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A Design for Quality Management Information System in Short Delivery Time Processes

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1. Introduction

Recently, by the advance of IT (information technology), the IT control charts have been paid attention and been used in quality management information system, for not only putting quality into products at the production stage but also improving communication between management and manufacturing [1], [2]. Because the high quality, low cost and short delivery time are demand from customer, delivery to the multi-item small-sized production, the reduction of delivery time is emphasized. For those needs, developing the methods and designs of control chart suitable for today’s work situations (For example, short delivery time process.) become a new problem for manager, which is also one research theme of control chart practical applications study group of JSQC [3].

The classical definitions of the control chart’s PDCA (Plan, Do, Check and Act) procedures are known. Recently, the evaluation of the economy of this control chart’s PDCA procedures is connected with "daily management". By investigating literature cases in the activities of control chart practical applications study group, it is recognized that the act procedure is the most important in the procedures of PDCA of control chart [4]. Because the systematic investigations of control chart’s PDCA design was not done in the works before, Sun, Tsubaki and Matsui defined and considered the PDCA designs based on the $\bar{X}$ control chart [5] and P control chart [6], respectively. In addition, the PDCA design of the $\bar{X}$ control chart with tardiness penalty is investigated [7]. However, the ACT time was not considered in above researches.

In this research, first a design of the $\bar{X}$ control chart is presented and its mathematical formulations are shown. Then, the presented design based on the judgment rules of JIS Z 9021 [8], [9] is studied, finally, by numerically consideration using the data from real situation, the relations of key parameters and delivery time and the total expectation cost are discussed.

2. The design

When the control chart is used in short delivery time processes, the penalties for delay of the delivery time should be imposed. In this research, the PDCA design is set up based on the...
case which starts from deciding the control lines of the $\bar{x}$ control chart, in which the penalties for delay of the delivery time ($T$) have been considered.

The evaluation function of this research is the expected total cost per unit time as follows:

$$C_{e(cost per cycle)} = \frac{E[cycle \ (PDCA)]}{E[cost per cycle]} = \frac{E[cost per cycle]}{\min(T_p + I_1 + O_1 + a, T)}$$  \hspace{1cm} (1)

The definition of the procedures of the PDCA design and the cost elements of equation (1) are explained in Table 1.

The time variables used in the design of this research are defined by Figure 1.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Definition</th>
<th>Element of cost (per unit time)</th>
</tr>
</thead>
</table>
| PLAN      | Constructs control lines of control chart. | $C_p = C_p(p) + C_p(pe)$  
$C_p(p)$ : cost of PLAN  
$C_p(pe)$ : cost of the penalty for delaying the PLAN |
| DO        | Samples and plots on control chart for monitoring the process. | $C_d = C_d(d) + C_d(p)$  
$C_d(d)$ : cost of DO  
$C_d(pe)$ : cost of the penalty for delaying the DO |
| CHECK     | Examines whether the points plotted on control chart are beyond the upper and lower control limits. | $C_c = C_c(c) + C_c(e) + C_c(pe)$  
$C_c(c)$ : cost of CHECK  
$C_c(e)$ : cost of type I error  
$C_c(pe)$ : cost of the penalty for delaying the CHECK |
| ACT       | Investigate the assignable cause and correct it. | $C_a = C_a(a) + C_a(pe)$  
$C_a(a)$ : cost of ACT  
$C_a(pe)$ : cost of the penalty for delaying the ACT |

Table 1. The definition and the cost elements of the design

Figure 1 shows some of the time variables used in the design of this research. At the start of the PDCA design, PLAN for deciding the control lines is made in $T_p$ time. Therefore, it is thought that the PDCA model starts from the in-control state, because the process is managed by these control lines. Let the process start at the point of $Q$, and let $S$ be the point in time at which the quality characteristic shifts to an out-of-control state as shown in Figure 1. An assignable cause is detected at the point of $C$, and then corrected at the point of $D$. Here, the random variables $I_1$ and $O_1$ represent the interval from $Q$ to $S$ and the interval from $S$ to $C$.

The assumptions of the design in this research are as follows:
1. The delivery time is short, and the process is repetitive.
2. The quality shift occurs in the middle of an interval between samples [10]

In this research, both the random variables $I_1$ and $O_1$ are assumed to be independently and exponentially distributed with mean $\lambda_1^{-1}$, $\mu_1^{-1}$, then (1) is
Fig. 1. Some of time variables used in the design
\[ C_I = \left[ \frac{1}{\lambda_1 - \mu_1} \left( e^{-\lambda_1(T - T_p - \delta)} - 1 \right) - \frac{\lambda_1}{\mu_1} e^{-\mu_1(T - T_p - \delta)} - 1 \right] + T_p + a \]

\[ \left( T \phi_1 + T_p (1 - \phi_1) \right) + c_{\beta P} \phi_2 + \left( \frac{c_2}{v} \right) \left[ \frac{1}{\lambda_1 - \mu_1} \left( e^{-\lambda_1(T - T_p - \delta)} - 1 \right) - \frac{\lambda_1}{\mu_1} e^{-\mu_1(T - T_p - \delta)} - 1 \right] \]

\[ \left( c_3 / v_1 \right) a \left( 1 - e^{-\lambda_1(T - T_p)} \right) + c_{\beta P} \left[ \frac{1}{\mu_1} + \frac{1}{\lambda_1 - \mu_1} e^{-\lambda_1(T - T_p)} - \frac{\lambda_1}{\mu_1} e^{-\mu_1(T - T_p)} - 1 \right] \]

\[ \left( c_4 / v_1 \right) a + \left( \frac{1}{\lambda_1 - \mu_1} \left( e^{-\lambda_1(T - T_p)} (1 - e^{-\lambda_1(T - T_p)} \right) \right. \]

\[ \left. \left. + c_{\beta D} \left[ \frac{\lambda_1}{\mu_1} (1 - e^{-\mu_1(T - T_p)} (1 - e^{-\lambda_1(T - T_p)} \right) \right. \right. \]

\[ \left. \left. + \frac{\mu_1}{\lambda_1} e^{-\lambda_1(T - T_p)} (1 - e^{-\lambda_1(T - T_p)} \right) \right] \right] + \left[ \frac{1}{\lambda_1 - \mu_1} \left( e^{-\lambda_1(T - T_p - \delta)} - 1 \right) - \frac{\lambda_1}{\mu_1} e^{-\mu_1(T - T_p - \delta)} - 1 \right] \]

Where

\[ \mu_1^{-1} = v(1 / P_a - 1) + v / 2 = v(1 / P_a - 1 / 2). \]

3. Numerical experiments

A. Explanation of parameters from a real situation

The parameters used in this research are from A company, which is based on a real situation. Where \( c_0 = 50, c_1 = 40, c_2 = 100, c_3 = 2000, c_4 = 8000, c_{\beta P} = c_{\beta D} = 1000000, \)

\( c_{\beta P} = 1000000, v = 1 \text{ day}, f = 20, \phi_1 = 0.01, \phi_2 = 0.001, 1 / \lambda_1 = 10 \text{ days}, \delta = 1, k = 3.0, a = 0.083 \text{ day}. \) The notation used is as follows:

\( n \) the sample size per each sampling

\( v \) the sampling interval

\( T \) delivery time

\( T_p \) the interval of PLAN

\( c_0 \) fixed sampling cost

\( c_1 \) variable sampling cost

\( c_2 \) cost of per unit time for checking the point plotted

\( c_3 \) cost of false alarm

\( c_4 \) cost of restoring an in-control state

\( c_{\beta P} \) cost of per unit time for penalties delay of PLAN

\( c_{\beta D} \) cost of per unit time for penalties delay of DO

\( c_{\beta C} \) cost of per unit time for penalties delay of CHECK (penalties for sending the mistake information)
In this research, the outside dimension of molding plate is a key quality characteristic. The difference between the outside dimension and set value is plotted on the $\bar{X}$ control chart.

### B. Investigations based on the judgment rules of JIS Z 9021

In the production process, the power ($Pa$) is different depending on the kind of the judgment rule. In this section, the presented design is considered based on the rule 1 ($3\sigma$ rule) and rule 2 (9 ARL rule) of JIS Z 9021. Because sample size $n$ is not only an influence element to test but also an important parameter of cost, at first, the two judgment rules are studied by the change of $n$.

From Figure 2, it can be noted that the $Pa$ by the two rules increases with the increase of sample size $n$, and the speed of increase of 9 ARL rule is faster. Next, the design based on the two judgment rules is studied by the change of $n$. From Figure 3, it can be note that when $n$ is small, the expected total cost $Ct$ of 9 ARL rule is cheaper. From Figure 3, it also can be note that the expected total cost $Ct$ of $3\sigma$ rule is the cheapest when $n$ is five. This result is corresponding to the sampling size actually used in A company. Therefore, it could be said that the presented design is applicability.

### C. Investigations of the relations between the power and delivery time and the total expectation cost

From Figure 4, it can be understand that the expected total cost per unit time ($Ct$) decreases with the increase of the power ($Pa$). This is because that the cost of defective goods decreases by the increase of the power ($Pa$).

![Fig. 2. Power by the two rules](www.intechopen.com)
From Figure 4, it also can be understood that a longer delivery time should be set when the higher power for higher quality is demanded; while a shorter delivery time should be set when the low power for not higher quality is demanded.

In addition, to understand a more detailed setting, Table 2 is shown, which is based on the case of A company. The axis of ordinate and abscissas are $P_a$ and $T$.

From Tables 2, it can be understood that this tables are divided into two areas: in the colourlessness area, a longer delivery time should be set for the higher power (higher quality) being demanded; in the Blue area, a shorter delivery time should be set for the low power (not higher quality) being demanded.
Table 2. The balance of $Pa$, $T$ and $C_t$

From Tables 2, it also can be understood that how much total expectation cost should be paid by the different power, when the delivery time is strictly demanded; how much total expectation cost should be paid by different delivery time, when the power of process is strictly demanded. Because Table 2 shows the relation (concrete value) of power, the delivery date and the total expectation cost, it would become a reference for business plan.

D. The balance of $k$, $T$ and $C_t$

In this section, we study the relations between the delivery time and ACT time and the total expectation cost, then we investigate the balance of control limits width ($k$) and delivery time ($T$) and the total expectation cost ($C_t$) by numerically analyzing the above design. Where, $c_0=1$, $c_1=0.1$, $c_2=10$, $c_3=50$, $c_4=25$, $c_β_a = c_β_p = c_β_b = 200$, $c_β = 2400$, $n_1=4$, $n_t=0.0316$, $T_p=1$, $a_β = 0.01$, $a_β = 0.001$, $λ_1=1$.

Table 3 show the balance of the quality (control limits width) and delivery time and the total expectation cost of the above case, which is useful for setting the optimal delivery time and control limits width to the supplier.
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From Table 3, it can be understood that this tables are divided into two areas by the changed control limits width: in the colorlessness area, the expected total cost per unit time \( C_t \) increases with the increase of delivery time \( T \); in the blue area, the expected total cost per unit time \( C_t \) decreases with the increase of delivery time \( T \).

From Table 3 and Figure 5, it can be noted that the expected total cost per unit time \( C_t \) increases with the increase of control limits width \( k \). This is because that the cost of defective goods increases by the increase of control limits width.

![Fig. 5. The relation between \( k \) and \( C_t \) \((T=2,T=5)\).](image)

From Table 3, it also can be understand that a longer deliver y time should be set when the high quality (when \( k \) is small) is demanded, while a shorter delivery time should be set when the low quality is demanded from an economic aspect.

In addition, to clarify it more, we also show the Figure 6 which is the same as the case of Table 3.

![Fig. 6. The relation between \( T \), \( k \) and \( C_t \).](image)
Table 4. The balance of $a$, $T$, and $C_t$.

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E. The relation between $T$, $a$ and $C_t$

Figure 7 shows the relation between the delivery time and ACT time and the total expectation cost, which is useful for setting the optimal delivery time and ACT time to the supplier. From Figure 7, it can be understood that the tables are divided into two areas by the changed ACT time: in the colorlessness area, the expected total cost per unit time ($C_t$) increases with the increase of delivery time ($T$); in the blue area, the expected total cost per unit time ($C_t$) decreases with the increase of delivery time ($T$).

From Figure 7 and Table 5, it can be noted that the expected total cost per unit time ($C_t$) increases with the increase of ACT time ($a$). This is because that the cost of defective goods increases by the increase of ACT time. Also it can be understand that a longer delivery time should be set when the ACT time is long, while a shorter delivery time should be set when the ACT time is short from an economic aspect.

In addition, to clarify it more, we also show the Figure 8 which is the same as the case of Figure 7.
4. Conclusions

In this research, from an economic viewpoint, a design of the $\bar{x}$ control chart is analyzed for quality management information system used in short delivery time processes. Because of competition in markets, studying the balance of quality and the delivery time and cost has become a new problem to manager. To resolve this problem, the mathematical formulations which correspond to this design were shown, and then by numerically considering using the data from real situation, the relations of the power of process and delivery time and the total expectation cost, the balance of quality (control limits width) and delivery time and the total expectation cost, the relations between the delivery time, ACT time and the total expectation cost are discussed, respectively. Moreover, the presented design based on the judgment rules of JIS Z 9021 was studied.

Some comments are drawn as follows, which would become useful references for setting the optimal delivery time, ACT time and the power of process to manager.

1. The expected total cost per unit time decreases with the increase of the power of process.
2. The power by the two rules (3σ rule and 9 ARL rule) increases with the increase of sample size $n$, and the speed of increase of 9 ARL rule is faster.
3. A longer delivery time should be set when the higher power for higher quality is demanded from an economic aspect.
4. A longer delivery time should be set when the ACT time is long, from an economic aspect.

5. References

The content of the book has been structured into four technical research sections with total of 18 chapters written by well recognized researchers worldwide. These sections are: 1. process and performance management and their measurement methods, 2. management of manufacturing processes with the aim to be quickly adaptable after real situation demands and their control, 3. quality management information and communication systems, their integration and risk management, 4. management processes of healthcare and water, construction and demolition waste problems and integration of environmental processes into management decisions.

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