Cpk/Process Capability: The process capability index as a benchmark for supplier quality

Cpk (Process Capability Index) is a metric that describes how well a production-related process is able to consistently comply with defined tolerance limits. For technical buyers, the process capability index is a central criterion in supplier selection, approval processes such as PPAP acceptance and ongoing supplier evaluation. It translates the spread and position of a process into a single figure and makes quality capability comparable. Those who agree and monitor Cpk requirements properly reduce scrap, sampling risks and rework along the entire supply chain.

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Key facts at a glance

01 Cpk describes both the spread and the position of a process relative to the tolerance limits.

02 A Cpk of 1.33 in practice frequently corresponds to a capability of around 66 ppm defective output for a centred, normally distributed process.

03 Cpk differs from Cp: only Cpk takes the centred position of the process into account.

04 In the automotive sector, Cpk values of typically over 1.33 are agreed, and over 1.67 in safety-critical environments.

05 The validity of the value assumes a controlled, stable process (Statistical Process Control).

06 Cpk values without documented measurement system analysis, sample size and process conditions are of hardly any use to procurement.

Definition: Cpk/Process Capability

The process capability index Cpk quantifies how reliably a process produces within the agreed tolerance limits. It is derived from the distance from the process mean to the nearer tolerance limit, divided by three standard deviations. The higher the value, the lower the probability that a characteristic will fall outside the specification.

Distinction from Cp

The potential index Cp only compares the tolerance width with the process width and ignores the position of the process mean. A process can therefore show a high Cp alongside a poor Cpk if it systematically operates off-centre. For buyers, Cpk is generally the more relevant measure because it reflects the actual risk of defects. Cp is at best suitable as a supplement to check whether a process could still be improved by centring.

- Cp: potential capability without taking position into account
- Cpk: actual capability including centring
- Cpm: additionally takes the deviation from the target value into account

Mathematical basis in brief

Cpk is calculated as the minimum of two quotients: the distance from the upper tolerance limit to the mean divided by three standard deviations, and the distance from the mean to the lower tolerance limit divided by three standard deviations. The formula assumes approximate normal distribution and a statistically controlled process. For non-normally distributed characteristics, transformation methods or non-parametric methods are used, which should be contractually agreed with procurement.

Methods and approach for the process capability study

A robust capability study follows a fixed sequence: define the characteristic, verify the measurement system, stabilise the process, take the sample, calculate the index and interpret the result. Procurement ensures that requirements, sample size and conditions are enshrined contractually and in the inspection plan.

Prerequisites: stability and measurement system

Cpk is only meaningful if the process is running under statistical control, typically demonstrated by means of control charts. In advance, measurement system capability must be confirmed, for example through suitable capability analyses of the measurement system, as measurement errors would otherwise distort the spread. In addition, the number of parts, the data collection period and the production conditions (machine, tool, parameters) should be documented. If this information is missing, the value is not comparable and unsuitable for supplier evaluations.

Short-term versus long-term capability

In practice, two perspectives are distinguished: short-term capability from a tightly limited sample

(frequently Ppk or Cpk from the start of series production) and long-term capability over longer periods with all expected influences such as tool wear or material changes. Usual requirements are at least 1.67 for short-term studies and at least 1.33 for ongoing series production, in individual cases higher. Procurement should define which value is to be provided when, for example as part of the initial sampling under PPAP.

Agreement as part of supplier qualification

Cpk requirements belong in drawings, inspection plans and quality assurance agreements. Important aspects are the reference characteristics (safety-relevant or function-relevant), the reference to current drawing statuses and the consequence of falling below the threshold, such as a sorting obligation or a block note. In addition, the capability requirement can be integrated into a pre-qualification gate in supplier selection, and a risk analysis can be used to prioritise which components require stringent evidence at all.

Important KPIs relating to Cpk and process capability

Cpk is one of several metrics in procurement quality controlling. It unfolds its effect above all in combination with delivery backlog, scrap and sampling rates as well as with structured supplier evaluations.

Typical guide values and their interpretation

A Cpk of 1.00 means that approximately 0.27 per cent of all parts lie outside the tolerance, which corresponds to about 2,700 ppm. At 1.33, the typical scrap falls to about 66 ppm, and at 1.67 to below one ppm, in each case for a centred, normally distributed process. These figures are regarded as guide values because real processes exhibit shifts and distribution deviations. Buyers should therefore assess not only the peak value of a sampling but also capability over time.

- Cpk 1.00: limited capability, increased inspection and sorting effort
- Cpk 1.33: usual series production requirement in mechanical engineering
- Cpk 1.67: frequently required for safety-relevant characteristics

Cpk in supplier evaluation

Many companies weight process capability evidence in their supplier evaluations alongside on-time delivery and complaint rates. It makes sense to link this with measurable quality metrics such as DPU (Defects per Unit) in order to compare capability values with actual defect impact. If agreed capability levels are persistently not met, this can be grounds for action plans, renegotiation or the gradual establishment of alternative sources of supply. Supplier credit checks and the D-U-N-S Number (DUNS) as an identification standard only come into play further downstream; Cpk, by contrast, has a direct impact at the part characteristic level.

Risks and controls: interpreting Cpk critically

Cpk values can turn out overly positive through the selection of favourable samples, inadequate measurement systems or manipulation of the data. Procurement therefore needs control mechanisms that go beyond merely accepting the figures.

Typical sources of error

Common weaknesses are samples that are too small, mixing of several machines or batches, outdated drawing statuses and tests that were carried out only with selected parts under laboratory conditions. A non-normally distributed characteristic, such as circular runout or flatness, also leads to distorted values when the formula is applied naively. Buyers who only check the index without inspecting measurement records and process charts carry a considerable procurement risk.

- Check sample size and sampling period
- Demand separation by machine and batch
- Request measurement records and MSA evidence

Contractual and procedural controls

Effective controls include defined reaction plans in the event of values falling below the threshold, regular repeat analyses after process changes and audit rights at the supplier. In the automotive environment, the PPAP logic stipulates that changes to the process require renewed approval; similar mechanisms can also be mapped contractually in other industries. In addition, quality processes and documentation obligations defined by procurement can be checked as part of policy compliance. For critical parts, a dock-to-stock approach is also recommended only if capability has been confirmed as stable over longer periods.

Current developments: Cpk in digital and sustainable procurement

Process capability is increasingly captured digitally and integrated into supplier portals, ERP and quality systems. At the same time, the concept of capability is expanding to include delivery capability and sustainability aspects of the upstream supply chain.

Digital quality data and data quality

Modern systems automatically transfer measurement data from the supplier's production and update capability metrics almost in real time. This requires high data quality; a metric such as the Data Quality Score can help to systematically assess the reliability of the quality data supplied. For buyers, this reduces effort during samplings and enables data-driven discussions with suppliers instead of occasional paper checks. Mobile approval (P2P) additionally accelerates the approval of the associated order and invoice processes.

Extended concept of capability: delivery and sustainability capability

The concept of capability is increasingly being extended to further dimensions: delivery reliability is controlled, for example, via safety stock calculation and service level agreements (SLA), and suppliers' financial stability via a structured supplier credit check. For material substitution (ESG), process capability evidence must be provided again for alternative materials, since spread and defect types may change. Procurement should consolidate these perspectives in its risk analysis rather than considering process capability in isolation.

Typical metrics

Metric	Typical value
Cpk (series production)	>= 1.33 *usual minimum requirement for ongoing series processes*
Cpk (safety-relevant)	>= 1.67 *frequently required for safety-critical characteristics*
Ppk (series production start-up)	>= 1.67 *preliminary evidence at initial and renewed sampling*
Defect rate at Cpk 1.33	typically approx. 66 ppm *guide value for a centred, normally distributed process*

Practical example

A medium-sized mechanical engineering company experienced recurring dimensional deviations at a supplier of precision components, even though the initial sampling had shown a Cpk of over 1.6. An analysis revealed that the values came from a short-term study on a single machine, while series production ran on several machines. Procurement consequently agreed binding rules for future samplings and incorporated the requirements into the quality assurance agreement.

- Define long-term Cpk across multiple machines and batches as a series production requirement
- Stipulate evidence of measurement system capability as a prerequisite for every capability study
- Include Cpk requirements in inspection plans and the PPAP documentation package
- Add a capability component to supplier evaluation and transfer deviations into action plans

Conclusion

For technical buyers, Cpk is more than a formula from statistics: it is a contractually usable instrument for assessing and permanently controlling process risks before series production. The prerequisites are cleanly agreed characteristics, reliable measurement data and clearly defined consequences in the event of values falling below the threshold. Anyone who considers Cpk in isolation can easily

misinterpret the value; embedded in supplier evaluation, risk analysis and digital quality data, it unfolds its full effect. In times of increasing supply chain transparency and rising sustainability requirements, systematic capability assessment is gaining further importance. Professional handling of the process capability index therefore pays directly into scrap costs, delivery reliability and negotiating power.

Frequently asked questions

? What does Cpk 1.33 mean?

A Cpk of 1.33 means that the distance from the process mean to the critical tolerance limit equals 1.33 times three standard deviations. For a centred, normally distributed process, this typically corresponds in practice to approximately 66 ppm defective output. The value is regarded in many industries as the usual production requirement.

? What is the difference between Cp and Cpk?

Cp only compares the tolerance width with the process spread and ignores the position. Cpk additionally takes into account how far the process mean is from the nearer tolerance limit. Consequently, Cp can be high while Cpk is significantly lower due to poor centring. For assessing the actual risk of defects, Cpk is the decisive measure.

? How is Cpk calculated?

Cpk is calculated as the minimum of two quotients: the distance from the process mean to the upper and lower tolerance limit respectively, each divided by three standard deviations. The calculation assumes approximate normal distribution and a statistically controlled process. For non-normally distributed characteristics, adapted methods are required.

? From what level is a process considered capable?

Typical guide values are at least 1.33 for ongoing series production and at least 1.67 for safety-relevant characteristics or initial sampling. Industries and customers may define deviating requirements, for example higher values in the automotive sector. What matters is the contractual agreement in the inspection plan or the quality assurance agreement.

? What does Ppk mean in comparison to Cpk?

Ppk describes the preliminary process capability based on a limited sample, frequently at the start of series production, and uses the overall spread. Cpk, by contrast, refers to the capability of a controlled process under stable conditions. In many companies, Ppk is therefore initially required as evidence and later replaced by long-term Cpk values.

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