Chapter 1

Defining Lean Six Sigma

In This Chapter

- Turning up trumps for the Toyota Production System
- Finding out the fundamentals of 'lean' and 'six sigma'
- Applying Lean Six Sigma in your organisation

Throughout this book we cover the tools and techniques available to help you achieve real improvement in your organisation. In this chapter we aim to move you down a path of different thinking that gets your improvement taste buds tingling. We look at the main concepts behind lean thinking and six sigma and introduce some of the terminology to help you on your way.

Introducing Lean Thinking

Lean thinking focuses on enhancing value for the customer by improving and smoothing the process flow (see Chapter 11) and eliminating waste (covered in Chapter 9). Since Henry Ford's first production line, lean thinking has evolved through a number of sources, and over many years, but much of the development has been led by Toyota through the Toyota Production System (TPS). Toyota built on Ford's production ideas, moving from high volume, low variety, to high variety, low volume.

Lean is called 'lean' not because things are stripped to the bone. Lean isn't a recipe for your organisation to slash its costs, although it will likely lead to reduced costs and better value for the customer. We trace the concept of 'lean' back to 1987, when John Krafcik (now with Hyundai), was working as a researcher for MIT as part of the International Motor Vehicle

Program. Krafcik needed a label for the TPS phenomenon that described what the system did. On a white board he wrote the performance attributes of the Toyota system compared with traditional mass production. TPS:

- Needed less human effort to design products and services.
- Required less investment for a given amount of production capacity.
- Created products with fewer delivered defects.
- Used fewer suppliers.
- Went from concept to launch, order to delivery, and problem to repair in less time and with less human effort.
- Needed less inventory at every process step.
- Caused fewer employee injuries.

Krafcik commented:

> *It needs less of everything to create a given amount of value, so let's call it Lean.*

The lean enterprise was born.

Bringing on the basics of lean

Figure 1-1 shows the Toyota Production System, highlighting various tools and Japanese lean thinking terms that we use throughout this book. In this chapter we provide some brief descriptions to introduce the lean basics and the TPS.

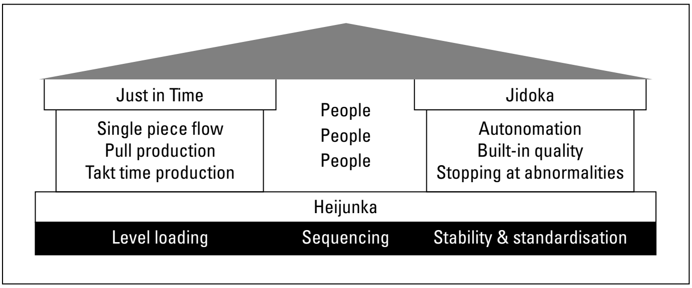


Figure 1-1: The TPS house.

Toyota's Taiichi Ohno describes the TPS approach very effectively:

> *All we are doing is looking at a timeline from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value-added wastes.*

Picking on people power

Figure 1-1 shows that people are at the heart of TPS. The system focuses on training to develop exceptional people and teams that follow the company's philosophy to gain exceptional results. Consider the following:

- ✓ Toyota creates a strong and stable culture where values and beliefs are widely shared and lived out over many years.
- ✓ Toyota works constantly to reinforce that culture.
- ✓ Toyota involves cross-functional teams to solve problems.
- ✓ Toyota keeps teaching individuals how to work together.

Being lean means involving people in the process, equipping them to be able, and feel able, to challenge and improve their processes and the way they work. Never waste the creative potential of people!

Looking at the lingo

You can see from Figure 1-1 that lean thinking involves a certain amount of jargon – some of it Japanese. This section defines the various terms to help you get lean thinking as soon as possible:

- ✓ **Heijunka** provides the foundation. It encompasses the idea of smoothing processing and production by considering levelling, sequencing, and standardising:
    - **Levelling** involves smoothing the volume of production in order to reduce variation, that is, the ups and downs and peaks and troughs that can make planning difficult. Amongst other things, levelling seeks to prevent 'end-of-period' peaks, where production is initially slow at the beginning of the

  month, but then quickens in the last days of the sales or accounting period, for example.

  - **Sequencing** may well involve mixing the types of work processed. So, for example, when setting up new loans in a bank, the type of loan being processed is mixed to better match customer demand, and help ensure applications are actioned in date order. So often, people are driven by internal efficiency targets, whereby they process the 'simple tasks' first to get them out of the way and 'hit their numbers', leaving the more difficult cases to be processed later on. This means tasks are not processed in date order, and a reluctance exists to get down and tackle a pile of difficult cases at the end of the week, making things even worse for the customer and the business.
  - **Standardising** is the third strand of Heijunka. It seeks to reduce variation in the way the work is carried out, highlighting the importance of 'standard work', of following a standard process and procedure. It links well to the concept of process management, where the process owner continuously seeks to find and consistently deploy best practice. Remember, however, that you need to standardise your processes before you can improve them. Once they're standardised, you can work on stabilising them, and now that you fully understand how the processes work, you can improve them, creating a 'one best way' of doing them.

    In the spirit of continuous improvement, of course, the 'one best way' of carrying out the process will keep changing, as the people in the process identify better ways of doing the work. You need to ensure the new 'one best way' is implemented and fully deployed.

- **Jidoka** concerns prevention; it links closely with techniques such as Failure Mode Effects Analysis (FMEA) covered in Chapter 10. Jidoka has two main elements, and both seek to prevent work continuing when something goes wrong:

  - **Autonomation** allows machines to operate autonomously, by shutting down if something goes wrong. This concept is also known as automation with human intelligence. The ‘no’ in auto*no*mation is often underlined to highlight the fact that no defects are allowed to pass to a follow-on process. An early example is from 1902, when Sakichi Toyoda, the founder of the Toyota group, invented an automated loom that stopped whenever a thread broke. A simple example today is a printer stopping processing copy when the ink runs out.

    Without this concept, automation has the potential to allow a large number of defects to be created very quickly, especially if processing is in batches (see ‘Single piece flow’ later in this section).

  - **Stop at every abnormality** is the second element of Jidoka. The employee can stop an automated or manual line if he or she spots an error. At Toyota every employee is empowered to ‘stop the line’, perhaps following the identification of a special cause on a control chart (see Chapter 7).

    Forcing everything to stop and immediately focus on a problem can seem painful at first, but doing so is an effective way to quickly get at the root cause of issues. Again, this can be especially important if you’re processing in batches.

- **Just in Time (JIT)** provides the other pillar of the TPS house. JIT involves providing the customer with what’s needed, at the right time and in the right quantity. The concept applies to both internal and external customers. JIT comprises three main elements:

  - **Single piece flow** means each person performs an operation and makes a quick quality check before moving their output to the next person in the following process. If a defect is detected, Jidoka is enacted; the process is stopped, and immediate action is taken to correct the situation, taking countermeasures to prevent reoccurrence. This concept is a real change of thinking that moves us away from processing in batches.

    Traditionally, large batches of individual cases are processed at each step and are passed along the process only after an entire batch has been completed. The delays are increased when the batches travel around the organisation, both in terms of the transport time, and the time they sit waiting in the internal mail system. At any given time, most of the cases in a batch are sitting idle, waiting to be processed. In manufacturing, this is seen as costly excess inventory. What's more, errors can neither be picked up, nor addressed quickly; if they occur, they often occur in volume. And, of course, this also delays identifying the root cause. With single piece flow, we can get to the root cause analysis faster, which helps prevent a common error recurring throughout the process.

- **Pull production** is the second element of JIT. Each process takes what it needs from the preceding process only when it needs it and in the exact quantity. The customer pulls the supply and helps avoid being swamped by items that aren't needed at a particular time.

  Pull production reduces the need for potentially costly storage space. All too often, overproduction in one process, perhaps to meet local efficiency targets, results in problems downstream. This increases work in progress, and creates bottlenecks. Overproduction is one of the 'seven wastes' identified by Ohno and covered in Chapter 9.

- **Takt time** is the third element of JIT, providing an important additional measure. It tells you how quickly to action things, given the volume of customer demand. Takt is German for a precise interval of time, such as a musical meter. It serves as the rhythm or beat of the process – the frequency at which a product or service must be completed in order to meet customer needs. It's a bit like the beat of the drum on the old Roman galleys.

Taking the strain out of constraints

Much of the focus in lean thinking is on understanding and improving the flow of processes and eliminating non-value-added activities. Eli Goldratt's *theory of constraints* (explained more fully in Chapter 11), provides a way to address and tackle bottlenecks that slow the process flow. Goldratt's theory proposes a five-step approach to help improve flow:

1. **Identify the constraint.** Data helps you identify the bottlenecks in your processes, of course, but you should be able to see them fairly easily, too. Look for backlogs and a build-up of work in progress, or take note of where people are waiting for work to come through to them. These are pretty good clues that demand is exceeding capability and you have a bottleneck.
2. **Exploit the constraint.** Look for ways to maximise the processing capability at this point in the process flow. For example, you may minimise downtime for machine maintenance by scheduling maintenance outside of normal hours.
3. **Subordinate the other steps to the constraint.** You need to understand just what the bottleneck is capable of – how much it can produce, and how quickly it can do it. Whatever the answer is, in effect, that's the pace at which the whole process is working. The downstream processes know what to expect and when, and having upstream processes working faster is pointless; their output simply builds up as a backlog at the bottleneck. So, use the bottleneck to dictate the pace at which the upstream activities operate, and to signal to the downstream activities what to expect, even if that means these various activities are not working at capacity.
4. **Elevate the constraint.** Introduce improvements that remove this particular bottleneck, possibly by using a DMAIC (Define, Measure, Analyse, Improve and Control) project (we delve into DMAIC in Chapter 2).
5. **Go back to Step 1 and repeat the process.** After you complete Steps 1–4, a new constraint will exist somewhere else in the process flow, so start the improvement process again.

Considering the customer

The customer, not the organisation, specifies value. Value is what your customer is willing to pay for. To satisfy your customer, your organisation has to provide the right products and services, at the right time, at the right price, and at the right quality. To do this, and to do so consistently, you need to identify and understand how your processes work, improve and smooth the flow, eliminate unnecessary steps in the process, and reduce or prevent waste such as rework.

Imagine the processes involved in your own organisation, beginning with a customer order (market demand) and ending with cash in the bank (invoice or bill paid). Ask yourself the following questions:

- How many steps are involved?
- Do you need all the steps?
- Are you sure?
- How can you reduce the number of steps and the time involved from start to finish?

Perusing the principles of lean thinking

KEY CONCEPT

Lean thinking has five key principles:

- Understand the customer and their perception of value.
- Identify and understand the value stream for each process and the waste within it.
- Enable the value to flow.
- Let the customer pull the value through the processes, according to their needs.
- Continuously pursue perfection (continuous improvement).

We've covered these briefly in the preceding pages, but look at them again in more detail in Chapter 2, when we see how they combine with the key principles of six sigma to form *Lean Six Sigma*.

Sussing Six Sigma

Six sigma is a systematic and robust approach to improvement, which focuses on the customer and other key stakeholders. Six sigma calls for a change of thinking. When Jack Welch, former General Electric CEO, introduced six sigma, he said:

> *We are going to shift the paradigm from fixing products to fixing and developing processes, so they produce nothing but perfection or close to it.*

In the 1980s Motorola CEO Bob Galvin struggled to compete with foreign manufacturers. Motorola set a goal of tenfold improvement in five years, with a plan focused on global competitiveness, participative management, quality improvement, and training. Quality engineer Bill Smith coined the name of the improvement measurements: six sigma. All Motorola employees underwent training, and six sigma became the standard for all Motorola business processes.

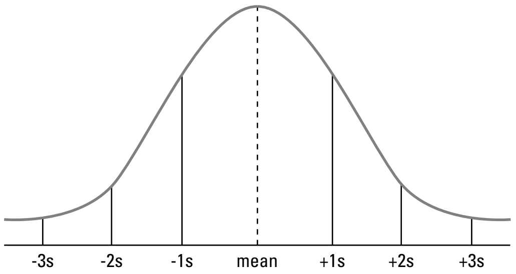
Considering the core of six sigma

A sigma, or standard deviation, is a measure of variation that reveals the average difference between any one item and the overall average of a larger population of items. Sigma is represented by the lower-case Greek letter s.

Introducing a simple example

Suppose you want to estimate the height of people in your organisation. Measuring everyone isn't practical, so you take a representative sample of 30 people's heights. You work out the mean average height for the group – as an example, let's say this is 5 foot, 7 inches. You then calculate the difference between each person's height and the mean average height. One sigma, or standard deviation, is the average of those differences. The smaller the number, the less variation there is in the population of things you are measuring. Conversely, the larger the number, the more variation. In our example, imagine the standard deviation is one inch, though it might be any number in theory.

Figure 1-2 shows the likely percentage of the population within plus one and minus one standard deviation from the mean, plus two and minus two standard deviations from the mean, and so on. You can see how your information provides a good picture of the heights of all the people in your organisation. You find that approximately two-thirds of them are between 5 foot 6 inches and 5 foot 8 inches tall, about 95 per cent are in the range 5 foot 5 inches to 5 foot 9 inches, and about 99.73 per cent are between 5 foot 4 inches and 5 foot 10 inches.



Sigma	Percentage
Plus and minus 1	68.26
Plus and minus 2	95.46
Plus and minus 3	99.73
Plus and minus 4	99.9937
Plus and minus 5	99.999943
Plus and minus 6	99.999998

Figure 1-2: Standard deviation.

In reality, the calculation is a little more involved and uses a rather forbidding formula – as shown in Figure 1-3.

Looking at a sample

$$\sqrt{\frac{\Sigma(X_i - \overline{X})^2}{n-1}}$$

Looking at the whole population

$$\sqrt{\frac{\Sigma(X_i - \overline{X})^2}{n}}$$

Figure 1-3: Standard deviation formula.

Using n – 1 makes an allowance for the fact that we're looking at a sample and not the whole population. In practice though, when the sample size is over 30, there's little difference between using n or n – 1.

The sigma values are calculated by looking at our performance against the customer requirements – see the next section.

Practising process sigma in the workplace

In the real world you probably don't measure the height of your colleagues. Imagine instead that in your organisation you issue products to customers. You take a representative sample of fulfilled orders and measure the *cycle time* for each order – the time taken from receiving the order to issuing the product (in some organisations this is referred to as *lead time*). Figure 1-4 shows the cycle times for your company's orders.

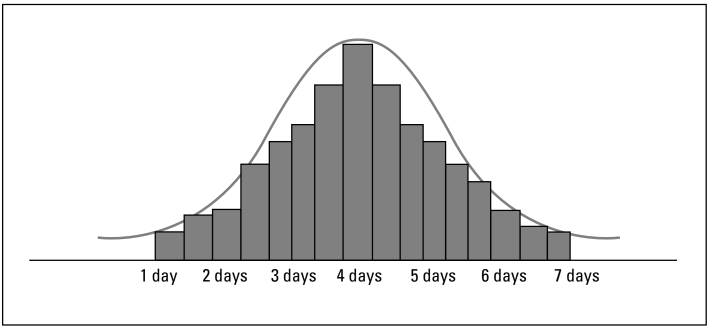


Figure 1-4: Histogram showing the time taken to process orders.

You can see the range of your company's performance. The cycle time varies from as short as one day to as long as seven days.

But the customer expects delivery in five days or less. In Lean Six Sigma speak, a customer requirement is called a CTQ – Critical To Quality. CTQs are referred to in Chapter 2 and described in more detail in Chapter 4, but essentially they express the customers' requirements in a way that is measurable. CTQs are a vital element in Lean Six Sigma and provide the basis of your process measurement set. In our example, the CTQ is five days or less, but the average performance in Figure 1-4 is four days. Remember that this is the average; your customers experience the *whole range* of your performance.

Too many organisations use averages as a convenient way of making their performance sound better than it really is.

In the example provided in Figure 1-4, all the orders that take more than five days are *defects* according to six sigma. Orders that take five days or less meet the CTQ. We show this situation in Figure 1-5. We could express the performance as the percentage of orders processed within five days or we can work out the *process sigma value*. The sigma value is calculated by looking at your performance against the customer requirement, the CTQ, and taking into account the number of ‘defects’ involved where you fail to meet it (that is, all those cases that took more than five days).

We explain the process sigma calculation in the next section.

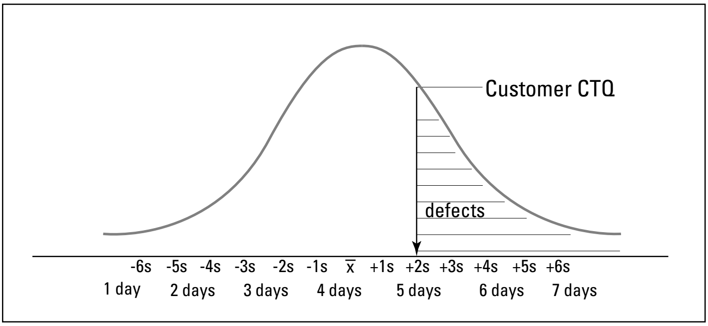


Figure 1-5: Highlighting defects.

Calculating process sigma values

Process sigma values provide a way of comparing performances of different processes, which can help you to prioritise projects. The process sigma value represents the population of cases that meet the CTQs right first time. Sigma values are often expressed as defects per million opportunities (DPMO), rather than per hundred or per thousand, to emphasise the need for world-class performance.

Not all organisations using six sigma calculate process sigma values. Some organisations just use the number of defects or the percentage of orders meeting CTQs to show their performance. Either way, if benchmarking is to be meaningful, the calculations must be made in a consistent manner.

Figure 1-6 includes ‘yield’ figures – the right first time percentage. You can see that six sigma performance equates to only 3.4 DPMO.

Yield	Sigma	Defects per 1,000,000	Defects per 100,000	Defects per 10,000	Defects per 1,000	Defects per 100
99.99966%	6.0	3.4	0.34	0.034	0.0034	0.00034
99.9995%	5.9	5	0.5	0.05	0.005	0.0005
99.9992%	5.8	8	0.8	0.08	0.008	0.0008
99.9990%	5.7	10	1	0.1	0.01	0.001
99.9980%	5.6	20	2	0.2	0.02	0.002
99.9970%	5.5	.30	3	0.3	0.03	0.003
99.9960%	5.4	40	4	0.4	0.04	0.004
99.9930%	5.3	70	7	0.7	0.07	0.007
99.9900%	5.2	100	10	1.0	0.1	0.01
99.9850%	5.1	150	15	1.5	0.15	0.015
99.9770%	5.0	230	23	2.3	0.23	0.023
99.670%	4.9	330	33	3.3	0.33	0.033
99.9520&	4.8	480	48	4.8	0.48	0.048
99.9320%	4.7	680	68	6.8	0.68	0.068
99.9040%	4.6	960	96	9.6	0.96	0.096
99.8650%	4.5	1,350	135	13.5	1.35	0.135
99.8140%	4.4	1,860	186	18.6	1.86	0.186
99.7450%	4.3	2,550	255	25.5	2.55	0.255
99.6540%	4.2	3,460	346	34.6	3.46	0.346
99.5340%	4.1	4,660	466	46.6	4.66	0.466
99.3790%	4.0	6,210	621	62.1	6.21	0.621
99.1810%	3.9	8,190	819	81.9	8.19	0.819
98.930%	3.8	10,700	1,070	107	10.7	1.07
98.610%	3.7	13.900	1.390	139	13.9	1.39
98.220%	3.6	17,800	1,780	178	17.8	1.78
97.730%	3.5	22.700	2,270	227	22.7	2.27
97.130%	3.4	28,700	2,870	287	28.7	2.87
96.410%	3.3	35,900	3,590	359	35.9	3.59
95.540%	3.2	44,600	4,460	446	44.6	4.46
94.520%	3.1	54,800	5,480	548	54.8	5.48
93.320%	3.0	66,800	6,680	668	66.8	6.68
91.920%	2.9	80,800	8,080	808	80.8	8.08
90.320%	2.8	96,800	9.680	968	96.8	9.68
88.50%	2.7	115,000	11,500	1,150	115	11.5
86.50%	2.6	135,000	13,500	1,350	135	13.5
84.20%	2.5	158,000	15,800	1,580	158	15.8
81.60%	2.4	184,000	18,400	1,840	184	18.4
78.80%	2.3	212,000	21,200	2,120	212	21.2
75.80%	2.2	242,000	24,200	2,420	242	24.2
72.60%	2.1	274,000	27,400	2,740	274	27.4
69.20%	2.0	308,000	30,800	3,080	308	30.8
65.60%	1.9	344,000	34,400	3,440	344	34.4
61.80%	1.8	382,000	38,200	3,820	382	38.2
58.00%	1.7	420,000	42,000	4,200	420	42
54.00%	1.6	460,000	46,000	4,600	460	46
50%	1.5	500,000	50,000	5,000	500	50
46%	1.4	540,000	54,000	5,400	540	54
43%	1.3	570,000	57,000	5,700	570	57
39%	1.2	610,000	61,000	6,100	610	61
35%	1.1	650,000	65,000	6,500	650	65
31%	1.0	690,000	69,000	6,900	690	69
28%	0.9	720,000	72,000	7,200	720	72
25%	0.8	750,000	75,000	7,500	750	75
22%	0.7	780,000	78,000	7,800	780	78
19%	0.6	810,000	81,000	8,100	810	81
16%	0.5	840,000	84,000	8,400	840	84
14%	0.4	860,000	86,000	8,600	860	86
12%	0.3	880,000	88,000	8,800	880	88
10%	0.2	900,000	90,000	9,000	900	90
8%	0.1	920,000	92,000	9,200	920	92

Figure 1-6: Abridged sigma conversion table.

Recognising that you're looking at 'first pass' performance is important. If you make an error but correct it before the order goes to the customer, you still count the defect because the rework activity costs you time and effort. And remember that you're looking at defects. Your customer may have several CTQs relating to an order – for example, speed and accuracy – thus there may be more than one defect in the transaction.

In calculating sigma values for your processes, you need to understand the following key terms:

- **Unit:** The item produced or processed.
- **Defect:** Any event that does not meet the specification of a CTQ.
- **Defect opportunity:** Any event that provides a chance of not meeting a customer CTQ. The number of defect opportunities will equal the number of CTQs.
- **Defective:** A unit with one or more defects.

In manufacturing processes you may find that the number of defect opportunities is determined differently, taking full account of all the different defects that can occur within a part. The key is to calculate the sigma values in a consistent way.

You can work out your sigma performance against the CTQs as shown in Figure 1-7. We have a sample of 500 processed units. The customer has three CTQs, so we have three defect opportunities. The CTQs are related to speed, accuracy, and completeness. We find 57 defects.

- Number of units processed: N=500
- Total number of defects made (include defects made and later fixed): D=57
- Number of defect opportunities per unit (equate to CTQs): O=3
- Calculate # defects per million opportunities

$$\text{DPMO} = 1{,}000{,}000 \times \frac{D}{(N \times O)}$$

$$= 1{,}000{,}000 \times \frac{57}{(500) \times (3)}$$

$$= 38000$$

- Look up process sigma in sigma conversation table (see Figure 1-6): Sigma = 3.3

Figure 1-7: Calculating process sigma values.

A difference exists between sigma and standard deviation (see the 'Introducing a simple example' section earlier in this chapter for how to work out standard deviations). This results from Motorola adjusting the tables to reflect the variation being experienced in their processes. This adjustment is referred to as a 1.5 sigma shift, reflecting the extent of the adjustment. Although this related to *their* processes, everyone adopting six sigma also adopted the adjusted sigma scale. Incidentally, without this adjustment, six sigma would equate to 0.002 DPMO as opposed to 3.4 DPMO – so, even harder to achieve.

When we talk about six sigma performance before the adjustment, we're talking about plus and minus six standard deviations, which embrace 99.999998 per cent of the data. And we are talking about the percentage of cases that are right first time in terms of meeting the requirements of the customer. Taking account of the adjustment, we're still looking at a truly demanding standard, with 99.999666 per cent of cases right first time.

Meeting the major points of six sigma

The five key principles of six sigma are:

- **Understand the CTQs of your customers and stakeholders.** To deliver the best customer experience, you need to know what your customer wants – their requirements and expectations. You need to listen to and understand the *voice of the customer* (VOC) – we talk about the customer's voice in Chapter 4.
- **Understand your organisation's processes and ensure they reflect your customers' CTQs.** You need to know how your processes work and what they're trying to achieve. There should be a clear objective for each process focused on the customer requirements, the CTQs.
- **Manage by fact and reduce variation.** Measurement and management by fact enables more effective decision making. By understanding variation, you can work out when and when not to take action.
- **Involve and equip the people in the process.** To be truly effective you need to equip the people in your organisation to be able, and to feel able, to challenge and improve their processes and the way they work.

- **Undertake improvement activity in a systematic way.** Working systematically helps you avoid jumping to conclusions and solutions. Six sigma uses a system called DMAIC (Define, Measure, Analyse, Improve and Control) to improve existing processes. We cover DMAIC in Chapter 2.

A natural synergy exists between lean and six sigma – your organisation needs both. Many people think of lean as focusing on improving the efficiency of processes, and six sigma as concentrating on their effectiveness. The reality is that both approaches tackle efficiency and effectiveness.