



*Lesson 3:*

The exact **steps to create** Smart Charts.

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How to Get the Truth Out of Your KPIs **USING SMART CHARTS**

*Your notes:*

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**In Lesson 3...**

- **Step-by-step instructions to create Smart Charts**
- **A demonstration of creating a Smart Chart**
- **The Smart Chart Excel template**

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Your notes:

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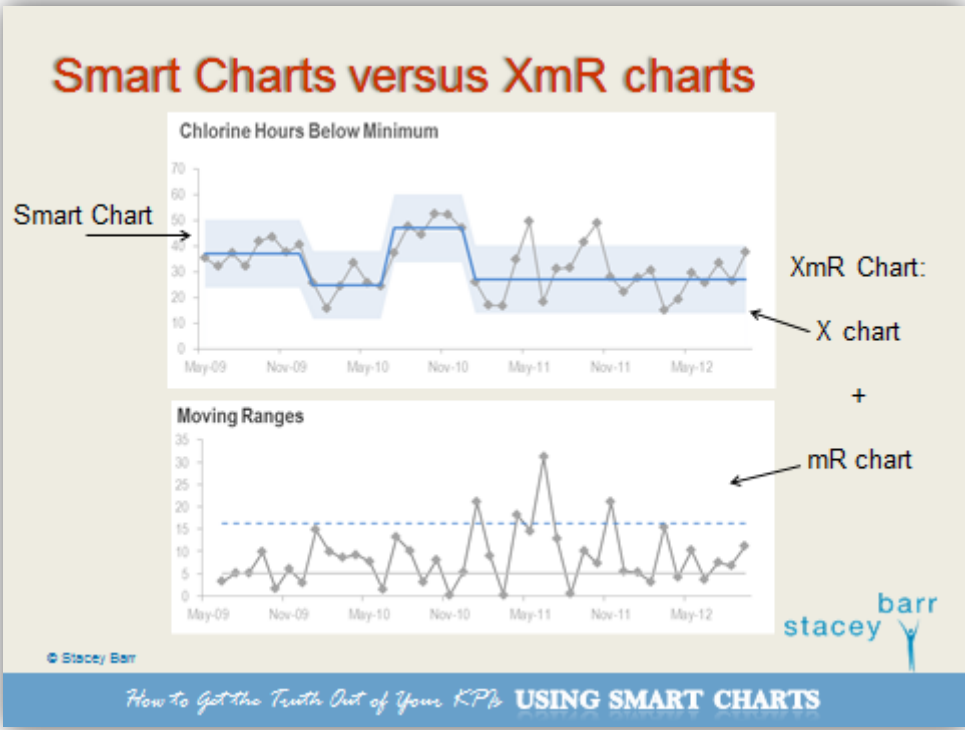
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Your notes:

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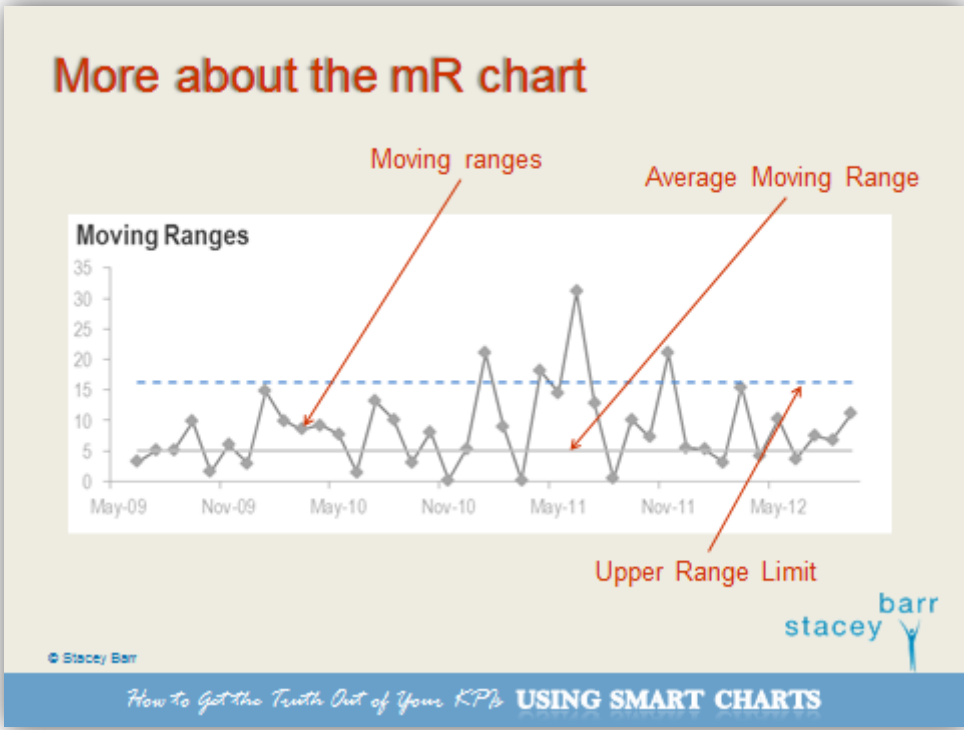
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Your notes:

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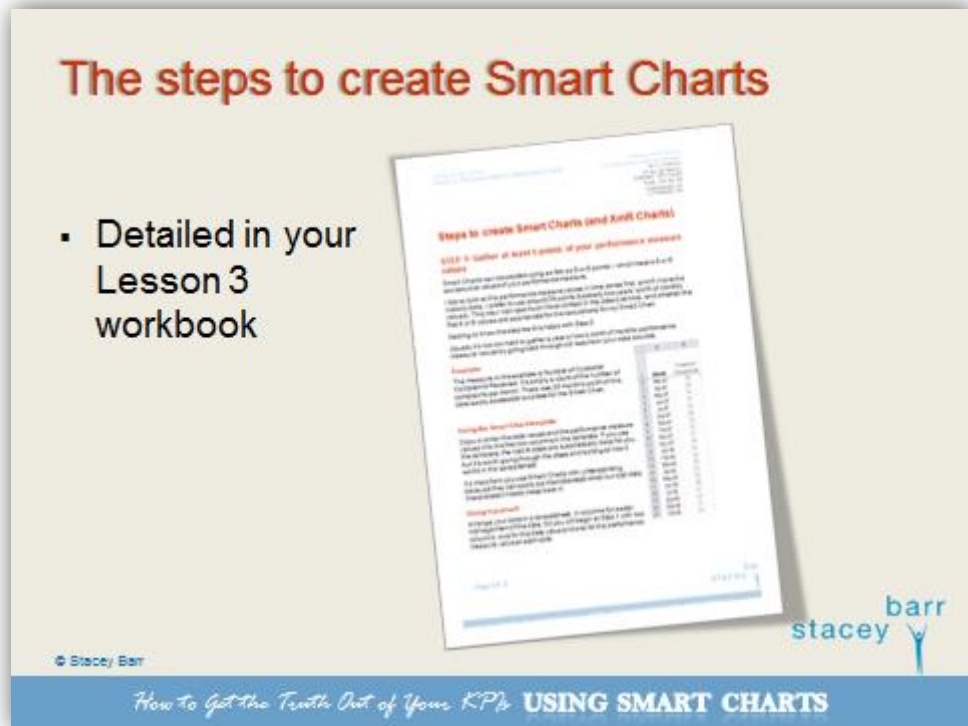
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Your notes:

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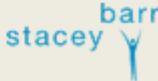
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**Live demonstration...**

	A	B	C	D	E	F	G	H
1	<b>Month</b>	<b>Customer Complaints</b>						
2	Mar-97	38						
3	Apr-97	28						
4	May-97	34						
5	Jun-97	41						
6	Jul-97	30						
7	Aug-97	28						
8	Sep-97	35						
9	Oct-97	43						
10	Nov-97	37						
11	Dec-97	36						

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Your notes:

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## Steps to create Smart Charts (and XmR Charts)

### STEP 1: Gather at least 5 points of your performance measure values

Smart Charts can be created using as few as 5 or 6 points – which means 5 or 6 consecutive values of your performance measure.

I like to look at the performance measure values in time series first, and if I have the historic data, I prefer to use around 24 points (basically two years' worth of monthly values). This way I can see much more context in the data over time, and whether the first 5 or 6 values are appropriate for the calculations for my Smart Chart.

Getting to know the data like this helps with Step 2.

Usually it's not too hard to gather a year or two's worth of monthly performance measure values by going back through old reports or your data sources.

#### Example:

The measure in the example is Number of Customer Complaints Received. It's simply a count of the number of complaints per month. There was 20 month's worth of this data easily accessible to collate for the Smart Chart.

#### Using the Smart Chart template:

Copy or enter the date values and the performance measure values into the first two columns in the template. If you use the template, the next 6 steps are automatically done for you, but it's worth going through the steps and looking at how it works in the spreadsheet.

It's important you use Smart Charts with understanding, because they can easily be misinterpreted when our bad data interpretation habits creep back in.

#### Doing it yourself:

Arrange your data in a spreadsheet, in columns for easier management of the data. So you will begin at Step 1 with two columns: one for the date value and one for the performance measure value at each date.

	A	B
1	Month	Customer Complaints
2	Mar-97	38
3	Apr-97	28
4	May-97	34
5	Jun-97	41
6	Jul-97	30
7	Aug-97	28
8	Sep-97	35
9	Oct-97	43
10	Nov-97	37
11	Dec-97	36
12	Jan-98	24
13	Feb-98	33
14	Mar-98	39
15	Apr-98	25
16	May-98	23
17	Jun-98	28
18	Jul-98	27
19	Aug-98	24
20	Sep-98	17
21	Oct-98	24

## STEP 2: Calculate the performance measure Central Line

Your performance measure's Central Line is simply the average of the first 5 or 6 values in the time series of your performance measure.

DON'T update the average as you add new performance measure values!

You're establishing a baseline with those first 5 or 6 values, a baseline that describes the performance level for the business process or result you're measuring.

You'll use this baseline for comparing new or subsequent performance measure values with. That's how you'll determine if and when performance has changed.

If performance doesn't change, you will continue to see the new or subsequent performance measure values randomly vary on either side of the Central Line calculated from those first 5 or 6 values.

### Example:

In the Customer Complaints example, the first 6 values were used to calculate the Central Line of 33.2.

This value is then "copied down" alongside the performance measure values, and will be used to draw the Central Line on the Smart Chart in a later step.

### Using the Smart Chart template:

If you use the Smart Charts template supplied with this course, then the calculation of the Central Line value and the copying of this value down next to all the performance measure values, is done automatically.

### Doing it yourself:

It's easiest if you create a third column, right next to your performance measure values column, to hold the Central Line calculation and values. This is because you'll display the Central Line on your Smart Chart.

In the first cell in that new column you put in the formula to calculate the average of the points you have. For example, in cell C2, you'll put in "=average(B2:B7)".

Then in the next cell, to copy the Central Line value all the way down your time series, you'll put in a link that references the first cell, such as "=C2". To put this same value into each subsequent cell in your time series, just "copy down", or copy the contents of C3 and paste it into the rest of the cells in column C, next to your performance measure values.

	A	B	C
1	Month	Customer Complaints	Central Line
2	Mar-97	38	33.2
3	Apr-97	28	33.2
4	May-97	34	33.2
5	Jun-97	41	33.2
6	Jul-97	30	33.2
7	Aug-97	28	33.2



## STEP 3: Calculate the performance measure's moving ranges

The purpose of the moving range calculations is to quantify the amount of routine variation in your performance measure.

Knowing how much routine variation there is helps you filter the noise and more easily see the non-routine or exceptional variation. It's this non-routine variation that signals changes in your performance measure that are worth investigating.

A moving range is simply a series of calculations where you take the difference between successive values in your performance measure. When you get a negative value, just ignore the negative sign (the minus sign) – you just want to know the size of the difference between the successive values, not the direction of the difference.

Be aware that you will have one less moving range value than you have performance measure values. If you have 6 performance measure values, you'll have 5 moving range values.

### Example:

The moving ranges for the Customer Complaints example are calculated by taking the successive differences between each adjacent set of measure values.

The first moving range value of 10 comes from the difference between 28 and 38. The value of 6 comes from the difference between 34 and 28. And so on.

	A	B	C	D
		Customer Complaints	Central Line	Moving Ranges
1	Month			
2	Mar-97	38	33.2	
3	Apr-97	28	33.2	10.0
4	May-97	34	33.2	6.0
5	Jun-97	41	33.2	7.0
6	Jul-97	30	33.2	11.0
7	Aug-97	28	33.2	2.0

### Using the Smart Chart template:

The moving range calculations are in the fourth column in the Smart Charts template, and the calculations are there for you. If you have more or less data than the sample data in the spreadsheet, either add or delete the moving ranges to match the number of performance measure values you have.

### Doing it yourself:

The fourth column in your spreadsheet should be for the moving ranges. You can set up a calculation to work out the absolute difference between the current performance measure value and the previous one, like this: `"=ABS(B3-B2)"`. Of course, this assumes your performance measure values are in column B. Just copy this down the column, to automatically get all the moving range values for each of your performance measure values.

## STEP 4: Calculate the Average Moving Range

To help quantify how much routine variation your performance measure has, you'll use those moving ranges you computed at Step 3.

Here, we calculate the Average Moving Range, following the same instructions as for Step 2 above. So you'll be averaging the first 4 or 5 values of your moving range series (not your performance measure series).

Why 4 or 5 instead of 5 or 6? That's because you'll have one less moving range value than you have performance measure values.

The Average Moving Range will be used in the calculations to quantify how much routine variation your performance measure has. In other words, the Average Moving Range will help you put those upper and lower "Natural Process Limits" on your Smart Chart.

### Example:

The Average Moving Range for Customer Complaints is the average of the first 5 values of the moving ranges.

Even though the measure's Central Line was calculated from the first 6 measure values, you only end up with 5 moving range values for those 6 measure values.

	A	B	C	D	E
1	Month	Customer Complaints	Central Line	Moving Ranges	Average Moving Range
2	Mar-97	38	33.2		
3	Apr-97	28	33.2	10.0	7.2
4	May-97	34	33.2	6.0	7.2
5	Jun-97	41	33.2	7.0	7.2
6	Jul-97	30	33.2	11.0	7.2
7	Aug-97	28	33.2	2.0	7.2

The Average Moving Range is therefore based on those first 5 moving range values. It will be used to calculate the Natural Process Limits in the Smart Chart (the X chart part of the XmR chart).

### Using the Smart Chart template:

The Average Moving Range calculation happens in the fifth column in the Smart Charts template. The calculation is there for you, along with the reference values that will copy this calculation down alongside the values of the moving ranges themselves.

### Doing it yourself:

Add a fifth column in your spreadsheet to compute the Average Moving Range. This will essentially be the same as the third column where you computed the performance measure Central Line, but of course it will be averaging the moving ranges in column D (NOT the performance measure values in column B).

## STEP 5: Calculate the Upper Range Limit

There is an optional second chart that accompanies a Smart Chart. Its role is very specific: it will help you work out if your performance measure's routine variation changes.

For this second chart, you will calculate an Upper Range Limit.

There is no lower limit for the mR chart because the moving ranges have a logical minimum of zero.

The Upper Range Limit is the Average Moving Range multiplied by 3.27.

This value of 3.27 is always the value you will use. It is a statistically derived constant that makes the Upper Range Limit roughly equivalent to 3 standard deviations from the Average Moving Range. In other words, it makes sure that the Upper Range Limit accurately describes the routine variation in the moving range values.

### Example:

In the Customer Complaints example, the Upper Range Limit is calculated from the Average Moving Range value of 7.2.

It's then "copied down" alongside each measure value. It will be used for the "mR" part of the XmR chart. But it doesn't impact the X chart (what we call the Smart Chart).

	A	B	C	D	E	F
		Customer Complaints	Central Line	Moving Ranges	Average Moving Range	Upper Range Limit
1	Month		33.2			
2	Mar-97	38	33.2			
3	Apr-97	28	33.2	10.0	7.2	23.5
4	May-97	34	33.2	6.0	7.2	23.5
5	Jun-97	41	33.2	7.0	7.2	23.5
6	Jul-97	30	33.2	11.0	7.2	23.5
7	Aug-97	28	33.2	2.0	7.2	23.5

### Using the Smart Chart template:

The Upper Range Limit calculation is already set up in the sixth column in the Smart Charts template. The calculation is there for you, along with the reference values that will copy this calculation down alongside the Average Moving Range values.

### Doing it yourself:

Here's the formula to use to calculate your Upper Range Limit: "=E3\*3.27", assuming that your Average Moving Range value is in column E.

## STEP 6: Calculate your performance measure's Natural Process Limits

The upper and lower Natural Process Limits on your Smart Chart will define the routine variation for the performance measure. They are set the same distance either side of your Smart Chart's Central Line.

To compute these limits we begin by multiplying the Average Moving Range by the constant value 2.66 (a statistically derived constant for XmR and Smart Charts).

This product is then used to find the Natural Process Limits by adding it to the Central Line value and by subtracting it from the Central Line value.

### A note about resetting illogical values of the Natural Process limits:

If you get a value for either the upper Natural Process Limit or the lower Natural Process Limit that is illogical, you can reset them to your measure's logical minimum value or logical maximum value. For example, if you are measuring a percentage that simply cannot go above 100%, but you get an upper Natural Process Limit of greater than 100%, you can reset the upper Natural Process Limit to 100%. Likewise, if you are measuring a count, like workplace accidents, it makes no sense to have a lower Natural Process Limit that is negative, so reset it to zero.

### Example:

The Natural Process Limits for Customer Complaints are calculated from the Average Moving Range value of 7.2 multiplied by 2.66.

This value is "copied down" alongside each measure value and will be used to place that band of routine variation on the Smart Chart.

	A	B	C	D	E	F	G	H
1	Month	Customer Complaints	Central Line	Moving Ranges	Average Moving Range	Upper Range Limit	Lower Natural Process Limit	Upper Natural Process Limit
2	Mar-97	38	33.2				14.0	52.3
3	Apr-97	28	33.2	10.0	7.2	23.5	14.0	52.3
4	May-97	34	33.2	6.0	7.2	23.5	14.0	52.3
5	Jun-97	41	33.2	7.0	7.2	23.5	14.0	52.3
6	Jul-97	30	33.2	11.0	7.2	23.5	14.0	52.3
7	Aug-97	28	33.2	2.0	7.2	23.5	14.0	52.3

### Using the Smart Chart template:

The upper and lower Natural Process Limits are calculated for you in the seventh and eighth columns in the Smart Chart template. They also automatically cascade down alongside the range of your performance measure values.

### Doing it yourself:

Here's the formula to use to calculate the lower Natural Process Limit for your Smart Chart:  $=C3-E3*2.66$ , assuming that your Average Moving Range value is in column E. Likewise for the Natural Process Limit, the formula is:  $=C3+E3*2.66$ .

## STEP 7: Assemble your "Smart Chart"

There are in fact two charts in the traditional XmR chart:

The first is a graph of your performance measure in a time series, with its Central Line and Natural Process Limits. It's called the X chart, traditionally, but we call this one the Smart Chart.

The second is a graph of the moving ranges, with the Average Moving Range and the Upper Range Limit. It's called the mR chart. It isn't part of the Smart Chart.

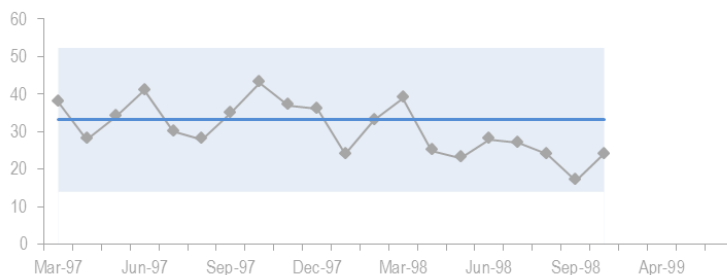
You use both charts in the XmR chart to help you find signals of change in performance that aren't just part of the normal "noise" or routine variation.

Again, the Smart Chart is simply the first of those two graphs in an XmR chart.

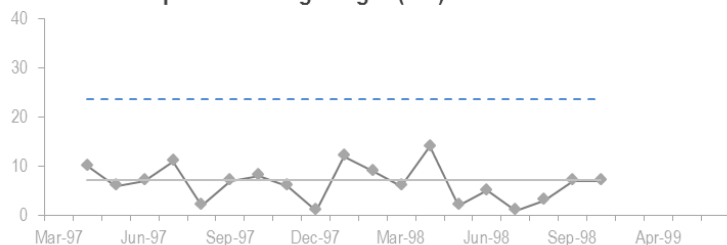
### Example:

Here's the Smart Chart (X chart) and the mR chart for Customer Complaints.

Customer Complaints (X)



Customer Complaints Moving Ranges (mR)



### Using the Smart Chart template:

If you use the Smart Chart template, both charts are already there and will populate with your own measure values and the XmR chart calculations.

You might need to alter a few things to finetune the charts:

- the title of the charts, to match your measure name
- the scale on the vertical axes, to match the range of your measure values
- the range of the horizontal axes, to match your date range

### Doing it yourself:

If you are creating your own Smart Chart or XmR chart from a blank spreadsheet, you'll need to set up the charts yourself.

The design principle I use is to visually highlight the most important information on these charts, and that is usually the comparison between the Central Line and its target. If your target is for the Natural Process Limits, then you will instead highlight the comparison between the limit(s) and their target(s).

To make the charts look like the ones in the Smart Chart template, with the targets as dots and the area between the Natural Process Limits shaded, then follow these steps:

1. Highlight the columns containing the date, your measure values, the Central Line, the upper and lower Natural Process Limits, and any target columns you're using.
2. Insert a chart, choosing a line chart. Delete the legend and the gridlines, if they are added by default.
3. Format your measure's line to have grey markers and line colour, and adjust the size of the markers and thickness of the line to suit your needs. I prefer to make the line thickness 1pt and the markers 5pt in size.
4. Format your Central Line to have no markers, a line thickness of 1.5pt to 2pt, and line colour that is relatively dominant. I prefer a medium strength blue, but it's really up to you.
5. Change your upper Natural Process Limit line to an area chart by right-clicking on the line and choosing 'change series chart type', then choosing the Area option. Format the upper Natural Process Limit fill to be a few shades lighter than the colour for your Central Line, and remove the border by choosing the 'no line' option in the Border Color setting.
6. Right-click on the chart and click the 'select data' option. In the list of series of your data, click on the upper Natural Process Limit and move it above the lower Natural Process Limit. This will make sure the shading works.
7. Change your lower Natural Process Limit line to an area chart, as you did for the upper Natural Process Limit. But this time, format the lower Natural

Process Limit fill to be white. This will act as a mask in front of the upper Natural Process Limit shading, which at the moment will extend all the way down to the horizontal axis. The effect that's created is that only the area between the Natural Process Limits is shaded.

8. Format your target line to have 'no line' in the Line Color setting, a round marker of size 7pt, and the same colour you made the Central Line.
9. Format the horizontal axis as you like, but I prefer to have the label text not rotated and only including every 4<sup>th</sup> or 6<sup>th</sup> label (to fit them all in with some white space between the labels).
10. Often I will also format both axes – the lines, tick marks and labels – to be a medium strength grey so they don't dominate visually.

Now you're ready to look for signals!



