Measurement for Improvement
Guidance note on key concepts

Introduction

"Successful measurement is a cornerstone of successful improvement. How do you know if the changes you are making are leading to improvement? Simple: you measure. Measurement doesn't have to be difficult or time-consuming. The key is to pick the right measurements, so that you can see results quickly and adapt your interventions accordingly, putting less strain on resources and more focus on outcomes."

- **Institute for Healthcare Improvement**

This guidance has been developed to assist services who are developing a quality profile to get to grips with some of the concepts for measurement that can be used in your profile. It also contains video links into the IHI's Open School which will assist in your understanding. This guidance includes an introduction to two commonly used types of chart; run charts and Shewhart charts. It is worth emphasising at this point that to use such tools effectively and to drive improvement, the availability of timely data is important. In particular, using old or out of date data makes it difficult to differentiate clearly between improvement initiatives that have been successful and those initiatives that did not lead to improvements.

Run Charts

There are many commonly used techniques for helping visualise changes in a process over time or comparing performance before and after an intervention. These can include bar charts, pie charts and histograms but in this section we will focus on run charts, and later on Shewhart charts.

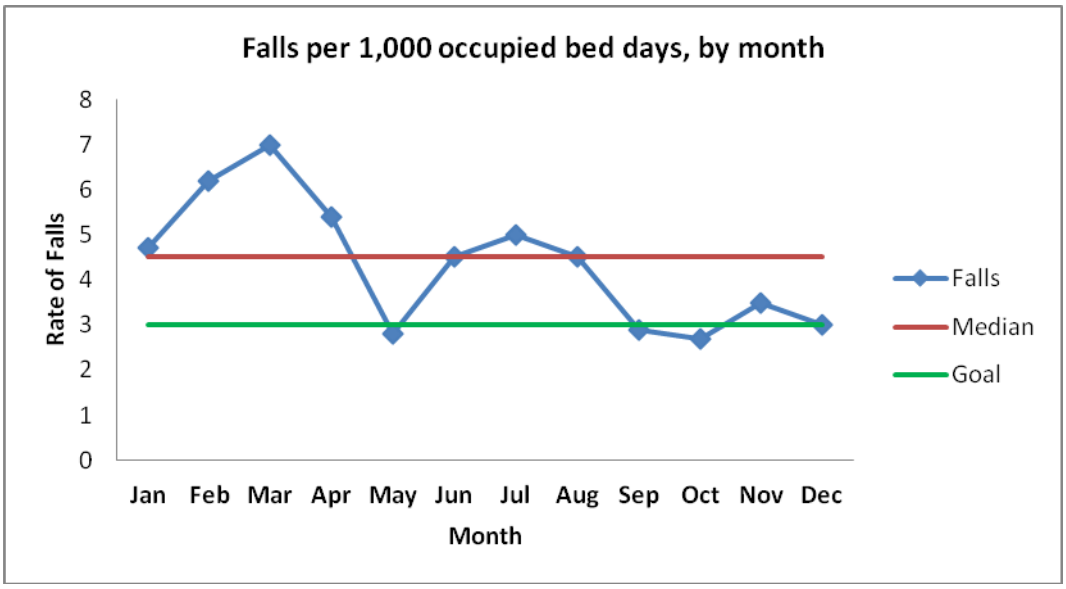
A run chart (sometimes termed a time plot) is a graphical display of data plotted in time order. Run charts can assist in understanding variation and are used to examine data for trends or other patterns that occur over time. Run charts visually depict the history and patterns of variation in an indicator or measure. Plotting data regularly on a graph shows when shifts and changes occur, and can help identify if and when problems appear.

Run charts are easy to construct. A run chart can be constructed with paper and pencil. Run charts do not require statistical methodology and can be easily and quickly understood.

The run chart is one of a number of tools that help people see patterns or trends in data over time. It is useful for:

- Understanding variation and identifying trends or other patterns in the data over time (see Figure 1)
- Demonstrating the impact of interventions over time. This is achieved by annotating the run chart (see Figure 3)
- Displaying and plotting data such as counts, mean values and proportions in chronological order.

Figure 1: Run Chart



The run chart is a running record of a process over time. The above chart is an example of a run chart with the months of the year listed on the X axis and the number of falls on the Y axis. Each month the number of falls is plotted and each point is joined with a short line (in this example a blue line). The blue line therefore outlines the number of falls per month over the period of one year. The red line provides the median number of falls. The median is the preferred centre line for a run chart, as it minimises the point to point variation.

The median can be easily found by simply taking a sheet of paper and sliding it over the chart from the top down until half of the data points are above and half below the centreline. In this case, with 12 points, there will be half of the points above and half below the median, with 2 points on the median. The green line shows the goal of the initiative i.e. a maximum of three falls per 1,000 occupied bed days occurring per month.

Note that the median is the middle value in a dataset when the numbers are reordered from highest to lowest value. If the number of observations is even, then the median is taken to be the average of the 2 middle values. For example, Table 1 shows the number of falls by week over a period of 7 weeks.

Table 1: Number of falls by week

Week	Number of Falls
1	5
2	4
3	9
4	7
5	6
6	6
7	2

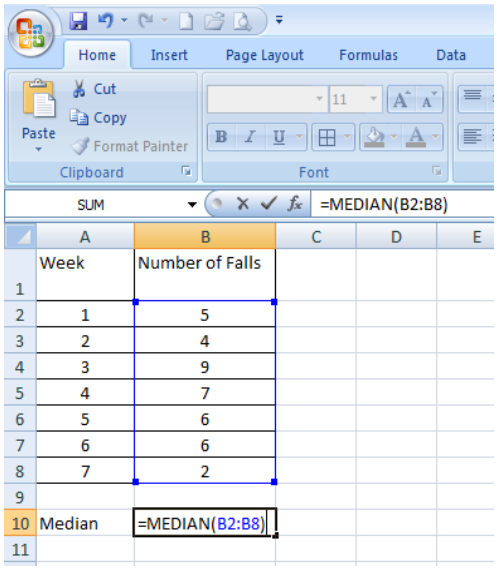
The number of falls reordered from highest to lowest value is as follows:

9 7 6 **6** 5 4 2

The median is the middle value: 6

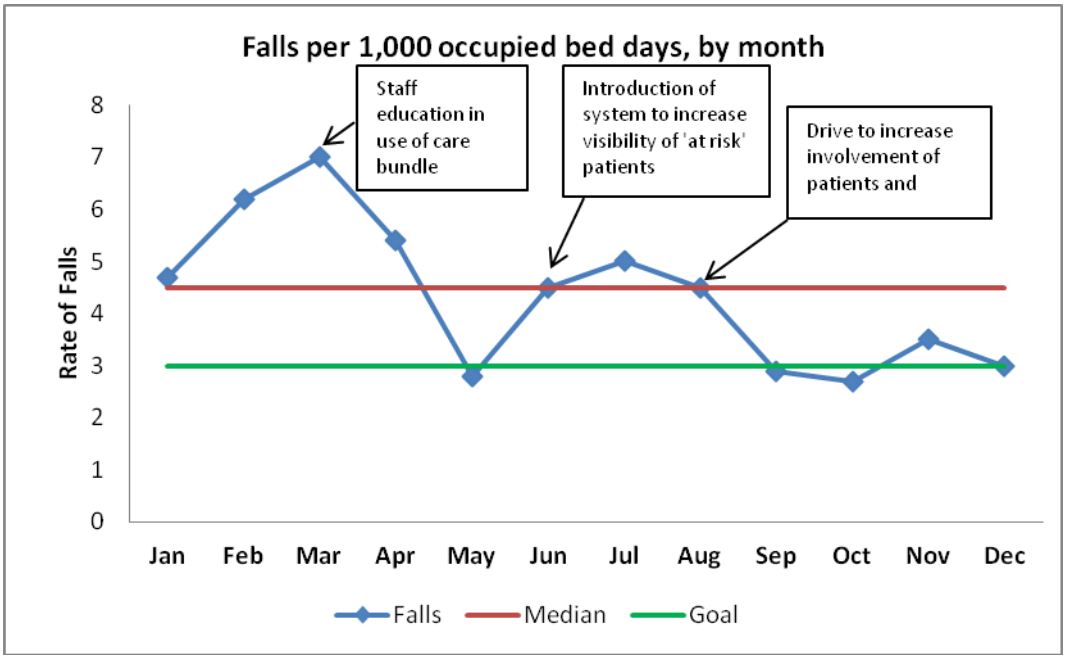
The median for a range of values can be calculated in Excel using the MEDIAN formula (Figure 2).

Figure 2: Calculating Median in Excel



Annotating the run chart, as illustrated in Figure 3, will assist you in identifying the impact of changes introduced.

Figure 3: Annotated Run Chart

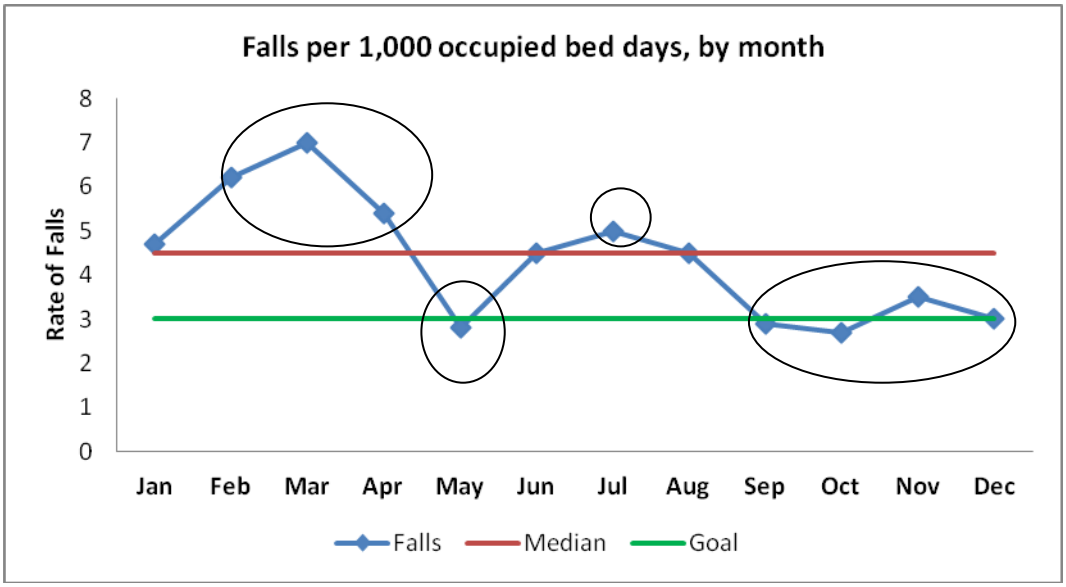


Multiple measures are usually required to evaluate an improvement process. Small multiples of run charts can be useful, e.g. the same measure plotted using data from a number of wards. It is important though to use the same scale for a rapid visual comparison. It is possible to plot more than one measure on a run chart, either on the same axis or by using two different vertical axes where the measures are dissimilar in scale.

What is a "Run"?

A run is defined as one or more consecutive data points on the same side of the median. A run could have a single point, or many points. Figure 4 shows a run chart with the runs circled. In this chart there are 4 runs. Notice that the runs exclude any points that are on the median line.

Figure 4: Run Chart with Four Runs



How to interpret a run chart

If improvement is not visually obvious on the chart, the following probability based rules may be helpful in identifying non-random signals in the data *(Perla RJ, Provost LP, Murray SK. The run chart: A simple analytical tool for learning from variation in healthcare processes. BMJ Quality & Safety. 2011 Jan;20(1):46-51.)*

1. A shift: 6 or more consecutive points either all above or below the median
2. A trend: 5 or more consecutive points all going up or all going down (ignoring consecutive values that are the same)
3. Too many or too few runs: based on how many times the data line crosses the median. This requires a table showing the number of runs that may be too few or two many based on the number of data points not crossing the median (Table 1, Perla et al.) This indicates that there is a non-random pattern.
4. An astronomical data point: this is a non-probability based rule and refers to an obviously different value. Anyone studying the chart would agree it's unusual. (Note every dataset will have a high and low data point – this does not mean that the high or low values are astronomical).

Run charts can be started immediately, even if there is only one data point. Even where there are several points it can be useful to extend the time period beyond the last data point. It is usual to wait until there are at least 10 points before using the median for the probability based rules. However rule 2 (a trend) can be detected early on, as can rule 4 (an astronomical point). Also note it is possible to calculate the median from baseline data that doesn't show any signals (shift, trend, runs or astronomical data point) and extend this initial median into the future. New data added to the chart will not influence the median, although a new median can be calculated at a later date and added to the chart.

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Run Chart Videos: https://youtu.be/YQd1QoMHYwU and https://youtu.be/8e38RCU8-uA

Variation

Variation exists in all aspects of life: among people and among institutions. In the early twentieth century, Walter Shewhart developed the concept that variation should be viewed in one of two ways:

1. Variation indicating that something has changed or is not right (special cause variation), or
2. Random fluctuation that continues over time and does not indicate that a particular change has occurred. (Common Cause variation).

Common Cause variation is created by many factors, which are commonly part of the process, and are acting totally at random and independent of each other. Their origin can usually be traced to the key elements of the system in which the process operates (Materials, Equipment, People, Environment, Methods). For example you may say it takes you 20 minutes to drive to work in the mornings but in reality your journey depends on traffic, road works, weather, school holidays etc. If you plotted the time taken to travel to work over a two week period, you would find variation depending on conditions; some days it could be 20 minutes and other days it may be 18 or indeed 25 minutes. This is common cause variation and therefore is normal to expect. If only common causes of variation are present, the output of a process forms a distribution that is stable over time.

Special Cause variation is created by a non-random event leading to an unexpected change in the process output. The effects are intermittent and unpredictable. If Special Causes of variation are present, the process output is not stable over time and is not predictable. All processes can only be brought into statistical control if Special Cause variation is first detected, and then removed.

The key to Shewhart's concept is that, while there should not be an automatic reaction to each observation of normal variation, patterns do require attention; hence decisions should be based on the nature of the variation. If special cause variation is found there should be a thorough examination of possible causes. If this examination reveals opportunities for improvement, these improvements must be instituted.

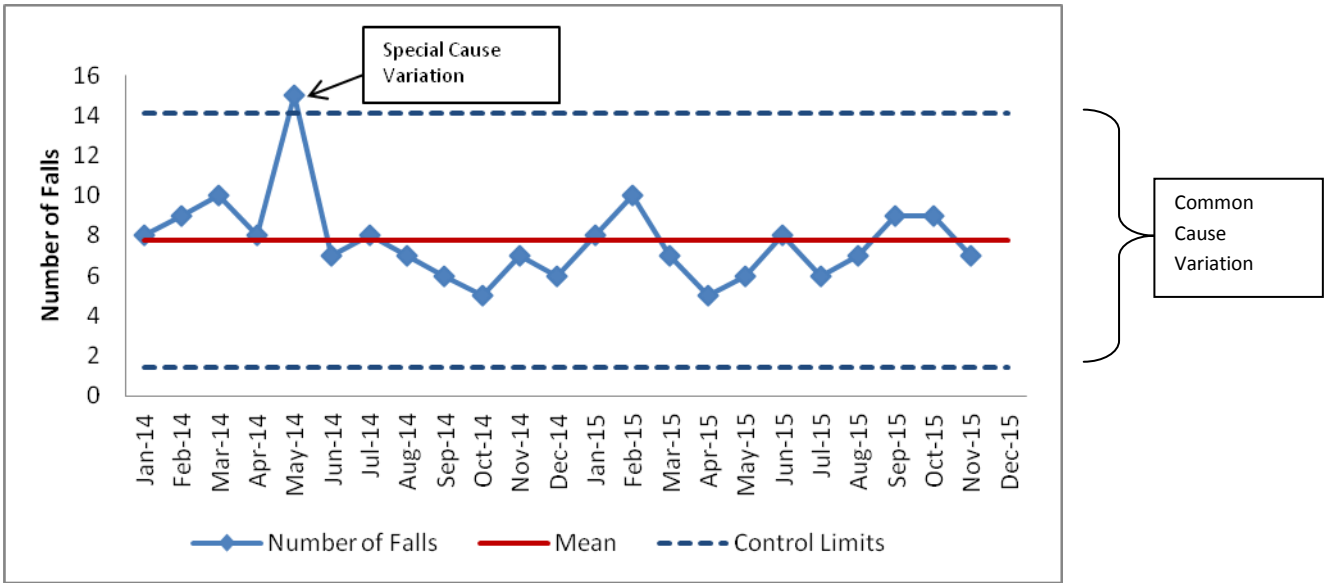
In order to examine data for variation, Shewhart charts, a type of statistical process control charts, are required.

Shewhart charts

Run charts are a first look at a measure of a process before going on to develop a Shewhart chart. A run chart is useful early on when you don't have a lot of data and want to quickly detect signals of improvement. Run charts are also easy to construct and less complex than a control chart. However run charts cannot distinguish special cause from common cause variation.

Shewhart charts are used when greater interpretation or knowledge of a process is required. A Shewhart chart is a run chart with the additional feature of displaying upper and lower statistical control limits for a particular process. These control limits, calculated according to statistical formulas, usually represent 3 standard deviations above and below the mean. They indicate how much variation is typical for the process. They provide boundaries for assessing how much variation in a process is within statistical control (common cause or random variation). When points fall outside the limits or form particular patterns, they may suggest the presence of a special cause of variation deserving of investigation (See Figure 5.)

Figure 5: Shewhart Chart Example – Number of Falls by Month



If special causes of variation are removed, or their impact at least reduced, a process is more likely to be 'in statistical control' and its performance more predictable. This opens the way for more fundamental improvements to the process. Shewhart charts may therefore be used to:

- Look at random variation in a process and whether the process is in control.
- Determine what the variation means – is it due to common factors or produced by special causes?
- Assess whether a team has gained more control of a process by reducing variation.

How to interpret a Shewhart chart:

Similar to run chart rules, there are a number of rules used in Shewhart charts that can be used to detect special cause variation:

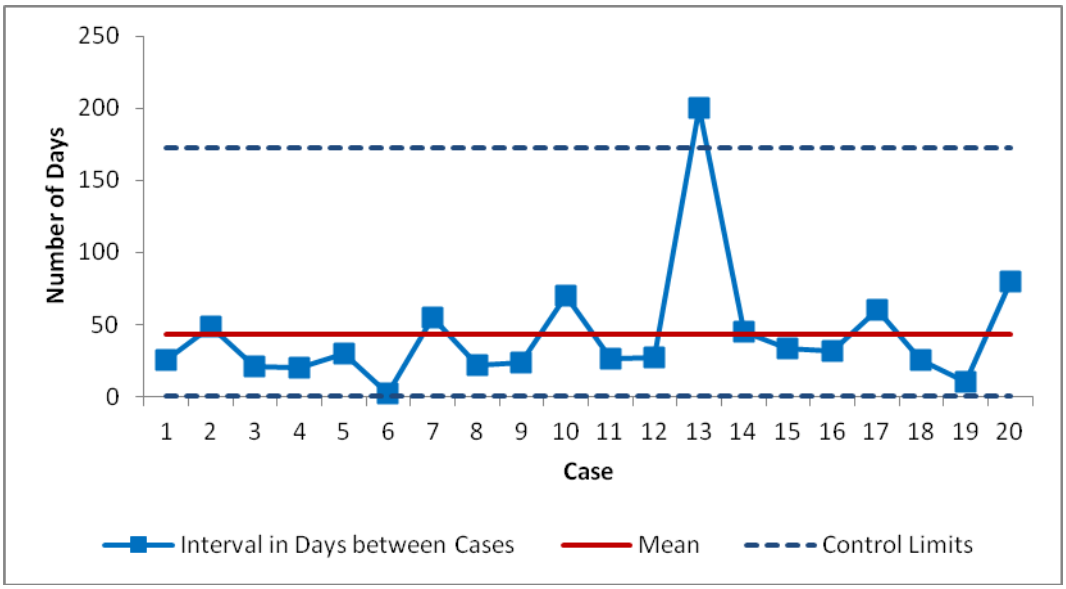
1. A single point outside the control limits (this doesn't include points exactly on the limit)
2. A run of 8 or more consecutive points above or below the centreline

3. A trend of at least 6 consecutive points going up or down
4. 2 out of 3 points near a control limit (outer third)
5. 15 consecutive points close to the centreline (inner third)

Choosing the right Shewhart chart:

Selecting the appropriate type of Shewhart chart depends on the data being analysed. The most common charts that you will be using in your quality profile are charts based on counts (e.g. the number of falls) or rates (e.g. the rate of falls per 1,000 bed days). For rare events, plotting the time between events on a Shewhart chart can be more useful than plotting the number or rate of events within a time period (see Figure 6).

Figure 6: Shewhart Chart Example – Interval in Days between Retained Foreign Objects



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Control Chart Videos: https://youtu.be/9kmbIj5zRtA and https://youtu.be/lQ3woMr822U