Process Capability & Performance (Pp, Ppk, Cp, Cpk)

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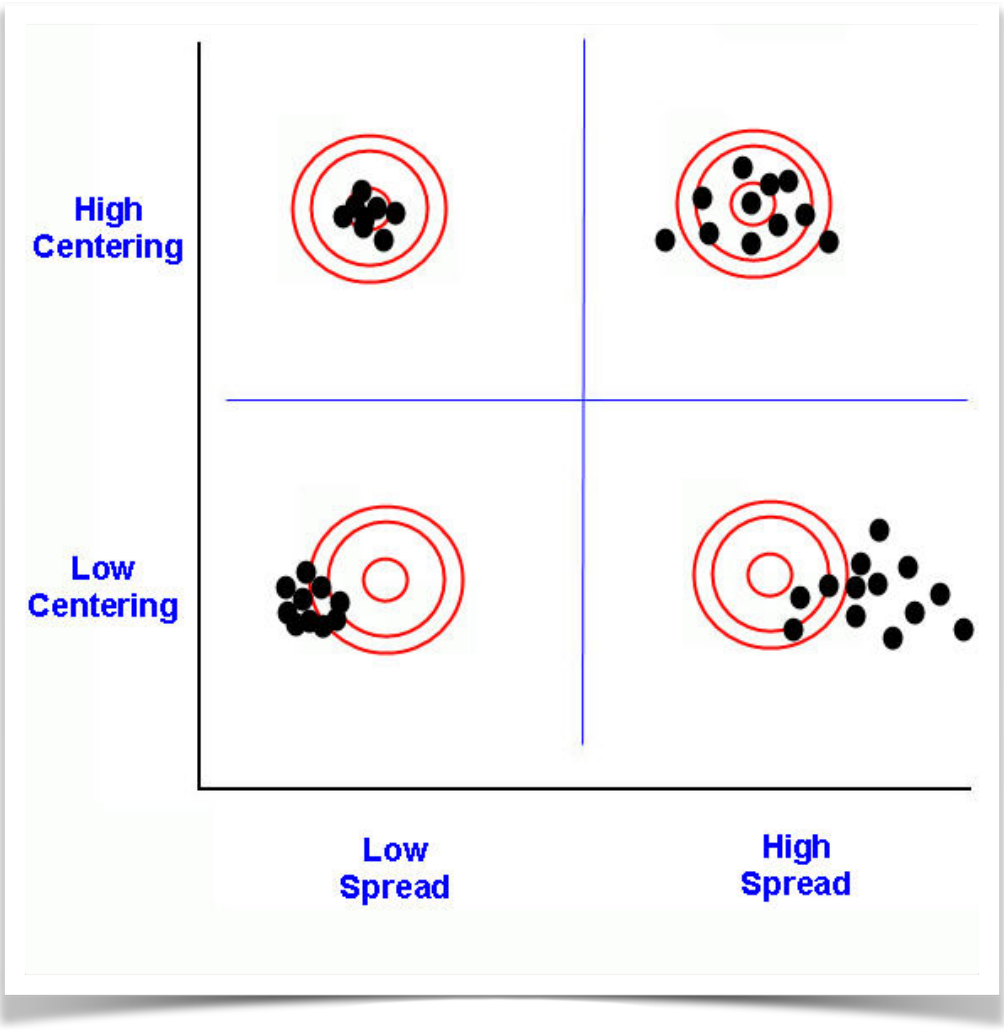
Cp, Pp, Cpk, and Ppk are capability and performance indicators for your process. Is a process capable? Is the process acceptable? How is the process actually behaving vs how it theoretically could be behaving? These are questions you can ask during a DMAIC project during both the measure phase (if you have good, existing data) or in the control phase after you have implemented your changes.

This article deals with an overall examination of Process Capability & Performance (Pp, Ppk, Cp, Cpk).



Process Spread vs. Centering

To begin to answer these questions it all starts with customer requirements and the follow up with what we know mathematically about the variation of the process.

Cp, Cpk, Pp and Ppk are all parameters (indices) that can help us to understand how our process is operating relative to the specifications, or in other words, they measure how close our process is running to its specification limits.

For requirements we measure the process specifications. To determine the answer to those questions we see how wide the process dispersion (spread of values) and how centered the process is relative to those specifications.

On the mathematical side we require the process to follow a normal distribution so we can take advantage of the properties there. Before using these indices to see how capable and acceptable your process is, test your process for normality. If it's not normal, see if you can apply a transform to get it there. If not, you may have to use non-normal distributions and methods (not part of the Six Sigma Black Belt curriculum. – See the Master Black Belt guide.)

When to Use Pp, Ppk, Cp, and Cpk

The main difference between Pp and Cp on one side and Ppk and Cpk on the other side is whether we use complete set of data for calculation (Pp and Ppk) where we calculate real performance of the system, or we use sample (pre-production, batch, logical subgroups) where we calculate capability of the process. In equation for Pp and Ppk we use standard deviation based on studied data (whole population), and in equation for calculation Cp and Cpk we use sample deviation or deviation mean within rational subgroups

	New Process or Process Not Under Statistical Control	Existing Process Under Statistical Control
Measure of Spread 'fit'	Pp	Cp
Measure of Centering	Ppk	Cpk

When to use Pp Ppk Cp Cpk

Differences Between Cp & Pp

The biggest difference between Cp and Pp is how the Standard Deviation is determined. Pp we use sampling and have to calculate an estimated standard deviation of the sample. In Cp we are assuming a stable process and will likely have enough data to calculate a true standard deviation.

What Can Process Capability and Process Performance Tell Us?

Process Capability Analysis tells us how well a process meets a set of specification limits, based on a sample of data taken from a process. It can be used to establish baseline for the process and measure the future state performance of the process for comparison.

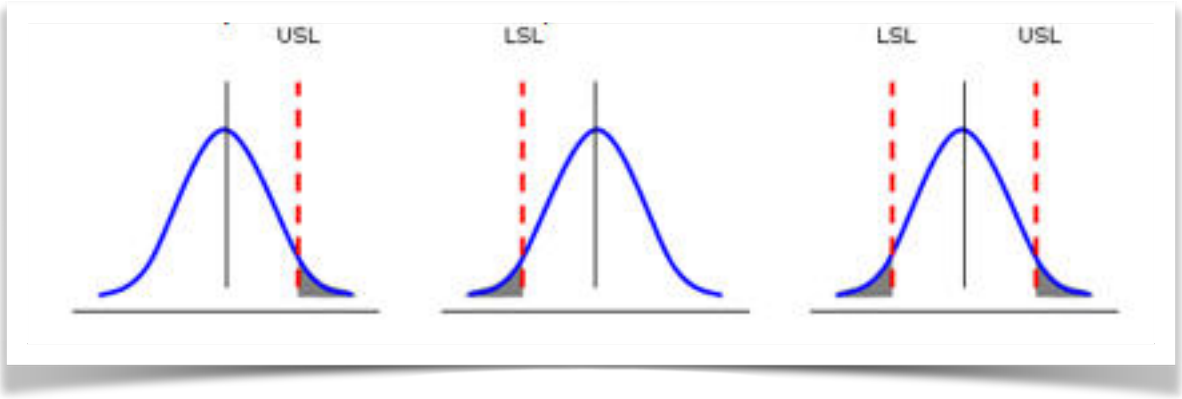
Cp for processes that are under statistical control and Pp for new processes. A good analogy is parking a car in a garage. If the car is bigger than the garage, it will not fit within the specification limits and thus is not capable – this case is clear. What about a case when our car is skinnier than the garage you're trying to park it in (the specification width)? Can we consider our parking process as a capable one? It depends on our specification and the width of the car. Are we satisfied with the probability of 99% that we will park our car, without hitting the wall? This mean that one in a hundred attempts to park our car will hit the wall of the garage!

One way to calculate Process Capability is through number of defects per opportunity. This is usually used for discrete data and in manufacturing is usually acceptable number of 3.4 Defects Per Million Opportunities (DPMO)

$$DPMO=\frac{\#Defects}{\#Opportunities}x1{,}000{,}000$$

The other way to calculate Process Capability is through use of statistical methodology. Processes with normal distribution of data, have restrictions from one or

both side of the curve, based on the Specification Limits (USL- Upper Specification Limit and LSL- Lower Specification Limit):



Shaded areas represent the probability of defects and our goal is to minimize the size of the shaded areas.

Is a Process Capable?

Process capability analysis is the determining if a process can meet specification.

Here we want to use Pp for new processes or Cp for processes that are under statistical control. A good analogy is parking a car in a garage. A process that is capable indicates the car (process) is skinnier than the garage you're trying to park it in (the specification width). If the car is simply much bigger than the garage, it is not enough to be capable of fitting within the specification limits and thus is not capable.

Is the Process Acceptable?

A capable process does not necessarily mean it is acceptable. Using the garage example, the car may have crashed into the side of the garage, or may have missed it completely. This point reflects how centered a process. We can measure this using Ppk or Cpk.

A Note on a Process Being Both Capable and Acceptable

A process is said to be capable and acceptable when it meets customer requirements. Having zero defects is usually unrealistic and not usually a part of customer requirements. A process could be capable, but not acceptable because it is poorly

centered and ends up outside the spec limits (ex car could fit in the garage, but the process for parking it is could have it just as easily end up in your front door as where it should be).

Six Sigma Process Capability & Performance Limits

According to Six Sigma philosophy, Cp or Pp and Cpk or Ppk should be greater than 1.50. From a technical standpoint, Six Sigma deems a process being acceptable only after achieving a maximum defect rate of 3.4 parts per million opportunities. There is a direct correlation between Cpk or Ppk and parts per million defects because only Cps or Pps and Cpks or Ppks that are greater than 1.50 are achieving this goal (3.4 Defects per million).

Control Limits, Specification Limits and Process Capability

Keeping a process in control limits is not sufficient to achieve good quality. Quality is always dictated by the user. For that we use specification limits when assessing process capability. The process specifications used in process capability are the voice of the customer and control limits of Statistical Process Control are the voice of the process.

It is very possible to have great process control (indicated on a control chart) yet have poor process capability. That would be a mismatch of where the process is centered versus where the customer wants it to be centered. Either that or the process has more variability than the customer desires.

Pp vs Cp (Capability Indices)

Both Cp and Pp are a monitoring indices for the spread of your process compared to the specification spread.

Cp is used when a process is under statistical control. Pp is used when a process is initially starting out.

Uses for Cp & Pp

- Used to see if a process is capable.

- Neither are concerned with centering. Cp or Pp takes into account dispersion, NOT centering. Since Cp does not consider process centering so it cannot be used to determine if a process is acceptable.
- Cpk & Ppk both take centering into account, so they can be used to see if a process is acceptable
- Cp & Pp are NOT concerned with the control of a process. The term “control” infers an element of time and Cp or Pp is merely a snapshot of the process variation at a given point in time.
    - For example, a Cp of < 1 does NOT indicate a process is out of control. “Control” is controlling variation over a period of time. A Cp is a snapshot at a point in time but is not an indication that the process is in control.
- Both indices are larger-is-better quality characteristics
- Can never be 0.
- If Cp or Pp >1, Tolerance is > spread, Process has potential to be capable (depending on centering).
    - A CP of >1 doesn’t mean quality One could have a Cp of 400 and be producing 100% defects, because the process was not centered within the specification limits.
- If Cp or Pp <1 process spread is > tolerance, and the variation will never fit and the process will never be capable.
    - A Cp of < 1 does NOT indicate a process is out of control. “Control” is controlling variation over a period of time
- If 0< CP <1, then the specifications are that percentage of the process.
    - Ex. Cp 0.70 = 70%. A Cp of 0.70 means the specifications are 70% of the process.

Ppk vs Cpk (Acceptable Performance)

Cpk and Ppk are ways to measure the capability of a process because they are monitoring indices for process centering.

Uses for Cp & Pp: Is The Process Acceptable?

Cpk or Ppk takes into account centering and thus can be use to determine if a process is acceptable.

- Ways to measure the capability of a process.
- Reflect the actual performance of the process.
- Both Cpk and Ppk can be a negative numbers.
    - It means that, on average, the process is not meeting customer requirements.

Can Cpk or Ppk be Negative? What does a negative Cpk or Ppk Indicate?

Yes, it is possible for Cpk and Ppk to be negative. Let's look at the equation – for simplicity we will use the Ppk.

Ppk = [USL – x(bar)] / 3 s

It is impossible to have a standard deviation be negative so that would mean that x(bar) was larger that the Specification Limit. In other words, the process average is out of specification.

This could be an indication that the process mean has drifted over either the upper specification or the lower one. This is not good because it means that the process is not meeting customer requirements.

Pp, Ppk vs Cp, CPK

- Cp & Cpk use an estimate for the standard deviation using the R Bar / d2 method.
- Pp, Ppk are more liberal where Cp, CPK are more conservative.
- Use Pp & Ppk when you are initially setting up your process.

- Use Cp & Cpk once the process is in a state of statistical control.
- Cpk or Ppk is less than CP or Pp.