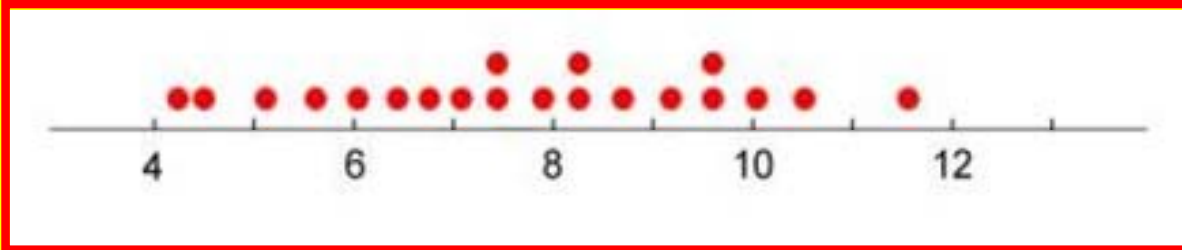
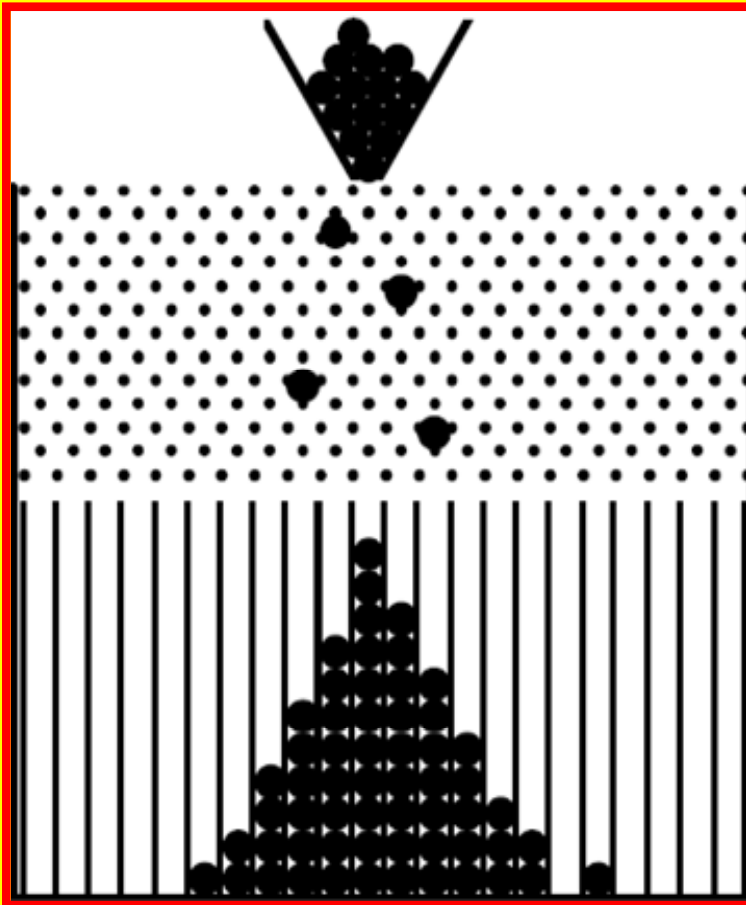


Dot Plots



A dot plot graphically records variable data in such a way that it forms a picture of the combined effect of the random variation inherent in a process and the influence of any special causes acting on it. To understand the power of dot plots as a basic tool, it first helps to visualize how variation occurs.

Sometimes, statisticians explain random variation by using a device called a quincunx.

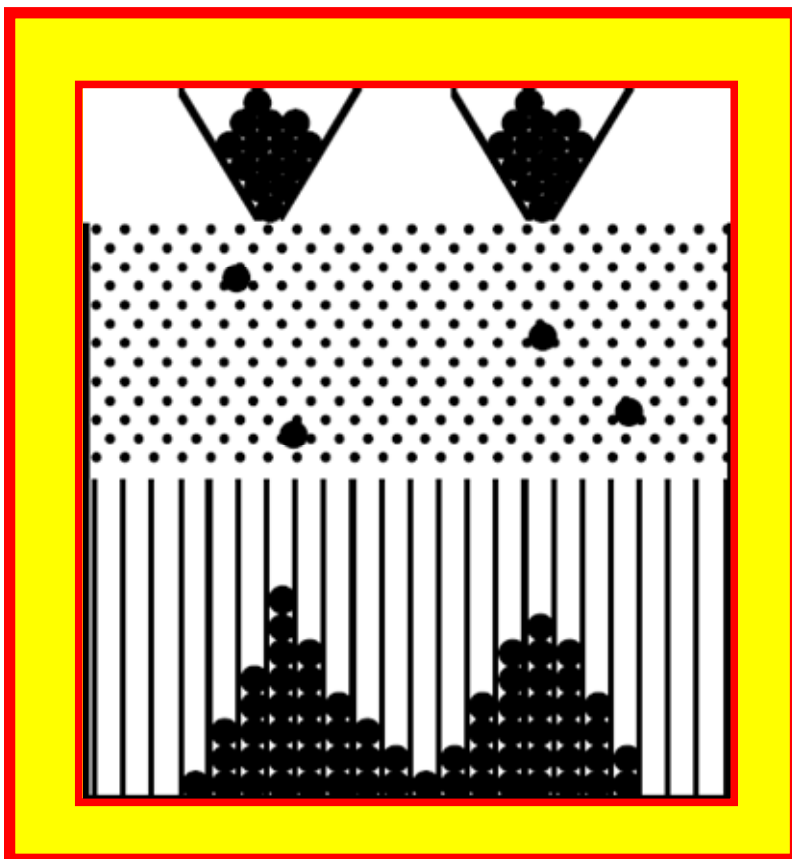
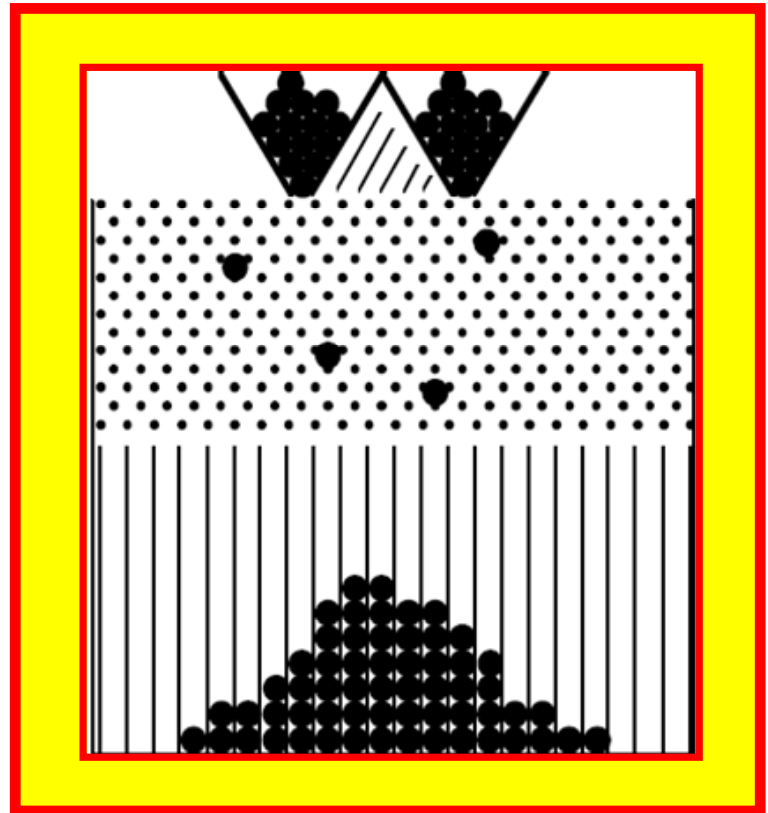


A quincunx is a box with a series of pins arranged in such a way that a ball dropped in the top will bounce randomly down the pins until it comes to rest in one of the channels at the bottom.

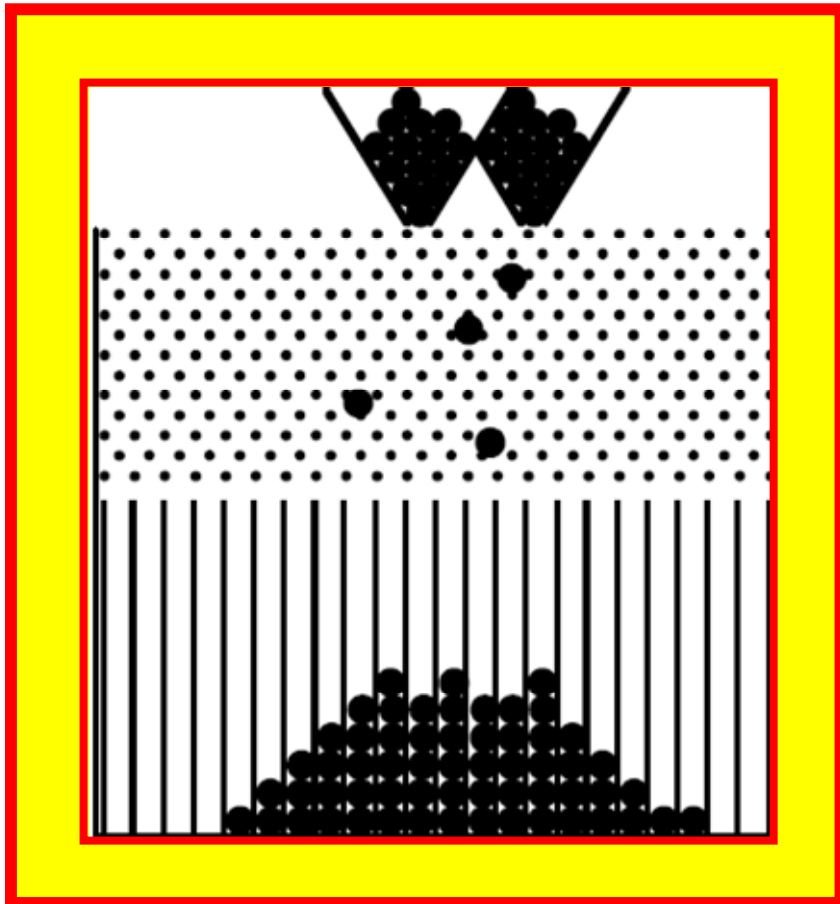
By varying the entry point of the balls, it is possible to show how adding special causes to random variation would affect the distribution of produced values.

A funnel is used to ensure that the balls start at the same place. The pins then act like the essential variation inherent in any process. After enough balls have been dropped through the funnel, the filled channels begin to resemble a standard distribution curve or a histogram of a uniform distribution.

If, for example, the position of the funnel were moved systematically around a central point (+1, +2, +3, +3, +1, 0, -1, -2, -3, -2, -1, 0, etc.), the distribution of the balls in the channels would widen and flatten.

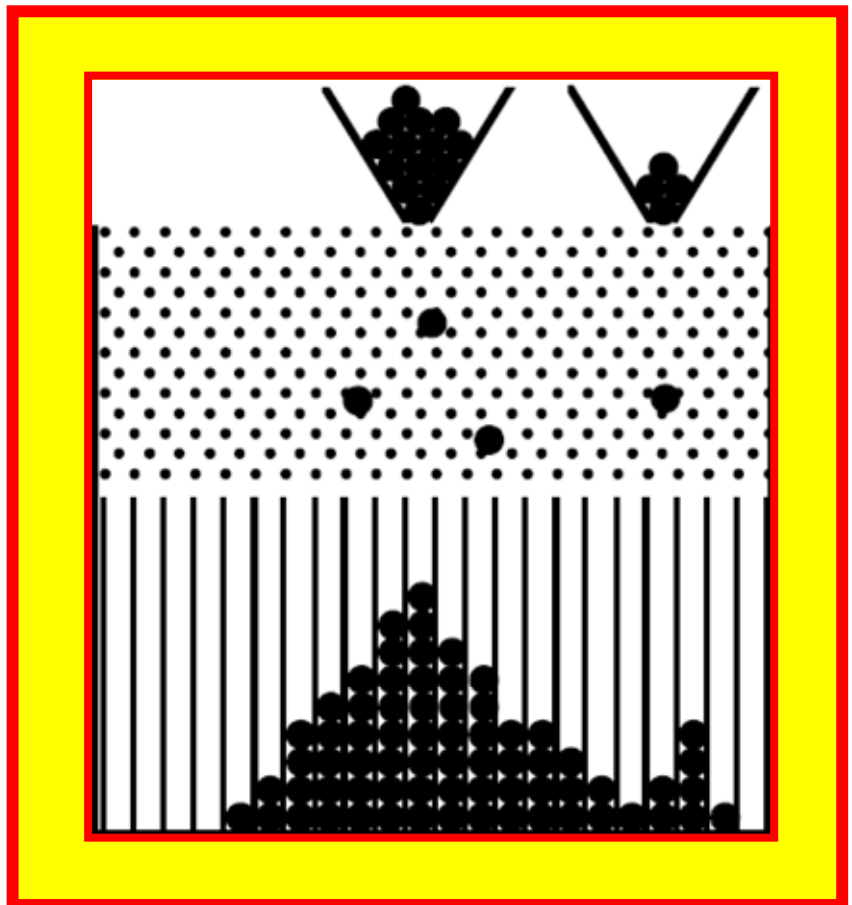


If the position of the funnel were alternated from side to side (+5, -5, +5, -5, etc.), the balls would eventually show a bi-modal or two-humped distribution. This is what a mixed lot of characteristics produced by two different suppliers, machines or workers might look like.



If the position of the funnel is moved steadily in one direction, then restarted and moved again in the same direction (0, +1, +2, +3, +4, 0, +1, +2, +3, +4, etc.), the distribution of the balls would form a plateau, a flat mountain with sloping sides. This may mimic what happens when a tool wears uniformly and then is replaced again and again.

If the position of the funnel is moved every now and then to a distant, off-center position, then returned to center (0, 0, 0, 0, 0, -7, 0, 0, 0, -7, 0, 0, 0, 0, 0, 0, 0, etc.), a group of outlying, disconnected balls would form. This could be like random, special-causes of variation, such as voltage spikes, that change process parameters.



Dot plots are the converse of quincunx experiments. To create a dot plot, each data point is recorded and placed as a dot on a graph. As additional data points with the same value as the first one occur, they are stacked like the balls in the quincunx channels. After many values have been recorded as dots, the resulting pattern can tell you something about the variation in your process.

What can it do for you?

- A dot plot can give you an instant picture of the shape of variation in your process. Often this can provide an immediate insight into the search strategies you could use to find the cause of that variation.
- Dot plots can be used throughout the phases of Lean Six Sigma methodology. You will find dot plots particularly useful in the measure phase.

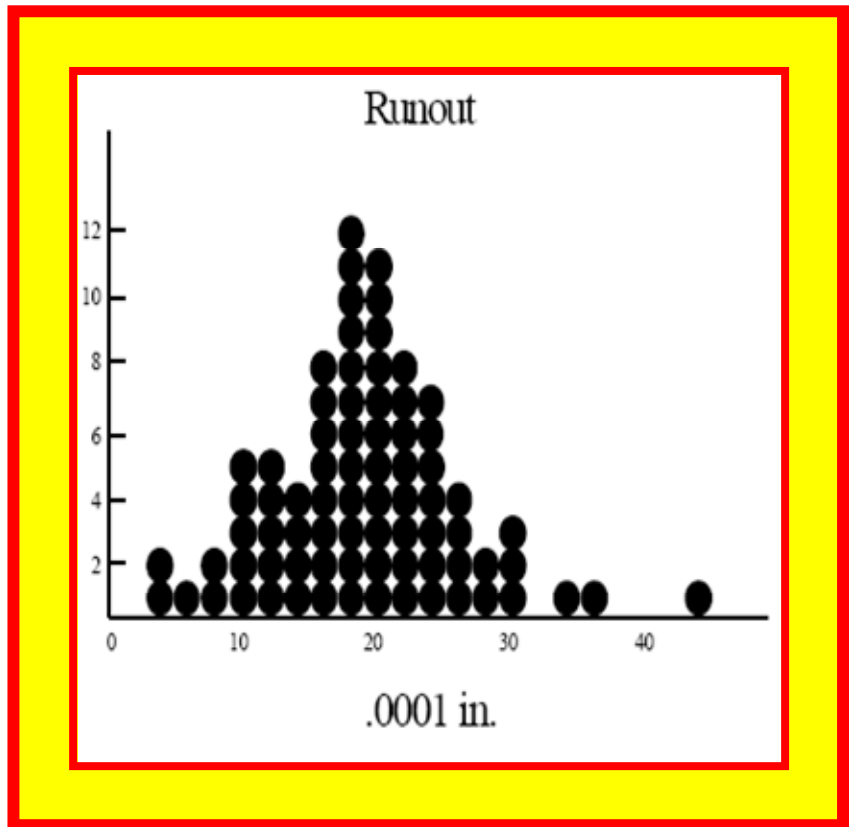
How do you do it?

1. **Decide which Critical-To-Quality characteristic (CTQ) you wish to examine.** This CTQ must be measurable on a linear scale. That is, the incremental value between units of measurement must be the same. For example, time, temperature, dimension and spatial relationship are usually able to be measured in consistent incremental units.
2. **Measure the characteristic and record the results.** If the characteristic is continually being produced, such as voltage in a line or temperature in an oven, or if there are too many items being produced to measure all of them, you will have to sample. Take care to ensure that your sampling is random.
3. **Count the number of individual data points.**
4. **Determine the highest data value and the lowest data value.** Subtract the lower number from the higher. This is the range. Use this range to help determine a convenient scale. For example, if the range of your data points was 6.7, you may want to use an interval of 8 or 10 for your scale.
5. **Determine how many subdivisions or columns of dots your scale should have.** To make an initial determination, you can use this table:

Data points	Subdivisions
under 50	5 to 7
50 to 100	6 to 10
100 to 250	7 to 112
over 250	10 to 20

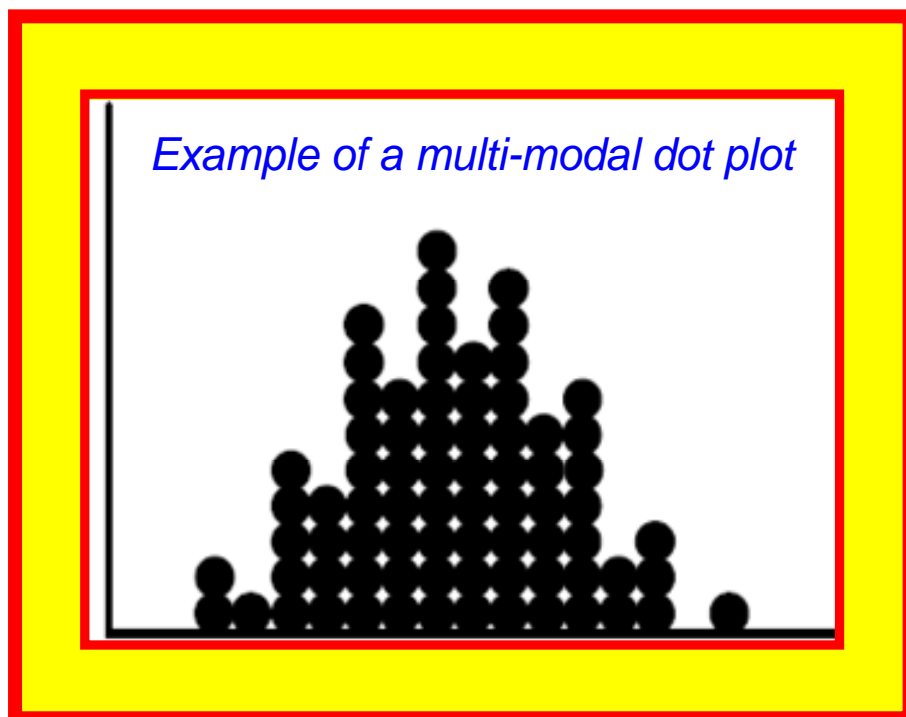
6. **Divide the range by the number of subdivisions.** You may round or simplify this number to make it easier to work with, but to get the best picture of the distribution of data points, the total number of subdivisions should be close to those shown above. You may want to increase the number of measurements, if that is possible, to provide a convenient scale. In determining the number of subdivisions, also consider how you are measuring data. Increase or decrease the number of subdivisions until there is essentially the same number of measurement possibilities in each one.

7. Divide the scale you have chosen by the appropriate number of subdivisions. Draw a horizontal line (x axis) and label it with the scale and the subdivisions.
8. Make a dot above the scale subdivision for each data point that falls in that subdivision. For subsequent data points in a subdivision, place a dot on top of the previous one. Make all the dots the same size and keep the columns of dots vertical.
9. If there are specification limits for the characteristic you are studying, indicate them as vertical lines.
10. Title and label your dot plot.



Now what?

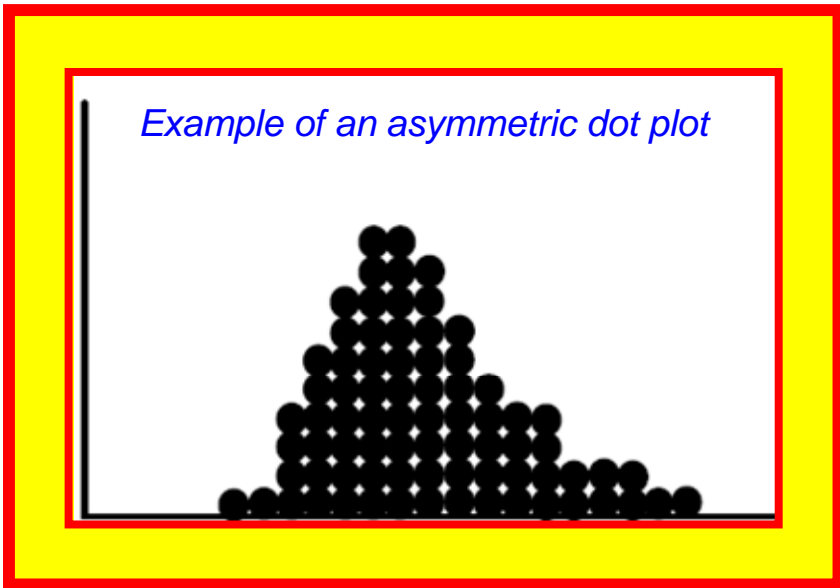
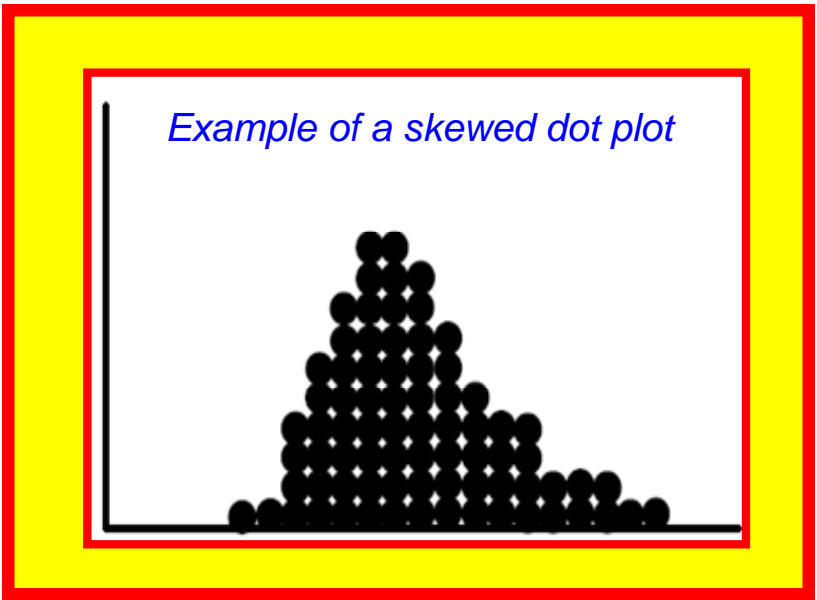
The shape that your dot plot takes tells a lot about your process. In a symmetric or bell-shaped dot plot, the frequency is high in the middle of the range and falls off fairly evenly to the right and left.



This shape occurs most often. If your dot plot takes other shapes, you should look at your process for otherwise unseen causes of variation.

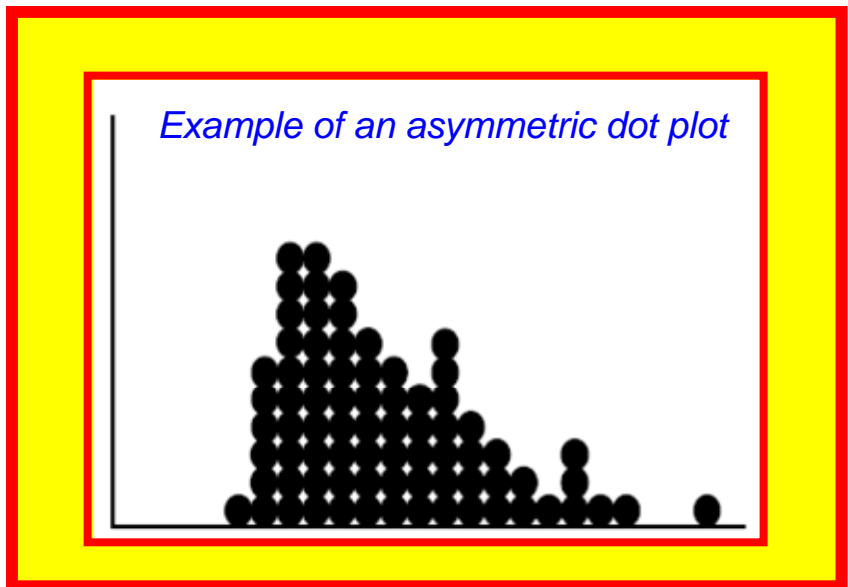
In a comb or multimodal type of dot plot, adjacent subdivisions alternate higher and lower in frequency. This usually indicates a data collection problem. The problem may lie in how a characteristic was measured or how values were rounded to fit into your dot plot. It could also indicate a need to use different subdivision boundaries.

If the distribution of frequencies is shifted noticeably to either side of the center of the range, the distribution is said to be skewed. When a distribution is positively skewed, the frequency decreases abruptly to the left but gently to the right. This shape normally occurs when the lower limit, the one on the left, is controlled either by specification or because values lower than a certain value do not occur for some other reason.

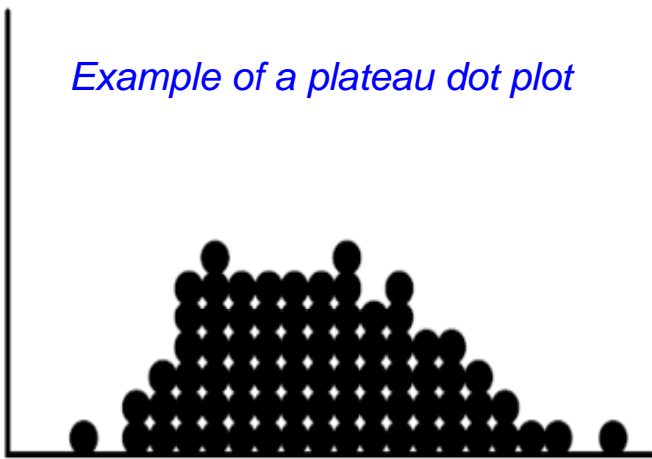


If the skewness of the distribution is even more extreme, a clearly asymmetrical, precipice-type dot plot is the result.

This shape frequently occurs when a 100% screening is being done for one specification limit.



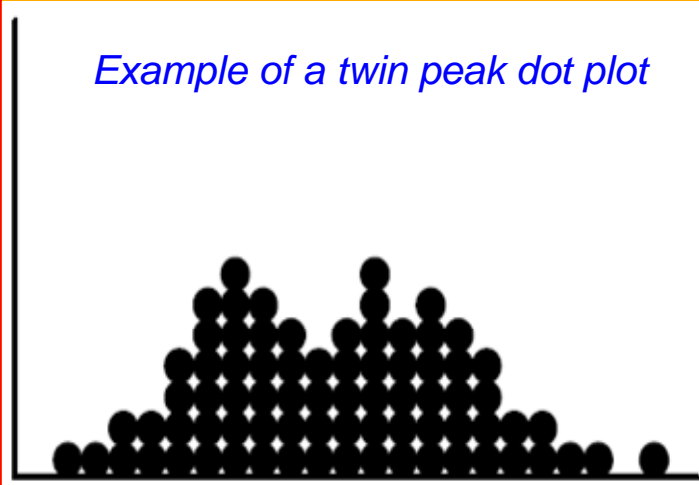
Example of a plateau dot plot



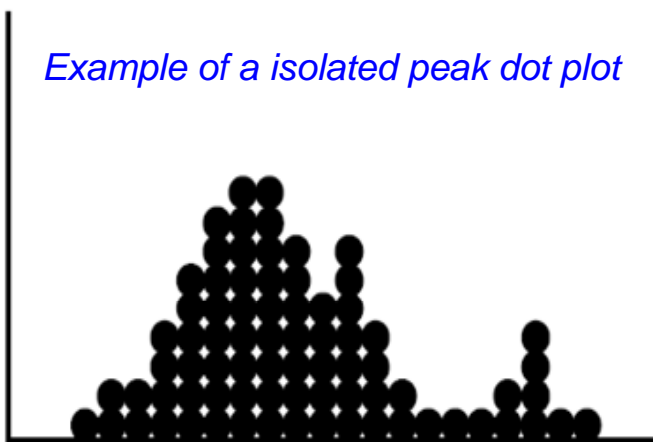
If the subdivisions in the center of the distribution have more or less the same frequency, the resulting dot plot looks like a plateau. This shape occurs when there is a mixture of two distributions with different mean values blended together. Look for ways to stratify the data to separate the two distributions. You can then produce two separate dot plots to more accurately depict what is going on in the process.

If two distributions with widely different means are combined in one data set, the plateau splits to become twin peaks. Here, the two separate distributions become much more evident than with the plateau. Again, examining the data to identify the two different distributions will help you understand how variation is entering the process.

Example of a twin peak dot plot



Example of a isolated peak dot plot



If there is a small, essentially disconnected peak along with a normal, symmetrical peak, this is called an isolated peak. It occurs when there is a small amount of data from a different distribution included in the data set. This could also represent a short-term process abnormality, a measurement error or a data collection problem.

Some final tips

- A dot plot is an easy way to make a picture of the statistical variation in your process.
- Dot plots can quickly give you a comparative feel of sets of data, but they do have limitations. Because of the rounding of measured data to fit into created subdivisions, the resulting shape of the dot plot may be somewhat arbitrary. A slight adjustment in defining the subdivisions may produce a slightly different picture.
- If specification limits are involved in your process, the dot plot can be an especially valuable indicator for corrective action.
- A dot plot can show you not only if your process is in control, but also if it is relatively centered on your target value and if the variation in your process is within the specified tolerances.
- Not only can dot plots help you see which processes need improvement, by comparing initial dot plots with subsequent ones, they can also help you track that improvement.



Steven Bonacorsi is a Certified Lean Six Sigma Senior Master Black Belt instructor and coach. Steven Bonacorsi has trained hundreds of Master Black Belts, Black Belts, Green Belts, and Project Sponsors and Executive Leaders in Lean Six Sigma DMAIC and Design for Lean Six Sigma process improvement methodologies. He has led some of the largest deployments in the world and has saved hundreds of millions with his project teams results.

The AIT Group, Inc.
Steven Bonacorsi, Vice President,
MBA, MS-CIS, PMP
Lean Six Sigma Master Black Belt
3135 South Price Road, Suite 115
Chandler, AZ 85248-3549
Phone: +(1) 888.826.2484

sbonacorsi@comcast.net
<http://www.linkedin.com/in/stevenbonacorsi>
<http://www.theaitgroup.com>

