



**CHAPTER 10** Step 7: Interpreting Signals From Measures  
XmR Chart Instructions

# XmR Chart Instructions

*Warning: These instructions are of a basic, introductory nature. There is great worth in taking the time to learn these powerful charts in more detail, so you understand the calculations, signals and special circumstances for measures that are seasonal, rare events, or have an underlying linear trend. You can learn more about XmR charts at [www.usingsmartcharts.com](http://www.usingsmartcharts.com)*

In an XmR chart, the X simply means your performance measure, and the mR stands for “moving range” which is the method that will be used to filter the noise from the signals in your performance measure.

There are other types of control charts, and courses to learn how and when to use them, but the XmR chart is a very simple and practical method that suits the majority of performance measures. It’s always superior to limited comparisons like comparing this month to last month, or to the same month last year, or to target!

Here are the steps for creating an XmR control chart using Microsoft Excel. The examples are excerpts from an Excel spreadsheet, and don’t show all the data, so you may not get the same values if you use the data you can see in the examples.

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

XmR Charts can be created using as few as 5 or so points – which means 5 or so consecutive values of your performance measure. If your measure has a lot of variability, you may need to use more than 5 points before your Central Line and Natural Process Limit calculations will be stable enough. There are no hard and fast rules here: you need to use your judgment and if necessary get some expert advice.

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 so values are appropriate for the calculations for my XmR 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 months’ worth of this data easily accessible to collate for the XmR Chart.

**Using the XmR Chart template:**

Copy or enter the date values and the performance measure values into the first two columns in the template, available as a download for *Practical Performance Measurement* readers. If you use the template, the next 6 steps are automatically done

	A	B
		Customer Complaints
1	Month	
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



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for you, but it's worth going through the steps and looking at how it works in the spreadsheet.

It's important you use XmR 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.

**STEP 2: Calculate the performance measure Central Line**

Your performance measure's Central Line is simply the average of the first 5 or so values in the time series of your performance measure. Remember, if your measure has a lot of variability, you'll probably need more than 5 values for the calculation. Use your judgment.

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

You're establishing a baseline with those first 5 or so 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 XmR Chart in a later step.

**Using the XmR Chart template:**

If you use the XmR Charts template supplied as a download for *Practical Performance Measurement* readers, then the calculation of the Central Line value, and copying this value down for all rows, is done automatically.

	A	B	C
		Customer Complaints	Central Line
1	Month		
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

**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 XmR 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



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“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.

### 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
1	Month	Customer Complaints	Central Line	Moving Ranges
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 XmR Chart template:**

The moving range calculations are in the fourth column in the XmR Charts template, available as a download for *Practical Performance Measurement* readers, 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 so values of your moving range series (not your performance measure series).



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Why 4 instead of 5? That's because you'll have one less moving range value than you have performance measure values. If you ended up using 12 values for the Central Line, then your Average Moving Range will be based on 11.

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 XmR 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.

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 XmR Chart (the X chart part of the XmR chart).

	A	B	C	D	E
		Customer Complaints	Central Line	Moving Ranges	Average Moving Range
1	Month				
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

**Using the XmR Chart template:**

The Average Moving Range calculation happens in the fifth column in the XmR Charts template, available as a download for *Practical Performance Measurement* readers. 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 an XmR 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.



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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 XmR Chart).

	A	B	C	D	E	F
		Customer	Central	Moving	Average	Upper
1	Month	Complaints	Line	Ranges	Moving	Range
					Range	Limit
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 XmR Chart template:**

The Upper Range Limit calculation is already set up in the sixth column in the XmR Charts template, available as a download for *Practical Performance Measurement* readers. 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 XmR Chart will define the routine variation for the performance measure. They are set the same distance either side of your XmR Chart's Central Line.

To compute these limits we begin by multiplying the Average Moving Range by the constant value 2.66. Just as for the value of 3.27 used for the Upper Range Limit calculation in Step 5, this value of 2.66 is always the value you will use. It is a statistically derived constant that makes the Natural Process Limits roughly equivalent to 3 standard deviations from the Central Line, since moving ranges were used as the measure of variability. Using the standard deviation statistic over-estimates the size of the Natural Process Limits.

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.



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**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 XmR 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 XmR Chart template:**

The upper and lower Natural Process Limits are calculated for you in the seventh and eighth columns in the XmR Chart template, available as a download for *Practical Performance Measurement* readers. 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 XmR 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 “XmR 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 XmR 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 XmR 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 X Chart is simply the first of those two graphs in an XmR chart.

**Example:**

Here’s the XmR Chart (X chart) and the mR chart for Customer Complaints.



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Customer Complaints (X)



Customer Complaints Moving Ranges (mR)



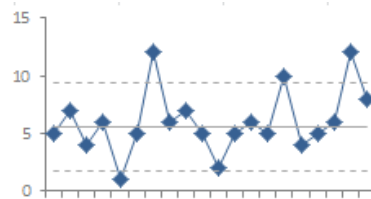
Now you're ready to look for signals!

## STEP 8: Interpret signals in your XmR Chart

Here are the most common signals you'll see in your performance measures, and how to recalculate your Central Line and Natural Process Limits:

### Unstable (chaos)

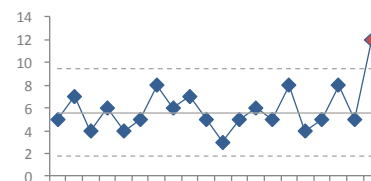
No predictability, heaps of random variability. There is little control or influence being exercised over the result (e.g. policies or standards or systems). Or perhaps there are actually a bunch of signals going on. Or it might just be very "noisy" performance.



Don't bother with when to change your Natural Process Limits and Central Lines – instead, focus on standardising the process that produces this result until you get more stability or predictability in performance.

### Special cause (or outlier)

A point outside the Natural Process Limits indicates something unusual happened. Just find out what it was, don't try to fix it unless it's a real problem, but it's likely to be a one-off.



Don't recalculate anything.

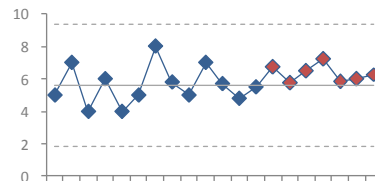


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**Long run**

At least 8 consecutive points running on one side of the Central Line (or 10 in 12, or 12 in 14) indicates a sudden change. It may be by design, and if not, find out the cause.

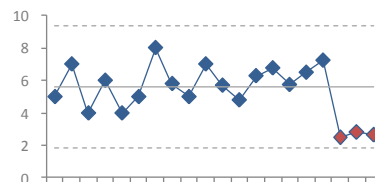
Use the 8 points that constitute this new suggested level of performance, and use those points to recalculate your Central Line and Natural Process Limits.



**Short run (near the limits)**

At least 3 out of 4 consecutive points closer to the control limit than to the Central Line is also a sudden change. Because the size of the change is so dramatic, 3 or 4 points are enough to be confident it's a real change. It may be by design, and if not, find out the cause.

Wait until you have at least 5 points that continue to follow the new suggested level of performance, and use those points to recalculate your Central Line and Natural Process Limits.



**STEP 9: When to recalculate your Central Line and Natural Process Limits**

When you get a signal in your performance measure's XmR Chart, it can often mean that performance has shifted to a new level.

That means it's behaving differently now, and it's the product of a different underlying business process or system. The process or system is somehow different (hopefully better), and that's why you're seeing the change in performance level.

For any signal, you want to investigate to find the likely cause. If it turns out that the signal is a true reflection of what you can now expect performance to continue doing, it's time to recalculate the Natural Process Limits and Central Line to reflect the change.

The recalculation is done at the point in time when the new level of performance started.

- For a "special cause", you don't recalculate anything, because it's not a pattern that is likely to continue – it's just a momentary blip in performance. But keep watching it, as it may be the beginning of a "short run".
- For a "long run", that means using the first 5 or so points from the beginning of the "long run".
- For a "short run", that means also using the first 5 or so points from the start of the "short run", so you'll need to wait until you get the extra 2 or more points after the "short run".

Note that you may need more points to recalculate the Central Line and Natural Process Limits after a signal, particularly if the pattern of variation after the signal is a bit more chaotic. This is fine, but you can at least start when you have 5 points.

*Remember, you can learn more about XmR charts at [www.usingsmartcharts.com](http://www.usingsmartcharts.com)*