NHS Improvement

An Overview of Statistical Process Control (SPC)

October 2011
**Statistical Process Control Charts (X, Moving R Charts)**

**What is Statistical Process Control (SPC)?**

We all know that measurement is integral to the improvement methodology in healthcare but how do we know whether or not we have actually made a difference and if the care being delivered is getting better, staying the same or getting worse each year? What we do not always take into account is the variation in the way that services are delivered – by individual departments, people and even different types of equipment. All of these differences in the way things are done lead to differences in the way services are delivered.

The main aims of using Statistical Process Control (SPC) charts is to understand what is ‘different’ and what is the ‘norm’. By using these charts, we can then understand where the focus of work needs to be concentrated in order to make a difference. We can also use SPC charts to determine if an improvement is actually improving a process and also use them to ‘predict’ statistically whether a process is ‘capable’ of meeting a target. SPC charts are therefore used:

- As way of demonstrating and thinking about variation
- As simple tool for analysing data – measurement for improvement
- As a tool to help make better decisions - easy and sustainable to use

The way in which data within healthcare is traditionally analysed leads to confusion and inaccuracy. The simple fact that important operational decisions are often made from data where there is limited understanding of the ‘process’ and its ‘variation’ is often worrying. If individuals do not understand variation, they often look at data (as in the chart below) and:

- They see trends where there are no trends
- They try to explain natural variation as special events
- They blame and give credit to people for things over which they have no control
- They can’t understand past performance
- They can’t make predictions or plan for the future
- Their ability to make improvements is limited
ABSENTEEISM BY DEPARTMENT

Variation

There are two types of variation found within SPC charts:

Natural (common cause) variation

- Is inherent in the design of the process
- Results in a stable – *IN CONTROL* – process because the variation is predictable
- Is due to random or chance causes of variation
Special cause variation

- Is due to irregular or unnatural causes that are not inherent in a process - extrinsic
- Results in an unstable – OUT OF CONTROL – process because variation is not predictable
- Is due to non-random or assignable causes of variation (i.e. a signal that the process has ‘changed’)

Control Charts vs. Run Charts

Run charts have traditionally been used in service improvement to measure changes in a process over time. There is however marked differences between run charts and SPC charts – in addition to the mean or average, control charts have 2 extra lines that are calculated using modified statistics and these determine the variation range. These lines are commonly referred to as the Upper Control Limit (UCL) – the upper line, and Lower Control Limit (LCL) – the lower line. SPC charts require an absolute minimum of 10 data points in order to create a valid chart, although there is increased reliability when using 20 or more data points. Data should also be plotted chronologically in date or process order and ideally represent an individual as opposed an aggregate value.

In summary, control charts:

- Are more sensitive than run charts – a run chart cannot detect special causes due to point to point variation or use rules for detecting special causes
- Have the added feature of control limits which estimate natural variation
- Define process capability
- Allow us to more accurately predict process behavior
What can SPC do for you?

SPC charts have multiple uses but in summary can be used:

- To identify if a process is sustainable - i.e. are your improvements sustaining over time
- To identify when an implemented improvement has changed a process - i.e. it has not just occurred by chance
- To understand that variation is normal and to help reduce it
- To generally understand processes - helping make better predictions and thus improve decision making
- To recognise abnormalities within processes
- To prove or disprove assumptions and (mis)conceptions about services
- To drive improvement – used to test the stability of a process prior to redesign work, such as Demand and Capacity

Further practical applications of SPC charts include the ability to calculate a ‘recommended capacity’ based on demand by using the charts to plot daily demand over time.

What will SPC not do for you?

SPC charts are very useful, but they will not:

- Solve your process issues – you will need background intelligence in order to understand the process for potential redesign
- Provide all the answers – SPC analysis is a tool to compliment all other methodologies i.e. process mapping and discovery interviews
- Validate data – SPC is only as valid as the data used

How do I create an SPC chart?

SPC charts can be created manually but this tends to be a rather laborious exercise. There is a host of software available commercially than can create these and many other types of SPC charts for you from the data you enter. You can however use the NHS Improvement System to create both SPC and Capacity charts subject to your access agreement to the system.

If you are interested in the calculations used to create an SPC chart (which can be done in excel for example), they are as follows:

- Use individual values to calculate the average
Calculate the difference between 2 consecutive values for all of the values as the moving range mR – these values are always i.e. the difference between 5 and 6 = 1 and the difference between 7 and 0 = 7

Calculate the average mR

Calculate one Sigma = Average mR/d2*

Calculate the Upper Control Limit (UCL) = Average + (3 x Sigma)

Calculate the Lower Control Limit (LCL) = Average – (3 x Sigma)

*The bias correction factor, d2 is a constant for given subgroups of size n (n = 2, d2 = 1.128)

What do I do next?

Once you have a chart, you will need to understand what it means in order to determine your next course of action. Initially you will be looking to see if a chart contains special cause variation or natural variation – is the process in control or out of control. You need to remember that a process containing special cause variation is unpredictable and the data should not be used to reliably calculate a processes capability.

<table>
<thead>
<tr>
<th>Is the initial process stable?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of variation</td>
<td>Natural (common)</td>
<td>Special + natural</td>
</tr>
<tr>
<td>Right Choice</td>
<td>Change the process</td>
<td>Investigate the origin of the special cause(s)</td>
</tr>
<tr>
<td>Wrong Choice</td>
<td>Treat normal variation as a special cause (tampering)</td>
<td>Change the process</td>
</tr>
<tr>
<td>Consequences of making the wrong choice</td>
<td>Increased variation</td>
<td>Wasted resources</td>
</tr>
</tbody>
</table>
Determining the type of variation contained within a process is crucial at this stage (see chart above) as your intervention could lead to increased variation or wasted resources if you take the wrong course of action. This is why it is sometimes better to use SPC to determine the type of variation before any service improvement work i.e. demand and capacity.

You should then develop improvement strategies - improvement strategies are determined by the sources of variation.

- Special cause variation – investigate and find out why it exists and what each special cause data point may mean
  - remember that not every special cause is a negative factor as by redesigning the process, you are inadvertently introducing special cause variation

- Natural (common cause) variation – change the process if you want to improve
  - Reduce the amount of variation by redesigning the process

The control limits will give you a reliable indication in terms of the overall variation within the process. For example, the chart below represents a call to needle process where individual patient call to needle times have been plotted chronologically over time. While the average time is 50.64 minutes, the variation is between 0 and 106.93 minutes. This would indicate that any patient entering this process could expect to wait between 0 and 107 minutes to receive thrombolysis treatment from their point of call. Special cause variation points have also been flagged which would require further investigation in order to understand this process.
There are different types of special cause variation points found within SPC charts – some software automatically highlights these points for you, such as the NHS Improvement System, but you can find more details about SPC by using the links to further resources within this section.

You can then continue to use SPC charts to see if there has been an improvement in the process. Usually as this occurs over time, you will see the overall variation reducing and the process capability increasing. SPC charts should not be considered as a ‘one-off’ methodology but used continually to monitor a processes performance and to measure for improvement.

**Process Capability**

SPC charts can also enable you to see if a particular process can meet a specific target. The calculation used will determine the process capability. Most software currently available to generate SPC charts will not calculate the process capability so this will have to be done manually. However, Rapport will calculate this for you.

The calculation used to determine process capability is:

\[
\text{Capability} = \frac{\text{Target} - \text{Average}}{3 \times \text{standard deviation}}
\]

A value of 1 means the process is 100% capable of achieving the target. A negative figure means more than 50% of patients will not meet a given target.

The procedure for calculating process capability is therefore:

- Test for stability by plotting a control chart first
- If unstable, gain control by identifying and controlling the main factors that affect the situation
- Only if it is stable, calculate a process capability to determine if it is capable of meeting the target

**Links to further resources**

For information on improvement knowledge and skills and on measurement for improvement, see the Improvement Leaders Guides produced by the NHS Institute for Innovation and Improvement

[http://www.institute.nhs.uk/Products/ImprovementLeadersGuidesBoxSet.htm](http://www.institute.nhs.uk/Products/ImprovementLeadersGuidesBoxSet.htm)
The series of guides covers General improvement skills, process and systems thinking and personal and organisational development in 13 booklets.

All of the service improvement tools and techniques training materials can be accessed by going to:

The Directory of Improvement Resources on the NHS Improvement System.