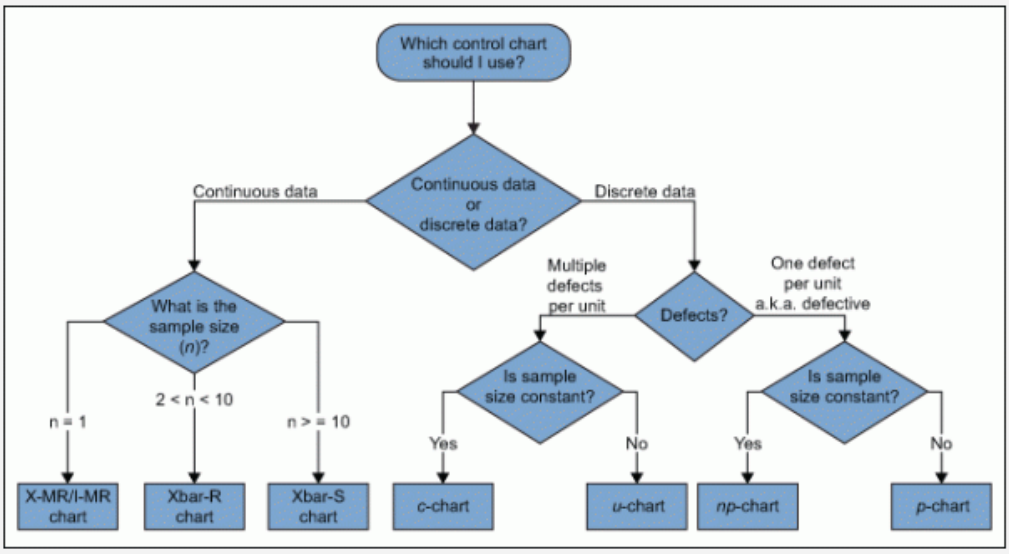
SPC Charts: A Primer

Figure 13: How to Select a Control Chart



Source: http://www.isixsigma.com/tools-templates/control-charts/a-guide-to-control-charts/

Summary of formulae for plotting four basic control charts

Type of data	Type of chart	Centre line	Three-sigma control limits
Continuous data (x) of which there are n items	x-chart	$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$	$\overline{x} \pm 2.26\,(\overline{mr})$
	mr-chart	$\overline{mr} = \frac{\sum_{i=2}^{n} mr_i}{n-1}$	$3.267\,(\overline{mr})$ (upper control limit only)
Proportion data (p) given by x/n where x is the number of occurrences and n is its number of opportunities.	p-chart	$\overline{p} = \frac{\sum_{i=1}^{n} x_i}{\sum_{i=1}^{n} n_i}$	$\overline{p} \pm 3\sqrt{\overline{p}(1-\overline{p})/n_i}$
Count data (u) with n observations each in a known "area of opportunity" n_i	u-chart	$\overline{u} = \frac{\sum_{i=1}^{n} u_i}{\sum_{i=1}^{n} n_i}$	$\overline{u} \pm 3\sqrt{\overline{u}/n_i}$
Count data (c) with n observations each with a constant "area of opportunity"	c-chart	$\overline{c} = \frac{\sum_{i=1}^{n} c_i}{n}$	$\overline{c} \pm 3\sqrt{\overline{c}}$

Source: Mohammed MA, Worthington P, Woodall WH. Plotting basic control charts: tutorial notes for healthcare practitioners. *Qual Saf Health care* 2008; 17: 137-145.

X-MR/I-MR Chart

Reading number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Systolic blood pressure (mmHg)	169	172	175	174	161	142	174	171	168	174	180	194	161	181	175	176	186	166	157	183	177	171	185	176	181	174
Moving range		3	3	1	13	19	32	3	3	6	6	14	33	20	6	1	10	20	9	26	6	6	14	9	5	7

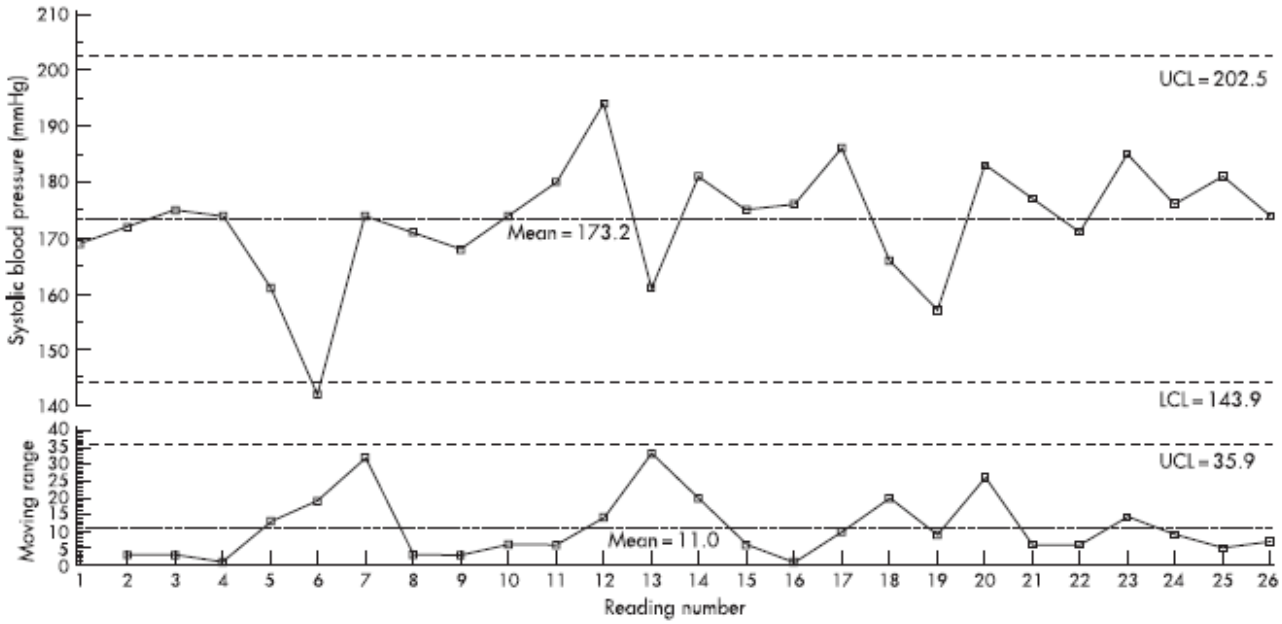


Figure 1 Example *xmr*-chart constructed by using systolic blood pressure readings of a patient. The top panel shows the data and the moving ranges, the middle panel is the *x*-chart and the lower panel is the *mr*-chart.

Source: Plotting basic control charts: tutorial notes for healthcare practitioners.

X-Chart: Used to detect trends and shifts in the data/process for an individual

- $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
- $CL = \bar{x} \pm 2.26(\overline{mr})$

MR-Chart: Used to assess the stability of process variation

- $\overline{mr} = \frac{\sum_{i=2}^{n} mr_i}{n-1}$
- $UCL = 3.267(\overline{mr})$
- $LCL = 0$

- Used with continuous data
- Used with scarce data
- Best when natural subgroup is unknown/not yet defined/unclear

p Chart

Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Number of patients admitted with fracture neck of femur (n)	56	53	45	44	46	50	48	48	42	46	41	55	48	58	62	72	57	60	65	100	77	76	84	73
Number died (x)	11	12	11	12	4	12	15	13	9	14	10	12	14	19	17	24	13	13	15	25	24	16	15	15
Proportion died (x/n)	0.20	0.23	0.24	0.27	0.09	0.24	0.31	0.27	0.21	0.30	0.24	0.22	0.29	0.33	0.27	0.33	0.23	0.22	0.23	0.25	0.31	0.21	0.18	0.21
Centre line	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Upper control limit	0.42	0.42	0.44	0.44	0.44	0.43	0.43	0.43	0.44	0.44	0.45	0.42	0.43	0.41	0.41	0.40	0.42	0.41	0.41	0.37	0.39	0.39	0.39	0.40
Lower control limit	0.07	0.07	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.04	0.07	0.06	0.08	0.08	0.09	0.07	0.08	0.09	0.12	0.10	0.10	0.10	0.09

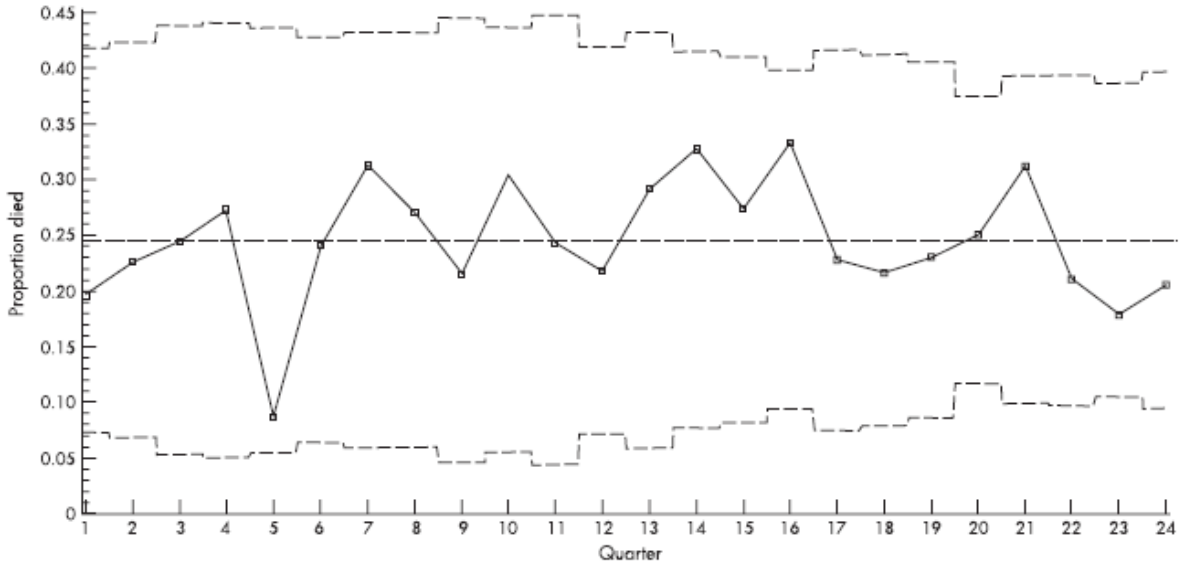


Figure 3 Example *p*-chart based on the proportion of deaths following admission to hospital for patients with a fractured neck of femur.

Qual Saf Health Care 2008;**17**:137–145. doi:10.1136/qshc.2004.012047

Source: Plotting basic control charts: tutorial notes for healthcare practitioners.

***p*-Chart (proportion chart):** Shows the number of tracked failures (np) divided by the number of total units (n)

- $\bar{p} = \frac{\sum_{i=1}^{n} x_i}{\sum_{j=1}^{n} n_j}$
- $CL = \bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_j}}$

- Used with discrete data
- Used when events are binary, independent of each other and have constant underlying probability of occurring
- Sample size is not constant

u Chart

Month	Oct 04	Nov 04	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05
Number of falls	1	4	3	4	2	3	5	2	0	2	6	2	5
Number of patient days	1048	896	918	995	866	896	864	930	732	630	492	622	612
Falls per patient day	0.000954	0.004464	0.003268	0.004020	0.002309	0.003348	0.005787	0.002151	0.000000	0.003175	0.012195	0.003215	0.008170
Centre line	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714	0.003714
Upper control limit	0.009361	0.009822	0.009748	0.009510	0.009927	0.009822	0.009934	0.009709	0.010471	0.010998	0.011956	0.011045	0.011104
Lower control limit	−0.001934	−0.002394	−0.002320	−0.002082	−0.002499	−0.002394	−0.002506	−0.002281	−0.003044	−0.003570	−0.004529	−0.003617	−0.003676

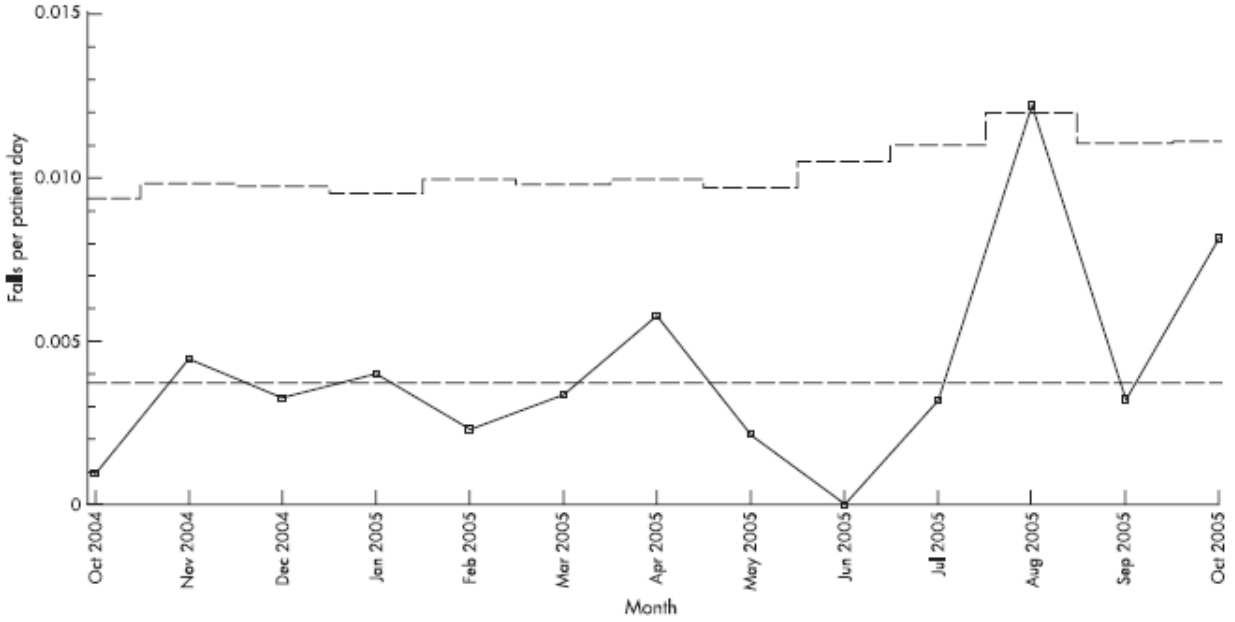


Figure 4 Example *u*-chart based on number of falls per patient-day over a 13-month period.

Source: Plotting basic control charts: tutorial notes for healthcare practitioners.

u-Chart: Shows the total count of defects per unit (u) that occur during the sampling period and can track a sample having more than one defect

- $\bar{u} = \frac{\sum_{i=1}^{n} u}{\sum_{j=1}^{n} n_j}$
- $UCL = \bar{u} \pm 3\sqrt{\frac{\bar{u}}{n_j}}$
- $LCL = 0$ – because count/attribute data cannot fall below 0

- Used with discrete data
- Used when events are binary, independent of each other and have constant underlying probability of occurring
- Best used for low frequency events
- Used when the number of samples of each period may vary significantly (unlike in *c*-charts)

c Chart

Monday number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of emergency admissions (c)	82	63	86	72	82	88	95	68	81	77	92	69	83	86	86	86	68	87	74	62	100	85

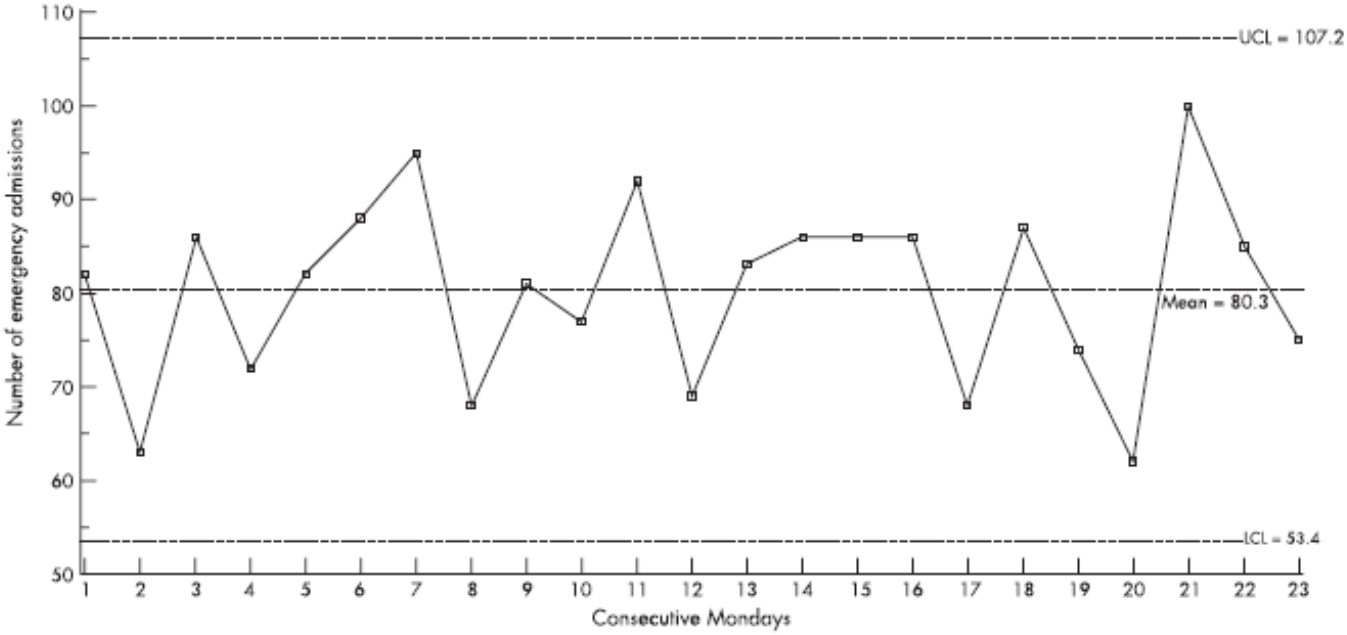


Figure 5 Example *c*-chart using number of emergency admissions on consecutive Mondays.

Qual Saf Health Care 2008;**17**:137–145. doi:10.1136/qshc.2004.012047

Source: Plotting basic control charts: tutorial notes for healthcare practitioners.

***c*-Chart:** Shows the total count of defects per unit (c) that occurred during sampling period

- $\bar{c} = \frac{\sum_{i=1}^{n} c_i}{n}$
- $CL = \bar{c} \pm 3\sqrt{\bar{c}}$

- Used with discrete data
- Used when events are binary, independent of each other and have constant underlying probability of occurring
- Usually unknown sample size, but assumed to be fairly large and constant