIP Management Process • SSPI Toolkit
Measure	4. Confirm Team 5. Define Current State 6. Collect and Display Data	• SSPI Toolkit • Process Mapping • Value Analysis • Brainstorming • Voting Techniques • Pareto Charts	• Affinity/ID • C&E/Fishbones • FMEA • Check Sheets • Run Charts • Control Charts • Gage R&R
Analyze	7. Determine Process Capability and Speed 8. Determine Sources of Variation and Time Bottlenecks	• C_p & C_{pk} • Supply Chain Accelerator Time Trap Analysis • Multi-Vari • Box Plots • Marginal Plots	• Interaction Plots • Regression • ANOVA • C&E Matrices • FMEA • Problem Definition Forms • Opportunity Maps
Improve	9. Generate Ideas 10. Conduct Experiments 11. Straw Models 12. Conduct B's and C's 13. Action Plans 14. Implement	• Brainstorming • Pull Systems • Setup Reduction • TPM • Process Flow • Benchmarking • Affinity/ID • DOE	• Hypothesis Testing • Process Mapping • B's and C's/Force Field • Tree Diagrams • Pert/CPM • PDPC/FMEA • Gantt Charts
Control	15. Develop Control Plan 16. Monitor Performance 17. Mistake-Proof Process	• Check Sheets • Run Charts • Histograms • Scatter Diagrams	• Control Charts • Pareto Charts • Interactive Reviews • Poka-Yoke

Design of Experiments: Secret Weapon of the Rapidly Improving

The complete tool set of Lean Six Sigma is vast, and important parts of it are discussed in Chapters 11 and 12 in some detail. One Six Sigma tool that demands special attention is Design of Experiments (DOE), an entire body of knowledge around how to manipulate process and product design factors to discover the *combination* that is most effective, efficient, and/or robust in actual operating conditions. There are many variations of DOE (the Classical, Taguchi, and Evolutionary Operations models, to name just a few) but all address the issue of yield improvement through reduction of variation. I'd like to give you an example from our Tier 1 Auto supplier.

If you look back at the list of Top 10 Time Traps (improvement opportunities) developed by the Tier 1 auto supplier (Figure 1-1), the fourth highest priority was "DOE at Brazing." The company had already contained the customer Critical To Quality problem by Mistake Proofing the tester. Now the internal time trap analysis indicated that the 1%-3% scrap rate at the Braze operation was the next major time trap and cost opportunity. This problem had been with the company for years.

Very briefly, the machined and threaded coupling was brazed onto a pipe. Typically, 3% – 5% of the output was rejected: If the viscosity of the solder was too low, the braze did not adequately cover the joint. If viscosity was too high, it did not provide a mechanically strong connection and might fail in a vibration test or in the field.

The challenge here arose because there were many major factors that could affect the quality of the brazing, and which *interacted* with one another. While viscosity is generally a function of temperature, many other factors affect adequate coverage and mechanical strength, including the chemical composition of the braze, the preparation method to assure cleanliness of the coupling and pipe, the temperature of the braze material, and the pre-heat temperature of coupling and pipe.

No one really knew enough about the physics and chemistry of this process to compute the best combination of factors: this company needed a method for looking at the key factors simultaneously. And that's why they turned to Design of Experiments.

After making sure that the measurement system was precise enough to detect the effects being measured, the company conducted a designed experiment around what they believed were the four most important process factors, each tested at two levels:

- Temperature of the brazing material (high or low, denoted as + and – in Table 2-3)
- Whether the components were preheated (yes or no)
- Chemical composition of the braze (two mixtures, denoted with H and L)
- Preparation Method (two methods, denoted as C and A)

Table 2-3: A 16-Trial Experiment for Brazing

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Braze Temp	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Pre Heat	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-
Braze Chemistry	H	H	H	H	L	L	L	L	H	H	H	H	L	L	L	L
Prep Meth	C	C	C	C	C	C	C	C	A	A	A	A	A	A	A	A

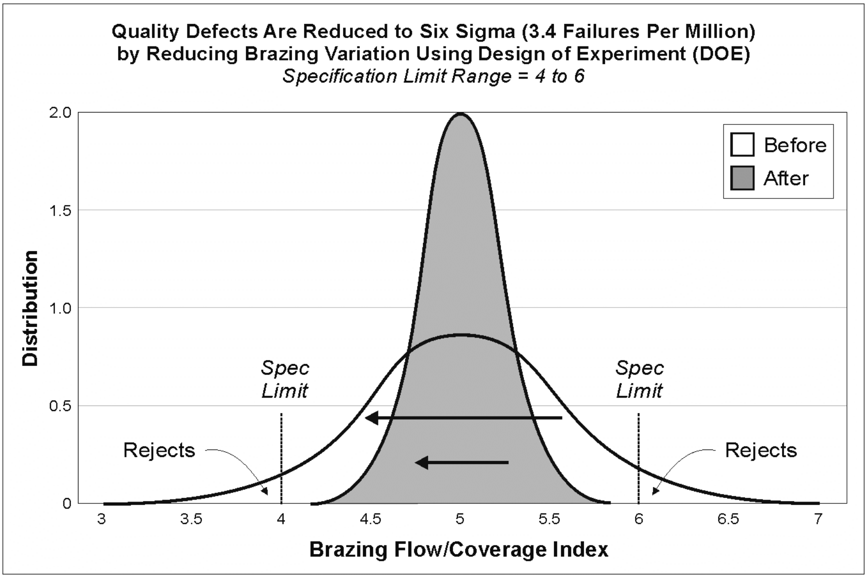
Table 2-3 shows that this designed experiment would consist of 16 trials in which every possible combination of the factors would be tested. During each trial, the results were measured by using an index to gauge the spread of the resulting flow/coverage (an index of “5” is ideal). As a result of these trials, the company was able to define which combination of these factors produced the best result (highest quality with fewest defects), as shown in Figure 2-3.

As a result of their designed experiment, this company was able to…

- Quickly and simultaneously test key factors and interactions (rather than experimenting on “one factor at a time”) to understand how main events and interactions affect yield
- Expand their knowledge of how key factors influenced the process
- Identify the *combination* of factor settings that would optimize output quality

- Understand how robust the optimum values were against environmental "noise"

Figure 2-3: Reduced Variation After DOE



This example also reinforces the links between Lean and Six Sigma—time *and* quality. Because Lean was implemented together with Six Sigma, the process velocity greatly increased. That meant the company could run smaller lots for each part number about *five times faster* than the initial process, with *no increase in cost*. In terms of learning, the company could even complete additional experiments for each major product five times faster than before the improvements, and hopefully reduce variation five times as fast. In the next chapter, you'll see additional reasons why this lead time gain is important.)

But does a busy CEO need to be aware of such an arcane quality tool? Let's hear from Lou Giuliano, the CEO of ITT Industries:

> *"We have some divisions within our businesses that I know we could not operate today if we didn't have the practice of regularly using quality improvement tools—tools such as Taguchi methodologies [Design of Experiments], on a regular and routine basis. The one that comes to mind specifically is our Night Vision business where we make night*

> *vision goggles for the U.S. Army and allied militaries all over the world. Producing Night Vision goggles is a very complex process…[T]en years ago there were four U.S. manufacturers in that business. Today there are two. The other two have gone out of business, and the other one that still is in business has been losing money for years. Over that ten-year period we've been making money consistently and earning in excess of our cost of capital—even though it's a very capital intensive business. I credit continuous process improvement for this success."*[1]

Design of Experiments is one of the most powerful tools in the Six Sigma repertoire, but similar gains can be made with many of the simpler tools as well—especially in organizations that have not yet applied Six Sigma methods to their processes. Tools such as flowcharts, run charts, and Pareto charts help organizations pinpoint the true causes of a problem, which is the most important step on the road to finding effective solutions.

The e-Infrastructure

There is one more tool associated with Six Sigma that usually doesn't appear on any lists but which is proving to be vital.

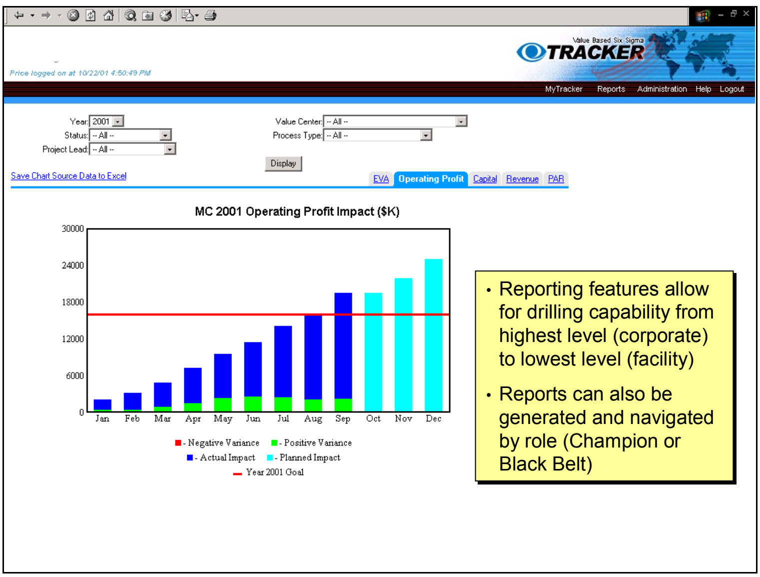
Two prerequisites for a successful Six Sigma effort are **learning** and **communication.** In any organization, for example, the CEO, Executives, P&L Managers, Champions and Black Belts need to know what projects are underway, and how their results roll up to meet corporate objectives. Numerous people need to receive both standard training, and customized education tailored to specific projects.

These learning and communication needs are the same whether a company is located in a single building or has facilities worldwide. That's why in recent years there has been a big emphasis on building computing capabilities to support the people infrastructure. Training classes rely on electronic format rather than notebooks of overheads. This allows Black Belts to refresh their skills, and do research searches of tools applicable to a given project, and to electronically export slides for use by Green Belts. Electronic media also help Black Belts navigate through a complex toolset to find tools appropriate to their projects.

e-Tracking systems also allow people throughout the infrastructure to monitor the effectiveness of Black Belt projects. All projects can be viewed on the web, and rolled up by the company Champion for easy comparison to the CEO's plan for increased ROIC and revenue growth. Plan versus actual outputs of each Business Unit are available, and can be drilled down to the project level detail if so desired. Some are even using software to evaluate team strengths and weaknesses.

In a Six Sigma organization, teams are not set adrift to wander through the DMAIC process on their own. Rather, the Deployment Champion and Project Sponsor conduct a Gate Review with the Black Belt at each phase of the DMAIC process, to make sure the project goals are attainable and still relevant to corporate needs. e-Tracking tools allow the operating profit results of Black Belt teams to be audited by the controller at the P&L unit, then rolled up to the group and corporate level. This allows the CEO to track improvements in Operating profit versus plan, as seen in the bar graph in Figure 2-4.

Figure 2-4: eTracker Year-to-Date Impact Chart



The Role of Six Sigma as a Metric

As a *process* metric, Sigma level undoubtedly has value as an indicator of how often your organization's work fails to meet customer needs.

Some advocates of Six Sigma have claimed that the concept also works at the corporate level. By some estimates, a manufacturer operating at 2 to 3 sigma guarantees that 15% of revenue is being wasted as cost of quality, and that by improving cost of quality to the 5 or 6 sigma level, that that wasted 15% of revenue can be transformed into operating profit.

But other companies have been disappointed in trying to use the sigma level of the whole corporation as a valid metric. In service organizations, and even at the enterprise level of manufacturing firms, it's not always clear what should be counted as a "defect":

- From customers' perspective, long lead-time and lead-time variation is a defect that causes them to invest more capital in inventory (because they can't rely on getting the product when they need it from you, the supplier).
- Long lead-time also causes excess internal costs, and that is certainly a defect from the shareholder's perspective.

Attempts at calculating a meaningful enterprise sigma level opens a Pandora's box. Do you count long lead time as one defect, or do you need to weight it by the thousands of products shipped late, or their cost to the client? Or the lost revenue they entail in the future? Should excess inventory be counted as one defect, or should each dollar, penny or mil be a defect? Should we not count a new product which has excessive cost or poor performance as a defect? Is it one defect or many?

These "non-manufacturing" defects have enormous impact on operating profit, and their removal can lead to huge improvements in operating profit and capital reduction. But is their importance really related to the number of defects per million opportunities, or to their value? These issues have not been addressed by many Six Sigma practitioners. Lean Six Sigma relates process improvement to specific income statement and balance sheet items rather than asserting that a company that achieves a higher sigma level will improve operating profit. I am sure it's true in a gross sense, but we prefer a more direct linkage.

The best approach is to use the Sigma level as a *process* metric. Measure initial sigma capabilities for specific core processes as a baseline, then re-calculate them once you have improved those processes. Defects—be they due to process quality or process velocity or any other source—should be weighted not on how *often* they occur, but on their importance to customers and impact on shareholder value at the enterprise level. This has the further merit that it ties the improvement process into metrics that the operating managers are trying to improve.

The Key is in the Culture

We have talked a lot about the culture of Six Sigma, whereas most books put far more emphasis on the tools. It is my contention that the culture of Six Sigma is the reason for its success. It has been wisely stated that "culture eats strategy for breakfast." In Chapter 4, for example, we will provide data which indicates that most efforts succeed or fail based on *execution; f*ew fail for lack of a good strategy. Six Sigma provides the cultural framework to convert good strategy into good execution.

Key Messages of Six Sigma

- Everything starts with the customer
- The infrastructure for cultural change is the most powerful contribution of Six Sigma
- Decisions about what projects to pursue must be based at least in part on the potential impact on Net Present Value
- Sustained improvement is only possible with management engagement
- CEO goals are translated to frontline projects and coordinated through an organization of people and technical resources
- A standard problem-solving process and associated tool set provides the means for basing decisions on data

To Learn More

- Chapter 3 will explore Lean methods, then the two key elements of Six Sigma and Lean are brought together in Chapter 4
- Implementation of the Six Sigma components are defined in Part II.

End Notes

1. Lou Giuliano speaking at the Value-Based Six Sigma Executive Summit on June 26, 2000 in New York. Transcript available from George Group.

Chapter 3

Lean Means Speed

Henry Ford

Process Velocity a Driver of Cost Reduction

"Our production cycle is 33 hours from iron ore to an automobile, compared to 12 days which we thought record breaking."

"The time element in manufacturing stretches from the moment raw material is separated from the earth to the moment when finished product is delivered to the ultimate consumer. Ordinarily, money put into inventory is thought of as live money,...but it is waste - which like every other form of waste, turns up in high prices. We do not own or use a single warehouse! Time waste differs from material waste because there can be no salvage."

Henry Ford was the first person to understand the impact of process speed on cost. His "process" was fabulously successful for a dozen years… but ultimately failed because it could only produce one product.

The sovereignty of the customer and the profusion of products to satisfy every need, require a process that can responsively deliver many different products with high velocity and high quality, and low cost and minimal invested capital. The goal of Lean is to quickly make-to-order a profusion of different products with the low cost first attained by Ford.

These seeming contradictions—low cost combined with high quality and high speed—were first overcome by Toyota. Their system was, however, limited to the repetitive manufacture of a limited variety of high volume products. The Lean Enterprise is a *generalization* of the Toyota Production System (also known as Just In Time) to all processes.

As we mentioned before, Lean thinking is counter-intuitive, hence a sound understanding is necessary to build a roadmap to achieve these goals. Lean remains a largely misunderstood improvement process. One of my principal goals in writing this book is to equip the diligent manager with a profound understanding of Lean, gained from more than a hundred implementations during the last dozen years. The natural place to start is by looking at what most people think of as Lean.

Is This Lean?

My friend Robert Martichenko of Transfreight, an expert in Lean Logistics, likes to explain Lean by describing an idealized plant tour inspired by actual experience. He "tours" a small company who believes they are practicing Lean manufacturing. This company has one of the simplest product lines imaginable: they make widgets in two different colors, red and green. While he is there, he notices they are making green widgets all day long. (When they don't have to change the paint line, they can make 400 green widgets per day.)

In the middle of the day, the Logistics Manager, John, tells Robert to "watch this… Lean at its best!" At that moment, the manufacturing line is on its last box of green widget handles. Wouldn't you know it, a truck load carrier shows up with a full load of green widget handles and the day is saved because of the Lean system in place. John is very proud that the truck showed up "Just in Time." After the day is over, Robert sits down and asks John a few basic questions:

1. How many customer orders do you have confirmed for green widgets?
2. Why are you only manufacturing green widgets today?
3. On Tuesdays, do customers only use Green widgets?
4. Why did you order a whole truckload of green widget handles?
5. Why will you still be making green widgets tomorrow when more than half of today's production is still in inventory?

John tells Robert that they only had orders for 200 green widgets on the books, but they make green ones all day because of the manufacturing economies of scale. As far as the truck load of green widget handles, well, the supplier gives such great volume discounts that John buys in truckload quantity. “But,” John said, “the truck never shows up until we are just running out.” (John didn’t mention that a truckload of widget handles would last for 2 months!)

Is John really practicing Lean production? Unfortunately for his company, he is not enjoying the cost and process speed advantages of Lean.

The truth is that Lean is not just a raw material procurement strategy, but rather a process philosophy where the purpose is to…

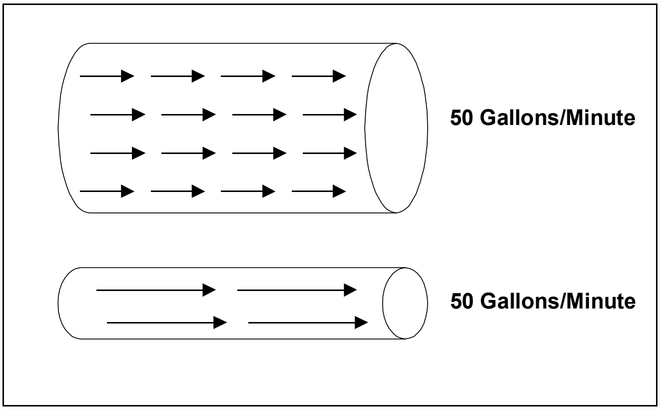
- eliminate wasted time, effort and material
- provide customers with make-to-order products
- reduce cost while improving quality

The Essentials of Lean

As in most factories, the material in the Widget line spent more than 95% of its time waiting …waiting for value to be added …or waiting in finished goods inventory for a customer. In contrast, the goal of Lean is to virtually eliminate wait time. Instead, every operation becomes so flexible that the *actual* usage by the customer creates a demand on the factory to build *only* the amount consumed by the customer, whether external or internal. The Lean factory is flexible enough to efficiently build in small batches to replace consumption. When this goal is achieved, parts will move directly from one workstation to another at high velocity and reduce the waiting time, WIP, and Finished Goods inventory by 50-80%.

Think of the factory as a water hose. If water is moving slowly, a larger diameter pipe is needed to deliver a given volume per minute, and lots of water (Work In Process) is effectively trapped in the pipe. Lean can increase the velocity by a factor of five, and we can reduce the cross section and hence the WIP by a factor of five.

Figure 3-1: Slow Velocity Traps "Things" in Process



As velocity increases, the cost of stockrooms, material movers and equipment, expeditors, scrap, rework, obsolescence, excess capex—the *Hidden Factory*—will be removed. As a rule of thumb, if the waiting time is reduced by 80%, the Manufacturing Overhead and Quality Cost will drop by 20%. If the allocation of costs shown in the pie chart in Figure 1-3 is true, this will increase Operating Profit by roughly 5%.

The Keys to the Kingdom of Lean are founded on two principles which are observed in every factory or process we have ever encountered:

- Material usually spends 95% of its time waiting, which is due to the time delay injected by fewer than 20% of the workstations, which are known as ***Time Traps***.
- Time Traps can be prioritized using MRP data and the spreadsheet calculations or software (see Chp 12), and eliminated using the Lean Six Sigma improvement methods of Table 2-2.

Identifying and prioritizing Time Traps… at the most basic level, that's all you need to know about Lean! The rest of this chapter discusses how this process is implemented, with the details discussed in Chapters 15 and 16. You'll see that the basic principles and improvement opportunities apply to *any* process, not just manufacturing, and together they create a Lean Enterprise.

The Lean Metric: Cycle Efficiency

Since speed is a key goal of lean, the natural questions are: How fast is fast? How slow is slow?

The answer comes by comparing the amount of **value-add time** (work that a *customer* would recognize as necessary to create the product or service they are about to purchase) by the **total lead time** (how long the process takes from start to end). If the value-add time needed to manufacture a product down the critical path is 100 hours of touch labor (including machining, assembly, testing, etc.), to be world class the total lead time should not exceed 400 hours. These two figures come together to produce a metric called **process cycle efficiency**[1] that we can use to gauge the potential for cost reduction:

Process Cycle Efficiency = Value Add Time/Total Lead Time

A marketing executive at a major ERP firm recently asked me for a metric that would tell him if a process was lean or not. The answer is:

"A Lean process is one in which the value-add time in the process is more than 25% of the total lead time of that process."

Let's look at one example. The Tier 1 auto supplier described earlier in this book knew that there was less than 3 hours of value-add time in their process (the time needed to machine, braze, assemble, and test a coupled hose fitting). However, the total lead time from release of raw material into the line to shipment was an average of 12 days.

Based on having an 8-hour work day at the plant, the ratio of these two measures gives us process cycle efficiency:

Value Add Time = 3 Hours

Total Lead Time = 12*8 = 96 Hours

Process Cycle Efficiency = 3 Hours / 96 Hours = 3%

In other words, it is taking 12 days to put 3 hours of value into the product—the material is *waiting* for 11.6 days. You may think that a 3% cycle efficiency is low, but in fact it is fairly typical. Most processes—manufacturing, order entry, product development, accounting—run at a cycle efficiency of less than 10%. (Take some data on your own processes and calculate the cycle efficiency. I think you will be surprised.)

Process Cycle Efficiency varies by application, but an average of 25% is world class (see Table 3-1).

Table 3-1: Typical and World Class Cycle Efficiencies

Application	Typical Cycle Efficiency	World Class Cycle Efficiency
Machining	1%	20%
Fabrication	10%	25%
Assembly	15%	35%
Continuous Manufacturing	30%	80%
Business Processes—Transactional	10%	50%
Business Processes—Creative/Cognitive	5%	25%

In this case, if the process lead time could be reduced to, say, 2 days, the wait time is reduced by 85%. The process cycle efficiency rises to 19% (still below the Lean goal of 25% but much better than the starting point).

Any process with low cycle efficiency will have great opportunities for cost reduction. As we mentioned, increasing process cycle efficiency from 5% to 25% will allow the reduction of manufacturing overhead and quality cost by 20%. Since less than 20% of workstations are the Time Traps that inject 80% of the delay, focusing on these Time Traps gives the improvement process enormous leverage.

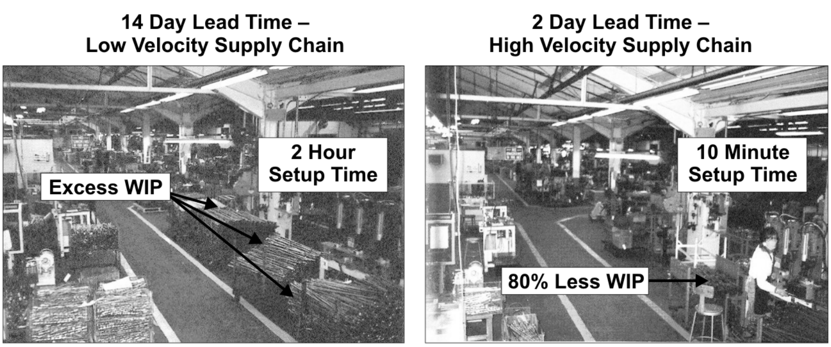
Where Do the Cost Reductions Come From?

The slowness of most processes—their low cycle efficiency—guarantees that there is a large amount of Work In Process (or Projects In Process) at any given time, either on the plant floor or finished goods in stock rooms. Much of the plant space is tied up holding idle inventory, idle machines, stockrooms, rework labor, QC, expeditors, schedulers and related non-value-add activities In other words, WIP generates hidden costs in overhead, rework, scrap, manufacturing overhead, invested capital and unhappy customers… and in consequence puts a company in constant jeopardy of losing existing business as well as revenue growth.

When process cycle efficiencies rise above 20%, much of these non-value-add activities can be eliminated. As a side benefit, the personnel associated with non-value-add work are often some of the most talented in the company, and sometimes the only people who really understand the whole process because they have had to cope with it. Thus their redeployment into value-add assignments in Manufacturing, Engineering, Marketing or the Lean Six Sigma process allows them to be in a value creation role.

Figure 3-2 shows dramatic "before/after" photos of the Tier 1 auto supplier reflecting the physical changes made possible by their speed and quality improvements. Since most factories do not produce such physically large parts, the effect of Lean improvements is generally not as visually dramatic, but the same types of improvements can be made.

Figure 3-2: Before/After Photos of Tier 1 Auto Supplier



Before Lean Six Sigma
Metal Ware Flare running large batches with large amounts of WIP at revenue of $145M

After Lean Six Sigma
Metal Ware Flare with pull system and setup reduction: inventory reduced 85% at revenue of $300M

The "after" outcome for this company was spectacular: If the volume of the company remained constant, they could have completed the needed work at two plants instead of three—saving most of the overhead for an entire plant (which would have amounted to about a 4% total operating margin improvement as a percent of revenue). This option was the one originally chosen but never executed because of the sales growth resulting from the dramatic reduction in lead time.

Sources of cost reduction

Let's again review the components of the Hidden Factory that can be eliminated through application of Lean methods. The reduction of cost is *not* just from reduced scrap and rework, or from having less money tied up in inventory. Faster lead-time and smaller inventory has a host of benefits that can be estimated in advance and tabulated (as you'll see later in this chapter):

- Faster lead time, which can increase revenue growth dramatically
- Less handling, which reduces the demand for people and equipment
- Less cost for storage, floor and stock room space
- Fewer customer service activities

A small inventory also *avoids* all the problems associated with large WIP, such as…

- Parts shortages and the resulting loss of productivity.
- The need for extra operators, expeditors, supervision and overtime.
- Having a disproportionate percentage of product shipped at the end of the month though you have to pay for this peak capacity of Plant Property & Equipment (PP&E), inspection, test, and overhead cost all month long.
- The increased likelihood that defects will be shipped to customers (who have been kept waiting for their parts), necessitating expensive field repair and loss of subsequent sales.

At a leading Defense electronics company, the lead time in Printed Circuit board production was cut from 6 weeks to 4 days. Several stockrooms were closed, and 17 expeditor positions were eliminated (the people were moved to value-add jobs, not fired!). A $200,000 expenditure for bar code tracking of the material was cancelled, the Operations manager exclaiming: "If I release the kit on Monday and it enters test on Thursday I don't care where it is in between!"

Faster lead time at this Defense contractor also made a huge reduction in the cost of quality: reducing lead time by a factor of five reduces WIP inventory by the same factor. One supplier to this company shipped a product with a subtle dimensional change that caused an electrical short circuit in the customer's product. Because the process was operating "Lean," with shorter lead times, the problem was detected in just 4 days in test; since there was also lower WIP, the changes only caused one-sixth the rework that would have been necessary with the higher WIP levels typical at this company before improvement. The Manager of Systems, Frank Colantuono said: "It was the difference between making the month's shipments and disaster."

(Taking a process view of the business, we say that shorter lead times means there are more cycles of learning per month. Processes move more quickly, so you have more opportunities to learn what is and is not working and to see the effects of changes.)

By dramatically *reducing overhead cost*, managers are no longer tempted to overproduce to absorb overhead, a practice which merely clogs the factory with WIP and makes on-time delivery or lead time prediction impossible as well as irrelevant.

Eliminating Time Traps is just as dramatic as watching a river flow after beaver dams have been removed, and it is one of those business experiences people never tire of recounting. In 1987, Lean was first applied to a factory that produced Army Radios. Eleven years later, in 1998, the former controller and then-President of an Automotive unit recounted his amazement as he had watched lead times drop from a chaotic 8 weeks to a stable 2 weeks in just a few months. He implemented Lean in his $2 billion division, leading to its sale at a very attractive price.

Speed Applies to All Processes

We've said it earlier in this chapter, but it bears repeating: When people hear "Lean," they think "manufacturing." But the principle of speeding up processes applies to non-manufacturing (transactional) processes as well as manufacturing. In fact, even if you only wished to improve manufacturing cost, quality, and lead time, you would have to improve the velocity, responsiveness and quality of the associated transactional processes as well.

One example of how you can't really separate manufacturing from non-manufacturing applications of Lean Six Sigma comes from an early

Lean implementation effort. A division of an $8 billion company that produced aircraft test systems had already used Lean tools, and reached a point where they built in batch sizes of 1 with short setup times. The short lead time reduced the releases of material into the line, cutting down the number of "things in process"—both of which are primary goals of Lean.

However, many of the printed circuit boards produced by this division required as many as 60 modifications (called "cut runs" and "jumpers") to meet the current revision level. The rework time spent on these modifications…

1) approached and often exceeded the total build time of the board,
2) greatly increased test time, and
3) had a much higher field failure rate.

Most of the variation in the process time and quality was induced by these problems.

Since the factory ran each board type at least once a month, a team began work on implementing new PC board artwork in hopes of making changes quickly so that the next month's production cycle could be free of cut runs and jumpers. All the boards were built in-house, so the team could achieve the desired production lead time for new boards… *if* it had the Engineering Change Notice (ECN) and new artwork release from Product Development in time for the next production round.

Unfortunately, no one person owned the ECN process. Rather, the Request For Engineering Change Notice required *eight* sign-offs before engineering would change the artwork—with the result that the ECN process normally took one to three months!

In creating a Process Map for the first time, the team found that of the eight people on the ECN review list, *only three of them could add value* (that is, understand the technical purpose of the change enough to offer useful advice). The other five needed to be informed of the change so they could work effectively, but they should not have had sign-off authority. Most of these five were fairly high level people with a lot on their plate, who frequently traveled. The ECN forms often were lying on their desks, and nobody wanted to expedite them. So the major Time

Traps in this process were all related to time the ECNs spent *waiting* in someone's Incoming box! To solve this process problem, the five managers agreed to be changed to an advise from a consent role. The ECN cycle time dropped to less than 2 weeks and allowed a major improvement on manufacturing quality and cost.

This example is by no means atypical; just the reverse in fact! I have seen that there is as much or more improvement opportunity in these business processes to improve speed/flexibility/ responsiveness and reduce cost. The point is that the manufacturing process could not have been improved if the non-manufacturing processes had not been leaned out.

Lean does not mean manufacturing, Lean means speed.

Specific Applications of Lean to the Service Industry

Remember Jack Welch's famous quote about the "awful *variation"* that some GE customers experienced in delivery time (it ranged from 4 days to 20 days)? Let's take an example of lean improvements in a service industry to illustrate the key points.…

Hotel chain industry statistics indicate that guests who are "very satisfied" at one hotel will return to that hotel or another in the chain anywhere from 3 to 6 times per year. Guests who are dissatisfied never return, but tell 8 to 12 friends about the experience. There is thus enormous revenue growth potential by moving guests into the "very satisfied" category, and reducing the numbers who are "dissatisfied." One of the biggest single factors in satisfaction is the speed of total check-in time.

For the sake of this discussion, let's say it takes a hotel clerk exactly five minutes to check in a guest. If a new guest arrives exactly every 7 minutes *on the dot*, how long would you wait in line? *No time at all, there would never be a queue*.

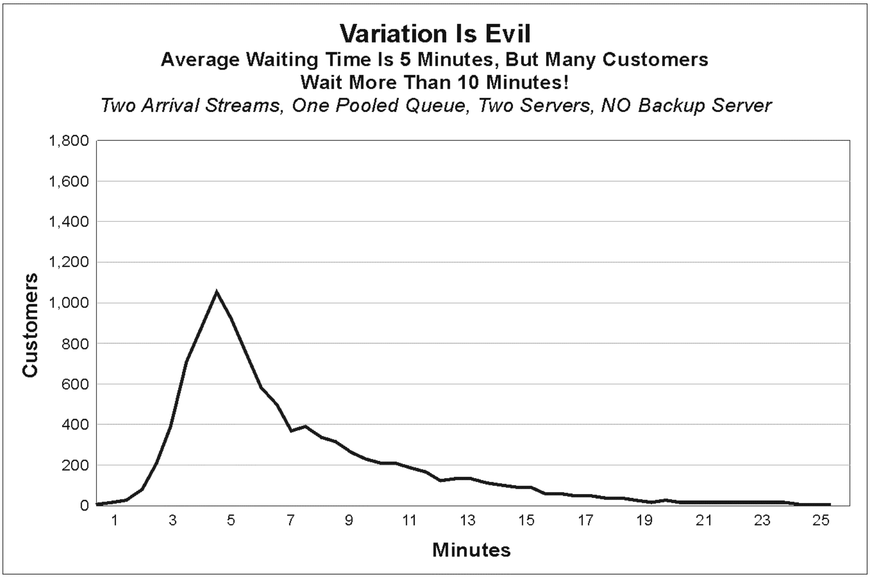
Yet if I changed the word "exactly" to "on average" many customers would end up waiting 10 minutes or more. How could this possibly happen? How would you feel if you were one of the people who had to stand in line 10 minutes rather than 5 minutes?

The root cause of the problem is *variation* in time: Many guests flash their preferred guest cards and register in 3 minutes or less. But others have requests that take up more time. One customer might request a room that connects with another guest's. Yet another may claim to have a reservation which the clerk cannot locate. As a result, most customers require between 3 and 7 minutes of clerk service, yet the *mean* is still 5 minutes.

To complicate things, there is variation in *arrivals*. Customers arrive in bunches—sometimes every 4 minutes, other times not for 10 minutes, but the mean arrival time is 7 minutes.

If you plug this data into special supply chain accelerator software used to identify Time Traps, you can *predict and ultimately prevent* the variability in span, as Jack Welch would call it.

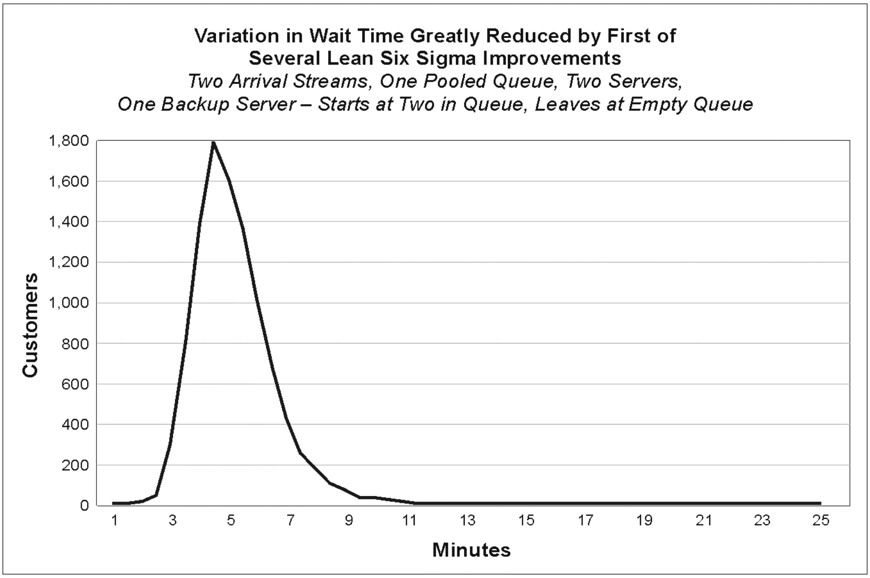
Figure 3-3: Variation in Unhappy Customers



As depicted in Figure 3-3, even though the average check-in time is 5 minutes and the average arrival time is 7 minutes, some customers experience "heroic" 3-minute check-ins while many others experience an "awful" 11 minutes or more. What is going on here? When guests arrive every 10 minutes, the clerks have nothing to do. But when a "difficult" guest happens to coincide with guests arriving every four minutes, the wait time can exceed ten minutes for many guests. We say that these guests are caught in a Time Trap.

We can't do much about the variation in guest arrivals, but we can do a lot by just pooling our clerks and by training backups (from accounting and reservations) to cover peaks. We can test the solution with software to make sure it works. The result is shown in Figure 3-4.

Figure 3-4: Reducing Variation Improves Customer Service



These gains can be achieved without adding any full-time personnel; just changing the queue design and cross-training personnel provides additional peak capacity. Thus the mean check-in time remained nearly the same and the variation in service was reduced despite great variation in customer arrivals. Now the same number of guests wait 7 minutes as formerly waited 11 minutes.

Even here, you can't ignore the key message of Lean Six Sigma: you have to focus your energies on *priority* problems that are most directly connected to significant shareholder value. In this example we assumed that it was the check in process itself that was the highest priority to illustrate the impact of variation on delay time. But often in situations like these it is upstream processes—such as information flows on the availability of clean rooms, the room cleaning process itself, the availability of maids, and linen queues in the laundry room—which in fact affect the check in time. That's why you need to use the tools described earlier in this chapter—value-stream mapping and Net Present Value analysis—to identify where you will have the greatest leverage.

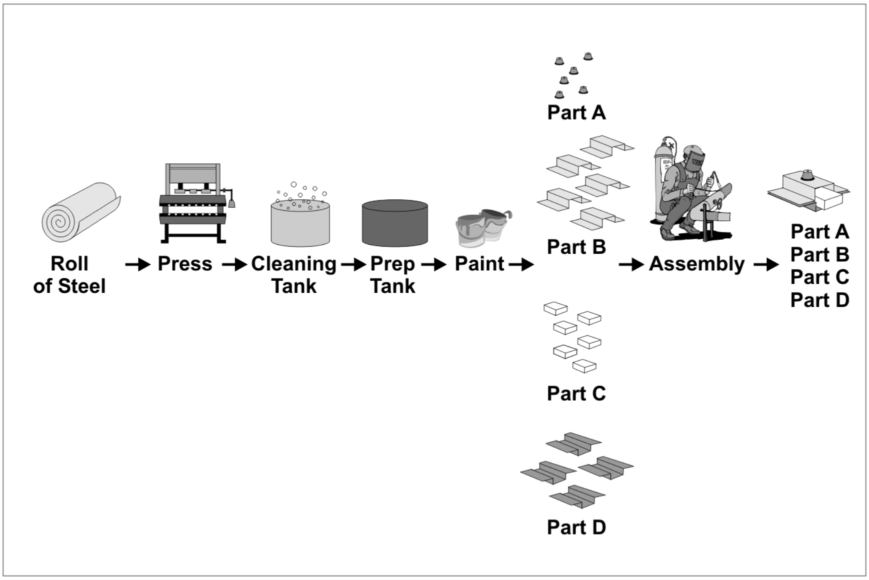
This hotel check-in example shows how variation in arrivals and processing time *intrinsically* causes delay, even in a process much simpler than most manufacturing processes. The work was done at a single "workstation" (the clerk). It had no setup time, no scrap, no downtime—each of which create delay in their own right and is a source of variation. There, it was absolutely clear where the delay occurred, why it caused the Time Trap and where the company needed to apply DMAIC improvement activities to reduce variation. The obvious question is whether these same principles apply to processes that are more complex, and can you find Time Traps by intuition or looking at the plant as some claim they can?

Pop Quiz: Where Are YOUR Manufacturing Time Traps?

If 80% of the delay is caused by 20% of the workstations, it is essential that we find those 20% and eliminate them using the Lean Six Sigma tools. So… how would you identify the Time Traps in your processes? The intuitive answer is "look for where the Work In Process (materials, hotel guests, mortgage applications…) is piled up." But is that really true?

Take a look at Figure 3-5. In this process, the value-add-time per part is a few minutes, yet the total lead time of the process, including queue time, is 28 hours. The low process cycle efficiency is a tip-off that this process has a lot of waste in it. You will notice a pileup of inventory in front of the Assembly station, and some would say that it is a "bottleneck" or Time Trap. Do you agree?

Figure 3-5: Where Are the Time Traps? Where the Inventory Stacks Up?



Most people would intuitively guess that Assembly is the Time Trap. But here's a radical idea supported by Lean principles: The assembly station is *not* the real time trap. How do we know? Like all Lean Six Sigma efforts, we replace intuition with data and calculation. Here's the data…

The assembly operation is the last of a five step process:

1. The press molds four different parts, A, B, C, and D, by cutting and stamping a roll of steel. It first performs a setup which takes 4 hours, then presses out a batch of 1000 of part A at the rate of 100/hour (36 seconds per part), then performs a setup and stamps a batch of part B, etc.

2. After a part is pressed out, it drops into a cleaning tank for about 30 seconds.

3. The part is moved to a Prep station where it spends 30 seconds being prepared for paint…

4. It is painted in 40 seconds…

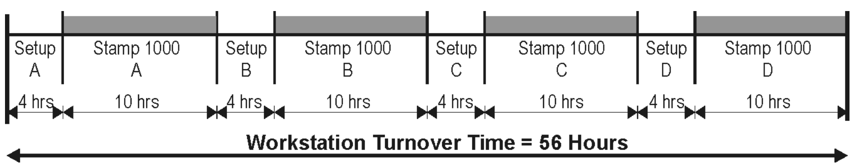
5. And finally moved to Assembly… where one A part is bolted to B, to C and D in 2.5 minutes, and the product which we will call ABCD is completed.

Using this process data we quickly see that the value-add time is just 4 minutes and 45 seconds—but the process lead time is 28 hours. Sounds like less than a 1% Cycle Efficiency to me, which means there is money to be made!

The Press operators perform a setup by changing the dies and making adjustments, all of which takes 4 hours. Because of the long setup time, these operators cannot just press out one part A, perform another setup, and press part B—because then the production rate will be one part every four hours, and the demand is for 17 of ABCD per hour.

So instead, after a setup is complete, the operators press out a batch of 1000 of Part A at the rate of 100 per hour, which takes 10 hours. They then perform another four hour setup, and press out a batch 1000 of Part B which takes another 10 hours, then C, then D. They are then ready to begin a setup for Part A and start the cycle again. The time taken for this cycle—called the **Workstation Turnover Time** (in analogy to inventory turns)—is 56 hours (see Figure 3-6).

Figure 3-6: Timing Diagram Shows Inflexibility



The 56-hour workstation turnover time for the Press is a reflection of its inflexibility. The WIP inventory of Part A is nearly 1000 after the batch is complete, and falls to near zero before the next batch of A is completed. On average, therefore, there are about 500 of each part in process at any one time, consumed at the rate of 17 per hour. Similarly, on average, there are about 28 hours of delay between the time a part is built and the time it flows out of Assembly.

So where is the Time Trap in this process? It's not the Assembly, where the parts pile up, it's the Press that's injecting 28 hours of delay into the process. That is, the Assembly would not have such a big pileup of inventory if the Press could work in smaller batches! That means we'd get the most leverage by attacked the Press workstation using the Lean Six Sigma tools.

Finding and Removing the Hidden Time Traps

Finding Time Traps is not a matter for guesswork. You have to use data to identify the sources of delays in a process. The key equation is captured in the **First Law of Lean Six Sigma for Supply Chain Acceleration:**

$$\text{Customer Demand Rate} = \frac{\text{Batch Size}_{\text{Min}}}{\text{Workstation Turnover Time}}$$

This can also be expressed with the following equation:

$$\text{Delay Time} \approx \frac{\text{Workstation Turnover Time}}{2} = \frac{\text{Batch Size}_{\text{min}}}{2} \times \text{Customer Demand Rate}$$

You can find the derivation for this equation in Appendix 1; the key thing to remember is that you can use data that is fairly simple to collect on a process step or workstation and determine if this workstation is injecting long delay times into the process. These calculations can be performed easily with a spreadsheet or specialized "supply chain accelerator" software, and the results tell you how much delay time each workstation is injecting, and how much WIP and batch size is really needed to satisfy customer demand.

In this case, the company knows that the Press is the Time Trap, so they then apply the appropriate Lean Six Sigma tool. The choice here is obvious: it's the long set-up time between parts that's driving the operators to work in batches of 1000. To reduce set up time, they'd use the Four Step Rapid Setup method (described in detail in Chapter 12)…

- This would allow them to reduce setup time by 90% with minor expenditure.
- A faster set-up substantially reduces workstation turnover time. Using the First Law equation, the operators know they can then

reduce batch size from 1000 to 100 and still meet the customer demand.

- The delay time for the process drops from 28 hours to 2.8 hours…
- Total WIP inventory drops from 2000 parts to 200 parts.

Naturally, this company wouldn't stop once this station is improved. They'd then move on to the next biggest Time Trap in some other part of the process, then the next largest one after than, and so on, until they achieve a Cycle Efficiency of 25% or more. As discussed above, achieving this level of efficiency means they can eliminate a lot of the non-value-add costs in Manufacturing Overhead and Quality cost.

Conclusion: The cause of delay in a process is a Time Trap. You can't just look for where material piles up; rather, you must calculate how much time each workstation injects in a process using the First Law of Lean Six Sigma.

Crucial Insight: Batch sizes must be calculated from Process Variables and the total number of parts produced at a given workstation

The Press-to-Assembly operations reduced the process lead time from 28 hours to 2.8 hours by…

1. Finding the Time Trap
2. Applying the Lean Six Sigma improvement tool
3. Reducing the batch size

The last step is critical: If they had not reduced the batch size, the delay time would have been only slightly improved and the WIP inventory would be nearly unchanged.

As the discussion above illustrated, batch size is related to the inflexibility: the more rapidly a workstation can switch to producing a new part, the smaller the batch size required, and the quicker the flow velocity. The inflexibility of most manufacturing processes has guaranteed that factories had to produce in large batches to meet production demand.

There's more to the batch-size picture. Traditionally batch sizes have been determined using formulas such as the EOQ formula or and those found in MRP systems. The problem is that these formulas do not consider how many different parts are produced at a workstation. Also, the batch sizes calculated from EOQ or most MRP systems are wrong because they do not consider the flow to the customer. They are fixed and are never reduced. ***This prevents improvement in the lead time and is a key contributor to the slow progress most companies are making.***

Once you learn to appreciate the First Law of Lean Six Sigma, you understand that flow velocity, batch size, and workstation turnover time are all intricately connected. Anything that affects one of these factors affects the others. That means batch sizes should be determined based on process variables—setup time, the processing time per unit, and most importantly the number of different parts it produces, etc.—and should be changed as a process improves. Fortunately, modern MRP/ERP/AP systems allow theses batch sizes to be externally input. (You’ll find more discussion of batch sizes in Chapter 15.)

Velocity of any Process

By reducing the WIP by 90%, we also reduced the overall delay time by 90%, yet still produced the same number of products per hour. This follows Little’s Law, that states that

$$\text{Process Lead Time} = \frac{\text{Number of "Things" in Process}}{\text{Completions per Hour}}$$

This is really just common sense. If I have 10 “things” to do on my desk, and it takes me an average of 2 hours to complete each one, then I have a 20 hour lead time for any new task (unless an expeditor interrupts me!).

In the Assembly described above, the materials traverse five workstations, and we can calculate the number of workstations per hour that the product moves through, which describes the ***velocity*** of the product through the process.

Third Law of Lean Six Sigma for Supply Chain Acceleration

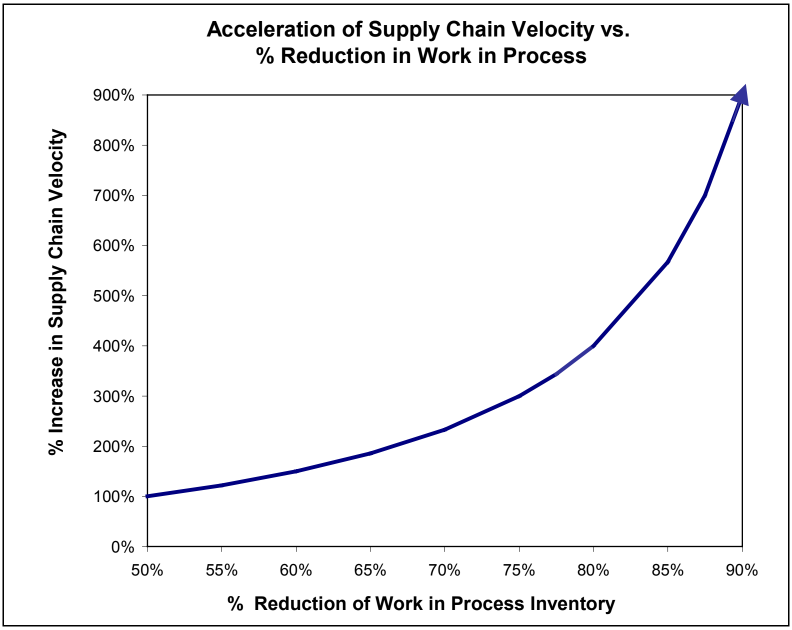
$$\text{Process Velocity} = \frac{\text{Number of Activities in the Process}}{\text{Process Lead Time}}$$

$$= \frac{(\text{Completions per Hour})(\text{Number of Activities})}{\text{Number of "Things" in Process}}$$

Why do I say “things” in process? Because it doesn’t matter whether it is WIP in manufacturing or Mortgage applications going down a chain of approvals; the velocity is inversely proportional to the number of Things in process. This is of such importance it is referred to as the **Third Law of Six Sigma for Supply Chain Acceleration.**

Figure 3-7 shows schematically how remarkably velocity increases as the number of “things” in process are reduced by improvement methods as in the example above.

Figure 3-7: Velocity Increases When “Things” in Process Are Reduced



It should be noted that the Third Law equation represents *average* process performance; it can tell you a lot about what is going on *across* a process consisting of several activities, but it can't tell you anything about a single activity, and hence cannot show the location of a time trap. For example, in the Press example, the Third Law gives tells you the overall process velocity for the five workstations, but if you applied it to just one workstation, it provides no information. As we've already determine, the Assembly operates at a very slow velocity with lots of WIP backed up—but this slow velocity is caused by the Press!

But that slow velocity is meaningless; Assembly is not the Time Trap. Improvements at the Press are the only way to improve velocity. Nevertheless, the Third Law provides a guide to understanding average velocities of processes which consist of many activities. (Locating a Time Trap requires the detailed calculations of the First Law of Lean Six Sigma discussed in Appendix 1 and in Part II.)

Of course, instead of minimizing sources of delay, you could adopt Henry Ford's solution to a problem: have one Press for part A and a separate Press for part B, etc. By having separate presses, Ford eliminated set up time and the resulting variation. Since he never performed a setup, his batch size was infinite! Unfortunately, that only works when you can produce vast quantities of a single product (like the Model T) to amortize the capital cost—which, as history has shown, eventually failed when consumers started demanding variety in the product. However, Ford accomplished so much in terms of showing the relationship between high process cycle efficiency (>50% at the Rouge) and low cost that we must acknowledge his huge contribution.

Knowing Who to Hit: the 80/20 Rule

The achievements possible with Lean Six Sigma principles will have little impact if you apply them to process steps that contribute little to delay time, costs, customer satisfaction, etc. As with other improvement strategies, to get the most out of Lean Six Sigma methods, you have to know where to focus your efforts, and how to determine priority order.

In many improvement methodologies, "focus" is largely a matter of making judgment calls about what *seems* most important at the time. With Lean Six Sigma, focus jumps out at us because of the Pareto Principle, which isn't just a theory but rather an empirical observation supported by years and years of data on actual factories: 80% percent of lead time delay is caused by less than 20% of the workstations (the Time Traps). We thus only have to find and improve 20% of the workstations to effect an 80% reduction in lead time and greater than 99% on time delivery. This is always true of processes in which the value add time is less than 5% of the total process lead time (i.e., have a 5% cycle efficiency).

The 80/20 rule is called the Second Law of Lean Six Sigma for Supply Chain Acceleration, and it holds true whether the root cause of the delay is variation in times (arrival times, service times), non-value-added delays such as machine downtime (or long set-up times, as seen in the Press example above), or quality problems (scrap, rework).

Using a Value Stream Map to Find the 20% Waste

In a Lean system, focus begins with a **value stream map**, which depicts all the process steps (including rework) associated with turning a customer need into a delivered product or service, and indicates how much value each of the steps add to the product. Any activity that creates a form, feature or function of value to the customer is termed **value-add**; those that don't are called **non-value-add.**

Value Stream Mapping provides a clear understanding of the current process by:

- Visualizing multiple process levels
- Highlighting waste and its sources
- Making "hidden" decision points apparent

With this knowledge, we can manage decision points, form a future roadmap for implementation, and identify opportunity areas. Value Stream Mapping also provides a communication tool to stimulate ideas by capturing critical organization knowledge and identifying locations for data gathering and process measurement.

We have given many examples of non-value-add activities (the largest contributors to non-value-add cost are Manufacturing Overhead and Quality Cost) and later in this book will create classifications that are useful helping to determine what tools are needed to remove each type of waste so cycle efficiency can increase from less than 5% to over 20%.

The key insight is that a majority of non-value-add costs are in fact currently *required* to move the product through the "molasses" flow. You can't remove these costs until you remove the underlying causes; trying to do so will just create greater costs in the long run.

Creating a Value Stream Map

A value stream map starts with a "pencil and paper" sketch of the process to understand the flow of material and information needed to produce a product or service. (This sketch can be supplemented with many flowcharting software tools.) The diagram gives a visual presentation of the flow of a product from customer to supplier, and presents both the current state map and future state vision.

Value Stream Mapping typically classifies each activity/task type by asking a series of questions:

(A) Customer Value Add (CVA) Questions:

- Does the task add form or feature to the product or service?
- Does the task enable a competitive advantage (reduced price, faster delivery, fewer defects)?
- Would the customer be willing to pay extra or prefer us over the competition if he or she knew we were doing this task?

(B) Business Value Add (BVA) Questions:

In addition to customer value add, the business may require you to perform some functions which add no value from the customers perspective.

- Is this task required by law or regulation?
- Does this task reduce owner financial risk?
- Does this task support financial reporting requirements?
- Would the process break down if this task were removed?

Recognize that these costs are really non-value-add but you are currently forced to perform them. You need to try to eliminate or at least reduce their cost.

(C) Non Value Add (NVA) Questions:

- Does the task include any of the following activities: Counting, Handling, Inspecting, Transporting, Moving, Delaying, Storing, All Rework Loops, Expediting, Multiple Signatures?
- Taking a global view of the Supply Chain, having made these improvements, to how many factories do we really need to deliver projected volume? Will the faster lead time and lower costs fill up existing facilities?
- With faster lead times, how many distribution centers can be eliminated? Experience shows that when three facilities are consolidated to two, you save half an overhead, about 17% of total overhead cost. This captures the operational value of higher cycle efficiency, but not the elimination of the Cost of Poor Quality.

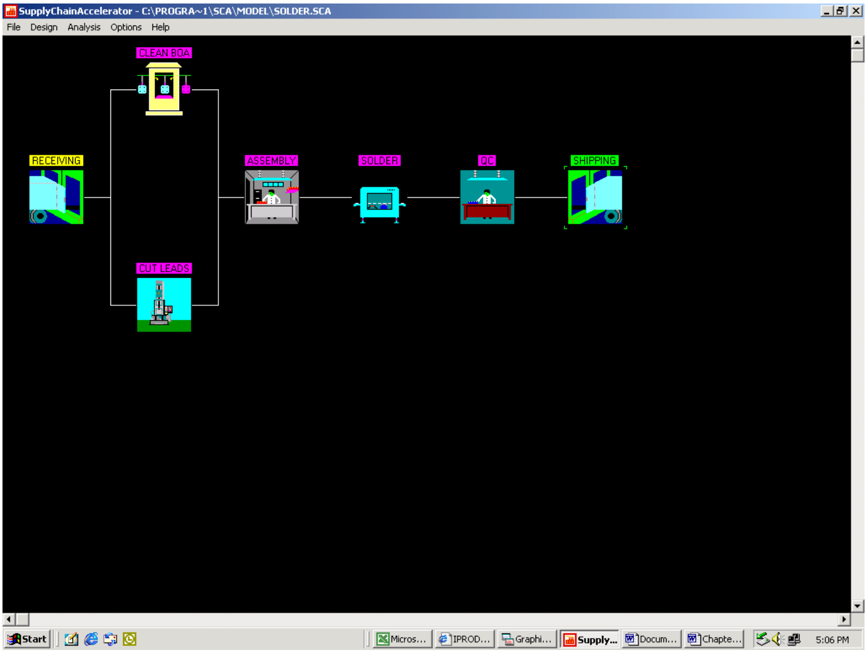
In an improvement project, Non-Value-Add tasks typically make up the majority of the time spent on any given task and are thus attacked first. Business-Value-Add tasks are challenged next, followed by Customer Value Add tasks.

Traditional Manufacturing Engineering a lá Frederick Taylor and Frank Gilbreath focused on the Customer Value Add processes, which are generally much smaller (less than half) than the Non Value Add costs. Although improving customer-value-add activities is important work, it is just a subset of the Lean Six Sigma DMAIC process.

Here is an overview of the creation of a value stream map

1. Select a value stream (product family, etc) whose improvement will create the greatest impact on operating profit.
2. Create a process map or download the MRP router information on that value stream. Because MRP routers generally have good data only on value-add steps, but not on the other 95% of the time used, you will initially start with a value stream that looks pretty clean (see Figure 3-8).

Figure 3-8: Value Stream Map Downloaded from MRP Router Information



3. Input the MRP data into a spreadsheet or supply chain acceleration software to identify Time Traps (details are in Appendix 1 and Chapter 9).

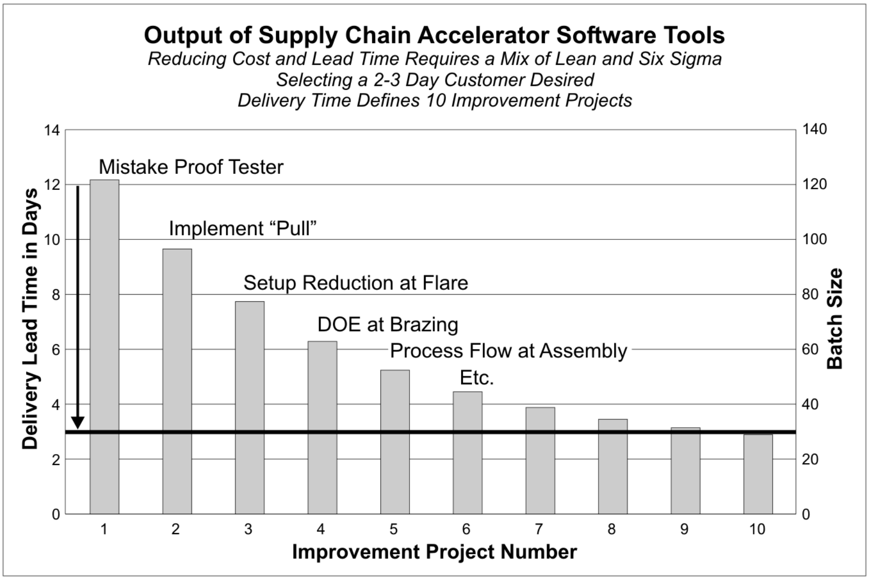
4. Have the Black Belt and his/her team "walk the process" to find out what really happens, and identify both value-add and non-value-add work, such as rework loops, quality inspections, moves in and out of stock (i.e., time that does not appear in MRP), and information flows. Most teams will be surprised to find more non-value-add steps in the process than value add (compare Figure 3-9, which includes non-value work, to Figure 3-8).

5. The team does a sanity check on MRP data such as setup times, etc., by verifying the numbers with operators.

Figure 3-9: Value Stream Map Highlighting the Hidden Factory

6. Finding the Time Traps: The data is input into a spreadsheet or supply chain acceleration software. The Time Traps are then sorted on a spreadsheet or displayed in a bar graph. Figure 3-10 shows the bar graph discussed in Chapter 1 for the Tier 1 auto supplier, which was the output from this step.
7. The delay time at each Time Trap is calculated, and a recommendation for application of Lean Six Sigma tools is recommended. The Black Belt can input how much improvement can be effected, and the spreadsheet or software will recalculate the delay time.
8. Implementation of the improvement activities to address the Time Traps in priority order.

Figure 3-10: Finding Focus



This process only works if the Black Belt and his/her team are trained to define and solve these problems:

- What are the non-value-add steps (rework, move, count, etc.) that can be eliminated
- What are the Time Traps in priority order
- What improvement methods are required at each Time Trap
- How much improvement is needed
- The smaller batch size that can now be run
- The shorter delay time at both the workstation and the whole process

The Road Map of Lean Six Sigma

As a result of a Value Stream analysis, you'll be able to identify the "vital few" Time Traps (usually less than 20% of the workstations) that are disrupting a critical value stream. You will also have a prioritized list of Lean Six Sigma targets and a means of eliminating the causes of delay. When the Time Trap analysis is performed for the whole factory, and prioritized improvements are executed, the total cost of manufacturing overhead and quality cost can be reduced by 20%, which makes a big impact on operating profit. Now that's focus!

In most cases, quality problems are usually near the top of the list, because of their **non-linear impact** on delay time—a 10% scrap rate can slow the whole process down by 40%! In other words, just a few quality problems can add an extraordinary amount of time to a process.

As noted, most people are amazed that the non-value steps outnumber the value add steps! If they work with MRP routers, that's because they're used to seeing an idealized *future state* of the value stream map, at a point when all the waste has been driven out. The future state map shows what can happen once the improvements are made to achieve a cycle efficiency of 30% and eliminate 20% of the Manufacturing Overhead and Quality costs.

As an aside, experience shows that the people who work on non-value-add activities are in fact a vital resource that should be redeployed to value-add opportunities in manufacturing, engineering, marketing and to staff the Lean Six Sigma effort. I have observed that rework is often performed by the most talented of workers; expediting is performed by people of the highest initiative. We generally suggest that the improvement process not be a cause of any reductions of associated personnel, but that these highly talented people be reassigned. Any reductions should be to the company at large in response to inadequate shareholder returns, volume reductions, or lack of revenue growth.

The Major Lean Improvement Tools

While Value Stream Mapping is the key Measure tool of Lean, other methods and their associated tools are needed to achieve the full potential of improved speed. Details of these tools are in Chapters 11 and 12; here are three of the most important:

- **Pull Systems**: As discussed earlier in this chapter, process velocity and lead time are absolutely determined by the amount of the Work In Process. It therefore stands to reason that we must have a mechanical or electronic mechanism to keep the WIP ("things in process") below some maximum level, else the process lead time will grow uncontrollably. The Lean tool that accomplishes this goal is the Pull system, which puts a cap on WIP and thus keeps process lead time below a maximum level.

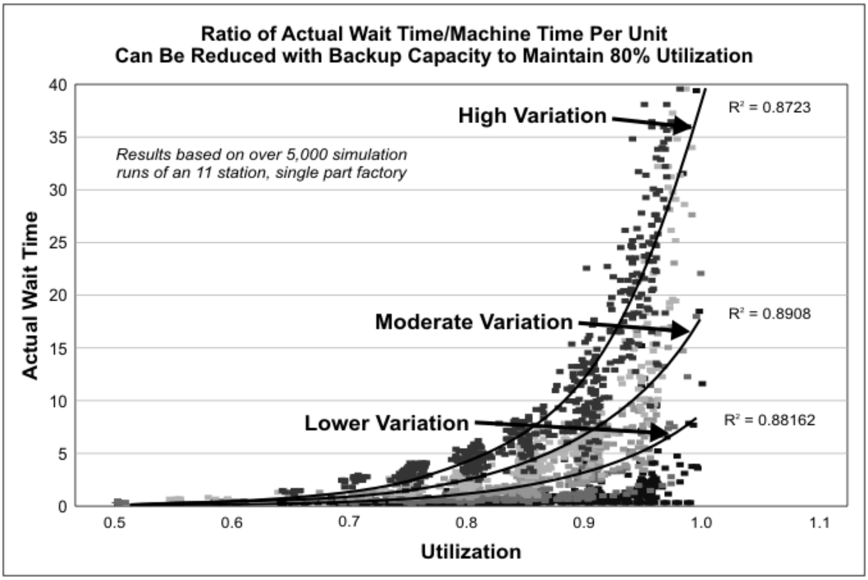
(This is sometimes called the Kanban system after the Japanese word for card; in Japan, WIP was released only when a card showed that consumption had occurred.)

- **Setup Reduction**: The setup time is defined as the interval between the last good part of one run of part numbers and the first good part of the next part number. Chapter 12 shows how to use Setup Reduction techniques to reduce setup time by 80% with little if any increased capital expenditures.
- **Total Productive Maintenance**: Data from scores of factories shows that machines are typically producing product only 60% of the time. About 20% of the downtime is scheduled for lunch, breaks, and maintenance. The other 20% is unscheduled, and is due to machine breakdown, setup time, parts shortages, absenteeism, etc. Total Productive Maintenance can virtually eliminate the unscheduled portion of downtime, and management initiatives can attack scheduled downtime. When a machine is running at near capacity, variation in the arrival of parts or machine processing times (similar to the hotel check-in example) can increase queue times by 10 to 20 times.

Just look at the Figure 3-11. As the variation in demand increases, the actual wait time as a multiple of value-add-time dramatically increases (notices the “high variation” curve is much taller than the other curves). In the hotel example, the process was running about 75% utilization with moderate variation, and a 5 minute service time became an 11- to 13-minute wait for some guests. By providing some backup capacity they reduced the comparable wait time to 7 minutes.

In consumer product demand, we often see high variation and workstations operating at 90% utilization. Look at Figure 3-11. An activity that is at 90% of utilization of capacity and has high variation of arrivals or service times will introduce a delay time that is 15 times the actual service time. While hotel guests complain and get results, WIP just sits their silently soaking up costs. By increasing the uptime of any workstation (machine, clerk, etc.) by 20%, we can effectively run the workstation at less than 80% utilization of capacity. As Figure 3-11 shows, this eliminates most of the queue time caused by variation.

Figure 3-11: High Variation Contributes To Longer Wait Times



For those of you who like equations, the steep rise of the high variation curve can be predicted from the wait time equation:

$$\text{Wait Time} \approx \left[\frac{\text{Utilization \%}}{(1 - \text{Utilization \%})}\right] \times [\text{Variation in Supply or Demand}]$$

As utilization approaches 100%, the first term on the right gets very large. Any variation in supply or demand can drive the wait time goes to infinity

The Hollywood Freeway

A lot of Lean was developed in manufacturing principally because the data existed to examine process performance, and a lot of clever people had the power to change things. In the service industry, the data often doesn't exist and people don't understand what is causing delays. Have you ever been driving at 70 miles an hour on a freeway, and suddenly had to come to a complete stop? When you finally get moving, you expect to see a wreck up ahead, but often you see nothing at all! It is just a matter of the freeway operating so close to capacity that any fluctuation will drive the wait time up the curve in Fig 3-10 to infinity (i.e., a complete stop). But on the Freeway, there isn't much data for the user, and not much he or she can do about it. Lean Six Sigma gives you the tools to attack delay time in any application.

The Lean Enterprise

It's difficult to overstate the opportunities represented by the slow processes found in nearly every organization. The problem that most firms have is in implementation. They perform training, conduct some isolated improvement efforts, but in the end make little measurable impact on overall lead time or cost (as we saw in the Preface).

Lean Six Sigma provides an unambiguous road map to implementation by prioritizing Time Traps and applying improvement methods in that order. Eliminating the causes of wasted time allows a process to improve cost, quality and responsiveness, characteristics that are critical to customers and shareholders. In most organizations, this can contribute 5% of revenue to operating margins. The speed and responsiveness of Lean can allow a company to increase revenue growth beyond its slower competitors. Finally, Lean methods apply to virtually all processes, from product development to order fulfillment. The increasing process speeds of Lean also enhance the power of Six Sigma tools such as Design of Experiment. But Lean alone, just like Six Sigma alone, isn't the complete answer. The next chapter will show how to bring Lean and Six Sigma together to create a powerful engine for value creation.

Epilogue on Ford

I began this chapter with a few quotations from Henry Ford. It may seem that this chapter is a complete refutation of his methods. But Lean "seeks not to destroy the Word, but to fulfill it." Ford certainly stood higher and saw further than anyone else in 1908, and I have often wondered why he, or his fabled team, failed to create Lean. I suspect the culprit was hubris: he had a difficult time abandoning his fabulous creation to the changing realities of the market. Nevertheless, we must remember that when the President of Ford visited Toyota in 1982 and asked how they had developed their system, his Japanese hosts graciously replied: "We learned it at the River Rouge complex [a Ford plant].” While the Japanese are too modest in acknowledging their own contributions, there is no doubt that Ford pointed the way to the Promised Land, even though he could never enter it.

Key Lean Concepts

- Lean means speed; it applies to *all* processes
- Slow processes are expensive processes
- The Lean metric is Process Cycle Efficiency
- Batch Sizes must be calculated using Flow variables (Appendix 1)
- 95% of the lead times in most processes is *wait* time
- To improve speed, you need to identify and eliminate the biggest Time Traps which is possible using the **Three Laws of Lean Six Sigma for Supply Chain Acceleration:**
    1. Workstation Turnover Time=Batch $Size_{Min}$/Customer Demand Rate
    2. 80% of process delay is caused by 20% of the activities
    3. Process velocity is inversely proportional to the number of “things in process”

To Learn More

- Chapter 4 will show how Lean and Six Sigma blend together to create a powerful engine for improvement.
- Specific Lean methods and tools are described in Part II.

End Notes

1. The actual calculation only counts value-add down the longest router, and subtracts process delays from heat treat, burn in etc., from both numerator and denominator.

Chapter 4

Creating Competitive Advantage with Lean Six Sigma

Lean Six Sigma offers the CEO the means of creating and sustaining a significant competitive advantage. The Value Proposition discussed in Chapter 1 is compelling: actual experience has shown that companies using *both* Lean and Six Sigma methods can reduce lead times by up to 80%, reduce manufacturing overhead and quality costs by 20%, and improve delivery times to above 99%. Applying Lean to the Product Development process can reduce Time-To-Market by 50% and enable the reduction of material cost by 5-10%. The creation of the competitive advantage comes from developing a superior and sustained vehicle for transforming the CEO's strategy from vision to project execution and creating new operational capabilities that can expand the range of strategic choices.

The prime question is thus "how can we bring Lean and Six Sigma together into an effective strategy for creating shareholder value?"

Thanks to the work of many companies, the road map is fairly clear. Implementation of Lean Six Sigma revolves around four major phases, each of which will be discussed in greater detail in Part II of this book. Here is a quick overview:

1. **Initiation** – Getting off to the critical good start. This involves…
    a. Obtaining CEO engagement, developing financial and performance goals for the 2 – 5 year horizon and gaining P&L manager commitment
    b. Creating the future vision and organizational infrastructure
    c. Training top leadership in Lean Six Sigma first

2. Select projects and resources

a. Select potential future leaders as Champions and Black Belts

b. Create an NPV mindset in Champions towards project selection

c. Train Black Belts in both team leadership and Lean Six Sigma tools

3. Implementing, Sustaining, Evolving

a. Providing expert coaching on initial projects

b. Track projects through the DMAIC process to final results

c. Building Lean Six Sigma into everything the company does and building the capability for Lean Six Sigma to remain an ongoing focus of the company

This process wraps the best of Lean (value-based project selection, cycle time efficiency) around a Six Sigma infrastructure and sets the roadmap for the long-term which overcomes hesitation and creates a sense of initiative in the organization. But the most important element is something that neither method can promise: **executive support and engagement**. Fortunately, getting executives involved in implementation is relatively easy since the Lean Six Sigma tool set includes ways for linking potential projects to **shareholder value creation.**

The Need for Executive Engagement

Lean Six Sigma has the potential to rapidly increase intrinsic value in less than a year. But this implicitly assumes that the criteria for success, defined by the Six Sigma *culture*, have been achieved:

- CEO and senior management engagement
- Commitment of 1 to 3% of personnel full time to improvement projects
- Infrastructure to prioritize, approve and track projects versus plan
- Focus on return on investment of Lean Six Sigma

Failure is just the reverse…

- CEO and top management not engaged
- Commitment of part time resources, or significantly less than 1% of personnel full time
- Black Belts are turned loose with no coaching or project prioritization
- No infrastructure for project management or tracking vs. plan
- Focus on cost of program, not returns or ROIC

Securing CEO/Executive Commitment

Many people have looked for a holy grail of increasing share value, and attributed it to leadership character, management vision, etc. Certainly the careers of Watson (IBM), Haggerty (TI), Noyce (Intel), and Welch (GE), as well as Carnegie, Ford and Sloan all confirm the importance of these leadership attributes.

A few years ago, however, a comparative study was made of 18 "visionary" companies that were considered far superior to "non-visionary" companies in the same industry. In examining this comparison, we were struck by an interesting insight: to the extent that public information was available, superior performance was even better correlated to those firms who pursued a process of *management-led continuous improvement* than to those with visionary leadership. Some non-visionary companies actually outperformed their visionary counterparts when they focused on continuous improvement (known by various names—Operational Excellence at Colgate-Palmolive; Workout and then Six Sigma at GE; Value Based Six Sigma at ITT Industries). In each case, *top management was engaged,* and had committed substantial resources to continuous improvement.

When a CEO shows passion and support, *I have never seen Lean Six Sigma fail*. If however, the CEO does not show this passion, *I have never seen it succeed*. If he or she leaves the initiative up to the divisions to decide to use Lean Six Sigma, it will generally fail to produce breakthrough results. If he or she fails to enforce the commitment of full time Champion and Black Belt resources, it will fail.

The CEO's engagement is necessary for another reason: to make sure the benefits of Lean Six Sigma impact the *whole* business. Isolated pockets of excellence cannot improve shareholder value, and this is best illustrated by an example:

We were once engaged to improve a factory that produced industrial hand tools. The company had a complicated product line of high volume, low volume and ultra low volume spare parts. The products were shipped to a warehouse a hundred miles away, and from that point sent to independent distributors upon demand.

The factory made a lot of progress in reducing quality defects, lead-time and inventory within the plant. For example, lead times of 80% of the high volume products had been reduced from 4 months to less than 3 weeks. However, the production "schedule" was generated from annual plan budgets and field sales forecasts, not actual consumption by dealers, let alone ultimate customers. As much as 40% of production was not related to immediate consumption, but was used to fill the warehouse to meet a forecast. (This external scheduling process was really a historical response to a 4-month lead-time.) The result was that a chaotic demand in terms of total volume and by SKU prevented the plant from eliminating the Hidden Factory.

These problems can only be solved by Lean methods that reflect *real* consumption demand plus safety stock on the factory production schedule. This requires an engaged CEO or Group president who has the whole supply chain process within his purview, and who is leading the Lean Six Sigma initiative.

The problem, viewed from the shareholder's perspective is that ROIC (= Profit After Tax/Invested Capital) principally equates to value. The profit numerator is depressed by extra plant cost, the lower gross profit due to lost sales, and the costs of maintaining a large warehouse. The denominator is increased by the large inventory, the Plant Property and Equipment cost of the Warehouse and the Factory. The combination means that only a small fraction of potential shareholder value can be gained by "pockets of excellence" in just a portion of the supply chain.

This story has a happy ending. In the next implementation at that company, the entire billion-dollar construction equipment division was the client, and the Group President was very much engaged. We trained the President and his senior staff, obtained 25 full time resources who were given four weeks of Black Belt training, and provided a few months of initial coaching. Cycle Time Reduction enabled a WIP Turn Increase of 92% and Labor Productivity Increase of 50%.

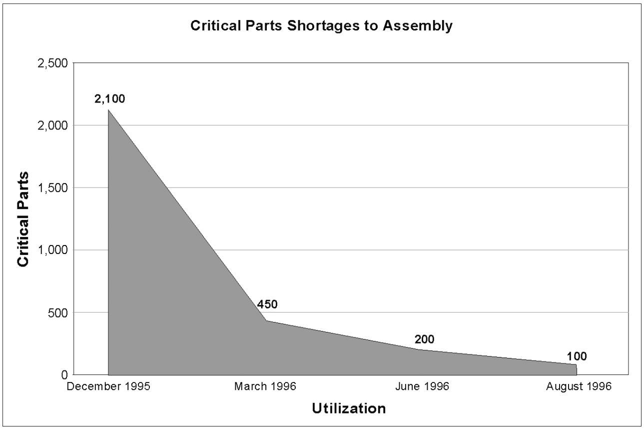
But of even greater importance was that the whole value stream was mapped, from supplier to end user, and true demand and dealer inventory was placed on the line. Let's look at the performance of one division (see Figure 4-1).

Just look at the impact of on-time delivery on sales growth: Adding $21 million dollars to a plant whose revenue had been $140 million would not have been accomplished without the President's engagement through the whole value stream. The ROIC was nearly doubled when the incremental operating profit was added to the $7 million in labor productivity, and the invested capital reduced by the inventory reduction. This occurred in a highly custom, low-volume business, far different from the highly repetitive high volume Tier One auto supplier. This is just the first testimony to the universality of Lean Six Sigma as a process improvement tool.

After working on the initial projects, the 25 trained Black Belts fanned out across the corporation and were permanently assigned to continuous improvement projects. They were also actively involved in operational due diligence for acquisitions. Remember, these two examples happened in the same company, under the same CEO. The difference is that learning had taken place, and the need to address quality and lead time issues across the whole value chain became manifestly evident.

Figure 4-1: Results from a Division of Example Company

Operational Improvements Improved Availability and Reliability to Enhance Sales



Before

- Lost 160 machine sales (~ $8M) due to lack of availability from January to June 1995
- Had 424 machine orders cancelled (~ $21M) from January to August 1995

After

- Lost 0 machine sales due to lack of availability from January to August 1996

Estimated Impact

- Revenue—424 units @ $50,000 = $21,200,000
- Operating income—$21,200,000 % 29% = $6,148,000

Record Divisional Performance in 1996 and 1997!

Realized Performance on Key Operating Measures

Initiative	Improvement ($000s)	
	Labor Productivity	Inventory Reduction
Product A	$5,468	($560)
Product B	$2,058	$3,530
Total	$7,526	$2,970
Improvement	275%	35%

"Within a 6-month period, we had 20% more sales, and we were using 30% less inventory and 15% less receivables."

– Group President

The Role of the CEO

The best way for me to describe the critical role of the CEO is to discuss what I have observed to be highly successful. I will give you a couple examples of what works in the words of several CEOs:

(A) Glen Barton, CEO of Caterpillar

> *"I'm delighted to be able to kick off your 6 Sigma Champions meeting today. I'm sure you share my passion for quality or you would not have been given these important jobs. To help set the level for today's meeting, I want to make sure this is very clear -- 6 Sigma is the enabler for our new corporate strategy. Just like we reinvented the company in the early '90s, we're going to do it again. It's a new world order for value creation, one that rewards growth and is very fickle. We've been punished in the capital markets recently, and 6 Sigma is the vehicle to provide the returns that we deserve. I'm counting on you to help deliver that.*
>
> *It's your job to launch this initiative with clarity, consistency, and commitment throughout the extended Caterpillar enterprise, as this impacts everyone — each and every continent, each and every employee, each and every supplier, and each and every dealer throughout the entire value chain. Everyone will be deeply impacted by this new way of working, an undertaking that will transform all that we do to achieve our quality and cost-reduction goals and help us deliver the $30 billion company we have promised by 2006.*
>
> *So be clear. Yes, 6 Sigma is a continuous improvement strategy and discipline that provides specific methods to recreate our business processes so that defects never appear in the first place. But even more important than that, it is a cultural change to enable all of us to achieve the highest quality products and services for our customers, investors and employees.*
>
> *And be consistent. You're dispersed in many different business units with different languages and cultures. For 6 Sigma you must operate as a team to ensure we get the global cultural change required. You must work together as a team with the same voice, the same methodology and the same metrics. We have the 6 Sigma recipe. You adapt that recipe to the local taste of your business unit. We work together or fail apart.*

And finally, you must be committed. Quality is my passion. I'm leading 6 Sigma, and I fully expect you to energize this organization to breakthrough performance levels. Some companies have failed at 6 Sigma, but when they have failed, it's not because of the process. The process is proven. They failed for lack of will. I can assure you that will not happen at Caterpillar. I am committed. I have placed myself as the owner of the 6 Sigma critical success factor and have listed it as corporate critical success factor number one. I fully expect your undying enthusiasm and commitment. Together, we'll achieve our bold goals. So listen intently to the messages you'll hear from Dave Burritt (the Corporate Deployment Champion) today and get organized for the formal launch in January.

Good luck, and thanks in advance for the leadership you will provide the enterprise. We're counting on you to pave the 6 Sigma path."

B. Lou Giuliano, Chairman, President and Chief Executive, ITT Industries

"Value-based Six Sigma is a subject that has become near and dear to my heart. The continuous improvement process is something that I've been involved in for a good number of years, something I believe in deeply, something that I have seen work. I know that it works. I know that it makes a difference in the organizations, and I know that it will continue to make a difference in our performance. ... Our best bet to create shareholder value was to become a premier multi-industry company.

One of the things we had noticed in our analysis was that while some people get a conglomerate discount, there are others like GE who get a conglomerate premium. And guess what? It all depends on performance, and if we could get our performance up significantly from where it was back then, we felt we'd be able to earn those types of premiums as well. So that's become our strategy. We've been making acquisitions. We went out and told the world that this is what we wanted to do. We set what we considered to be significant, aggressive targets for ourselves.

The first thing that had to be done was to convince the management team that even though they were doing well in their industries and some of these businesses were doing better than others on a comparative basis, when you measured them to the multi-industry, premier peers — the GE's, the Tyco's, the Danaher's, the ITW's— we were a mediocre performer, even at 10 percent. That just wasn't going to get us where we wanted to go. Even though we had set high targets, we also recognized that those were just interim targets. We had to do a lot better.

That's how we started what eventually became for us Value Based Six Sigma, or VBSS. Based upon my experience, I knew that the continuous improvement process would be important. It was the best way I knew of to change the way we did business. We were doing a lot of it in different parts of the company. We left it up to each company manager, each company president, to figure out how much effort and energy they put into this. There were a lot of different things being done, a lot of good work being done, but the results were spotty. They weren't getting us moving at the rate that we needed to move to reach our targets. So we decided that something else needed to be done, and I brought everybody together and asked how are we going to do this? Should we have a corporate-wide program? Do we know enough to do it ourselves? We've got a lot of people who have experience in problem solving methodologies and quality tools. Should I leave it up to each management company, to go out and figure out what to do? I knew if that happened everybody would pick some different solution that they liked. We went around and got everybody involved, and we said let's go find out what's going on outside.

We wanted to be able to track what we were going to do, and that winds up in the software support tools. We wanted to have Six Sigma tools. That was clear. That was a capability that would supplement the tools of quality that we'd been using around the corporation. Here again, based on our experience over the years, you can clean up a lot of processes, but what really makes change in a factory are some of the Lean tools — putting in a pull system, reducing batch sizes, significantly changing setup times. All of a sudden everything starts to flow. Those are the types of things that we saw over time that really made a difference in our factories, and so we said that has to be a part of this training. That's where the Lean manufacturing comes in.

> *We've got a lot of people out there working hard at it. We're looking at saving roughly $400 million in operating income over four years. For us, that's a significant number. It's something that will make a difference to the corporation. It'll make a difference in our stock price. That's based upon a rather rough algorithm that I put together that takes a conservative look at what I think we can do with our black belts. That's where we want to go."*

These are just two examples of many that share a common theme: the CEO makes it clear that she/he links the corporate strategy to the continuous improvement initiative, on which she/he is betting success. He or she is providing the resources and infrastructure, and the personal leadership of the process. This communication kick off is supplemented with articles in the company newspapers, the Annual Report, "town meetings," and sometimes discussions with analysts. Everybody in the corporation knows that "this is it," and everyone had better get on board and support it.

The subsequent engagement of the CEO also takes the form of actively building Lean Six Sigma into the everyday management of the company by leading an Executive Overview class (typically 1-2 days), and conducting review sessions with the Corporate Deployment Champion and his/her P&L managers so they know that their support via resources and engagement is being monitored. In some companies, this has taken the form of reporting an organization's or unit's performance in terms of a Traffic Light metric (Green/Yellow/Red). A "Red Light" is given to any part of the business that has not provided the required number of Black Belt and Champion resources. "Nobody likes to have a review with the Chairman and have a red light by their name," says Dave Burritt of Caterpillar.

CEO's are busy people, but Lou Giuliano made it a point to visit the kickoff of nearly every Black Belt and Champion training class around the World. He visited China and commented on their Design of Experiment projects. He lives the process and is passionate about the process because it is congruent with his goals.

Part II of this book will go into much more detail about CEO/executive involvement in designing and launching a Lean Six Sigma initiative. The major milestone event in getting the P&L managers on board with Lean Six Sigma is a one- to two day meeting referred to as "The

Transforming Event." At these events, the CEOs are carefully listened to by all. They should deliver presentations that show that Lean Six Sigma is integral to meeting their business plan objectives. Through this two-day session, the top executives of the company learn what Lean Six Sigma is and how it meshes with the other initiatives to support execution of the CEO's agenda. The inclusiveness of the Transformation Event has proven to be a critical lever in obtaining the managers' commitment—not just compliance—in assigning the top 1% of their resources as Black Belts and Champions.

Clearly a CEO who is unacquainted with Lean Six Sigma will be wary of making such a commitment of his or her executive resources. Like any marriage, this step should not be taken for light or transient causes. One of the goals of this executive overview is to provide adequate depth in 100 pages such that a rational CEO could judge whether this initiative is worthy of further study in the full knowledge of the magnitude of his, and his team's, personal engagement.

Winston Churchill once wrote that people who wish to initiate great projects are very ill advised to do so without the commitment of their Chief. He was referring to his efforts as First Lord of the Admiralty to force the Straits of Gallipolli in World War I. His Prime Minister was a very hands-off manager, and was too weak to order the Army to coordinate his attack with the initial Naval barrage. The Army finally did attack six months after the Naval bombardment. During the interval, the Turks had been prepared by their German allies, and a slaughter ensued. Churchill was blamed, losing his great office in 1916, and apparently ending his career forever.

I ask you to remember that "politics is the science of the possible," and that a campaign of first enlisting the CEO is far better than launching an effort without his or her engagement. Part II of this book is titled Implementation, and includes an entire chapter describing preparation for the Transforming event and another for creating the infrastructure for change. This may seem an inordinate amount of detail, but I assure you that it is *the pre-requisite* for shareholder value creation, and the difference between success and failure.

Value Stream Selection a lá Warren Buffett

The element of Lean Six Sigma that resonates most with executives is selecting the Value Streams that will be targeted for improvement, because that's the juncture **where the CEO's strategic goals are linked to frontline implementation**. Here is Lou Giuliano's linkage:

> *"We think about value-based management as a strategy made up of a series of processes and principles, that creating shareholder value is the number one, overall arching goal for the organization. We want to measure ourselves based upon value creation. We use Economic Value Add (ROIC% less the WACC%) as one of our primary measures."*

As we have discussed earlier, this linkage between economic value and project selection was missed in most TQM implementations. In contrast, Lean Six Sigma begins and ends with a simple proposition: Improving Value Streams that have a high Return on Invested Capital (ROIC) creates value; picking areas with low ROIC destroys value.

The majority of Champions, Black Belts, and Quality Professionals do not have an MBA degree, and even those who do often do not connect their learning with project selection. Prioritizing based on shareholder value in particular is an area of their knowledge that cannot be left to chance.

We have found that we can drive home all the necessary concepts with just two graphs, as follows.

Graph 1: The Drivers of Shareholder Value

Project selection in Lean Six Sigma starts by identifying the *Value Streams with the highest potential increase in shareholder value per investment of resource*—that is, finding the sets of activities (value streams) that contribute directly to customer satisfaction, and are likely to have the biggest impact on revenues and/or costs.

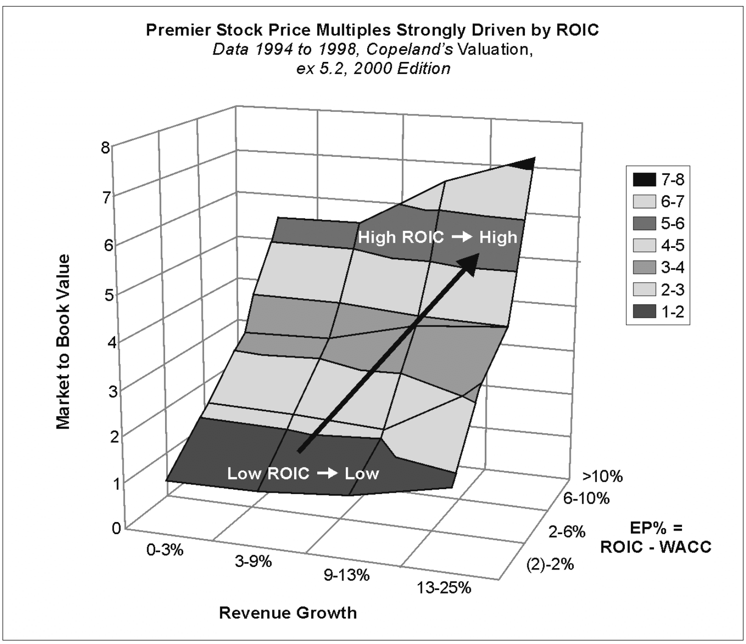
To identify these value streams, Lean Six Sigma has borrowed a method developed by investors such as Warren Buffett and Phil Fisher to selection of projects:

> *"Businesses logically are worth far more than net tangible assets when they can be expected to produce earnings on such assets considerably in excess of market rates of return."*
>
> Warren Buffett, Berkshire Hathaway 1992

Buffet applies this wisdom to selecting investments. Lean Six Sigma applies it to prioritizing the investment of people and capital resources in projects that will create the highest ROIC (Return on Invested Capital) and growth rates.

But can we really adapt Buffett's philosophy? Can we quantify potential gains in shareholder value based on ROIC and growth? Remember the stock price multiples chart from Chapter 1 (reproduced in Figure 4-2)? This chart was based on empirical stock market data gleaned from hundreds of financial reports.

Figure 4-2: Stock Price Multiples and ROIC



As you can see, companies whose Return On Invested Capital is much larger than their cost of capital ("market rates") trade at 5-7 times book value which confirms Buffett's thesis. Let's focus first on companies with no or little Revenue Growth (the left side of the chart). Such companies that just earn their cost of capital—Economic Profit (EP%) of about 0, at the lower left corner—trade at about book value. These companies can increase their market value to *5 times* that of their book value if ROIC exceeds cost of capital by 6% (upper left corner). And that's lesson #1: Even if you don't anticipate revenue growth, you can still substantially improve shareholder value if your Lean Six Sigma efforts increase ROIC.

Even greater potential lies in the upper RIGHT side of the chart—with companies that are increasing revenue. Growth is important because it allows profits to be re-invested at above "market rates of return." When revenue growth of more than 10% is combined with improvements in ROIC, shareholder value (Market to Book ratio) improves by a factor of 7!

What does this mean for Lean Six Sigma? You can answer this for yourself by determining where on this graph you'd want *your* company to be. The obvious answer is wherever Market to Book value is high—i.e., towards the back of the chart…and "back of the chart" translates to high ROIC compared to the cost of capital (Weighted Average Cost of Capital, or WACC%).

And there's the premise for all of Lean Six Sigma: We want to make sure that the sum of your improvement efforts drive your company's ROIC far above its cost of capital.

Though Revenue Growth, per se, is not often a direct goal of Lean Six Sigma, in many cases it results from the other improvements made. Look at the dark arrow on Figure 4-2: this shows the impact of Lean Six Sigma on the Tier 1 auto supplier we've discussed several times. They went into Lean Six Sigma hoping to just retain the business they already had. But once they achieved Six Sigma capability and achieved fast, reliable delivery of a wide range of products, they attracted additional market share (= revenue growth).

Net Present Value for Project Selection

While Figure 4-2 clearly makes the point that we need to select projects with high ROIC, its practical use is limited in terms of project selection—no one has a lot of empirical stock market data lying around that relates to their own Value Streams! It would be much simpler if we had a formula we could plug into an Excel spreadsheet that would allow us to evaluate the potential impact of ROIC improvement *in our specific value streams* on shareholder value. Again Buffett provides an insight:

"The value of any stock, bond, or business today is determined by the cash inflows and outflows-discounted at an appropriate interest rate- that can be expected to occur during the remaining life of the asset."

Berkshire Hathaway 1992

We want a formula which relates the Net Present Value of discounted cash flows to ROIC and Revenue Growth. Fortunately, there is such an equation, derived by Weston in his book[1]. For you math-philes, here it is:

$$Value = \frac{No(1-G/R)}{(1+W)} + \frac{No(1-G/R)(1+G)}{(1+W)^2} + \frac{No(1-G/R)(1+G)^2}{(1+W)^3} + \ldots = \sum_{n=1}^{N} \frac{No(1-G/R)(1+G)^{n-1}}{(1+W)^n}$$

where G = Growth rate%, R = ROIC%, W = Cost of Capital%

"Value" is what we call **Net Present Value (NPV)** in this book, and it substitutes for the "Market to Book ratio" shown in Fig 4-2.

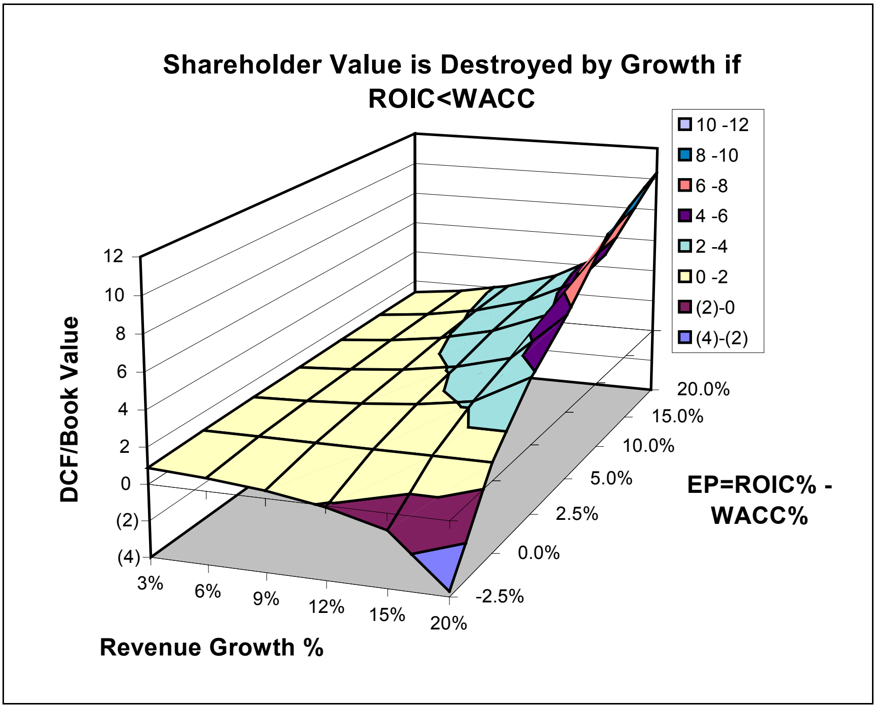
But wait! A project that has a high ROIC today may turn around tomorrow—and we don't want to invest in buggy whips that are going obsolete! So how do we identify value streams that will have a high ROIC *into the future*? Look again at the equation shown above. Because NPV is calculated based on the "discounted value of future cash flows," it captures both the present *and projected future* performance. (An implicit link here is that performance is determined by customers' reaction to the product or service—therefore NPV also embodies the Voice of the Customer.)

Graph 2: The Destruction of Shareholder Value

Another benefit of using graphs based on NPV is that they clearly disclose information about value *destruction* that is not evident from empirical stock market graphs.

This is a graph (Figure 4-3) of the value equation rotated to show areas of the graph where ROIC is low—notice the plunge in shareholder value (as reflected by NPV/Book). In fact, NPV is less than Book Value if the ROIC is less than the cost of capital, and the faster you grow, the more value you destroy! This makes logical sense: Shareholders would be much better off having their money invested at market rates rather than at lower rates of return inside a business.

Figure 4-3: Destruction of Shareholder Value



When ROIC is less than cost of capital, the NPV formula is telling you that the assets actually are worth less than book value. How can this be? When Buffett sold Berkshire Hathaway's spinning equipment, he provided us a graphic example:

> *"Some economists and academicians believe replacement values are of considerable importance in calculating stock price, and would have received an education… Good equipment, with a replacement cost of $30-50 Million had to be sold at auction for $168,000 because it had no earning power!*
>
> Warren Buffett, Berkshire Hathaway 1985

The lesson: It is critical to pick value streams and projects such that you can drive ROIC at least 5% above the cost of capital. If you pick a value stream (and projects) with low ROIC, you destroy shareholder value!

Taken together, we're back at the basic value proposition of Lean Six Sigma: picking projects and value streams which have the potential for the greatest increase in NPV creates the fastest rate of increase in shareholder value.

Seeing these charts often has a real impact on Champions, and causes them to "get it." We recommend the NPV approach because it allows us to apply analytical tools that are widely known and easy to teach. When Champions start using the language of Net Present Value, we know the company is headed for success. A clear linkage is established from the CEO's strategy all the way to the shop floor initiatives, with tracking and reporting on the process.

Competing with Lean Six Sigma

With every executive under the gun to improve profit sooner rather than later, Lean Six Sigma offers advantages that are critical in today's marketplace. The acceleration of cost reduction in particular, and process speed in general, allows a firm to respond to market conditions and opportunities faster than the competition. In the June 2001 issue of *Wired,* Andy Grove of Intel stated:

> *"The most direct way of increasing productivity is doing the same thing in a lesser period of time—turning things faster. And productivity is the key to everything—greater productivity increases economic growth."*

If every company suddenly made these cost improvements, competitive pressures would no doubt pass the savings on to the customers in terms of lower prices. Yet so far, it seems that comparatively few companies are in fact improving lead time, and we can infer that continuous improvement in general is very slow (see the survey results described in the Preface). Thus, the company that aggressively pursues Lean Six Sigma will have a sustainable advantage over the competition.

One of the most critical factors in Lean Six Sigma is creating a culture that incorporates *learning*, and provides a well-defined infrastructure for CEO engagement, training, coaching, results tracking and re-generation via internal training capabilities (i.e., Master Black Belts). Because of this infrastructure, Six Sigma has been able to deliver operating profit improvements of $250,000 to more than $1,000,000 per Black Belt.

Combining the capability for those kinds of achievements with the gains provided by Lean methods—including reduced costs and improved speed—provides the key link of an improvement methodology with the everyday business of the organization. The ability to equate *output value* to *input cost* makes it possible for a CEO to view Lean Six Sigma not as a quality cross to bear (as was true of TQM), but as a means of translating strategic goals for shareholder value creation into an implementable set of initiatives.

The payoffs of Lean Six Sigma have an interesting phasing. Projects that are primarily Lean (concerned with process velocity and efficiency) payoff very quickly in inventory and manufacturing cost reductions. Then Six Sigma projects that are working to improve quality (reduce defects) provide a mid-range addition, aided by the faster process cycle times achieved from the Lean efforts. Design for Lean Six Sigma efforts (which can require a year or more) have much larger payoffs as they impact the 50% of the product or service cost determined by design.

The present value of all these payoffs is strongly positive. Lean Six Sigma will convey competitive advantage and better shareholder returns at a faster rate than any other currently known process.

Is Lean Six Sigma the last word on continuous improvement? It's an old joke that each generation thinks it invented sex, and the same is probably true of improvement methods. Starting with Zero Defects in the 1960s, over a score of fads have come and gone, most of them making some advance on the predecessor. Six Sigma has performed better due to its cultural strength, and the addition of Lean speed gives it legs. To my knowledge no other continuous improvement process has ever encapsulated so much wisdom in such an effective and sustainable form.

As I mentioned on the Dedication page, I don't claim that Lean Six Sigma is the last word, I just say it is the best current practice to create shareholder value. Given the rapid state of advance it is best to remain humble about Lean Six Sigma, as the next generation will no doubt be even better equipped. I think it's appropriate here to include the full text of the quotation which appeared in the Dedication:

> *"Our days comprise the happiest period of the Eighteenth Century. Emperors, Kings and Princes step down from their feared heights and as friends of men scorn pomp and glitter*

and become fathers, friends and confidantes of their people. Religion tears off its ornament and stands forth in its divinity. Enlightenment advances in giant steps. Hatred born of dogma and the compulsion of conscience sink away; love of man and freedom of thought gain the upper hand. The arts and sciences blossom, and our vision into the workshop of nature goes deep. Artisans approach artists in perfection, useful skills flower at all levels. Here you have a faithful portrait of our time. ***Look not proudly down upon us if you stand higher or see farther than we, but rather recognize from this picture how, with courage and strength, we raised and supported your standard. Do the same for those who come after you and rejoice!"*** [2]

End Notes

1. *Takeovers, Restructuring, and Corporate Governance*, J. Fred Weston et al., p. 198.
2. Quoted in *Science and the Common Understanding* by J. Robert Oppenheimer

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