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SUPPLIER SELECTION BASED ON CAPABILITIES INDEX FOR MULTIPLE CHARACTERISTICS WITH ONE SIDED SPECIFICATION

Erik Bagus Prasetyo, Nani Kurniati
Industrial Engineering Departement, Faculty of Technology Industry, Institut Teknologi Sepuluh Nopember
Jl. Arif Rahman Hakim Sukolilo, Surabaya 60111
Email: erikbagusp@gmail.com nanikur@gmail.com

Abstract *-- Raw materials are a significant requirement in the production process for manufacturing companies. In meeting the needs of raw materials for the production process, most manufacturing firms rely on suppliers. Supplier selection is an essential part of manufacturing companies. From several supplier selection criteria, quality is one of the fundamental standards and is used in supplier assessment. Selecting suppliers based on the quality of their products will have a positive impact on manufacturing companies, such as increased profits through reduced operational costs and increased market share. The problem faced is the lack of accuracy in choosing qualified suppliers. In this study will compare two suppliers at manufacturing companies and pick one that has a higher capability value. Supplier selection is made by using multiple characteristic capability index* C_{pl}^{T} *es. The Supplier will be selected by comparing the ratio of two suppliers. Numerical calculations are performed on leather suppliers in shoe companies based on bursting quality, tear strength, tensile strength and elongation. The result of the calculation can be seen that supplier B is chosen as a better supplier. Characteristics of quality will affect the production process and application of shoes.*
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Keywords: *Supplier selection; Quality; Capability index; Multiple characteristics; One-sided specification*

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INTRODUCTION

Manufacturing companies have relationships with many parties, one of which is a supplier. The Supplier is a company that provides material that cannot be provided by the manufacturing company itself (Mitrega, et al., 2017; Santoso and Besral, 2018).

Manufacturing company must have the ability to choose the right supplier for succeeding. Supplier selection is a fundamental and critical decision for companies (Kuo and Lin, 2012; Rezaei and Davoodi, 2012; Wu et al., 2013). The decision in choosing a supplier impact directly on the competitiveness of the company and accelerates the company's response to market demand. Of the various criteria, quality is considered the most essential factor for supplier assessment (Liao et al., 2012).

The problem faced is the lack of accuracy in choosing qualified suppliers. The process capability index provides a numerical measure of the ability of a process to produce goods that meet specified quality requirements. The advantage of using index capability processes is more accurate and reliable when compared to traditional methods (Pearn and Wu, 2007).

Some authors have used index capability process with multiple quality. Pearn et al., (2013) considers the supplier selection problem for a normally distributed process with some independent characteristics based on the process capability index C_{pu}^{T}.

LITERATURE REVIEW

Process Capability Index Single Characteristic

Process capability index has been widely used to measure process capability and is essential for quality improvement activities. Some process capability index has been developed such as C_p, C_{PU}, C_{PL}, dan C_{pk} (Kane, 1986).

$$C_p = \frac{USL - LSL}{6\sigma} \quad (1)$$

$$C_{pu} = \frac{USL - \mu}{3\sigma} \quad (2)$$

$$C_{pl} = \frac{\mu - LSL}{3\sigma} \quad (3)$$

$$C_{pk} = \min\left\{\frac{USL - \mu}{3\sigma^2}, \frac{\mu - LSL}{3\sigma^2}\right\} \quad (4)$$

where USL and LSL respectively are upper and lower specification limits, μ is the process mean, σ is the standard deviation of the process. Index C_p only measure the distribution of distribution (process precision), which only reflects the consistency of product quality characteristics. Index C_{pk} taking into account the magnitude of the process variance as well as the level of the average specification limits. C_p and C_{pk} used to measure the process with two sides of the specification, i.e., *Lower Specification Limit* dan *Upper Specification Limit*. C_{pu} and C_{pl} designed specifically for processes with one specification that only requires USL or LSL only. C_{pu} is an index that measures the ability of a process *smaller-the-better* with *Upper Specification Limit* (*USL*), while C_{pl} is an index that measures the ability of a process *larger-the-better* with *Lower Specification Limit* (*LSL*).

Process Capability Index Multiple Characteristics for One Side Specifications

Wu and Pearn (2005) discusses multiple characteristic processes for one-sided specifications with upper specification limits and proposes a process capability index for *smaller the better* as,

$$C_{pu}^{T} = \frac{1}{3}\phi^{-1}\left\{\prod_{j=1}^{v}\phi\left(3C_{puj}\right)\right\} \tag{5}$$

where C_{puj} show the value C_{pu} of characteristics j_{th} for j = 1,2, . . . , v and v is the number of characteristics. The relationship between the index C_{pu}^{T} and overall *process yield P* can be defined as,

$$P = \prod_{j=1}^{v} P_j = \prod_{j=1}^{v}\phi\left(3C_{puj}\right) = \phi\left(3C_{pu}^{T}\right) \tag{6}$$

Overall process yield in *parts per million* (*PPM*) can be given as follows,

$$yield = 10^6 \times \phi\left(3C_{pu}^{T}\right) \tag{7}$$

For every single characteristic, the value C_{puj} can be estimated using natural estimator,

$$\hat{C}_{puj} = \frac{\left(USL_j - \bar{x}_j\right)}{s_j},\ j = 1,2,...,v \tag{8}$$

where $\bar{x}_j$ = *mean sample characteristics* j_{th}, s_j = standard deviation of sample characteristics to j_{th} and estimators of $\hat{C}_{pu}^{T}$ defined as,

$$\hat{C}_{pu}^{T} = \frac{1}{3}\phi^{-1}\left\{\prod_{j=1}^{v}\phi\left(3C_{puj}\right)\right\} \tag{9}$$

Pearn et al. (2012) calculates the asymptotic distribution $\hat{C}_{pu}^{T}$ using Taylor expansion for the following multiple variables,

$$\hat{C}_{pu}^{T} \approx N\left(C_{pu}^{T}, \frac{1}{9n}, \frac{C_{pu}^{T\ 2}}{2n}\right) \tag{10}$$

The above method can be used for processes that only have many lower specification limits (LSL) with exact mathematical transformation. The previously mentioned results can be implemented to compare two suppliers with index values $\hat{C}_{pu1}^{T}$ and $\hat{C}_{pu2}^{T}$.

Then Pearn & Wu (2013) shows the ratio of 2 (two) natural estimators as follows,

$$R = \frac{\hat{C}_{pu2}^{T}}{\hat{C}_{pu1}^{T}} \tag{11}$$

Thus, the test statistic distribution R is the result of two normally distributed random variables and therefore is related to the Cauchy distribution. Using the Jacobian transformation and the convolution approach, the probability density function R can be obtained as,

$$f_R(r) = \frac{1}{2\pi\sigma_1\sigma_2}\left\{2\sigma_3^2\exp\left(-\frac{\mu_3^2}{2\sigma_3^2}\right) + \mu_3\sigma_3\sqrt{2\pi}\left[1-2\phi\left(\frac{\mu_3}{\sigma_3}\right)\right]\right\} \times\exp\left[-\frac{1}{2}\left(\frac{\mu_1^2}{\sigma_1^2}+\frac{\mu_2^2}{\sigma_2^2}-\frac{\mu_3^2}{\sigma_3^2}\right)\right] \tag{12}$$

where,

$$\mu_1 = C_{pu1}^{T}, \mu_2 = C_{pu2}^{T}, \sigma_1^2 = \frac{1}{9n_1}+\frac{C_{pu1}^{T\ 2}}{2n_1}, \sigma_2^2 = \frac{1}{9n_2}+\frac{C_{pu2}^{T\ 2}}{2n_2},$$
$$\mu_3 = \frac{\frac{\mu_1}{\sigma_1^2}+\frac{r\mu_2}{\sigma_2^2}}{\frac{1}{\sigma_1^2}+\frac{r^2}{\sigma_2^2}} = \frac{r\mu_2\sigma_1^2+\mu_1\sigma_2^2}{r^2\sigma_1^2+\sigma_2^2}, \sigma_3^2 = \left[\frac{1}{\sigma_1^2}+\frac{r^2}{\sigma_2^2}\right]^{-1} = \frac{\sigma_1^2\sigma_2^2}{r^2\sigma_1^2+\sigma_2^2} \tag{13}$$

RESEARCH METHODS

The histogram is made with a one-sided specification limit and a normal probability plot of skin quality data collection with bursting, tear strength, tensile strength and elongation characteristics for supplier A and supplier B to determine the position and distribution of data. The next step is to calculate the value of C_{pl}^{T} from each supplier C_{pl1}^{T} and C_{pl2}^{T}.

$$\hat{C}_{pli}^{T} = \frac{1}{3}\phi^{-1}\left\{\prod_{j=1}^{v}\phi\left(3C_{puj}\right)\right\},\ i = \text{A,B} \tag{14}$$

$$C_{pli} = \frac{\mu_i - LSL}{3\sigma_i}, \ i = \text{A,B} \quad (15)$$

where,

LSL	*lower specification limit*
μ_i	*mean* sample
σ_i	standard deviation sample

To compare the yield process of two suppliers, a hypothesis test was performed for the ratio of two indices yields as follows,

$$H_0 = \frac{C_{pl2}^T}{C_{pl1}^T} \leq 1 \quad (16)$$

$$H_1 = \frac{C_{pl2}^T}{C_{pl1}^T} > 1 \quad (17)$$

After the hypothesis then calculate the ratio of statistical tests R based on the standard approach to the distribution C_{pl}^T

$$R = \frac{C_{pl2}^T}{C_{pl1}^T} \quad (18)$$

Analyze is done to test ratio and critical value with supplier requirement C_{pl}^T = 1.30. For supplier A and supplier, B is calculated the mean sample, standard deviation sample, an index C_{pli}^T for each of the characteristics obtained from the data with $n_1 = n_2$ =150

The following hypotheses can be used to select suppliers,

$$H_0 : C_{pl2}^T \leq C_{pl1}^T \quad (19)$$

$$H_1 : C_{pl2}^T > C_{pl1}^T \quad (20)$$

So that can be obtained which supplier is better and will be prioritized.

The step of the experiment:

1. Bursting Test
   Cut test specimen with a diameter of 4.5 cm. Attach it to the lastometer testing machine. Observe the specimen until it cracks.
2. Tear Strength
   Cut test specimens with the slit parallel to the long direction of the material (backbone direction for leather and selvage (warp) or machine direction. Mark the along direction of all the test specimens. Zero the tensile tester force measuring system and move the jaws together to enable the test specimen to be fitted. Hold the test specimen flat between the jaws of the tensile testing machine so that the slit is aligned and parallel with the axis of the machine. Clamp one of the legs in the lower jaw and then fold the other leg upwards through 180° and clamp it into the upper jaw. In each case ensure that the end of the leg is parallel with the clamping edge of the jaw and that the slit is positioned in the axis of the tensile tester.
3. Tensile Strength
   Cut the specimen with a dumbbell shape. Attach it to the tensile test machine.
4. Elongation
   The procedure follows a tensile test by installing an extensometer.

RESULTS AND DISCUSSION

In this study using bursting quality data, tear strength, tensile strength and elongation of two suppliers. Each supplier has 150 data for each quality characteristic. The minimum specification limit of each quality characteristic for *bursting* = 20 kg/cm^2, *tear strength* = 10 *Newton*, *tensile strength* = 60 *Newton*, dan *elongation* = 70%.

The processing of the leather itself determines the quality characteristics of the leather. Characteristics of quality bursting, tear strength, tensile strength and elongation will significantly affect the production process and application of the use of shoes. In this study using the limit with Lower Specification Limit (LSL). The following is presented data from each supplier.

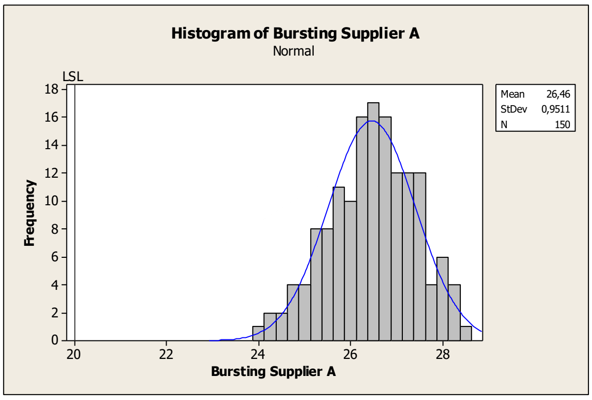


Figure 1. Histogram of Bursting *supplier* A

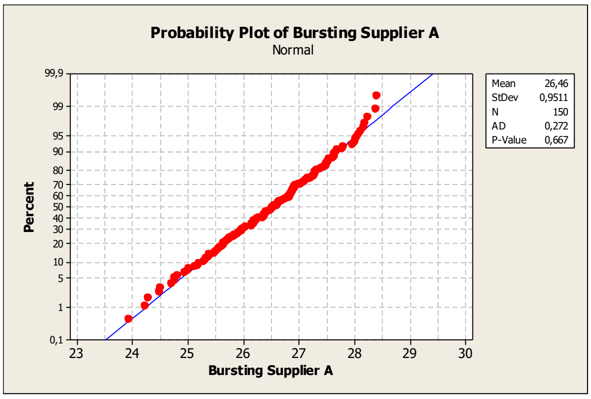


Figure 2. Probability plot of Bursting supplier A

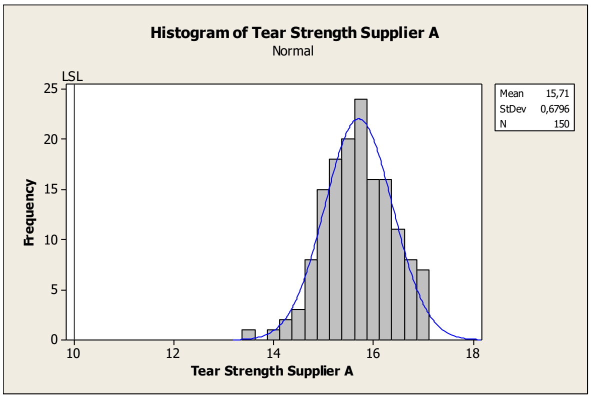


Figure 3. Histogram of Tear Strength *supplier* A

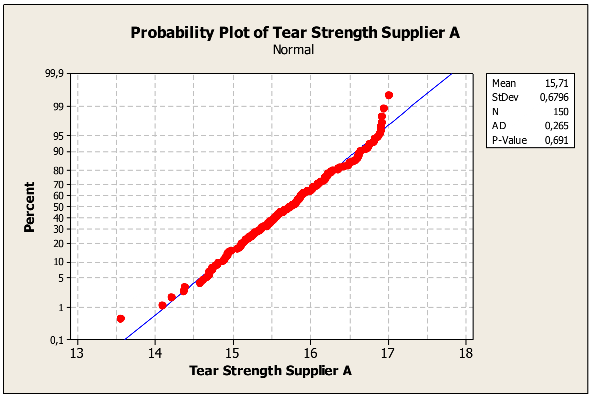


Figure 4. Probability plot of Tear Strength *supplier* A

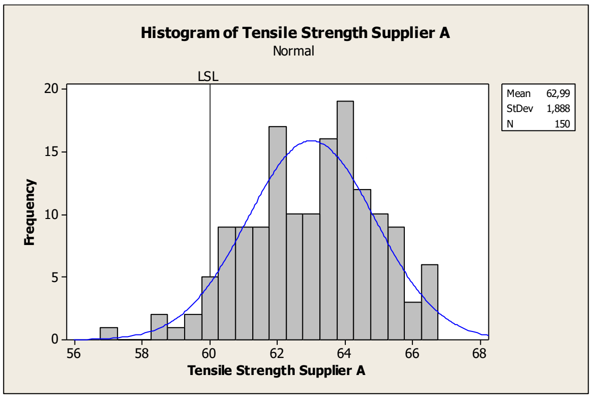


Figure 5. Histogram of Tensile Strength *supplier* A

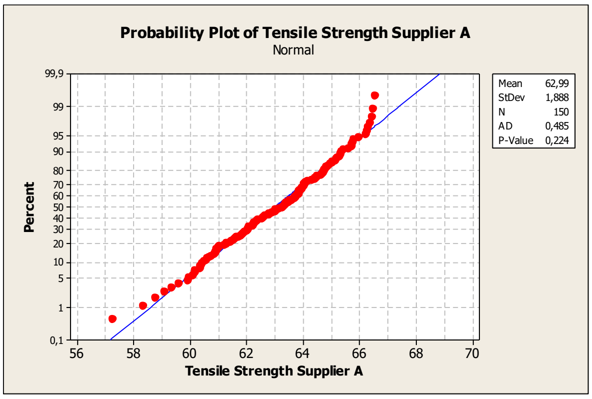


Figure 6. Probability plot of *Tensile Strength supplier* A

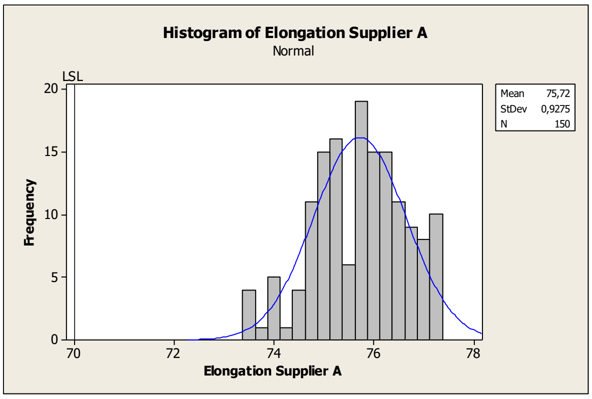


Figure 7. Histogram of Elongation *supplier* A

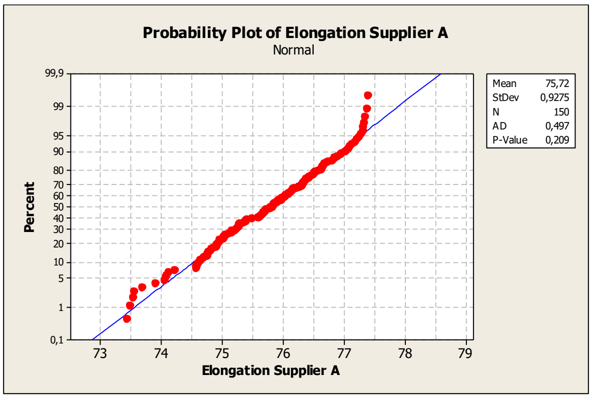


Figure 8. Probability plot of *Elongation supplier* A

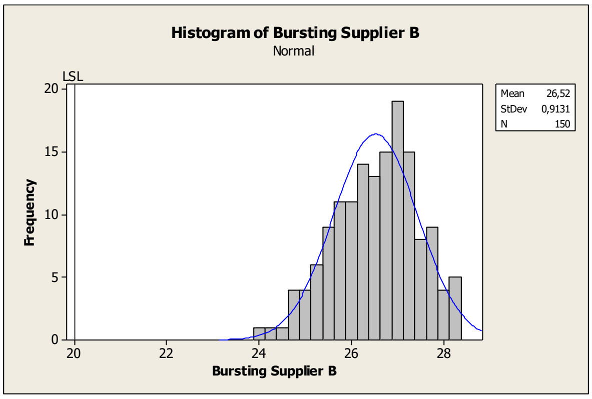
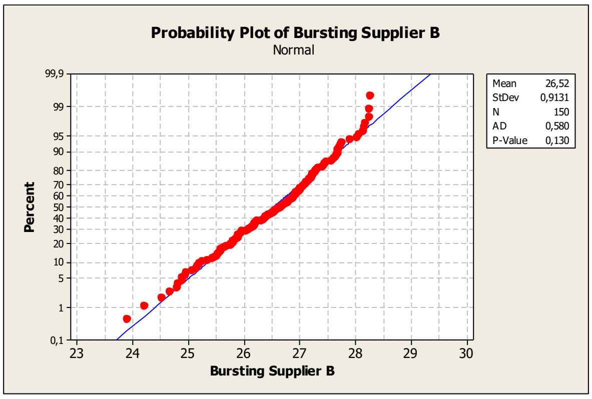


Figure 9. Histogram of Bursting *supplier* B



Gambar 10. Probability plot of Bursting *supplier* B

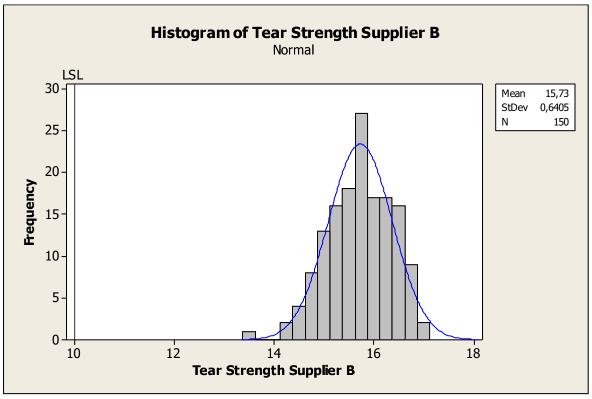


Figure 11. Histogram of Tear Strength *supplier* B

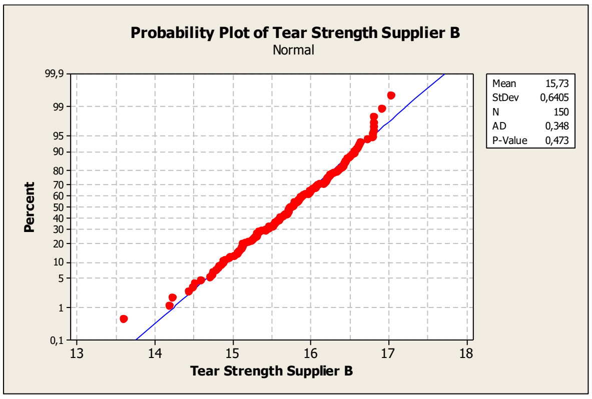


Figure 12. Probability plot of Tear Strength *supplier* B

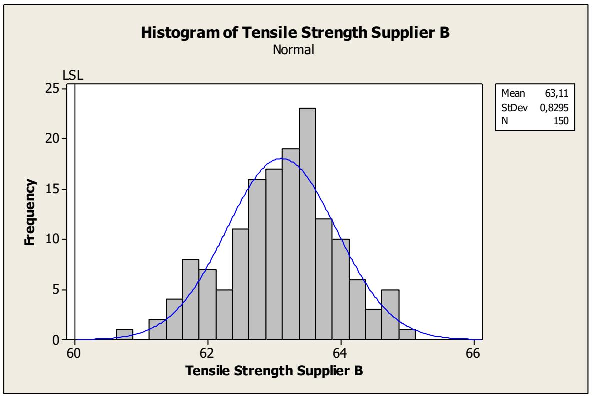


Figure 13. Histogram of Tensile Strength *supplier* B

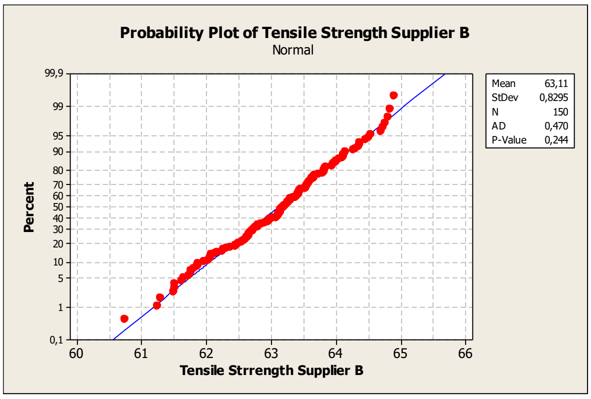


Figure 14. Probability plot of *Tensile Strength supplier* B

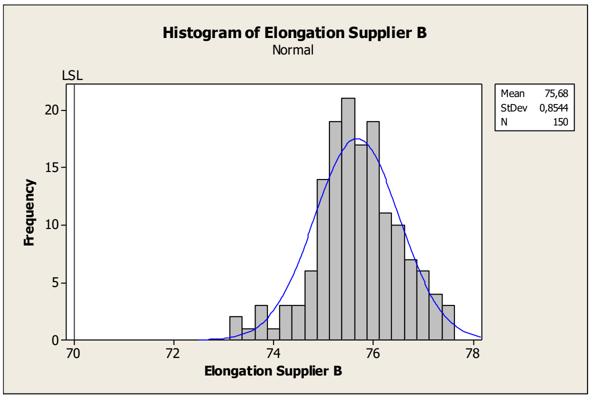


Figure 15. Histogram of Elongation *supplier* B

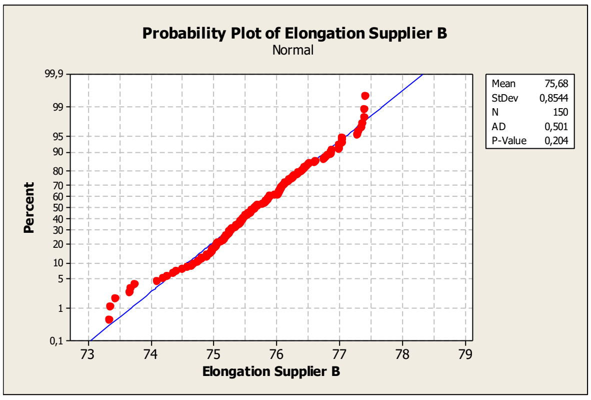


Figure 16. Probability plot of *Elongation supplier* B

From Fig. 1 to Fig. 16 shows the histogram with lower specification limits and standard probability plots with Anderson-Darling test from each supplier A and supplier B data. From histogram data, it can be seen that some quality tensile strength values in supplier A do not meet the requirements (outlier).

Based on the above measurements, the sample means, sample deviation standard and capability index value C_{pl}^{T} for each supplier can be calculated.

For supplier A, the sample mean, the sample deviation standard of each is already known, and the first step is to calculate the value C_{pl} for bursting, tear strength, tensile strength, dan elongation use the following formula,

$$C_{pl} = \frac{\mu - LSL}{3\sigma}$$

The result of the calculation C_{pl} for supplier A as follows, bursting = 2,2654; tear strength = 2,8004; tensile strength = 0,5287; elongation = 2,0563. Then calculate the value for C_{pl}^{T} as follows,

$$\hat{C}_{plA}^{T} = \frac{1}{3}\phi^{-1}\left\{\prod_{j=1}^{v}\phi\left(3C_{puj}\right)\right\}$$

= 0,5286

As for supplier B, the sample mean, the standard deviation of each sample is known, and the first step is to calculate the value of C_{pl} for bursting, tear strength, tensile strength, and elongation using the following formula,

$$C_{pl} = \frac{\mu - LSL}{3\sigma}$$

The result of the calculation C_{pl} for supplier B as follows, bursting = 2,3815; tear strength = 2,9828; tensile strength = 1,2505; elongation = 2,2147. Then calculate the value for C_{pl}^{T} as follows,

$$\hat{C}_{plB}^{T} = \frac{1}{3}\phi^{-1}\left\{\prod_{j=1}^{v}\phi\left(3C_{puj}\right)\right\}$$

= 1,2505

The hypothesis used to compare from two suppliers is as follows,

$$H_0 = \frac{C_{plB}^{T}}{C_{plA}^{T}} \leq 1$$

$$H_1 = \frac{C_{plB}^{T}}{C_{plA}^{T}} > 1$$

While the calculation of R statistic test ratio based on the normal approach to the distribution C_{pl}^{T} as follows,

$$R = \frac{C_{plB}^{T}}{C_{plA}^{T}}$$
$$= \frac{1,2505}{0,5286}$$
$$= 2,3656$$

The critical value of α = 0.05 with the sample value n = 150 is 1.8047 (Pearn et al., 2012). From the above ratio, values note that $R > c_0$; R = 2.3656 > 1.8047 then H_0 will be rejected, and it can be concluded that the capability index of the process differs significantly by α = 0.05.

Then the hypothesis to select a supplier based on the capability index C_{pl}^{T},

$$H_0 : C_{plB}^{T} \le C_{plA}^{T}$$
$$H_1 : C_{plB}^{T} > C_{plA}^{T}$$

From the results of the capability index C_{pl}^{T} obtained C_{plB}^{T} = 1,2505 < C_{plA}^{T} = 0,5286, then H_0 rejected, so from these results can be derived a better supplier B and will be prioritized.

CONCLUSION

Effective supplier selection will significantly determine success for manufacturing companies. From several supplier selection criteria, quality is one of the preferred criteria in supplier assessment. Selecting a supplier based on the quality of its product will have a positive impact on the manufacturing company.

Capability process index is an important criterion used in the manufacturing industry to measure process performance. Capability process index C_{pl}^{T} provides a measure with a one-sided specification limit for normal processes and provides a precise numerical measurement of process performance on suppliers. Higher accuracy to assess the two suppliers is obtained using the capability index C_{pl}^{T}. From the above calculation obtained capability index C_{plA}^{T} = 0,5286 and C_{plB}^{T} = 1,2505. Process capability index C_{plB}^{T} greater than C_{plA}^{T}, so that supplier B is better to choose.

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