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PROCESS CAPABILITY AND PRICE EVALUATION CHART FOR A PHARMACEUTICAL COMPANY

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Abstract

Supplier selection is a critical decision process in a company. Since, gaining a competitive advantage is a great challenge in today's economy; firms need a well-managed supply chain to compete in these circumstances. Supply chain is an integrated system in which individual companies perform interdependent activities. Therefore, the success of a supply chain is highly dependent on establishing a longer-term working relationship among members of the supply chain community. Supplier selection process is a multi-criteria problem which includes different attributes such as quality, delivery, price, supply variety, distance etc. In our study, we consider two major criteria price and quality together with using incapability index Cpp and price advantage chart in order to evaluate supplier performance. In this paper a case study of the pharmaceutical industry is illustrated. The results obtained in this study show that capability and price advantage chart is useful to the practitioners in choosing the best supplier.

Keywords: Supplier Selection, Incapability Index, Capability And Price Advantage Chart, Quality

Jel Code: M10, M11, M19

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BİR İLAÇ FİRMASI İÇİN SÜREÇ YETENEK ANALİZİ VE FİYAT DEĞERLENDİRME GRAFİĞİ

Özet

Tedarikçi seçimi, firmalardaki kritik karar verme süreçlerinden biridir. Günümüzün ekonomik şartlarında rekabet avantajı elde etmek firmalar için oldukça zorlu bir süreç olduğundan, firmaların bu şartlarda başarılı olabilmeleri için iyi yönetilmiş bir tedarik zincirine ihtiyaçları vardır. Tedarik zinciri, içerisinde birden fazla bağımsız firmanın birbirinden bağımsız birçok aktiviteyi gerçekleştirdiği bütünleşik bir yapıdır. Bu nedenle, bir tedarik zincirinin başarılı bir şekilde yönetilmesi tedarik zincirini oluşturan firmalar arasında uzun süreli ve başarılı bir ilişki kurulması ile doğrudan ilişkilidir. Tedarikçi seçim süreci kalite, teslimat, fiyat, ürün çeşitliliği, uzaklık vb. birbirinden farklı birçok kriteri içeren çok kriterli bir karar verme problemidir. Bu çalışmada, tedarikçi performanslarını değerlendirmek için, süreç yetenek indeksi Cpp ve fiyat avantaj grafiği kullanılarak en temel iki kriter olan fiyat ve kalite kriterleri ele alınmıştır. Çalışmanın uygulama bölümünde geliştirilmiş olan model bir ilaç firmasının tedarikçi seçim sürecinde uygulanmıştır. Uygulamada elde edilen sonuçlar göstermiştir ki, süreç yetenek analizi ve fiyat değerlendirme grafiği karar vericiler tarafından tedarikçi seçim süreçlerinde kullanılabilecek basit ve etkili bir araçtır..

Anahtar Kelimeler : Tedarikçi Seçimi, Süreç Yetenek İndeksi, Süreç Yetenek Analizi Ve Fiyat Avantaj Grafiği, Kalite
Jel Kodu : M10, M11, M19

1. INTRODUCTION

In today’s competitive environment firms need to focus on their supply chain’s success. The success of a supply chain is highly dependent on selection of good suppliers. Since suppliers can have a very positive or a very adverse impact on the overall performance of the organization, supplier selection is one of the key strategic decision processes in a supply chain (Ramanathan, 2007). Supplier assessment is gradually switching from traditional price comparison and selecting lowest price, to diversified and multi-direction consideration (Che and Wang, 2008). Supplier selection process is a multi-criteria problem, which includes different attributes such as quality, delivery, price, supply variety, distance etc. Although considering all attributes can give comprehensive result, it is challenging and noteworthy time and money consuming, further some intangible aspects cannot be clearly evaluated. This study considers two important attributes quality and price, which are base and essential factors for customer satisfaction.

One of the overriding concerns of all organizations today is quality. In the competitive marketplace, no company dares to fall behind in providing quality to fall behind in providing quality to its customers, consumers, or end users. Much of the focus in supply chain management is ensuring product quality that meets customer requirements (Bowersox et al., 2002). It has been estimated that for the average American manufacturer, the cost of poor quality ranges from 10 to 30 percent of sales, an astounding and too often accepted cost leak (Juran and Blaclick, 1998). Additionally to this, price is the considerably important for gain a competitive advantage in the market. Consumers prefer to buy high- quality products from affordable price. The raw material cost can affect product price directly. Therefore companies should prefer suppliers who give lowest cost in order to keep their market shares in competitive environment. Hence, price and quality are fundamental factors in the supplier selection process. To achieve an effective supplier selection this two essential factors should be evaluated in an integrated manner.

There is a need for a convenient method for to evaluate suppliers’ process capability and quoted price simultaneously. In our study, we consider two major criteria price and quality together with using incapability index C_{pp} and price advantage chart in order to evaluate supplier performance. The incapability index C_{pp} and price index I_p are briefly discussed in Section 2. Capability and price analysis chart is considered in Section 3. A case study of the pharmaceutical industry is illustrated in Section 4. Finally, conclusion of the study is presented in Section 5.

2. INCAPABILITY AND PRICE INDEX

The process capability indices are used to evaluate whether the process ability meets the given specification limits or not. These indices provide an easily understood qualification of a process performance. There are several statistics that can be used to measure the capability of a process: C_p, C_{pk}, C_{pm} and C_{pp}. Process Capability index, C_p denotes the ability of a process to meet the specification limits. The disadvantage of the C_p is that it does not consider whether the process is centered within its limits, which causes in a process with both a low C_p value and undesired rejects. In order to avoid from unwanted results of the inadequate information of the previous process capability index, C_{pk} index is developed which measures process variation and the location of process mean simultaneously (Kahraman and Kaya, 2009).

The process capability index C_{pm} is used to assess the ability of a process to be clustered around a target. In literature the process capability index has been studied extensively for solving supplier selection problem. Firstly, Chan et al. (1988) proposed an index, which is called as C_{pm}. C_{pm} is more sensitive to process loss than C_p and C_{pk}. C_{pm} take in to account the departure of the process mean from the nominal value (Greenwhich and Schaffrath, 1995). Huang and Lee (1995) developed a mathematical complicated model based on the incapability C_{pm} for supplier selection problem. Also they showed their model on an application. Pearn et al. (2007) implemented Huang and Lee's (1995) model and improved a two-phase procedure for supplier selection decisions. Also, they applied this procedure on the super twisted nematic liquid crystal display manufacturing process.

Process incapability index, C_{pp}, was proposed by Greenwich and Schaffrath (1995). The index C_{pp} is a simple transformation of C_{pm}, a general form of the capability index C_{pm} is considered by Chan et al., which provides an uncontaminated separation between information concerning the process precision and the process accuracy. Chen et al. (2005) used process incapability index C_{pp} to obtain the score index R_i and applied it to assess contract manufacturer quality performance. They showed that process capability index C_{pp} is easy to apply and contains additional information than other process indices such as process inaccuracy and process impression. Chen et al. (2005) evaluated supplier performance using C_{pp} index and price index. They drew a graph, which is named as supplier's capability and price analysis chart (SPAC) to show difference between the expected price and the supplier's quoted price. Also, their study provides an opportunity to consider quality and price simultaneously. Linn et al. (2006) developed an easy tool, namely, capability index and price comparison chart (CPC) to evaluate the price and quality in an integrated manner when selecting appropriate supplier. This approach uses the process capability index C_{pk} to assess the quality performance of the suppliers. Hui-ming (2007) provided a supplier capability and price advantage chart (SCPIC) to determine the process quality performance of each supplier in terms of supplier locations and adequate price level. They used SCPIC chart to evaluate the candidate suppliers of an electronic company. The application results showed that SCPIC is an effective and simple tool, which measures the quality performance and the price level of the supplier simultaneously. Chen et al. (2008) generated a PCAC/C_{pm} (product capability analysis chart) to evaluate the process capability for a multi-process product in terms of indices C_{pu}, C_{pl} and C_{pm} for smaller-the-better, larger-the-better and nominal-the-best specifications, respectively. This chart helps to identify unsatisfactory process capability in a multi-process system to take an action to improve the integrated process capability of a multi-process product.

Wu et al. (2009) carried out extensive literature study. They investigated behavior of the actual process yield in terms of the number of non-conformities. They compared the process capability indices based on the different criteria. Additionally, the recent developments were discussed about capability indices in the study. Chen et al. (2015) presented a process improvement capability index C_{PIM} to evaluate supplier selection process. Also, a mathematical model proposed how the confidence intervals of index C_{PIM} can be used to measure process improvement capability of suppliers.

In this study, we use C_{pp} index to assess the performance of the candidate suppliers.

C_{pp} index is defined as follows,

$$Cpp = \frac{1}{C_{pm}^{2}} = \left(\frac{\mu - T}{D}\right)^2 + \left(\frac{\sigma}{D}\right)^2 \qquad (1)$$

Where T presents the target value, d=(USL-LSL)/2, D= d/3; USL is upper specification limit and LSL is lower specification limit, μ denotes process mean, σ represents the standard deviation (Pearn and Lin, 2001).

C_{pp} is composed of C_{ia} and C_{ip} ($C_{pp} = C_{ia} + C_{ip}$). While, the inaccuracy index C_{ia} indicates the departure of process mean from the target, the imprecision index C_{ip} shows the extent of process variation. $C_{ia} = \delta^2$ and $C_{ip} = 9\gamma^2$. The parameter δ can be used to detect the process mean deviation from the target value ($\delta = (\mu - T)/d$) and γ can be used to determine the size of the process standard deviation ($\gamma = \frac{\sigma}{d}$). From this C_{pp} can be rewritten as $C_{pp} = 9(\delta^2 + \gamma^2)$ (Chen and Chen, 2006)

The other two common indices are C_{pu} and C_{pl}, which are used to measure the unilateral tolerances covering smaller-the –better and larger-the-better process capabilities. C_{pu} and C_{pl} are defined as follows:

$$C_{pu} = \frac{USL - \mu}{3\sigma}, C_{pl} = \frac{\mu - LSL}{3\sigma} \qquad (2)$$

Price index is a helpful tool for managers about supplier selection decisions. It can be calculated for each supplier with using the component price data obtained from suppliers. The price index I_p is defined as follows (Chen et al., 2005),

$$I_p = \left(p - p_0 / p_0\right) \qquad (3)$$

3. CAPABILITY AND PRICE ADVANTAGE CHART

DEA To establish a CPAC, C_{pp} C_{pu}, C_{pl} and price index values are used. Capability indices, C_{pu} and C_{pl}, represent the X and Y coordinates successively, C_{pp} defines the capability regions on the chart. Hence,

$$\delta = (y - x)/(x + y) \text{ and } \gamma = 2/3(x + y) .$$

The Cpp index can be rewritten as,

$$Cpp = \left(\frac{4}{(x+y)^2}\right) + 9\left(\frac{y-x}{x+y}\right)^2 \qquad (4)$$

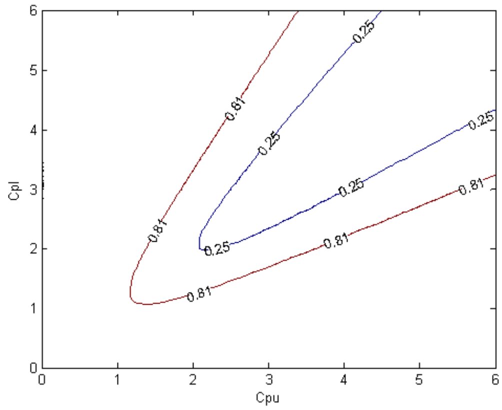

Figure 1. Initial Capability and Price Advantage Chart

The initial CPAC can be seen in Figure 1, this figure is obtained by drawing contour plot of C_{pp}. The super capability zone can be derived by converting $C_{pk} \geqslant 2.00$ to $C_{pp} \leqslant 0.25$; congruently, the Motorola requirements can be written by converting the index in $C_{pk} \geqslant 1.5$ at index $C_p \geqslant 2.00$ to $C_{pp} \leqslant 0.81$. These transformations were clearly explained in Chen et al. 2005.

In this study, Motorola requirements are followed for determining the process performance standard. If suppliers' process capability outside of the C_{pp} =0.81 region, process is considered as non-capable, if the data of process capability is inside the C_{pp} =0.81, process is identified as capable. The Motorola process capability requirements are satisfied by the respective supplier if the obtained process capability data is in the C_{pp} =0.81 but not in the C_{pp} =0.25 region. If the capability data is in the C_{pp} = 0.25 region, the process is super capable (Chen et al., 2005).

Table 1. The six Capability Zone

Index value	Quality Condition
$C_{pk} < 1.00$	Inadequate
$1.00 \le C_{pk} < 1.33$	Capable
$1.33 \le C_{pk} < 1.50$	Satisfactory
$1.50 \le C_{pk} < 2.00$	Excellent
$1.50 \le C_{pk}$, $C_p \ge 2.00$	Motorola
$2.00 \le C_{pk}$	Super

Depending on the capability index value, process can be classified into six different categories as shown in Table-1.

A process is called "inadequate" if $C_{pk} < 1.00$; it indicates that the process is not adequate with respect to the given manufacturing specifications. A process is called "capable" if $1.00 \le C_{pk} < 1.33$; it indicates that caution needs to be taken regarding process distribution. A process is called "satisfactory" if $1.33 \le C_{pk} < 1.50$; it indicates that process quality is satisfactory. A process is called "excellent if $1.50 \le C_{pk} < 2.00$. A process satisfies Motorola's requirement if $C_{pk} \ge 1.50$ and; $C_p \ge 2.00$. Finally, a process is called "super if $C_{pk} \ge 2.00$ (Pearn and Chen, 1997).

Normally, the true values of μ and σ are unknown. These values are calculated from collected data. But, sampling error can occur and cause incorrect decisions. Confidence interval approach is used to prevent incorrect decisions. The confidence interval is used as %95 percent in this study.

Confidence interval for δ can be established as,

$$\left[\delta - t_{\frac{\alpha}{2},n-1} x\frac{\gamma}{n}, \delta + t_{\frac{\alpha}{2},n-1} x\frac{\gamma}{n}\right] \quad (5)$$

Confidence interval for γ can be constructed as,

$$\left[(n-1)\gamma^2 / X^2_{\alpha/2,n-1}\right]^{1/2}, \left[(n-1)\gamma^2 / X^2_{1-\alpha/2,n-1}\right]^{1/2} \quad (6)$$

Confidence intervals calculated from the formulas for upper and lower limits being represented as $\left[L_\delta, U_\delta\right], \left[L_\gamma, U_\gamma\right]$.

Convert the price index values into symbols either ‘+’ or ‘-‘ or ‘*’ as their superscripts. ‘+’ means that the price is quoted by the suppliers is more than expected value. Furthermore, ‘-‘ indicates that quoted price is lower than expected price. Finally, ‘*’ denotes that quoted price and expected price are equal.

4. NUMERICAL EXAMPLE

This application illustrates that how the supplier selection procedure can be performed to the data taken from a pharmaceutical company. The company purchases 100 ml bottles from suppliers. These bottles are used for two types of syrup. Height of bottles is important quality specification for the quality department. Specified target value for the bottle height is 10.5 cm and tolerance is ±.1.5 cm; that is the upper specification limit is 12 cm lower specification limit is 9 cm.

There are five suppliers from whom 50 random samples are taken. Based on the collected sample, mean and standard deviation are calculated for every supplier and using these values δ, γ and C_{pp} index can be computed. Hereafter, confidence interval of δ and γ and price index are calculated to construct the graph (CPAC).

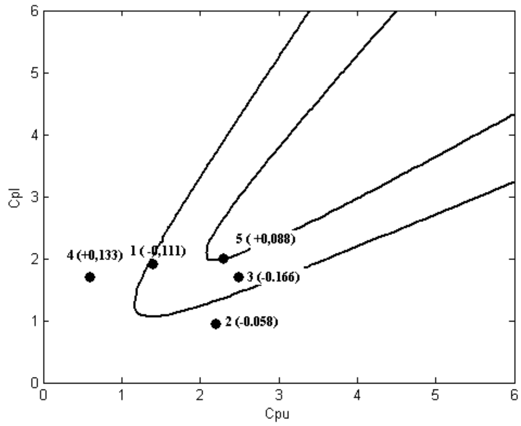

Figure 2. Capability and Price Advantage Chart for Five Suppliers

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Sample statistics for each supplier are showed in Table2, and Figure 2 denotes the location of each supplier on the CPAC.

meaning that the products of suppliers 1 and 3 are suitable in terms of the price. In a conclusion, Supplier 3 is the best choice in terms of quality and price.

Table 1. Sample Statistics

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
X	10.3	11.1	10.8	9.8	10.7
S	0.30	0.32	0.24	0.43	0.23
C_{pp}	0.72	1.84	0.59	2.69	0.25
C_{pl}	1.9	0.94	1.7	1.7	2
C_{pu}	1.4	2.2	2.5	0.6	2.3
δ	-0.13	0.4	0.2	-0.5	0.07
(L_δ, U_δ)	(-0.19,-0.07)	(0.34, 0.46)	(0.15, 0.25)	(-0.58, -0.42)	(0.03, 0.11)
γ	0.20	0.21	0.16	0.29	0.15
(L_γ, U_γ)	(0.16, 0.25)	(0.17, 0.26)	(0.13, 0.19)	(0.24, 0.36)	(0.12, 0.18)
Price index	-0.111	-0.058	-0.166	0.133	0.088

The capability point of suppliers 2 and 4 are located in the non-capability region. Their incapability indexes are 0.81, which means the process capabilities of 2 and 4 don't satisfy the company's quality requirements. Therefore supplier 2 and 4 are named as non-capable and eliminated.

The capability point of supplier 5 is located on the C_{pp} =0.25 contour plot. Supplier 5 has an acceptable C_{pp} value, but unacceptable price index. Since, price index value is I_p >0. Consequently, these suppliers are not preferred for the company.

The capability point of supplier 1 and 3 are located in the C_{pp} =0.81 contour region. Incapability index is 0.72 for supplier 1 and 0.59 for supplier 3. This means that process comply with the requirement of Motorola. These two suppliers satisfy buyer demands for quality. The price index of suppliers 1 and 3 is < 0, their values are -0.111 and -0.166 respectively,

5. CONCLUSION

Supplier selection is one of the company's most critical decision processes therefore, it should be carefully and systematically considered by decision makers. Supplier selection problem has been studied in the literature for years. Various techniques, criteria and factors are developed in order to evaluate suppliers effectively. This study considers supplier selection process as a multi-criteria problem and discusses two important attributes, quality and price, which are base and essential factors for customer satisfaction. We proposed a model with using incapability index Cpp and price advantage index Ip and presented an actual case study in a pharmaceutical company. In addition to this, process capability index and price advantage chart (CPAC) is developed, based on the Cpp index and price index Ip, to display the process quality performance of each supplier. Using this chart, we evaluated five candidate suppliers and selected adequate one in terms of the process

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capability and price index. Consequently, this model presents a simple but efficient and effective selection process. Adding new supplier attributes such as delivery time, productivity, can extend this study.

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