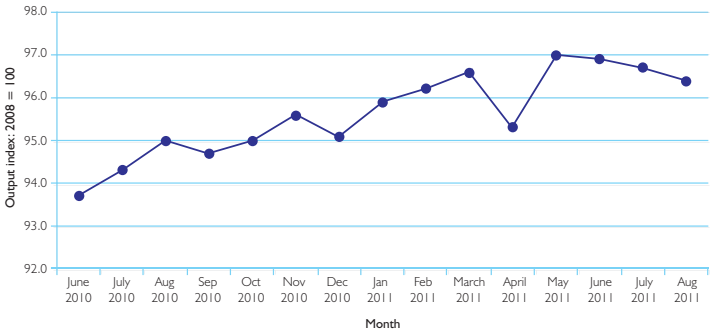
Understanding business performance data

'Our ability to produce rapid, sustained improvement is tied directly to our ability to understand and interpret variation.' *Brian Joiner, Fourth Generation Management*

'UK manufacturing output stalls' announced the *Financial Times* on 11th October 2011, as it went on to tell us that: 'Manufacturing production fell in August for the third month in a row and is now barely higher than it was a year ago.' Other reputable news outlets gave us similarly downbeat analyses. But is it all doom and gloom for the economy?

I went to the Office for National Statistics website and downloaded the data for output of manufacturing industry. The data is analysed in a number of different ways, but Table 1 shows an extract of the index of production for manufacturing industries. The average output index for this 15-month period is 95.6. I graphed the data to try and see if this helped me understand what was happening – see Figure 1.

We jump to knee-jerk reactions based on one or two data points or very limited analysis. Most of us are taught statistics in school and in later studies, but it is rarely in the context of business management.



Output of production industries

Figure 1. Source: Office for National Statistics

Although still well below the 2008 level of 100, the trend is clearly upwards, with a dip in the last three months that may cause some concern. Perhaps the picture is not as gloomy as the papers would have us believe, though I would certainly want to analyse the causes of last summer's trailing off of growth in more detail. Statistical analysis of the 2011 data alone suggests that the results for the last three months are within the range we would expect from random variation and, thus, monthly output is broadly average for the eight months to August. You can argue that this fits with the FT's description of stalled, but, overall, monthly average manufacturing output for the eight months of 2011 is notably better than the 2010 monthly average.

	Output of manufacturing industries	Index: 2008 = 100
2010	June	93.7
	July	94.3
	August	95.0
	September	94.7
	October	95.0
	November	95.6
	December	95.1
2011	January	95.9
	February	96.2
	March	96.6
	April	95.3
	May	97.0
	June	96.9
	July	96.7
	August	96.4

Extract of index of production for manufacturing industries

Table 1. Source: Office for National Statistics The full data set is on website: www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-233027

One of the biggest weaknesses in management, I feel, is the inability to understand data. We jump to knee-jerk reactions based on one or two data points or very limited analysis. Most of us are taught statistics in school and in later studies, but it is rarely in the context of business management. The problem is that we usually compare the data – the results of a business process – with some management target we have created without reference to the process; and we make a judgement of good or bad on the basis of that comparison. Managers are then castigated for bad performance or praised for good performance, which in turn leads to unproductive behaviour from managers who may try to massage or obscure the results, or dream up suitably complex – but feasible – reasons for their results. All of these behaviours damage our ability to see the issues and make improvements.

In fact, all data from a business process is bound to vary randomly in ways we cannot predict, and that undermines the simplistic comparisons and judgements that most managers seek to make. We need to be able to understand the *behaviour* of the process before we make judgements. As Donald Wheeler says in *Understanding Variation: The Key to Managing Chaos*: 'While every data set contains noise, some data may contain signals. Therefore, before you can detect a signal within any given data set, you must first filter out the noise.'

Comparing a small number of data items with some target or budget, or even with the same time last year tells us very little. The difference could just be random variation in the process. What we actually should do is review the data over time. By presenting our business data as time series we can begin to filter out the noise – random variation – and start to highlight the signals of change in the process.

Let us consider two of the performance indicators that a small UK manufacturing firm collects. This business, with about 35 employees, has one manufacturing process assembling electrical components to order. Among other things, it collects data on its delivery performance, and on the average number of days from order to delivery for its products – see Table 2.

We see that only twice in the 11 weeks have we met the delivery target set by management, and we have never met the lead-time target of three days from order to delivery. So, are management justified in being pretty cross with the people supervising and working on this line?

Here we need to apply some basic statistical analysis. We want to analyse the data as a time series and filter out the random variation in the process. The techniques for doing this are explained fully in the books listed in the references and in other books on business statistics. Essentially what we want to do is set the natural process limits for the business process. These limits represent the range of variation we would currently expect in the process.

Week number	25	26	27	28	29	30	31	32	33	34	35	Target
On-time delivery %	88.73	91.04	93.68	75.61	90.80	95.05	92.56	92.13	95.40	80.26	91.07	**95**
Days from order entry to delivery	6.3	5.5	7.2	7.2	7.9	5.4	3.8	3.2	3.2	3.5	4.0	**3.0**

Delivery performance data

Table 2

Let us first consider on-time delivery performance. Table 3 shows the weekly data and the absolute change between each data point.

The phrase 'natural process limits' is used by Donald Wheeler. Other writers use different terms, with 'upper and lower control limits' being a fairly common phrase. However, I have avoided this latter phrase as it is reminiscent of measures that use standard deviation. Calculations of standard deviation rely on the assumption that the data is normally distributed, and this does not necessarily apply in all cases in business processes. The calculation for natural process limits does not require the data to be normally distributed.

As Wheeler says: 'The natural process limits are the *voice of the process*. They define what the process will deliver as long as it continues to operate as consistently as possible.' That is to say, natural process limits set the upper and lower points that would be expected from the process through random – natural – variation. Anything outside these limits will be a signal of change in the process. Change in the process may also be signalled within the natural process limits in certain circumstances, which we will discuss shortly.

The upper natural process limit is defined as the mean average of the data points *plus 3.14 times the median absolute change between the points*. The lower natural process limit is defined as the mean average of the data points *minus 3.14 times the median absolute change between the points*.

The multiplier of 3.14 is derived from statistical theory and is outside the scope of this article. The median of the absolute change between the data points is used to avoid the influence of outliers – abnormal data points. Other methods of calculating the natural process limits are available, but I prefer this median method because using the median avoids the influence of extreme data points. It is important to note, however, that the method for calculating the process limits is not critical. There are minor differences between them, but the important issue is that the natural process limits give us a *frame* within which we can examine the picture that the data forms.

Let us graph the on-time delivery performance above – see Figure 2. The purple line represents the average, while the red lines set the upper and lower natural process limits. Since percentage performance cannot exceed 100%, the upper limit is set at 100%, rather than the level indicated in the calculation above.

This graph tells us that on-time delivery performance is stable around the average of just under 90%, apart from week 28, when there was clearly a change in the process that we should investigate further. Perhaps the most important point that emerges from this analysis is that the firm's current delivery process varies randomly around natural process limits between 78% and 100%. This is quite a wide range and nowhere near the target set by management of 95%. This means that, *with the current process*, there is no way that management can consistently achieve their on-time delivery target of 95%. The natural process limits simply show the limits of the current process's performance. If we are not happy with this range or it does not meet the customer's target, then we must improve the process. In short, it is no good castigating the supervisors and managers: it is the *process* that must change if the target is to be met.

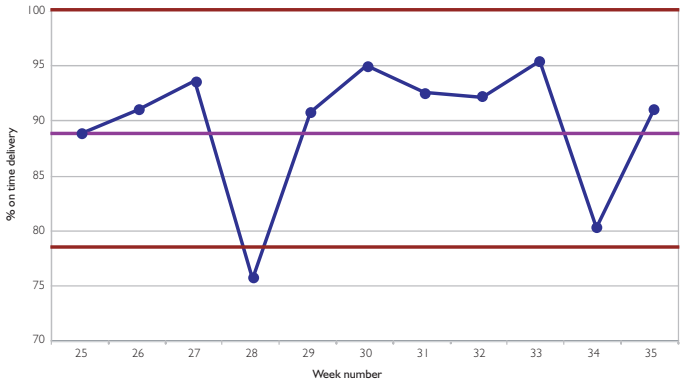
Week number	On-time delivery %	Absolute change
25	88.73	n/a
26	91.04	2.31
27	93.68	2.64
28	75.61	18.07
29	90.80	15.19
30	95.05	4.25
31	92.56	2.49
32	92.13	0.43
33	95.40	3.27
34	80.26	15.14
35	91.07	10.81
TARGET	**95.00**	
Average	89.67	
Median of absolute change		3.76
Upper natural process limit	101.47	
Lower natural process limit	77.86	

On-time delivery performance as a percentage of orders

Table 3

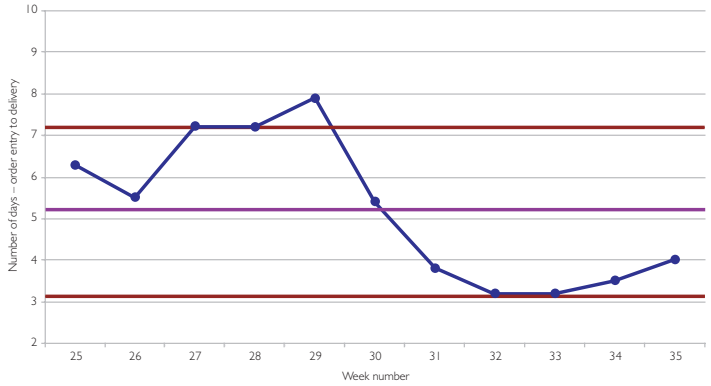
Let us continue our analysis with the same firm's performance in terms of average number of days from order to delivery for its products. Table 4 shows the weekly data and the absolute change between each data point.

The natural process limits are calculated in the same way as before to give us a process behaviour chart – see Figure 3. Here the average number of days between order entry and delivery



On-time delivery

Figure 2



Days between order entry and delivery

Figure 3

over the 11 weeks is 5.2 days, with the range due to random variation lying between 3.16 days and 7.24 days. Again, the range is wide, reflecting the variable performance of the process.

In week 29 we see that order entry to delivery performance was significant, being outside the expected range. Since the data can only be calculated once delivery has been made, it is fair to assume that these figures probably reflect what went on in the process in the previous week, which is the same week that on-time delivery performance was abnormal. Clearly there were problems around week 28.

We can also see that the performance in weeks 31 to 35 is well below – that is, better than – average. Although these data points remain within the limits expected from natural – random – process variation, we might wonder whether this is an indication that we have begun to improve this process.

As mentioned earlier, data points do not have to lie outside the natural process limits to signal that something has changed within the process. W Edwards Deming called this special cause variation. In his book: *Fourth Generation Management*, Brian Joiner offers three indicators of process changes in data that lies within natural process limits:

Week number	On-time delivery %	Absolute change
25	6.3	N/a
26	5.5	0.8
27	7.2	1.7
28	7.2	0.0
29	7.9	0.7
30	5.4	2.5
31	3.8	1.6
32	3.2	0.6
33	3.2	0.0
34	3.5	0.3
35	4.0	0.5
TARGET	3.00	
Average	5.20	
Median of absolute change		0.65
Upper natural process limit	7.24	
Lower natural process limit	3.16	

Number of days between order entry and delivery

Table 4

- Six or more points in a row increasing or decreasing – a trend
- Eight or more points on the same side of the centre line
- 12 or more points alternating up and down

Donald Wheeler adds a fourth indicator: at least three out of four points that are closer to one of the limits than they are to the central – average – line.

The data on the number of days between order entry and delivery does not meet any of Joiner's indicators: a few more weeks' data is needed; but does meet the one added by Wheeler: the final five data points are closer to the lower natural limit than they are to the average. It looks like some improvement may have been made to the process to reduce processing time – lead-time. If we can embed and sustain this improvement, then we will have improved the process.

Analysing performance data in this way gives us a way of understanding and improving business processes. Further analysis may be necessary to identify the root causes of anomalies in the data in order to target our improvement actions – for example, analysis by day of the week, shift or by breaking the process down into steps.

Nevertheless, this approach to analysing performance data helps us to focus on issues arising in a process, and therefore to plan improvement activity that will actually help us meet our targets and improve performance sustainably.

Understanding business performance data is not about comparing this month with last month or this time last year, or cumulatively comparing to budget. Such single point comparisons miss that fact that performance data varies naturally, and such a comparison may, therefore, be judged good or bad depending on natural and random variations in the process. Neither does understanding business performance data require detailed statistical knowledge. The basic approach is given in this article, with more information provided in the books referenced.

But what you do need to do to understand business performance data is to understand it over time, using the approach presented. Only by understanding the behaviour of the process over time can we judge it. In particular, the range between the natural process limits will tell us how stable the process is – the wider the range, the less consistent the process; and the pattern of data points will, in relation to the natural process limits, signal any changes in the process itself.

Blaming managers and supervisors for good or bad results is not helpful. In fact, it is demoralising and counterproductive. The only way meet the performance targets we desire is to improve the process, so that average process performance matches our target, and the natural process range is narrow enough to be acceptable to our customers.

As Brian Joiner concludes in *Fourth Generation Management*: 'Nothing happens in a predictable sustained way unless you build mechanisms that cause it to happen in a predictable sustained way.'

About the author

Ross Maynard is a Fellow of the Chartered Institute of Management Accountants, and a consultant specialising in process improvement and business decision-making.

References

There are a number of books on the analysis of business data. Two of the most readable and accessible are:

JOINER, BRIAN, *Fourth Generation Management*, McGraw-Hill Professional, 1994

WHEELER, DONALD J, *Understanding Variation: The Key to Managing Chaos*, Longman Higher Education 1993 – also published by SPC Press

Donald Wheeler, in particular, has written many excellent books and articles on business data analysis and process improvement. Davis Balestracci, a colleague of Donald Wheeler, has also written many very readable articles on the subject, notably for *Quality Digest Magazine* – for example, this one on analysing the data: www.qualitydigest.com/aug05/departments/spc_guide.shtml

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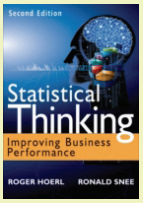

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