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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  $\overline{x}$  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

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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:

$$C_{t(CAPD)} = \frac{E[cost \ per \ cycle]}{E[cycle \ (PDCA)]} = \frac{E[cost \ per \ cycle]}{E[min(T_p + I_1 + O_1 + a, T)]}$$
(1)  
$$= C_p + C_d + C_c + C_a.$$

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.

Procedure	Difinition	Element of cost (per unit time)
PLAN	Constructs control lines of control chart.	Cp=Cp(p)+Cp(pe) Cp(p) cost of PLAN Cp(pe) cost of the penalty for delaying the PLAN
DO	Samples and plots on control chart for monitoring the process.	Cd=Cd(d)+Cd(pe) $Cd(d)  cost of DO$ $Cd(pe)  cost of the penalty for delaying the DO$
CHECK	Examines whether the points plotted on control chart are beyond the upper and lower control limits.	Cc=Cc(c)+Cc(e)+Cc(pe) $Cc(c)$ cost of CHECK $Cp(p)$ cost of type I error $Cp(pe)$ cost of the penalty for delaying the CHECK
ACT	Investigate the assignable cause and correct it.	Ca=Ca(a)+Ca(pe) $Ca(a)  cost of ACT$ $Ca(pe)  cost of the penalty for delaying the ACT$

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 *Tp* time. Therefore, it is thought that the PDCA model starts from the in-control state,

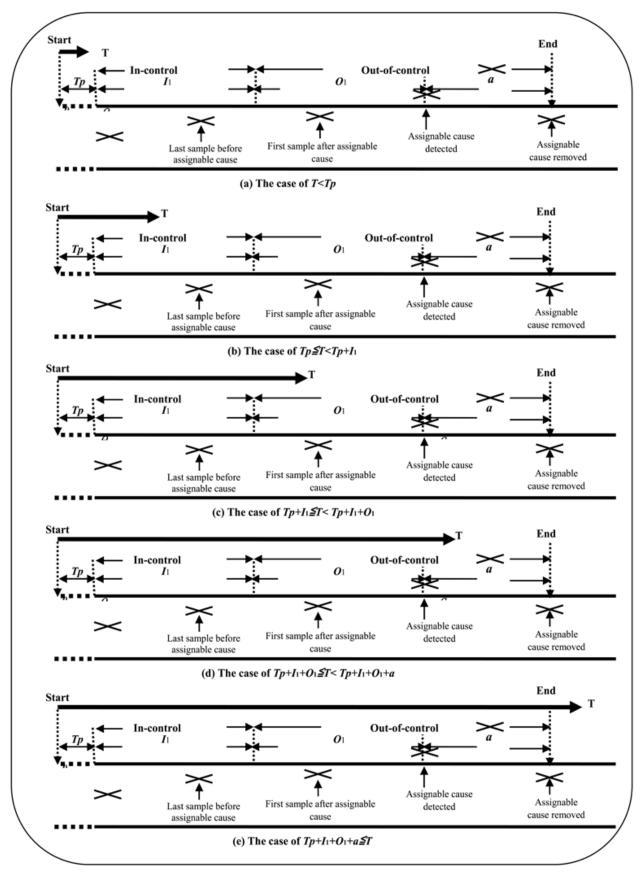
because the process is managed by these control lines. Let the process start at the point of Q, and let S be the point in time at which the quality characteristic shifts to an out-of-control state as shown in Figure 1. An assignable cause is detected at the point of C, and then corrected at the point 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



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

Fig. 1. Some of time variables used in the design

$$Ct = \{((c_{0} + c_{1}n) / v)[T\phi_{1} + T_{p}(1 - \phi_{1})] + c_{\beta p}\phi_{1} + [(c_{0} + c_{1}n) / v] \\ \left[\frac{1}{\lambda_{1} - \mu_{1}} \{\frac{\mu_{1}}{\lambda_{1}} (e^{-\lambda_{1}(T - T_{p} - a)} - 1) - \frac{\lambda_{1}}{\mu_{1}} (e^{-\mu_{1}(T - T_{p} - a)} - 1)\} + T_{p} + a - (T\phi_{1} + T_{p}(1 - \phi_{1}))] + c_{\beta d}\phi_{2} + (c_{2} / v)[\frac{1}{\lambda_{1} - \mu_{1}} \{\frac{\mu_{1}}{\lambda_{1}} (e^{-\lambda_{1}(T - T_{p} - a)} - 1) - \frac{\lambda_{1}}{\mu_{1}} (e^{-\mu_{1}(T - T_{p} - a)} - 1)\} + T_{p} + a - (T\phi_{1} + T_{p}(1 - \phi_{1}))] + (c_{3} / v_{1})\alpha \frac{1}{\lambda_{1}} (1 - e^{-\lambda_{1}(T - T_{p})}) + c_{\beta c}[\frac{1}{\mu_{1}} + \frac{1}{\lambda_{1} - \mu_{1}} (e^{-\lambda_{1}(T - T_{p})} - \frac{\lambda_{1}}{\mu_{1}} e^{-\mu_{1}(T - T_{p})})] + c_{4}[a + \frac{1}{\lambda_{1} - \mu_{1}} (\frac{\lambda_{1}}{\mu_{1}} e^{-\mu_{1}(T - T_{p})}(1 - e^{\mu_{1}a}) - \frac{\mu_{1}}{\mu_{1}} e^{-\lambda_{1}(T - T_{p})}(1 - e^{\lambda_{1}a}))] + c_{\beta a}[\frac{\lambda_{1}\mu_{1}}{\lambda_{1} - \mu_{1}} (-\frac{1}{\mu_{1}} e^{-\mu_{1}(T - T_{p})}(1 - e^{\mu_{1}a}) + \frac{1}{\lambda_{1}} e^{-\lambda_{1}(T - T_{p})}(1 - e^{\lambda_{1}a}))]\} / [\frac{1}{\lambda_{1} - \mu_{1}} \{\frac{\mu_{1}}{\mu_{1}} (e^{-\lambda_{1}(T - T_{p} - a)} - 1) - \frac{\lambda_{1}}{\mu_{1}} (e^{-\mu_{1}(T - T_{p} - a)} - 1)\} + T_{p} + a]$$

Where

$$\mu_1^{-1} = v(1/P_a - 1) + v/2 = v(1/P_a - 1/2).$$
(3)

#### 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 c0=50, c1=40, c2=100, c3=2000, c4=8000,  $c_{\beta a} = c_{\beta p} = c_{\beta d} = 1000000$ ,

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

- *n* the sample size per each sampling
- *v* the sampling interval
- *T* delivery time
- Tp the interval of PLAN
- $c_0$  fixed sampling cost
- *c*<sub>1</sub> variable sampling cost
- *c*<sub>2</sub> cost of per unit time for checking the point plotted
- $c_3$  cost of a false alarm
- *c*<sub>4</sub> 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)

34

- $c_{\beta a}$  cost of per unit time for penalties delay of ACT
- *f* number of samples taken during *T*-*Tp*
- $\delta$  size of the quality shift in the mean
- *a* the ACT time
- *k* control limits width

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).

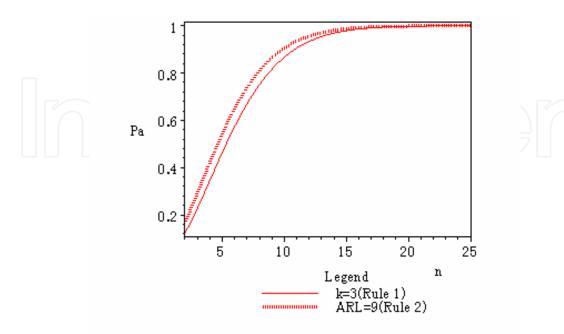


Fig. 2. Power by the two rules

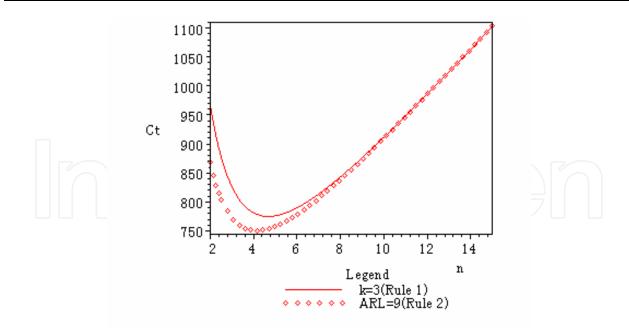
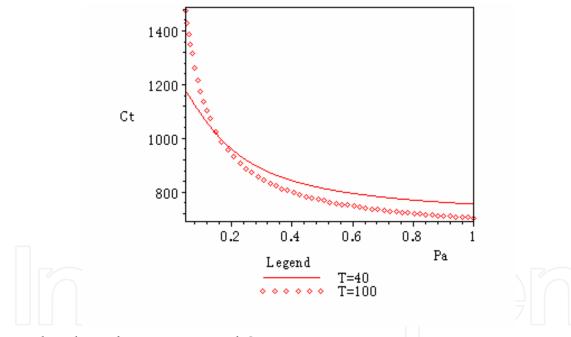
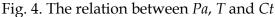


Fig. 3. Investigating the design by the two rules





From Figure 4, it also can be understand 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 *Pa* 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.

D					Т				
Pa	40	50	60	70	80	90	100	110	120
0.05	1176.9	1302.2	1377.4	1422.1	1448.7	1464.6	1474.0	1479.5	1482.7
0.10	1090.8	1135.5	1155.3	1163.8	1167.3	1168.6	1169.05	1169.06	1168.9
0.15	1017.8	1023.5	1024.6	1024.8	1024.6	1024.4	1024.15	1023.88	1023.6
0.20	961.3	949.7	944.8	942.8	941.9	941.4	941.03	940.71	940.4
0.30	890.0	863.6	855.2	852.0	850.6	849.9	849.47	849.11	848.8
0.35	860.0	836.8	827.7	824.2	822.8	822.0	821.58	821.21	820.9
0.40	840.0	816.2	806.6	802.9	801.4	800.6	800.12	799.74	799.4
0.46	824.1	796.0	786.0	782.1	780.5	779.7	779.25	778.87	778.5
0.50	810.0	786.4	776.1	772.2	770.5	769.7	769.25	768.87	768.5
0.55	800.0	775.2	764.8	760.8	759.1	758.3	757.79	757.40	757.1
0.60	799.0	765.9	755.2	751.1	749.5	748.6	748.13	747.74	747.4
0.65	791.0	757.9	747.1	742.9	741.2	740.4	739.88	739.49	739.1
0.70	781.4	751.0	740.0	735.8	734.1	733.3	732.76	732.37	732.0
0.75	775.7	744.9	733.9	729.7	727.9	727.1	726.55	726.15	725.8
0.80	770.6	739.6	728.5	724.2	722.4	721.6	721.08	720.68	720.3
0.85	766.2	734.9	723.7	719.4	717.6	716.7	716.23	715.83	715.5
0.90	762.1	730.7	719.4	715.1	713.3	712.4	711.90	711.50	711.1
0.95	758.5	726.9	715.5	711.2	709.4	708.5	708.01	707.61	707.3
1.00	755.3	723.5	712.0	707.7	705.9	705.0	704.50	704.10	703.7

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

Table 2. The balance of *Pa*, *T* and *Ct* 

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 Ct

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 (*Ct*) by numerically analyzing the above design. Where,  $c_0=1$ ,  $c_1=0.1$ ,  $c_2=10$ ,  $c_3=50$ ,  $c_4=25$ ,  $c_{\beta a} = c_{\beta p} = c_{\beta d} = 200$ ,  $c_{\beta c} = 2400$ ,  $n_1=4$ ,  $v_1=0.0316$ , Tp=1,  $\phi_1 = 0.01$ ,  $\phi_2 = 0.001$ ,  $\lambda_1=1$ .

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.

ŀ								k						
-	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
2.50	284.941	285.070	286.939	290.475	295.984	304,187	316.349	334.550	362.096	403.805	465.203	548.437	645.798	740.137
2.75	283.866	283.992	285.869	289.420	294.957	303.206	315.447	333.810	361.788	404.863	470.364	563.733	679.704	798.529
3.00	283.039	283.164	285.046	288.609	294.166	302.448	314.745	333.210	361.406	405.115	472.825	572.936	703.662	844.432
3.25	282.376	282.500	284.385	287.957	293.529	301.836	314.174	332.713	361.056	405.130	474.100	578.676	720.880	880,838
3.50	281.825	281.947	283.836	287.414	292.998	301.322	313.691	332.286	360.737	405.055	474.801	582.367	733.437	196'606
3.75	281.351	281.473	283.364	286.947	292.539	300.878	313.270	331.907	360.438	404.934	475.194	584.798	742.705	933.441
4.00	280.933	281.054	282.947	286.534	292.133	300.483	312.893	331.562	360.155	404.784	475.404	586.425	749.612	952.502
4.25	280.554	280.676	282.570	286.161	291.765	300.123	312.548	331.241	359.882	404.612	475.495	587.523	754.794	968.065
4.50	280.206	280.327	282.223	285.816	291.424	299.789	312.225	330.938	359.616	404.424	475.505	588.260	758.701	980.833
4.75	279.879	280.001	281.897	285.492	291.103	299.474	311.918	330.647	359.354	404.224	475.456	588.746	761.652	991.350
5.00	279.568	279.690	281.587	285.184	290.798	299.173	311.624	330.366	359.096	404.014	475.363	589.053	763.881	1000.038
5.50	278.980	279.102	281.000	284.600	290.218	298.599	311.062	329.821	358.585	403.572	475.085	589.309	766.817	1013.199
6.00	278.420	278.542	280.441	284.042	289.664	298.050	310.520	329.292	358.078	403.111	474.728	589.271	768.430	1022.266
6.50	277.875	277.998	279.898	283.500	289.124	297.513	309.989	328.770	357.573	402.636	474.322	589.064	769.250	1028.517
7.00	277.340	277.462	279.363	282.967	288.592	296.985	309.465	328.253	357.068	402.154	473.887	588.757	769.588	1032.807
7.50	276.809	276.932	278.834	282.438	288.065	296.460	308.944	327.738	356.563	401.666	473.434	588.391	769.632	1035.723
8.00	276.281	276.405	278.307	281.913	287.541	295.938	308.425	327.224	356.058	401.175	472.970	587.989	769.497	1037.673

Table 3. The balance of k, T and Ct

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 (Ct) increases with the increase of delivery time (T); in the blue area, the expected total cost per unit time (Ct) 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 (Ct) 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.

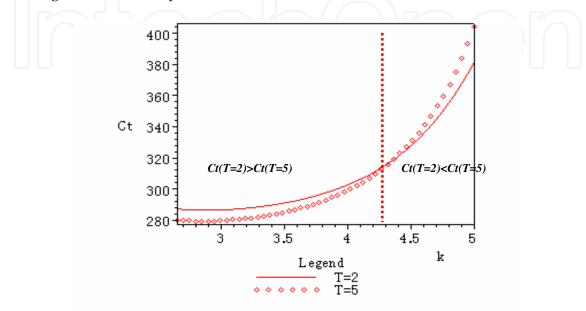


Fig. 5. The relation between *k* and *Ct* (T=2, T=5).

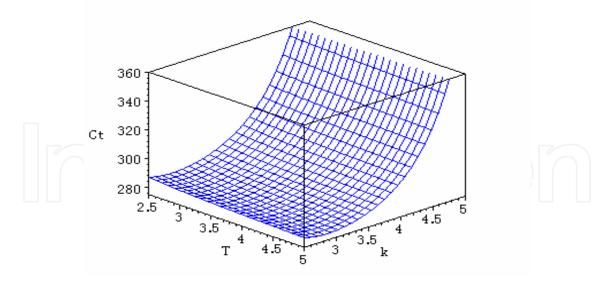


Fig. 6. The relation between *T*, *k* and *Ct*.

From Table 3, it also can be understand that a longer delivery 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.

015         0.25         0.45         0.45         0.56         0.65         0.65         0.75         0.80         0.85         0.90         0.95         100           251694         251.491         287.45         245.52         253.992         257.612         261.473         265.877         265.875         265.875         265.875         275.942         275.942         281.462         281.463           275         220.101         244.462         255.126         257.112         256.173         265.875         265.875         265.875         265.875         275.942         275.942         281.473         283.164           375         274.462         251.266         257.174         266.173         265.767         265.875         265.875         265.875         265.875         275.942         275.942         281.475         283.143           375         274.462         257.128         255.126         257.112         266.447         267.201         275.345         275.345         278.347         281.447           375         274.462         274.462         257.265         266.447         267.261         275.345         276.342         278.347         281.473           375         244.512 <t< th=""><th>T</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>a</th><th></th><th></th><th></th><th></th><th></th><th></th></t<>	T								a						
21.040         28.745         24.532         253.90         257.612         261.164         266.465         266.337         266.393         272.060         278.363         281.046           220.101         244.402         257.171         256.171         256.171         256.171         256.171         256.171         256.171         256.171         256.933         772.060         275.632         278.393         281.046         277.383         281.046         277.383         280.070         277.383         277.383         277.383         277.383         277.383         277.383         277.383         277.383         277.383         277.383         277.383         277.383<		0.15	0.25	0.35	0.45	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
205.160         243.98         242.000         249.31         259.11         259.41         261.164         265.807         268.993         275.122         271.80         281.046           229.311         271.191         244.462         251.266         257.612         267.693         269.549         275.122         271.383         280.070           231.681         249.162         257.632         287.112         261.619         264.47         267.201         269.549         275.532         271.383         280.070           231.512         248.162         258.163         265.163         267.603         267.632         274.492         271.110         293.31           235.513         249.161         258.183         255.516         255.16         267.633         270.134         274.492         271.10         273.345           235.515         249.161         256.316         265.316         267.633         267.633         274.442         277.105         278.347           235.515         248.171         260.347         265.316         267.633         270.432         276.432         278.343         277.345         277.345         277.345         277.345         277.343         277.246         277.346         277.346	0	221.694	230.491	238.745	1991 V 19	253.999	257.612	261.164	264.665	268.122	271.545	274.942	278.323	281.696	285.070
29.311         271.101         241.462         251.266         260.567         266.5680         269.549         275.360         275.122         277.389         280.070           231.666         291.02         246.148         255.652         268.167         267.201         269.877         275.561         277.362         277.355         277.363         277.310           231.561         240.148         255.652         265.168         267.502         270.072         275.552         274.849         277.110         279.317           235.352         241.623         281.64         265.56         265.563         267.653         267.662         267.672         274.462         276.612         279.317           235.352         249.147         260.192         265.306         267.663         267.663         267.661         274.462         276.611         279.317           235.352         249.314         250.304         262.803         265.306         267.462         276.661         276.357         277.362         276.361         277.362         277.362         277.362         277.362         277.362         277.362         277.362         277.362         277.362         277.362         277.362         277.363         277.362         277.36	5	226.160	234.398	-	-	256.171	259.474	261.164	265.877	268.993	272.060	275.087	278.080	281.046	283.992
231.68         299.192         246.148         252.632         288.712         261.619         264.471         267.301         269.887         275.512         275.681         277.598         277.358         277.355         277.365 <td< td=""><td>0</td><td>229.371</td><td>237.191</td><td>-</td><td></td><td>257.674</td><td>260.750</td><td>263.750</td><td>266.680</td><td>269.549</td><td>272.360</td><td>275.122</td><td>277.839</td><td>280.518</td><td>283.164</td></td<>	0	229.371	237.191	-		257.674	260.750	263.750	266.680	269.549	272.360	275.122	277.839	280.518	283.164
23.351         24.0610         24.738         25.417         26.198         26.4897         267.500         270.072         27.559         24.985         271.355         279.675           23.4513         24.1623         284.164         254.238         265.565         265.168         267.503         270.145         275.88         271.10         279.317           235.543         242.711         248.718         256.6159         265.366         265.765         267.169         270.146         276.862         276.862         276.862         276.862         276.862         276.862         276.862         276.862         276.862         276.867         276.867         278.371         278.371           235.512         244.759         240.067         254.895         265.306         265.316         270.366         267.762         279.369         277.346         277.346         277.366         278.361           235.512         243.154         249.047         265.869         265.316         267.355         269.369         271.366         271.362         277.342         277.342           235.543         243.647         266.348         265.317         267.355         269.365         271.365         271.366         271.366         271.366 <td>2</td> <td>231.686</td> <td>239.192</td> <td>-</td> <td>252.632</td> <td>258.712</td> <td>261.619</td> <td>264.447</td> <td>267.201</td> <td>269.887</td> <td>272.512</td> <td>275.081</td> <td>277.598</td> <td>280.070</td> <td>282.500</td>	2	231.686	239.192	-	252.632	258.712	261.619	264.447	267.201	269.887	272.512	275.081	277.598	280.070	282.500
234.533         241.623         248.164         254.28         259.878         265.546         265.168         267.55         267.143         272.410         274.682         276.862         278.985           235.554         242.311         248.718         256.306         267.757         270.134         272.440         276.862         278.985           235.554         249.766         256.030         265.306         267.757         270.146         274.492         276.611         278.671           235.902         242.759         249.344         260.304         262.867         265.306         267.537         270.146         274.492         276.611         278.671           235.902         249.344         255.013         260.304         265.306         267.535         269.940         271.487         276.511         278.671           236.424         243.154         249.341         256.306         265.317         267.335         269.782         276.461         276.611         278.671         278.671           236.483         245.617         256.317         267.373         269.782         276.461         276.461         276.461         276.461         276.461         276.461         276.461         276.461         276.461 <td>0</td> <td>233.351</td> <td>240.619</td> <td>-</td> <td></td> <td>259.417</td> <td>262.198</td> <td>264.897</td> <td>267.520</td> <td>270.072</td> <td>272.559</td> <td>274.985</td> <td>277.355</td> <td>279.675</td> <td>281.947</td>	0	233.351	240.619	-		259.417	262.198	264.897	267.520	270.072	272.559	274.985	277.355	279.675	281.947
255.354         242.311         248.718         254.647         260.159         265.346         265.346         265.346         265.346         265.346         265.346         267.751         274.492         276.611         278.671           235.902         242.759         249.067         258.033         260.346         265.344         267.740         271.462         274.922         276.511         278.671           236.242         243.154         249.260         255.013         260.345         265.310         267.353         269.940         271.482         276.101         278.608           236.242         243.154         249.334         256.033         260.307         266.970         267.132         269.597         271.748         273.328         277.796           236.438         249.317         254976         260.311         267.535         269.597         271.748         273.328         273.742           236.438         242.989         255.012         264.694         266.517         266.597         271.748         273.328         273.742         277.242           236.438         242.983         254.710         259.443         261.317         266.543         266.516         271.242         277.242         277.242 <td>S</td> <td>234.533</td> <td>241.623</td> <td>-</td> <td>254.228</td> <td>259.878</td> <td>262.565</td> <td>265.168</td> <td>267.693</td> <td>270.145</td> <td>272.528</td> <td>274.849</td> <td>277.110</td> <td>279.317</td> <td>281.473</td>	S	234.533	241.623	-	254.228	259.878	262.565	265.168	267.693	270.145	272.528	274.849	277.110	279.317	281.473
235.902         242.759         249.067         254.895         260.345         265.344         267.740         270.061         274.492         276.611         278.671           236.242         243.154         249.260         255.013         260.345         265.306         265.306         267.662         269.940         272.146         276.361         278.671           236.242         243.154         249.361         260.345         265.303         265.311         267.535         269.940         271.956         274.061         276.101         278.373           236.422         243.175         249.317         254.976         260.313         260.315         265.677         267.335         269.597         271.748         275.323         277.242           236.432         243.175         249.317         259.488         265.677         267.373         269.587         271.748         275.323         277.242           236.338         242.602         258.413         261.886         266.473         266.497         268.681         270.782         277.792         277.242           235.645         244.61         253.417         259.48         261.887         266.497         268.681         270.789         276.601         276.668 <td>0</td> <td>235.354</td> <td>242.311</td> <td>-</td> <td>254.647</td> <td>260.159</td> <td>262.775</td> <td>265.306</td> <td>267.757</td> <td>270.134</td> <td>272.440</td> <td>274.682</td> <td>276.862</td> <td>278.985</td> <td>281.054</td>	0	235.354	242.311	-	254.647	260.159	262.775	265.306	267.757	270.134	272.440	274.682	276.862	278.985	281.054
236.242         243.026         255.013         260.345         262.869         265.306         267.305         267.305         267.305         267.305         267.305         267.305         267.305         267.305         267.313         267.305         271.364         271.364         276.301         278.304         278.301         278.304         278.305         277.706         278.304         278.305         277.705         277.706         277.706         277.706         277.328         277.705         277.706         277.328         277.328         277.705         277.328         277.705         277.328         277.705         277.242         277.328         277.328         277.328         277.328         277.328         277.328         277.328         277.328         277.326         277.328         277.328         277.326         277.328         277.328         277.326         277.328         277.328         277.326         277.328         277.328         277.326         277.326         277.326         277.326         277.328         275.328         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326         277.326 <t< td=""><td>5</td><td>235.902</td><td>242.759</td><td></td><td>1000</td><td>260.304</td><td>262.867</td><td>265.344</td><td>267.740</td><td>270.061</td><td>272.310</td><td>274.492</td><td>276.611</td><td>278.671</td><td>280.676</td></t<>	5	235.902	242.759		1000	260.304	262.867	265.344	267.740	270.061	272.310	274.492	276.611	278.671	280.676
236.424         243.154         249.334         255.033         260.308         265.211         267.535         269.597         271.956         274.061         276.101         278.080           236.482         249.317         254.976         260.211         265.070         267.373         269.597         271.748         275.843         277.796           236.482         249.317         254.976         260.211         262.635         265.070         267.373         269.597         271.748         273.828         275.322         277.796           236.338         242.989         249.087         259.488         262.335         264.694         266.970         269.166         271.287         273.328         275.322         277.796           235.963         242.602         258.940         261.376         265.983         268.163         270.267         272.825         274.794         276.698           235.450         242.602         258.940         261.376         265.983         268.163         270.267         271.763         275.626         275.325         274.762         275.626         275.426         275.426         275.626         275.426         275.426         275.626         275.626         275.225         270.617         275	0	236.242	243.026		255.013	260.345	262.869	265.306	267.662	269.940	272.146	274.284	276.357	278.371	280.327
236.482         243.175         249.317         254.976         260.211         265.670         267.373         269.597         271.748         273.828         277.343         277.342         277.342           236.338         242.989         249.087         254.700         259.886         262.335         264.694         266.970         269.166         271.287         273.338         277.342         277.342           235.963         242.602         248.685         254.281         261.886         264.234         266.497         268.681         270.789         275.322         271.242         271.342           235.963         242.602         248.685         254.281         261.886         264.234         266.497         268.681         270.267         274.792         271.242           235.9543         242.602         248.679         263.172         265.983         268.163         270.267         271.262         273.172         275.698           235.455         241.511         247.610         258.391         260.3179         265.463         267.625         269.730         271.762         273.772         275.626           234.852         241.511         247.610         257.816         260.831         267.625         269.730	10	236.424	243.154			260.308	262.803	265.211	267.535	269.782	271.956	274.061	276.101	278.080	280.001
236.338         242.989         249.087         254.700         259.886         262.335         264.694         266.970         269.166         271.287         273.338         275.322         277.242           235.963         242.602         248.685         254.281         259.448         261.886         264.234         266.497         268.681         270.789         275.325         274.794         276.698           235.953         242.093         248.179         253.776         258.940         261.376         265.433         268.163         270.267         271.763         275.698         276.6161           235.450         241.511         247.610         253.217         258.391         261.376         265.443         267.657         269.130         271.763         273.702         275.626           234.852         241.511         247.610         253.217         258.391         263.179         265.443         267.657         269.130         271.763         273.702         275.626           234.203         240.884         247.003         257.816         260.262         265.443         267.627         269.130         271.263         273.109         275.626           234.203         240.884         240.8847         267.625	0	236.482	243.175	-	254.976	260.211	262.685	265.070	267.373	269.597	271.748	273.828	275.843	277.796	279.690
235.963         242.602         248.685         254.281         259.448         261.886         264.234         266.497         268.681         270.789         272.825         274.794         276.698           235.450         242.093         248.179         253.776         258.940         261.376         263.722         265.983         268.163         270.267         274.262         276.161           235.450         241.511         247.610         253.217         258.391         263.179         265.443         267.655         269.730         271.763         273.727         275.626           234.852         241.511         247.603         253.217         258.391         260.831         263.179         265.443         267.074         271.763         273.727         275.626           234.823         240.884         247.003         252.627         257.816         260.262         262.618         264.887         267.074         269.185         271.222         273.190         275.626           234.233         240.884         247.003         252.627         257.816         260.262         264.887         267.074         269.185         271.222         273.190         275.692           233.522         240.230         246.317 </td <td>0</td> <td>236.338</td> <td>242.989</td> <td></td> <td>254.700</td> <td>259.886</td> <td>262.335</td> <td>264.694</td> <td>266.970</td> <td>269.166</td> <td>271.287</td> <td>273.338</td> <td>275.322</td> <td>277.242</td> <td>279.102</td>	0	236.338	242.989		254.700	259.886	262.335	264.694	266.970	269.166	271.287	273.338	275.322	277.242	279.102
235.450         242.093         248.179         253.776         258.940         261.376         263.722         265.983         268.163         270.267         272.299         274.262         276.161           234.852         241.511         247.610         253.217         258.391         260.831         263.179         265.443         267.625         269.730         271.763         273.727         275.626           234.852         241.511         247.003         252.627         257.816         260.262         262.618         264.887         267.074         269.185         271.222         273.190         275.092         275.092           234.203         240.884         247.003         252.627         257.816         260.262         262.618         264.887         267.074         269.185         271.222         273.190         275.092           233.522         240.230         246.372         252.018         257.225         259.681         264.321         266.516         268.633         270.677         272.651         274.559	0	235.963	242.602	-		259.448	261.886	264.234	266.497	268.681	270.789	272.825	274.794	276.698	278.542
234.852         241.511         247.610         253.217         258.391         260.831         263.179         265.443         267.625         269.730         271.763         273.727         275.626           234.203         240.884         247.003         252.627         257.816         260.262         262.618         264.887         267.074         269.185         271.222         273.190         275.092           234.203         240.884         247.003         252.627         257.816         260.262         262.618         264.887         267.074         269.185         271.222         273.190         275.092           233.522         240.230         246.372         252.018         257.225         259.681         262.044         264.321         266.516         268.633         270.677         272.651         274.559	0	235.450	242.093	248.179	120	258.940	261.376	263.722	265.983	268.163	270.267	272.299	274.262	276.161	277.998
234.203       240.884       247.003       252.627       257.816       260.262       262.618       264.887       267.074       269.185       271.222       273.190       275.092         233.522       240.230       246.372       257.018       257.225       259.681       262.044       264.321       266.516       268.633       270.677       272.651       274.559	0	234.852	241.511	247.610	253.217	258.391	260.831	263.179	265.443	267.625	269.730	271.763	273.727	275.626	277.462
233.522         240.230         246.372         252.018         257.225         259.681         262.044         264.321         266.516         268.633         270.677         272.651         274.559	0	234.203	240.884		252.627	257.816	260.262	262.618	264.887	267.074	269.185	271.222	273.190	275.092	276.932
	0	233.522	240.230	-	252.018	257.225	259.681	262.044	264.321	266.516	268.633	270.677	272.651	274.559	276.405
					2										

Table 4. The balance of *a*, *T* and *Ct* 

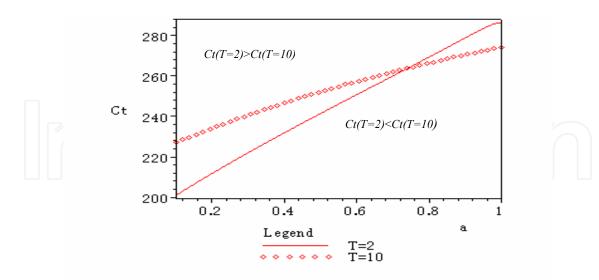
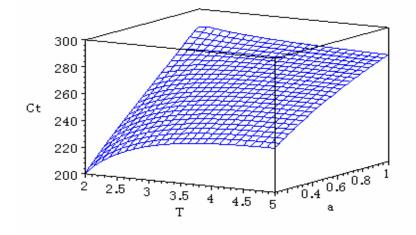




Fig. 7. The relation between *a* and *Ct* (T=2, T=10)



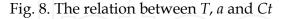


Figure 7 show the relation between the delivery time and ACT time and the total expectation cost, which is useful for setting the optimal delivery time and ACT time to the supplier.

From Figure 7, it can be understood that this tables are divided into two areas by the changed ACT time: in the colorlessness area, the expected total cost per unit time (Ct) increases with the increase of delivery time (T); in the blue area, the expected total cost per unit time (Ct) 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 (*Ct*) 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 consideration 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.

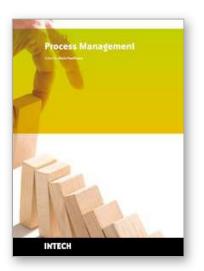
Some comments are drawn as follows, which would become useful references for setting the optimal delivery time, ACT time and the power of process to manager.

- 1. The expected total cost per unit time decreases with the increase of the power of process.
- 2. The power by the two rules (3o 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.

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42



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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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