PROCESS CAPABILITY RATIO

Semester IV **STAT CC410**

Unit 2

- Use and Interpretation of C_p
- Values of C_p and Associated Process Fallout
- Recommended Minimum Values of PCR (C_p)

Dr. Vijay Kumar
(Assistant Professor)
Department of Statistics
Patna Women's College, Patna

PROCESS CAPABILITY RATIO

Use and Interpretation of C_p:

- It is frequently convenient to have a simple, quantitative way to express process capability.
- One way to do so through the **process capability ratio (PCR) C_p**.

$$C_p = \frac{USL - LSL}{6\sigma} \qquad \text{…………… (1)}$$

where *USL* and *LSL* are the upper and lower specification limits respectively.

- C_p and other process capability ratios are used extensively in industry.
- They are also widely misused. We will point out some of the more common abuse of process capability ratios.
- In practical application, the process standard deviation σ is always unknown and it must be replaced by an estimate of σ.
- To estimate σ we typically use either standard deviation s or $\bar{R}/d_2$ (when variable control chart are used in the capability study).

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- Thus, the estimate of C_p is given by,

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}} \qquad \text{............ (2)}$$

- The process capability ratio C_p may be practically interpreted another way. The quantity

$$P = \left(\frac{1}{C_P}\right)100 \qquad \text{............ (3)}$$

is the percentage of the specification used by the process.

- Equation (1) and (2) assume that the process has both upper and lower specification, one-sided process capability ratios are used.

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- One sided process capability ratios are defined as follows:

$$C_{pu} = \frac{USL - \mu}{3\sigma} \qquad \text{(upper specification only)} \qquad \dots (4)$$

$$C_{pl} = \frac{\mu - LSL}{3\sigma} \qquad \text{(lower specification only)} \qquad \dots (5)$$

- The estimates $\hat{C}_{pu}$ and $\hat{C}_{pl}$ would be obtained by replacing μ and σ in equation (4) and (5) by its estimates $\hat{\mu}$ and $\hat{\sigma}$ respectively.
- The process capability ratio is a measure of the ability of the process to manufacture product that meets the specifications.
- If $C_p > 1$, this means that the process uses up much less than 100% of the tolerance band and consequently, few nonconforming units will be produced by this process.
- If $C_p = 1$, this means that the process uses up all the tolerance band. For a normal distribution, this would imply that about 0.27% (or 2700 ppm) nonconforming units produced by the process.

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- If $C_p < 1$, this means that the process uses up more than 100% of the tolerance band. In this case process is very yield sensitive, and a large number of nonconforming units will be produced.
- In all the above three cases, it is assumed that the process is centered at the mid point of the specification band.
- In many situations this will not be the case and some modification in process capability ratio (PCR), C_p is necessary to describe this situation adequately.

Values of C_p and Associated Process Fallout

Values of the Process Capability Ratio (C_p) and Associated Process Fallout for a Normally Distributed Process (in Defective ppm) That Is in Statistical Control

	Process Fallout (in defective ppm)	
PCR	One-Sided Specifications	Two-Sided Specifications
0.25	226,628	453,255
0.50	66,807	133,614
0.60	35,931	71,861
0.70	17,865	35,729
0.80	8,198	16,395
0.90	3,467	6,934
1.00	1,350	2,700
1.10	484	967
1.20	159	318
1.30	48	96
1.40	14	27
1.50	4	7
1.60	1	2
1.70	0.17	0.34
1.80	0.03	0.06
2.00	0.0009	0.0018

Table 1

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- Table 1 shown above presents several values of C_p along with the associated values of process fallout for a normally distributed process, expressed in defective parts or nonconforming units of product per million (ppm).
- To illustrate the use of Table 1, notice that a PCR for a normally distributed stable process $C_p = 1.00$ implies a fallout rate of 2700 ppm for two-sided specifications, whereas a PCR of $C_p = 1.50$ for this process implies that fallout rate of 4 ppm for one-sided specifications.
- The ppm quantities in Table 1 were calculated using the following important assumptions:

1. The quality characteristic has a normal distribution.
2. The process is in statistical control.
3. In the case of two-sided specifications, the process mean is centered between the lower and upper specifications limits.

Recommended Minimum Values of PCR (C_p)

Recommended Minimum Values of the Process Capability Ratio

	Two-Sided Specifications	One-Sided Specifications
Existing processes	1.33	1.25
New processes	1.50	1.45
Safety, strength, or critical parameter, existing process	1.50	1.45
Safety, strength, or critical parameter, new process	1.67	1.60

Table 2

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- Table 2 shown above presents some recommended **guidelines for minimum values** of the PCR.
- We point out that the values in Table 2 are only minimums.
- In recent years, many companies have adopted criteria for evaluating their processes that include process capability objectives that are more stringent than those in Table 2.
- For example, a six-sigma company would require that when the process mean is in control, it will not be closer than six standard deviations from the nearest specification limit. This, in effect, requires that the minimum acceptable value of the process capability ratio will be at least 2.0.