How to use Statistical Process Control (SPC) charts?

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Contents

Why do we use statistical process control (SPC) charts?

Statistical Process Control (SPC) charts are used to study how a system or process changes over time. It allows us 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 the best tools to determine:

- The variation that lives in the process.
- Predict how the process will perform in the future.
- If our improvement strategies have had the desired effect.
- Determine if an improvement strategy has sustained the gains.

What is a statistical process control (SPC) chart?

Statistical Process Control (SPC) charts consist of data over time and come in two forms:

1. **Run charts**
2. **Control chart** (also known as a Shewhart chart).

Figure 1a and 1b illustrate the elements of both charts.

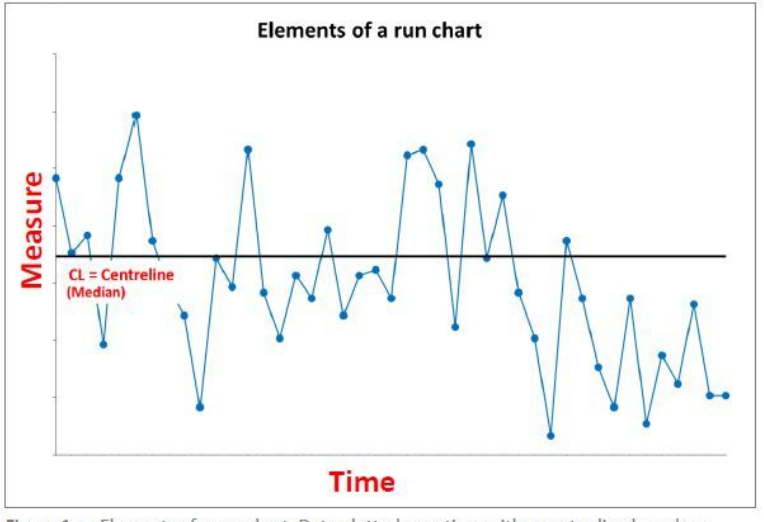


Figure 1a – Elements of a run chart. Data plotted over time with a centre line based on the median value

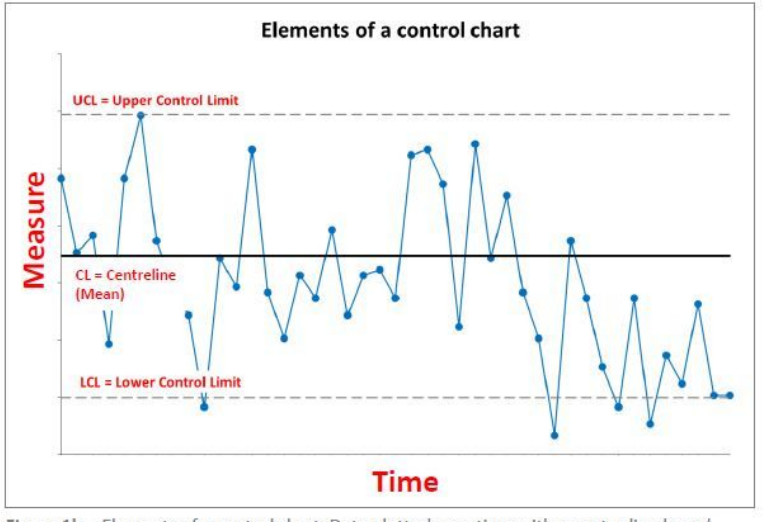


Figure 1b – Elements of a control chart. Data plotted over time with a centre line based on the mean value, an upper control limit and a lower control limit.

What is a statistical process control (SPC) chart?

Statistical Process Control (SPC) charts consist of data over time and come in two forms:

1. **Run charts** – *can take any data type i.e. count, percentage, rate, days between etc*
2. **Control chart** (also known as a Shewhart chart) – *each data type has a specific chart*

There is only one type of run chart and many different types of control charts (figure 2).

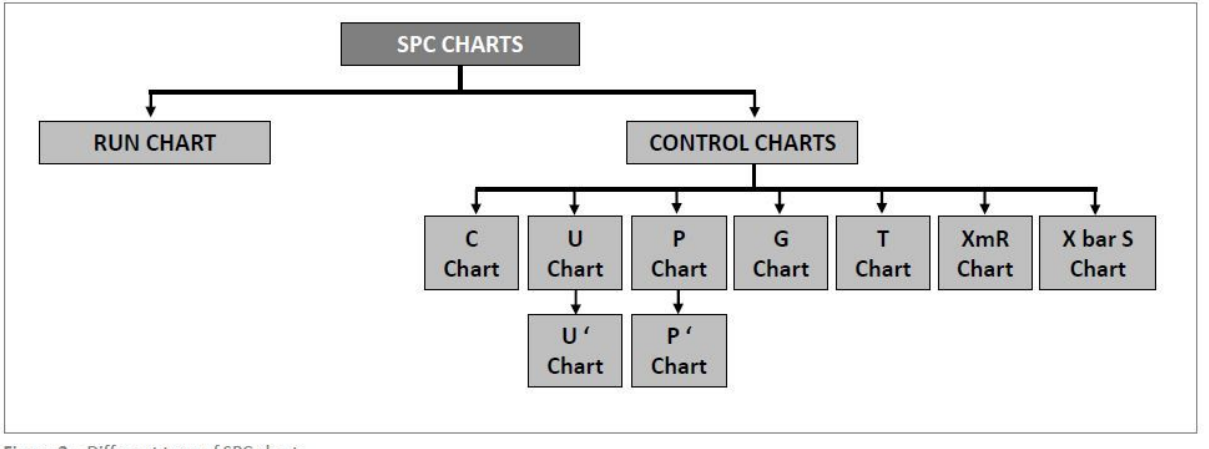


Figure 2 – Different type of SPC charts

How to choose between a line chart, run chart and control chart?

When constructing an SPC chart, you need to make sure you have the correct number of data points. Figure 3 explains how to choose the right chart?

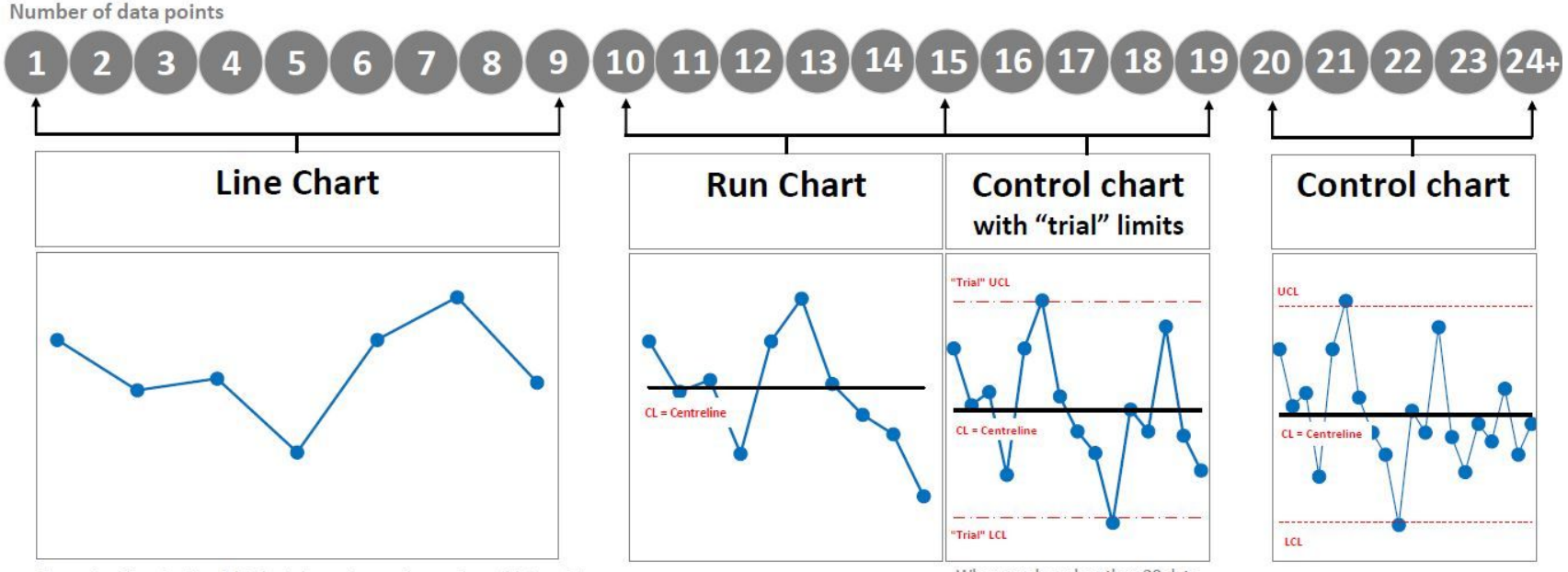
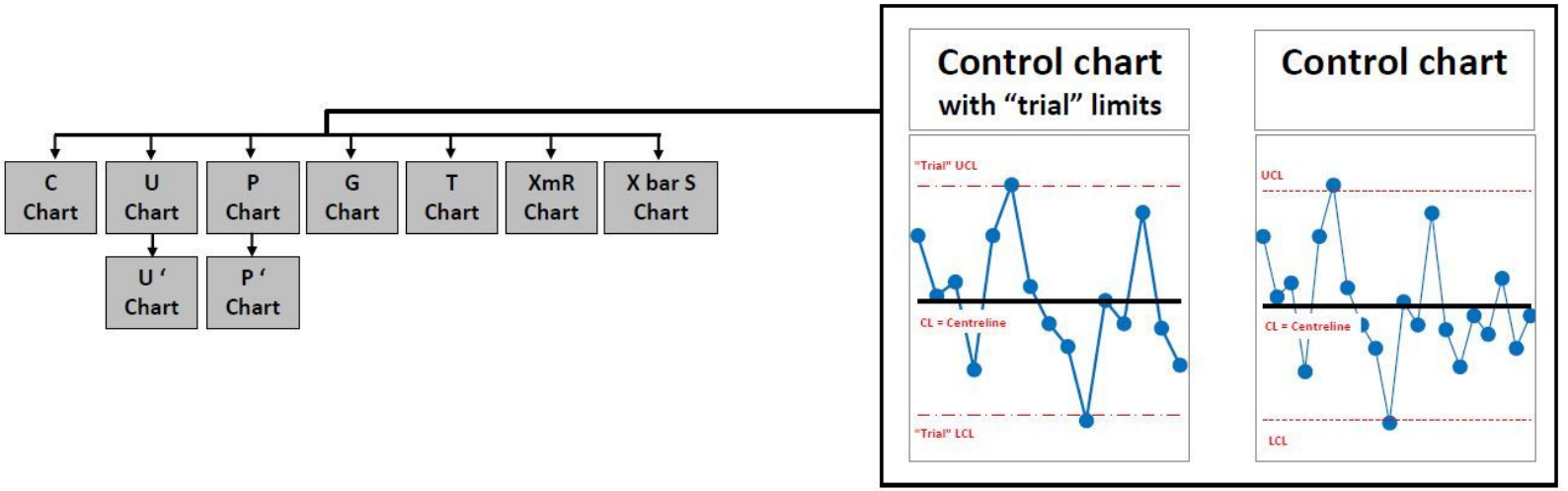


Figure 3 – Choosing the right chart depending on the number of data points.

When you have less than 20 data points, you can create a control chart with "trial" limits. Once you reach 20 points, you would recalculate the limits again.

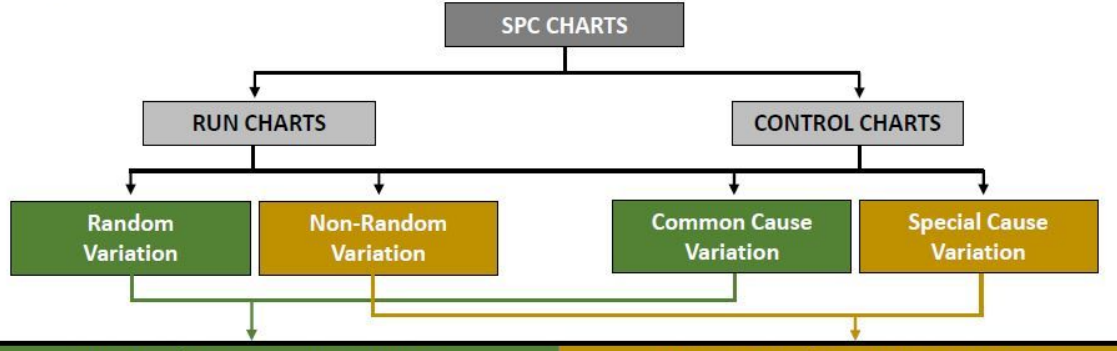
How to choose between a line chart, run chart and control chart?

When using a control chart, it is important you choose the right one. There are different types of control charts depending on what type of data you're looking at. **Appendix 1** and **Appendix 2** provide guidance on choosing the correct chart.



The different type of variation that exists within a process/system

By ordering the data points over time, we can identify the variation that exists within process/system. Figure 4 describes how we describe these.



Random / Common cause variation	Non-random / Special cause variation
Is inherent in the design of the process	Is due to irregular or unnatural causes that are not inherent in the design of the process
Is due to regular, natural or ordinary causes	Affect some, but not necessarily all aspects of the process
Affects all the outcomes of a process	Results in an "unstable" process that is not predictable
Results in a "stable" process that is predictable	Also known as non-random or assignable variation
Also known as random or unassignable variation	

Figure 4 – Different type of variation that exists within a process/system

What to do when seeing non-random/special cause variation

There are specific rules that help us identify non-random variation (**Appendix 3**) / special cause variation (**Appendix 4**) within an SPC charts.

When we see any of these rules within a chart, we need to take the following steps:

1. Investigate what caused it? Was it due to internal (i.e. change in process) or external factors (i.e. cyber attack)?

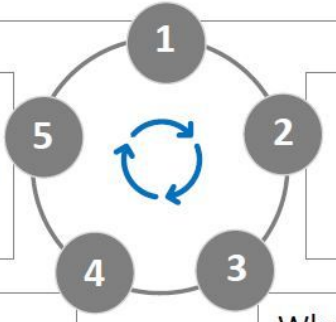
2. Determine if any action is needed

3. Revise centreline and control limits (if appropriate)

When do you revise the centre line and control limits?

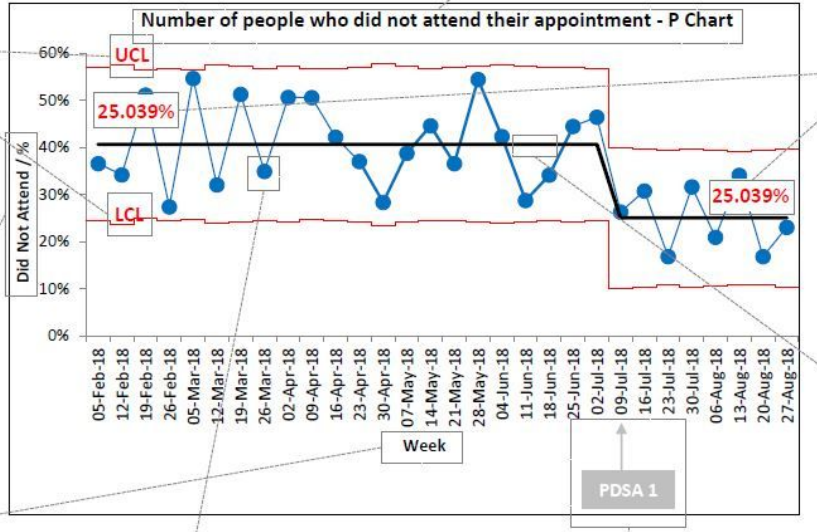
Below are **five reasons** that warrant recalculating of limits.

1. When "trial" limits have been calculated with fewer than 20 subgroups.
2. When the initial control chart has special causes and there is a desire to use the calculated limits for analysis of data to be collected in the future
3. When the control chart remains unstable for 20 or more subgroups and approaches to identify and remove the special causes have been exhausted.
4. When improvements have be made to the process and the improvements result in special causes on the control chart.
5. When you change the operational definition.



Formatting recommendations when creating an SPC

When creating SPC charts at ELFT, please note the following recommendations regarding formatting.



Title of chart explains what you're measuring and the type of chart you're using

Limits clearly labelled

Centreline clearly labelled and value added. Rounded to 3 decimal places

Don't use bright colours for centreline. As a standard, ELFT uses **Black**

X-axis and Y-axis clearly labelled

Don't use bright colours for data points. As a standard, ELFT uses **Blue**

Annotations added to chart to explain special cause

Limit recalculation based on the five reasons explains in previous slide

APPENDIX 1 – Control (Shewhart) chart selection guide

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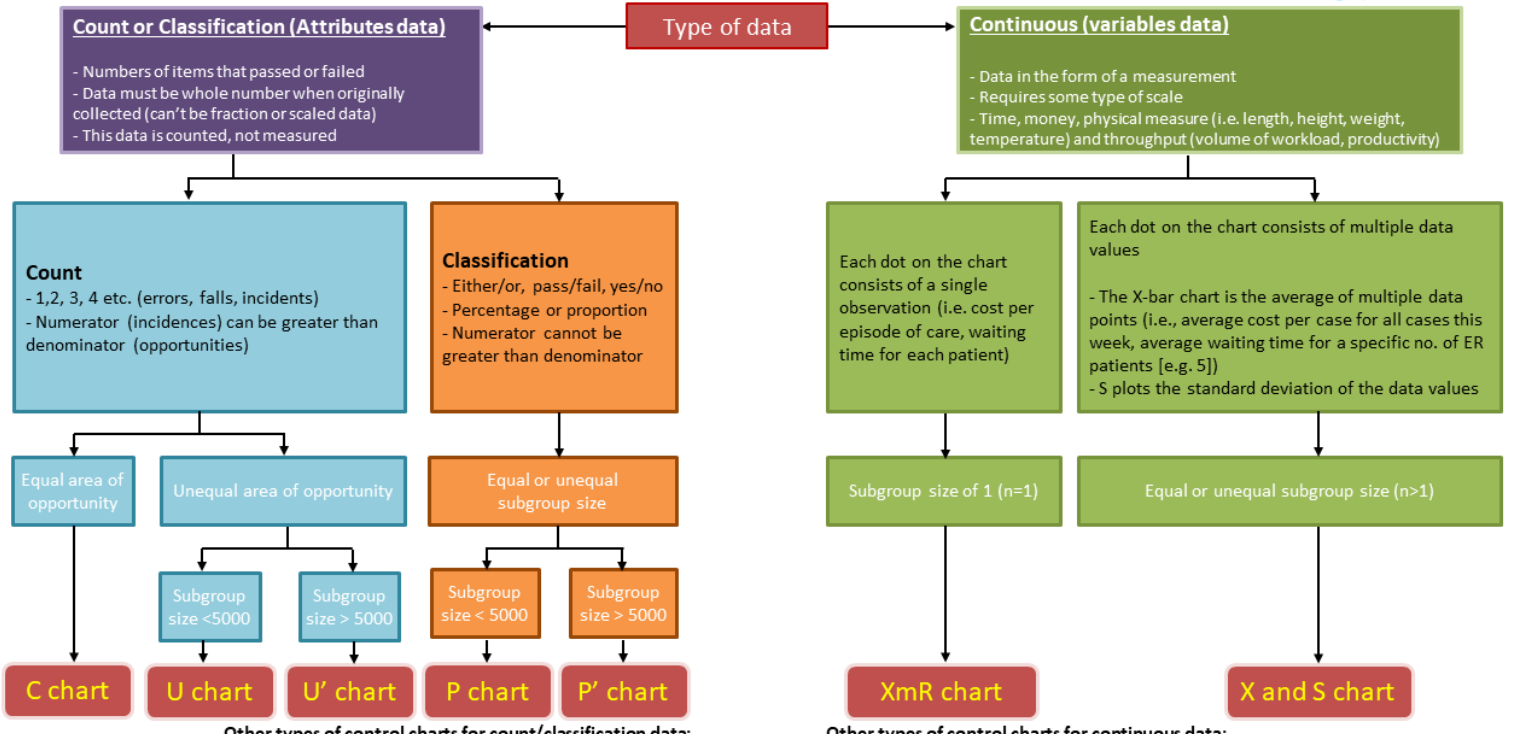

Other types of control charts for count/classification data:

- T Chart [time between rare events]
- G Chart [case between rare events]

Other types of control charts for continuous data:

- X-bar and Range Chart
- Median and Range Chart

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APPENDIX 2 – Flowchart for selecting the most appropriate control (Shewhart) chart

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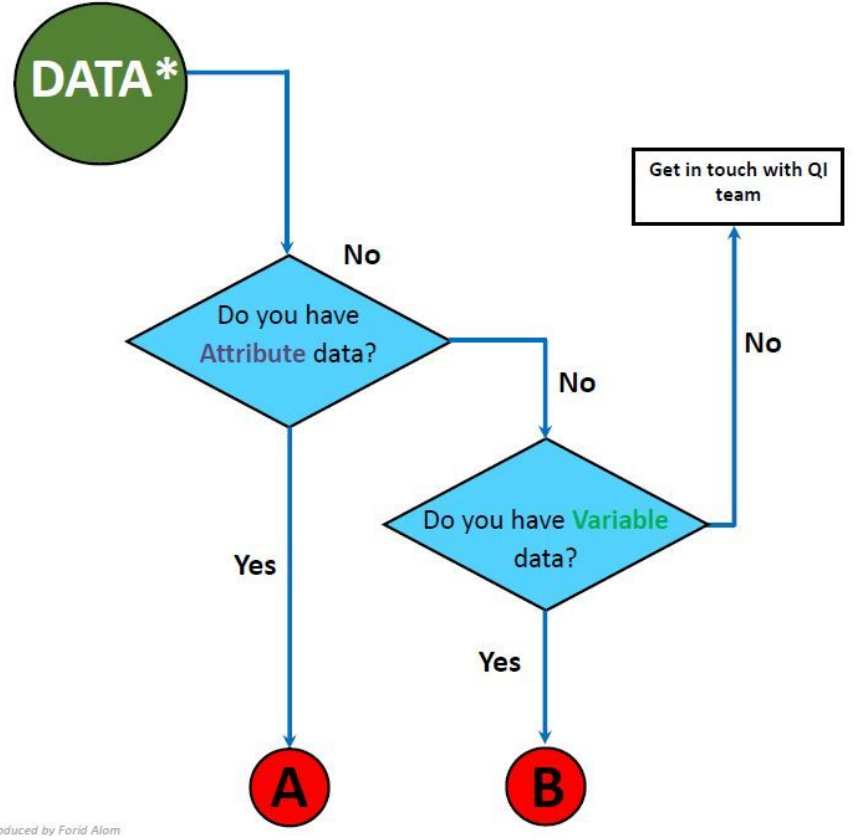

*A **run chart** may be used with any type of data. It is often the starting point for viewing data over time when little data are yet available.

Attribute data can only take particular values. There may potentially be an infinite number of those values, but each is distinct and there's no grey area in between. The data can be numeric when counting unwanted events – for example *number of falls* – but it can also be categorical – such as *pass or fail, male or female, good or bad.*

Important points about **attribute** data:

- It is counted, not measured.
- Data must be whole numbers when collected (can't be fraction or scaled data)
- There is two sub-types:
  - Count of attribute data
  - Classification data

Typical examples:

- Number of falls
- Number of violent incidents per 1,000 occupied bed days
- % of missed doses
- % of service users scoring "effective" or "very effective" for patient care

Variable data relates to counting of activity, and also measurement on a scale (e.g. time, money).

Important points about **Variable** data:

- Data is sometimes counted and sometimes measured. When measured, it might be in decimals or fractions.
  - Measurement of time
  - Measurement of money
  - Physical measure (length, height, weight, temperature)
  - Counting throughput (volume of workload, activity)
- It requires some type of scale

Typical examples

- Waiting times for 1st appointment
- Service user length of stay
- Service user weight
- Number of referrals received

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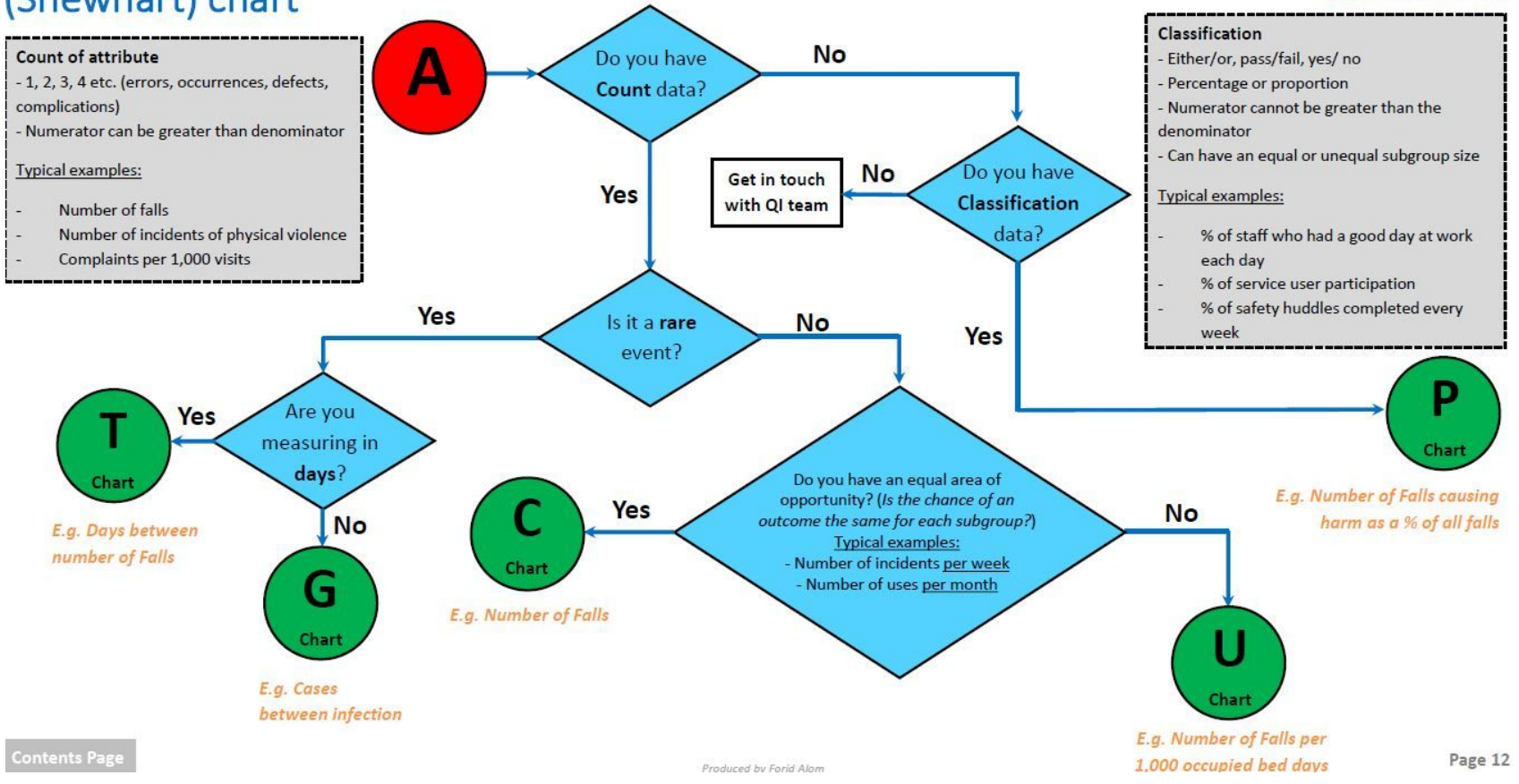
APPENDIX 2 – Flowchart for selecting the most appropriate control (Shewhart) chart



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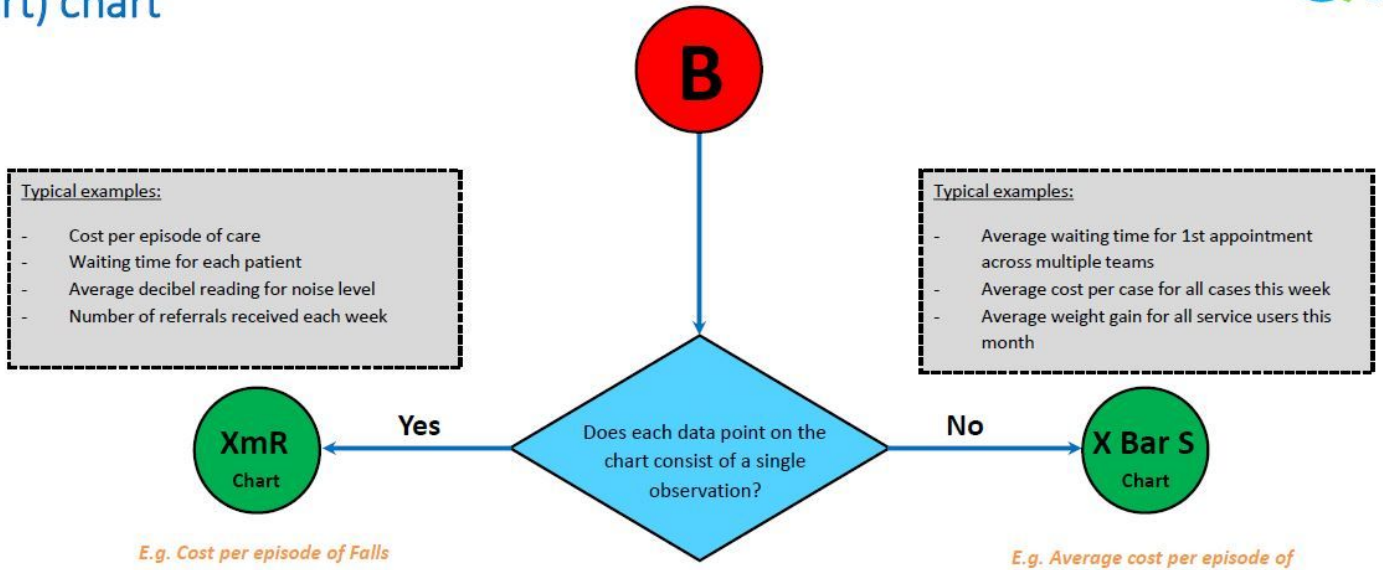
APPENDIX 2 – Flowchart for selecting the most appropriate control (Shewhart) chart

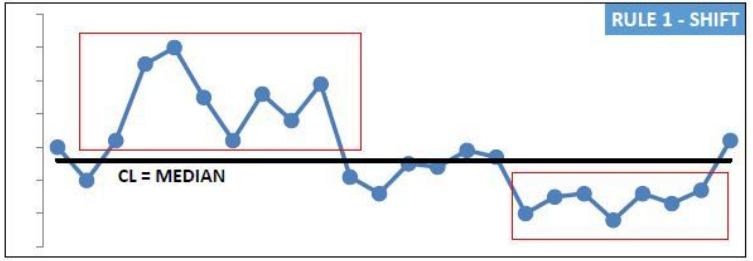


X Bar S chart characteristics:

- Two charts are created:
  - An average chart known as the X bar chart
    - Upper and lower control limit vary with sample size
    - Y-axis usually the average of a measurement
  - A standard deviation chart known as the S chart
    - Y-axis is the standard deviation of all data points making up each point on the X bar chart

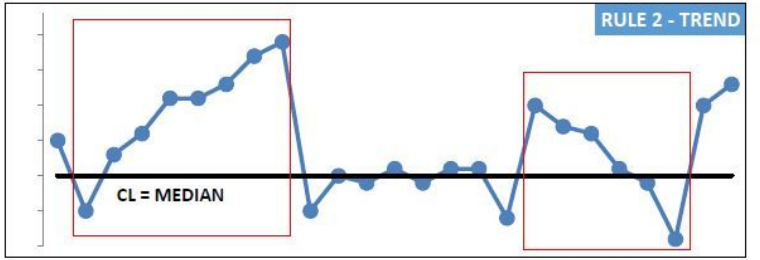
APPENDIX 3 – Rules of Non-Random Variation for a Run Chart

There are **four rules** for a run chart that help you identify non-random variation.



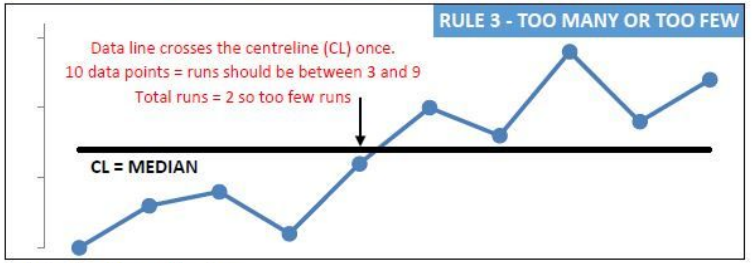
Rule 1 – Shift

Six or more consecutive points either all above or all below the centreline (CL). Values that fall on the CL do not add to nor break a shift. Skip values that fall on the median and continue counting



Rule 2 – Trend

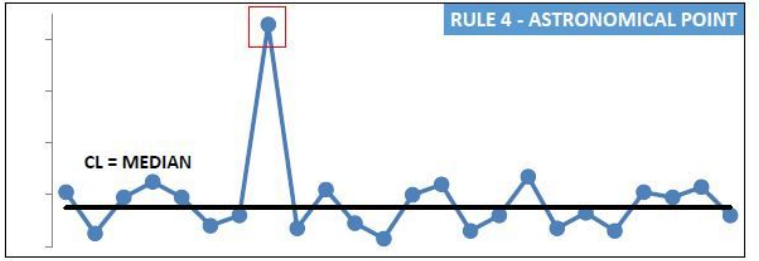
Five or more consecutive points all going up or all going down. If the value of two or more successive points is the same (repeats), ignore the like points when counting.



Rule 3 – Too Many or Too Few

If there are too many or too few runs, this is a sign of non-random variation. To see what an appropriate number of runs for a given number of data sets, refer to the table on the next page. An easy way to count the number of runs is to count the number of times the line connecting all the data points crosses the median and add one. If the number of runs you have are:

- Within the range outlined in the table, then you have a random pattern.
- Outside the range outline in the table, then you have a non-random pattern or signal of change.



Rule 4 – Astronomical point

This is a data point that is clearly different from all others. This is a judgement call. Different people looking at the same graph would be expected to recognise the same data point as astronomical.

APPENDIX 3 – Rules of Non-Random Variation for a Run Chart

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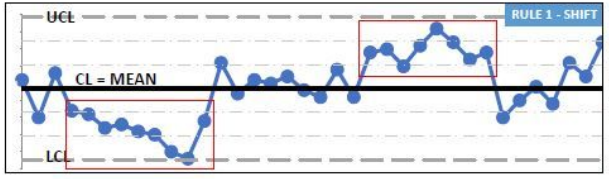
Table 1 - Runs Rule Guidance – Table for checking too many or too few runs on a Run chart

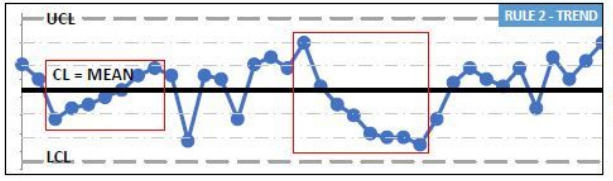
Total no. of data points on run chart not falling on	Lower limit for no. of runs (< than this is "too few")	Upper limit for no. of runs (>than this is "too many")	Total no. of data points on run chart not falling on	Lower limit for no. of runs (< than this is "too few")	Upper limit for no. of runs (>than this is "too many")
10	3	9	**37**	13	25
11	3	10	**38**	14	26
12	3	11	**39**	14	26
13	4	11	**40**	15	27
14	4	12	**41**	15	27
15	5	12	**42**	16	28
16	5	13	**43**	16	28
17	5	13	**44**	17	29
18	6	14	**45**	17	30
19	6	15	**46**	17	31
20	6	16	**47**	18	31
21	7	16	**48**	18	32
22	7	17	**49**	19	32
23	7	17	**50**	19	33
24	8	18	**51**	20	33
25	8	18	**52**	20	34
26	9	19	**53**	21	34
27	10	19	**54**	21	35
28	10	20	**55**	22	35
29	10	20	**56**	22	36
30	11	21	**57**	23	36
31	11	22	**58**	23	37
32	11	23	**59**	24	38
33	12	23	**60**	24	38
34	12	24			
35	12	24			
36	13	25			

APPENDIX 4 – Rules of Special Cause for a Control Chart

There are **five rules** for a control chart that help you identify special cause variation.

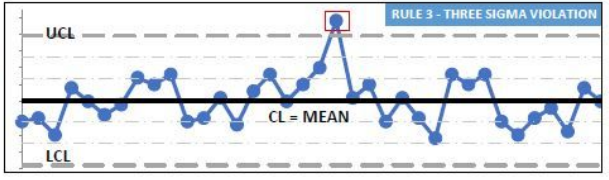


Rule 1 – Shift
Eight or more consecutive points either all above or all below the centreline (CL). Values that fall on the CL do not add to nor break a shift. Skip values that fall on the mean and continue counting

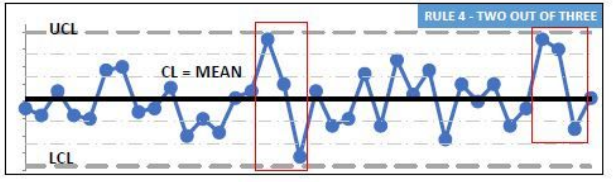


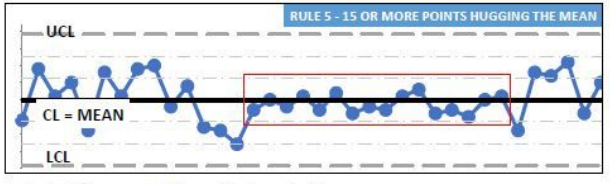
Rule 2 – Trend
Six or more consecutive points all going up or all going down. If the value of two or more successive points is the same (repeats), ignore the like points when counting.

Rule 3 – Three Sigma Violation
When you have a data point that exceeds the UCL/LCL.



Rule 4 – Two out of three
When you get two out of three consecutive points in the outer one-third of chart.





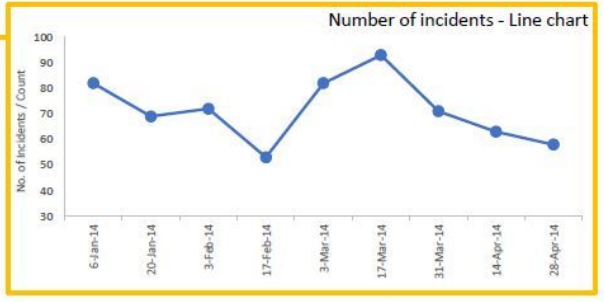
Rule 5 – 15 or more data points hugging the mean
15 or more data points hugging the centreline (inner one-third of the chart). In a normal distribution, you should have around 68% of the data near the mean of the distribution (+/- 1 standard deviation). When you get a pattern like this, you're exceeding the 68%.

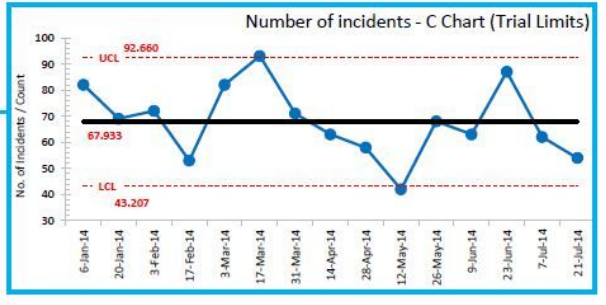
APPENDIX 5 – Chart Example 1 (Count Data)

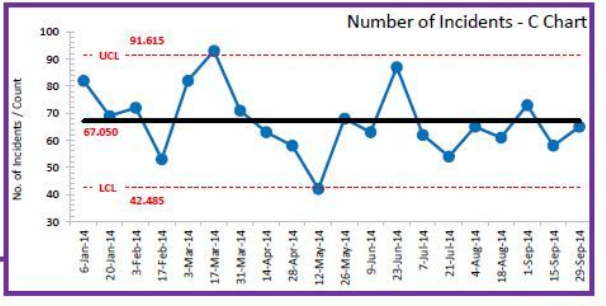
Here is an example of the SPC charts you'd expect when measuring **count** data i.e. No. of incidents.

Type of data			
Attributes data		Variables data	
Count	Classification	Single Observation	Multiple Observations

Date	No. of Incidents
6-Jan-2014	82
20-Jan-2014	69
3-Feb-2014	72
17-Feb-2014	53
3-Mar-2014	82
17-Mar-2014	93
31-Mar-2014	71
14-Apr-2014	63
28-Apr-2014	58
12-May-2014	42
26-May-2014	68
9-Jun-2014	63
23-Jun-2014	87
7-Jul-2014	62
21-Jul-2014	54
4-Aug-2014	65
18-Aug-2014	61
1-Sep-2014	73
15-Sep-2014	58
29-Sep-2014	65







APPENDIX 5 – Chart Example 2 (Classification Data)

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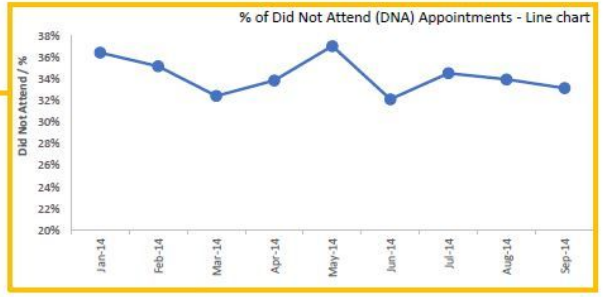
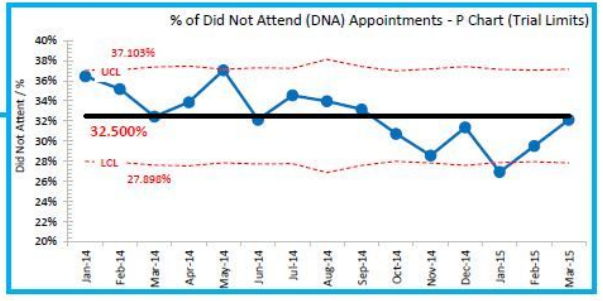
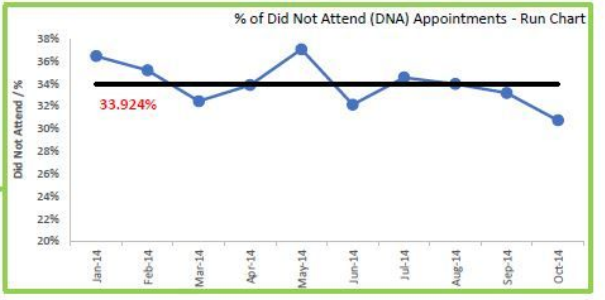
Here is an example of the SPC charts you'd expect when measuring **classification** data i.e. DNA %

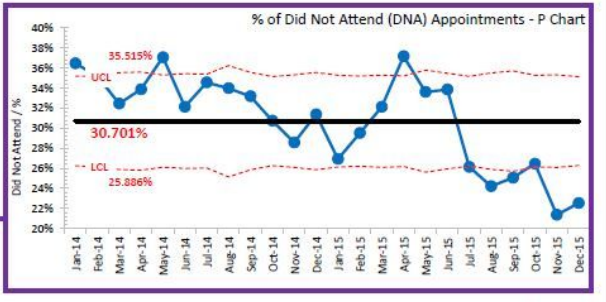
Type of data			
Attributes data		Variables data	
Count	Classification	Single Observation	Multiple Observations

Month	DNA	Total Appts	% DNA
Jan-14	351	963	36.45%
Feb-14	328	932	35.19%
Mar-14	268	826	32.45%
Apr-14	272	803	33.87%
May-14	338	912	37.06%
Jun-14	277	862	32.13%
Jul-14	303	877	34.55%
Aug-14	212	624	33.97%
Sep-14	271	817	33.17%
Oct-14	300	976	30.74%
Nov-14	258	903	28.57%
Dec-14	256	816	31.37%
Jan-15	247	917	26.94%
Feb-15	281	952	29.52%
Mar-15	291	906	32.12%
Apr-15	350	942	37.15%
May-15	249	741	33.60%
Jun-15	286	845	33.85%
Jul-15	251	960	26.15%
Aug-15	201	830	24.22%
Sep-15	193	770	25.06%
Oct-15	243	918	26.47%
Nov-15	193	903	21.37%
Dec-15	222	985	22.54%









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APPENDIX 5 – Chart Example 3 (Variables Data)

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Here is an example of the SPC charts you'd expect when measuring **variables** data i.e. sickness days

Type of data			
Attributes data		Variables data	
Count	Classification	Single Observation	Multiple Observations

Date	Sickness (Days)
01-Jan-14	252
01-Feb-14	108
01-Mar-14	120
01-Apr-14	130
01-May-14	175
01-Jun-14	183
01-Jul-14	230
01-Aug-14	220
01-Sep-14	183
01-Oct-14	201
01-Nov-14	262
01-Dec-14	189
01-Jan-15	203
01-Feb-15	128
01-Mar-15	220
01-Apr-15	198
01-May-15	156
01-Jun-15	134
01-Jul-15	148
01-Aug-15	198
01-Sep-15	169
01-Oct-15	170
01-Nov-15	197
01-Dec-15	242
01-Jan-16	203