Supplier Selection based on Process Yield for LED Manufacturing Processes

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Abstract: In today's fierce competitive business environment, it is very essential to work with right suppliers in the supply chain systems. Consequently, supplier selection problem is very important and has received considerable attention. In the supplier selection problem, quality is the most popular criterion. In the paper, we consider a supplier selection problem of comparing two suppliers and selecting the one that has a significantly higher process capability for the light emitting diode (LED) assembly process with multiple characteristics. Testing hypotheses for the LED assembly supplier selection are presented. For practitioners' convenience, the corresponding critical values for the supplier selection in LED assembly process are tabulated. For illustration purpose, an application is presented.

1 INTRODUCTION

In today's fierce competitive business environment, to provide high-quality products, it is very essential to work with right suppliers in the supply chain systems. Consequently, the success of a supplier chain is highly dependent on selection of good suppliers (Ng, 2008). In the last decades, the supplier selection problems have been investigated extensively. Various decision making approaches have been proposed to tackle the problem. The first investigation for the supplier selection problem is presented by Dickson (1966). He identified over twenty supplier attributes and ranked their importance, such as quality, net price, and service. In addition, Degraeve et al., (2000), De Boer et al., (2001) reviewed the literature up to 2000. Recently, Aissaoui et al., (2007) provided a literature review that covers the entire purchasing process involving parts and services outsourcing activities. Ho et al., (2010) reviewed the papers from 2000 to 2008 and provided some recommendations for related future work among various supplier selection methods.

From the extensive investigations on the supplier selection problem, Ho et al., (2010) summarized popular criteria including quality, delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment. It should be noted that quality is the most popular one for the supplier selection problem in the investigation of Ho *et al.* (2010). In most of high-tech manufacturing industries, process yield has been the most basic and common quality criterion for measuring process performance. Process yield is defined as the percentage of processed product unit passing inspection. That is, the process characteristic must fall within the manufacturing tolerance. Due to fierce competition on consumption products, the high-tech manufacturing processes require very low fraction of defectives in parts per million (ppm). Consequently, it can be found in the literature reviewed by Ho et al., (2010), the criterion of acceptable parts per million is a critical quality related attribute. However, if we make decision only based on the values of acceptable parts per million provided by individual supplier, the unreliable supplier selection decision may be made.

In this paper, we investigate a case of supplier selection problem regarding a material part of light emitting diode (LED) assembly that is the critical devices in smart phones. It should be noted that the manufacturing process of LED assembly require very low fraction of defectives in parts per million (ppm). Consequently, process capability indices (PCIs) methods are effective to evaluate the non-conformation of the units produced from a

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manufacturing process and to obtain the corresponding process yield.

In this paper, we presented an exact process capability index with multiple characteristics for the supplier selection problem in a LED case. The testing hypotheses for the light emitting diode assembly supplier selection are presented. For practitioners' convenience, the corresponding critical values for the supplier selection in LED assembly process are also computed and tabulated. The supplier selection method which is applied in the LED assembly process is practical and useful for practitioners and factory in-plant applications.

2 LIGHT EMITTING DIODE ASSEMBLY PROCESS

In this case, we provide an effective test to check whether the new supplier can provide better process yield than the existing supplier. It should be noted that LED backlight modules involve many attracting characteristics such as power-saving, wide color gamut, high dimming ratio, long lifetime, and high brightness. They have been widely applied in portable devices and computer monitors. A LED backlight module is a critical light source for liquid crystal display (LCD) panels since LCD panels cannot luminesce themselves. When the smart phone manufacturers select their suppliers for the LED assembly on the LED backlight module (see Figure 1), those popular criteria summarized by Ho *et al.* (2010) are considered. However, quality is a very important consideration in the real selection processes. It should be noted that the industrial practitioners commonly use C_{pk} to assess the process capability. The index C_{pk} only provides an approximate rather than an exact measure of the process yield. In addition, C_{pk} is restricted to processes with single characteristic. However, in LED assembly process, some critical quality characteristics are considered simultaneously since these quality characteristics may affect the yield of the finished goods. Thus, in the paper, to access exact process yield measure in supplier selection process, we consider the application of statistical selection processes based on the process capability index with multiple characteristics.

In the LED assembly process, LEDs are bonded on the FPC (flexible printed circuit) and are referred to as LEDs light-bar (see Figure 2). It is noted that there are multiple characteristics are very critical and should be considered when we evaluate and select the suppliers. One of the essential characteristics is the distances between two neighboring LEDs, since the distance may cause different maximum uniformities. However, the optical performance issue is very important. In addition, the LED assembly is extremely thin and need to connect with other components. The characteristic of the length of LED assembly is also critical since it may cause the situation of unexpected shut-down. Consequently, the length of the LED assembly should not fall outside the specification intervals.

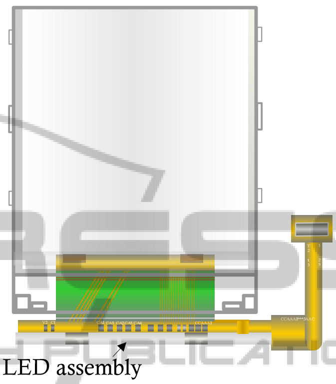

Figure 1: LED assembly on a backlight module.

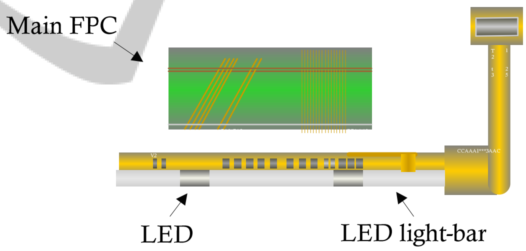

Figure 2: LED light-bar in a LED assembly.

3 SUPPLIER SELECTION BASED ON PROCESS CAPABILITY INDEX APPROACH

The most commonly used process capability indices, C_p and C_{pk} are discussed in Kane (1986). More-advanced indices C_{pm} and C_{pmk} are developed by Chan, Cheng and Spiring (1988) and Pearn, Kotz and Johnson (1992). Many authors have promoted the use of various PCIs for evaluating a supplier's process capability. Based on analyzing the PCIs, a production department can trace and improve a poor process so that the quality level can be enhanced and the requirements of the customers can be satisfied. However, the index C_{pk} can only provide an approximation rather than an exact measure on the process yield. To obtain an exact measure, Bolyes (1994) considered a yield index, referred to as S_{pk} for normally distributed processes. The index S_{pk} is defined as:

$$S_{pk} = \frac{1}{3}\Phi^{-1}\left\{\frac{1}{2}\Phi\left(\frac{USL-\mu}{\sigma}\right)+\frac{1}{2}\Phi\left(\frac{\mu-LSL}{\sigma}\right)\right\},$$

where USL and LSL are the upper and the lower specification limits, respectively, μ is the process mean, and σ is the process standard deviation.

To make more reliable supplier selection decision, some existing research works have been presented to perform the effective test. Pearn et al., (2004) presented a supplier selection procedure based on the index C_{pm} which can tackle a process with single characteristic. Wu et al., (2008) applied the bootstrap method and recommended a procedure for assessing capability index C_{pk} to solve supplier selection problems. Pearn et al., (2011) provided an effective powerful test for one-sided supplier selection problem. Lin and Pearn (2010) considered the process selection problem by using the yield index S_{pk} to compare two production processes and select one that has higher process yield. However, factory practitioners usually consider a process with multiple characteristics for supplier selection decisions, particularly, in the LED assembly process. In this paper, we consider the exact yield index S_{pk}^T and apply the proposed supplier selection method with multiple characteristics for the light emitting diode assembly process to help the participators to make more reliable decisions for supplier selections.

3.1 Supplier Selection Bases on S_{pk}^T

To obtain accurate yield assessment for processes with multiple characteristics, multiple characteristics should be considered simultaneously for the LED assembly processes. In the paper, we apply the process capability index S_{pk}^T which was proposed by Chen et al., (2003) and can be defined as follows.

$$S_{pk}^T = \frac{1}{3}\Phi^{-1}\left\{\frac{1}{2}\left[\prod_{i=1}^{v}(2\Phi(3S_{pki})-1)+1\right]\right\},$$

where S_{pki} denotes the S_{pk} value of the ith characteristic for i= 1, 2, . . . , v, and v is the number of characteristics. The index can be viewed as a generalization of the single characteristic yield index, S_{pk}.

Since the index S_{pk}^T provides an exact measure on the process yield of multinormal processes in which the characteristics are mutually independent (Pearn and Cheng, 2010). Pearn and Cheng (2010) displayed various commonly used capability requirements and the corresponding production as well as non-conformities in ppm in Table 1.

Table 1: Various commonly used capability requirements and the corresponding production as well as non-conformities in ppm.

S_{pk}^T	Yield	NCPPM
1.00	0.997300204	2699.796
1.20	0.999681783	318.217
1.40	0.999973309	26.691
1.60	0.999998413	1.587
1.80	0.999999933	0.067
2.00	0.999999998	0.002

3.2 Statistical Test for Supplier Selection

In this paper, we apply a powerful approach for supplier selection. Suppose that the process yield requirement by S_{pk}^T for given processes is C, and the current supplier has reach the yield requirement. In real applications, the supplier replacement is time consuming and costly since the validation of a new process is complicated. Consequently, when we find a new supplier to compete with the current supplier, we can consider the following hypothesis testing to test whether the new supplier can provide convincing information to claim that its process yield is higher than the current supplier. The considered hypothesis testing for comparing the two S_{pk}^T values: H_0: $S_{pk1}^T \geq S_{pk2}^T$ versus H_1: $S_{pk1}^T < S_{pk2}^T$ (or equivalently, H_0: $S_{pk2}^T -$ S_{pk1}^T $\leq$ 0 versus H_1: $S_{pk2}^T -$ S_{pk1}^T >0). The test statistic W can be expressed as $\hat{S}_{pk2}^T - \hat{S}_{pk1}^T$.

4 A LED APPLICATION

To demonstrate the applicability of the supplier selection method, we consider a case for light emitting diode assembly process. In the case, two essential quality characteristics are considered simultaneously. As described in Section 2, the distances between two neighboring LEDs and the length of LED assembly are the two critical quality characteristics for supplier selection. In the case, the LED assembly products require a minimal capability. The minimal requirement of the LED assembly characteristic is S_{pk}^T = 1.20.

For the product type we investigated, the upper and lower specification limits of the distance between LEDs are set to 12.2 and 15.4 millimeter. In addition, the upper and lower specification limits of the length of LED assembly are set to 19.5 and 21.5 millimeter. The millimeter is used as the unit for the two specifications.

To determine whether the new Supplier (Supplier II) provides a better process capability of the LED assembly products than current Supplier (Supplier I), we perform the hypothesis testing: $H_0: S_{pk2}^T \le S_{pk1}^T$ versus $H_1: S_{pk2}^T > S_{pk1}^T$. We collected two data sets from suppliers I and II with $n_1 = n_2$ =100. Based on the observations, we compute the sample estimate $\hat{S}_{pk}^T$ of S_{pk}^T for both suppliers. The sample average ($\bar{x}_j$), sample standard deviation (s_j) and $\hat{S}_{pkj}$ for each characteristic are also calculated. Thus, we can obtain that $\hat{S}_{pk1}^T$ = 1.104 and $\hat{S}_{pk2}^T$ =1.415.

We calculated the test statistic $W = \hat{S}_{pk2}^T - \hat{S}_{pk1}^T$ = 0.311 for the proposed supplier selection method. In the paper, we used a commercial computation software to compute the critical value (see Table 2) that is very useful to help us to make the decision for the hypothesis testing. The input parameters of the program involving the values of S_{pk1}^T , S_{pk2}^T , the corresponding sample sizes n_1, n_2, C, and α.

Table 2: Critical values for rejecting $S_{pk2}^T \le S_{pk1}^T$ with $n_1 = n_2$ =30(10)100 and α =0.05.

n	$S_{pk1}^T = S_{pk2}^T = C$			
	1.0	1.2	1.4	1.6
30	0.3003	0.3604	0.4204	0.4805
40	0.2601	0.3121	0.3641	0.4161
50	0.2326	0.2791	0.3257	0.3722
60	0.2123	0.2548	0.2973	0.3398
70	0.1966	0.2359	0.2752	0.3146
80	0.1839	0.2207	0.2575	0.2942
90	0.1734	0.2081	0.2427	0.2774
100	0.1645	0.1974	0.2303	0.2632

In the case, we use the Pearson-Correlation test to justify the correlation. The result shows the relationship among the two characteristics can be regarded as independent. In addition, we run the developed program with $n_1 = n_2$ =100, $S_{pk1}^T = S_{pk2}^T$ =1.20, and α= 0.05 to obtain the critical value as 0.1974 for the presented supplier selection method (it also can be found in Table 2).

Since the testing statistic W = 0.311 > 0.1974, we can conclude that the new supplier is superior than the current supplier with 95% confidence level.

5 CONCLUSIONS

Supplier selection problem in light emitting diode assembly process is very important and frequently occurred. Since the multiple characteristics should be considered in the light emitting diode (LED) assembly process for supplier selection, in the paper, we presented and applied a supplier selection method based on process yield index to provide exact measures on process yield with multiple characteristics. For users' convenience in applying the supplier selection method in LED assembly process, the critical values of the hypothesis testing with various sample sizes are presented and tabulated. The supplier selection method which is applied in the LED assembly process is very useful for factory in-plant applications.

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