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EFFECT OF PROCESS VARIABILITY ON THE ECONOMIC VALUES OF AVERAGES CONTROL CHART PARAMETERS

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ABSTRACT– *When the averages control chart is applied to monitor a manufacturing process, three parameters should be determined, sample size, sampling interval between successive samples and the control limit for the chart. This study shows how the effect of process variability caused by common and assignable causes on the values of averages control chart parameters. An example is presented and then based on this example, sensitivity analysis is performed to show the direction of control chart parameters changes in the presence of changes in the magnitude and frequency of process shift and the costs of discovering and correcting the causes of these shifts.*

KEYWORDS: *Process variability, Control Chart for Averages.*

1. INTRODUCTION

The control charts used to continuously monitor the production process to quickly detect any deterioration in quality. Part of the observed variation in a quality variable is caused by complex set of causes, and the variations produced by these causes can be treated an inherent to the process in its current state. The causes, which produce this random or chance variation, are called common causes because their effect is common to all of the process output. The variation produced by any one individual common cause is small, but the total variation produced by all of the common causes together can be substantial. In addition to the common causes that produced the random variation, there may be other sources of variation, called assignable causes or special causes, which are present at certain times and which can individually produce a substantial amount of variation. The main purpose of a control chart is to detect special causes of variation so that these causes can be found and eliminated.

One of the simplest control charts is the averages control chart ($\overline{X}$ - chart) originally developed by Shewhart (1931). This control chart is designed for detecting special causes, which produce a change in the mean of the process. When an $\overline{X}$ - chart is used to monitor a process, three parameters should be determined: the sample size (n), the sampling interval between successive sample (h) and the control limits of the chart (k). Duncan [1] presented the first cost model to determine the three parameters for the $\overline{X}$ -chart, which is called the economic design of $\overline{X}$ - chart. The problem with the commonly used rational approach to control chart design is that it is used in almost all process as the standard procedure for implementing control charts without regard to the cost consequences of the design. In order to overcome this shortcoming, a number of researchers have proposed economic models for the design of control charts, e.g. [2-9]. These models have not been widely used because the models are complex, and difficult to use. Also, these models are typically optimized for a particular size of process mean shift, frequency of out of control, and cost of diagnosis. In practice, the mean period of the process remains in control is not static, the size of the process shift is not constant and the cost of diagnosis change with time. Williams [10] incorporated the concept of statistical consideration into the economic design of control charts and presented the economic statistical design of $\overline{X}$ - chart for normal data. Review of the literature in economic designs of control charts has been published by Ho and Case [11]. Alexander [12] presented economic model of $\overline{X}$ - chart with Taguch's loss function to incorporate losses that result from process mean departure from target value. Chau and Cheng [13] presented minimum loss design of $\overline{X}$ - charts for non-normal data. Chou et al [14] developed the economic design of $\overline{X}$ - charts for correlated data. Bai and Lee [15] presented variable sampling interval $\overline{X}$ - control charts with an improved switching rule which use a long sampling interval if consecutive sample means fall close to control chart centerline and short interval otherwise. Chen and LIAO [16] presented a model for the design of an $\overline{X}$ control chart from a multiple criteria. With this model, sets of design parameters (n, h, k) for the $\overline{X}$ chart are chosen based on data envelopment analysis and provide the quality control manager a variety of choices to arrive at the requirement of long run quality of product or minimal cost concurrently.

The effect of process variability caused by common and assignable causes on the $\overline{X}$ - chart parameters are not considered in the most of the previous studies. In this study, Duncan's cost model for $\overline{X}$ - chart is employed as the objective function, which is intended to be minimized. This function is used with the Taguchi loss function to consider losses due to in –control and out –of –control variability. The direction of control chart parameters changes due to changes in magnitude and frequency of process shift and the costs of discovering and correcting the causes of these shifts are presented. In the next section, Duncan's cost model will review and the effect of process variability caused by common and assignable causes on the values of averages control chart parameters will be presented.

2. THEORETICAL ANALYSIS

In this section, the cost model for $\overline{X}$ - chart given by Duncan will be reviewed. Also, the Duncan's cost model with Taguchi's loss function will be presented. Duncan's cost model for $\overline{X}$ - chart is more realistic than the other models. The components of Duncan's cost model include:

(1) the cost of an out-of-control condition;
(2) the cost of false alarms;

(3) the cost of searching for an assignable cause; and
(4) the cost of sampling, inspection, evaluation and plotting.

Duncan assumes that the process starts in control and subject to random shifts in the process mean. Once a shift occurs, the process remains there until corrected. The cycle length is defined as the total time from which the process starts in-control, shifts to an out-of-control condition, has the out-of-control condition detected, and results in the assignable cause being identified. These four time intervals are respectively the interval the process is in-control, the interval the process is out-of-control before the final sample of the detecting subgroup is taken, the interval to sample, inspect, evaluate and plot the subgroup results, and the interval to search for assignable cause. When the average cycle length is determined, the cost components can be converted to a per hour of operation basis. Given associated cost and time parameters, the optimal values of the three decision parameters for the model are then determined by using optimization techniques. In Duncan's model, the four average cycle length components are as follows.

(1) Assuming that the process begins in the in-control state, the time interval that the process remains in control is an exponential random variable with a mean $1/\lambda$, which is the average process in-control time.
(2) When an assignable cause occurs, the probability that this out-of-control condition will be detected on any subsequent subgroup is $1-\beta$, which is the power of the chart. Thus, the expected number of subgroups taken before a shift in the process mean is detected is $1/(1-\beta)$. The average time of occurrence within an interval between the jth and $(j+1)st$ subgroups, given an occurrence of the shift in the interval between these subgroups, is

$$\tau = \frac{1-(1+\lambda h)e^{-\lambda h}}{\lambda\left(1-e^{-\lambda h}\right)} \tag{1}$$

Therefore, the expected length of the out-of-control period is $\frac{h}{(1-\beta)} - \tau$.

(3) The average sampling, inspecting, evaluating and plotting time for each sample is a constant g proportional to the sample size n, so that the delay in plotting a subgroup point on the $\bar{X}$ - chart is $g\,n$.
(4) The time to search for the assignable cause following an action signal is a constant D.

Therefore, the expected length of a cycle, denoted by $E(T)$, is

$$E(T) = \frac{1}{\lambda} + \frac{h}{1-\beta} - \tau + g\,n + D \tag{2}$$

and the expected cost per hour, denoted by $E(C)$, incurred by the process is

$$E\,(\,C\,) = \frac{a_1 + a_2\,n}{h} + \frac{a_4\left[\;E\,(T) - \left(\frac{1}{\lambda}\right)\right] + a_3 + \alpha\,a_5\,e^{\frac{-\lambda h}{1-e^{-\lambda h}}}}{E(\,T\,)} \tag{3}$$

Where a_1 and a_2 the respectively the fixed and variable components of sampling cost, a_3 is the cost of searching for an assignable cause, a_4 represents the hourly penalty cost associated with production in the out-of-control state, and a_5 is the cost of investigating a false alarm. The economic design of an $\overline{X}$ - chart is to determine the appropriate values of n, h and k such that $E\,(\,C\,)$ may be minimized.

The Taguchi loss function provides a means of explicitly considering the loss due to process variability. Taguchi introduced the quality loss function as a quality performance measure for a product. Consider a product with bilateral tolerances of equal Δ. If the loss (or cost) to society of producing a product out of specification is $A\ \$\ /\ unit$, then the Taguchi loss function defines the expected loss to society as

Expected loss per unit = $\frac{A}{\Delta^2} V^2$ (4)

Where V^2 is the mean squared deviation of the process, defined as

$$V^2 = \sigma^2 + (\,T - \mu)^2 \tag{5}$$

and T is the target of the process characteristic. When the process is in control, its mean is centered on the target (i.e., $\mu = T$), and its $V^2 = V_1^2 = \sigma^2$. When the process mean shifts to $\mu = T + \delta\,\sigma$, its mean shifts of process target and

$$V^2 = V_2^2 = \sigma^2 + (\mu - T)^2 \tag{6}$$

By assuming that the production rate is $P\ \ units\,/\,hr$ and applying some approximations on the terms of equation (3) such as

$$\tau \;\approx \frac{h}{2} - \frac{\lambda h^2}{12}\;,\; B = \left[\;\frac{1}{1-\beta} - \frac{1}{2} + \frac{\lambda h}{12}\right] h + D + gn\;,\; \frac{\alpha\,exp\,(-\lambda h)}{1 - exp\,(-\lambda h)} \approx \frac{\alpha}{\lambda h}\;,$$

$L_1 = \frac{A}{\Delta^2}\;V_1^2$ and $L_2 = \frac{A}{\Delta^2}\;V_2^2$, the expected cost (or loss) per hour, denoted by $E(L)$, can be obtained as

$$E(L) = \frac{a_1 + a_2\;n}{h} + \frac{a_3\;\lambda + a_5\;\alpha / h + L_1\;P + L_2\;P\;\lambda\;B}{1 + \lambda\;B} \tag{7}$$

Equation (7) determines the minimum loss design of an $\overline{X}$ - chart involves determining the optimal values of the sample size (n), the sampling interval between successive sample (h) and the control limits of the chart (k) such that $E(L)$ is minimized. In other words, the optimal values for n, h and k can be obtained by minimizing the above cost function, $E(L)$.

3. AN EXAMPLE AND ITS SOLUTION

In this section, an example is presented to illustrate the solution procedure of the minimum loss design of an $\overline{X}$ - chart. A plant manufactures packed orange juice that has a quantity of content specification of 250 cc with a tolerance of ± 0.3 cc (i.e., $\Delta = 0.3$). From past data, the process standard deviation is estimated as 0.1cc (i.e., $\sigma = 0.1$). Process shifts occur at random with a frequency of about one every 4 hours of operation ($\lambda = 0.25$). The manufacturer uses $\overline{X}$-chart to monitor the process. Based on an analysis of quality control technicians salaries and the costs of test equipment, it is estimated that the fixed cost of taking a sample is \$1(i.e., $a_1 = 1$). The estimated variable cost of sampling is about \$0.10 per quantity of content (i.e., $a_2 = 0.10$) and it takes approximately 0.01 hour (i.e., $g = 0.01$) to measure and record the quantity of content of a bottle of orange juice. On average, when the process goes out of control, the magnitude of the shift is approximately one standard deviation ($\delta = 1.0$). The average time required to investigate an out of control signal is two hours (i.e., $D = 2$). The cost of investigating an action signal that results in the elimination of an assignable cause is \$50 while the cost of investigating a false alarm is \$50 (i.e., $a_3 = 50$ and $a_5 = 50$). The process is assumed to continue to produce packed orange juices at a rate of 100/h during the period of investigating and elimination of out-of-control signals (i.e., $P = 100$). The cost of reworking or scraping a package of juice that is found to be outside the specification limits is \$5 (i.e., $A = 5$).

A computer program is coded for minimization of the cost model in equations (3) and (7). The program calculates the optimum values of n, h and k by evaluating a wide range of possible solutions. For a certain combination of n, h and k, the program also calculates the corresponding α risk and power $1-\beta$. The computer program is found in the Appendix. This program is easy to run on any computer with BASIC. The output from this program, using the values of the model parameters given in the above example, is shown in **Table 1**. The program calculates the optimal control limit width k and sampling frequency h for values of n and resulting values of the cost function. The optimal control chart design can be found by inspecting the values of the cost function to find the minimum. From table 1, note that the minimum cost is 88.45 per hour, and the optimal $\overline{X}$ - chart would use samples of size $n = 11$, the control limits would be located at $\pm k\, \sigma / \sqrt{n}$, with $k = 2.5$, and the samples would be taken at intervals of $h = 1.1$ *hour* (about every 66 min.). Type I error probability of this design is $\alpha = 0.02$, and the power of the chart is $1-\beta = 0.78$.

Table 1: The results of a computer search for the optimum design parameters.

Sample Size n	Control Limit Width k	Sampling Interval h	Type 1 Error α	Power of the Chart $1-\beta$	Cost per hour $E(L)$, ($)
2	1.8	0.7	0.07	0.35	90.07
3	1.9	0.7	0.06	0.43	91.64
4	2.1	0.8	0.04	0.46	90.69
5	2.1	0.8	0.04	0.55	90.02
6	2.2	0.9	0.03	0.60	90.54
7	2.2	0.9	0.03	0.67	89.20
8	2.3	1.0	0.02	0.74	89.60
10	2.4	1.0	0.02	0.76	88.65
11	2.5	1.1	0.02	0.78	88.45
12	2.5	1.1	0.01	0.82	88.52
13	2.6	1.2	0.01	0.87	88.70

4. SENSITIVITY ANALYSIS

Continuing the above example, the behavior of the presented model through sensitivity analysis are investigated, the sensitivity of the $\overline{X}$ – control chart parameters such as, sample size (n) and sampling interval between successive samples (h) are shown in **figures 1-4**. **Figures 1** and **2** show the changes in the optimum sample size and optimum sampling interval versus the mean time between assignable causes (1/λ). These figures indicate that, when the mean time between assignable causes increases, the optimum sample size increases and the optimum sampling interval decreases. **Figures 3** and **4** indicate that, increases in the magnitude of the shift in process average warrants a decrease in the sample size and the sampling frequency.

5. CONCLUSIONS

From the previous discussion the following conclusions can be drawn:

1- The presented model for designing $\overline{X}$ – control chart parameters defines losses owing to the process variability caused by both chance and assignable causes.

2- To keep the cost low, the $\overline{X}$ – control chart parameters must be adjusted based on the mean time between assignable causes and the required magnitude of the shift in the process average to be detected.

3- Small mean time between assignable causes requires smaller value of sample size, while requires larger value of sampling interval.

4- Small process shift requires larger values of sample size and sampling interval to be detected.

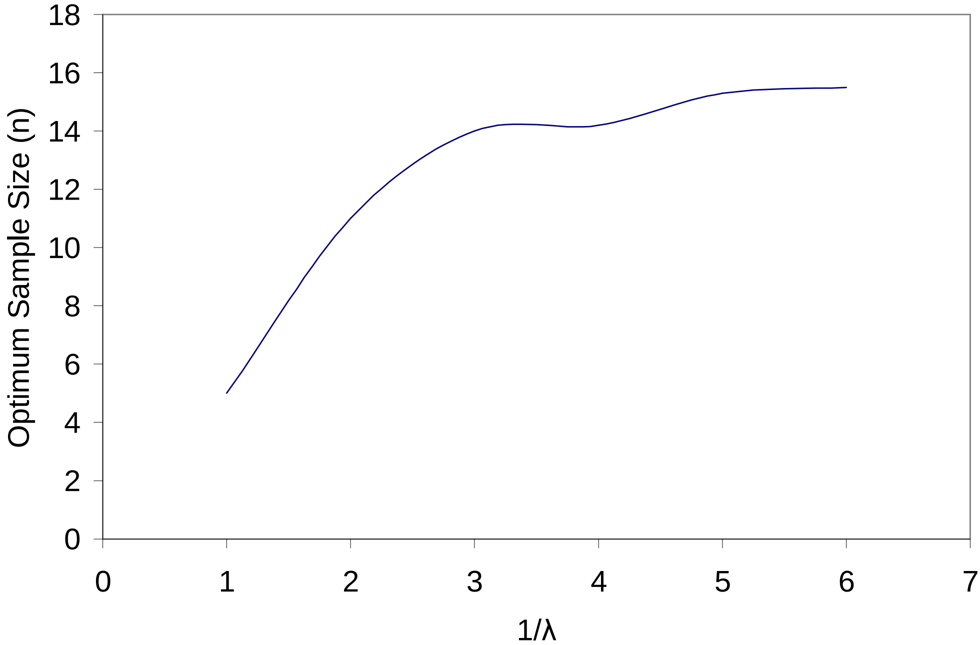

Fig. 1: Optimum sample size versus the mean time between assignable causes (1/λ).

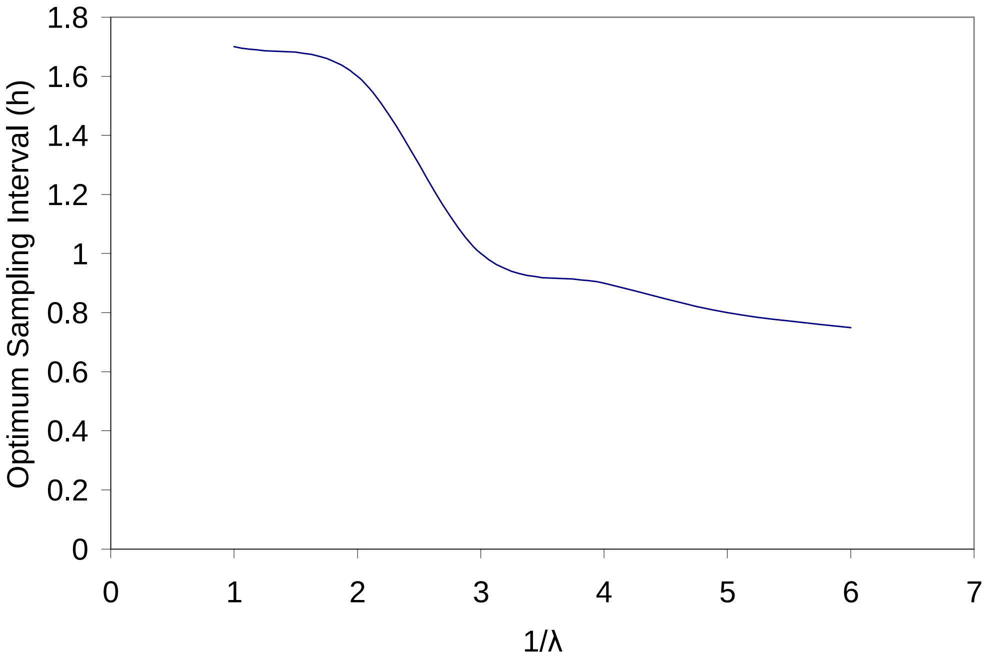

Fig. 2: Optimum sampling interval versus the mean time between assignable causes (1/λ).

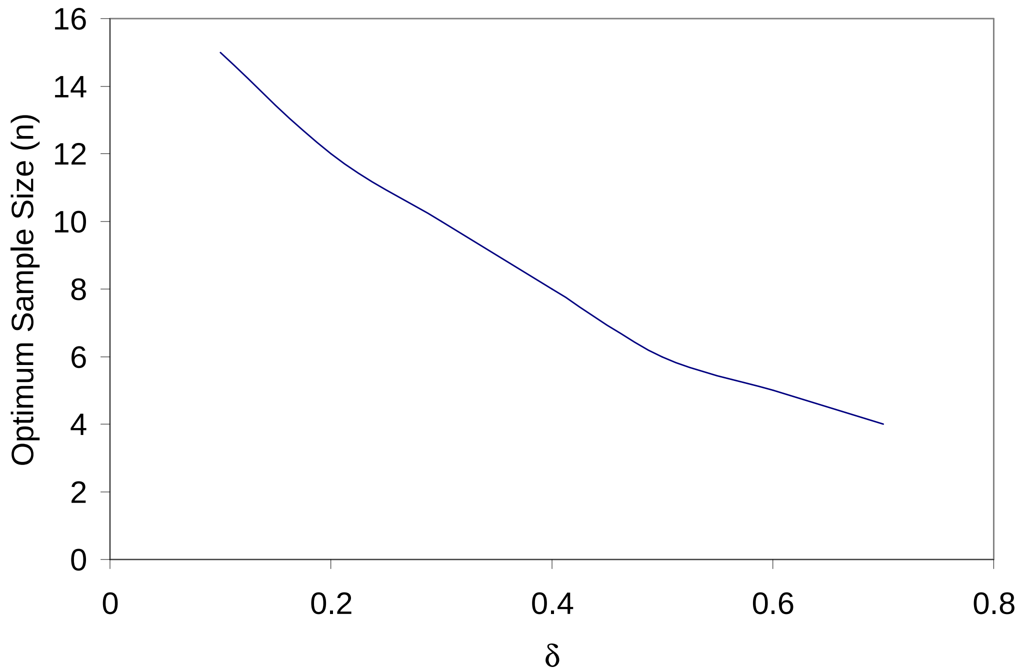

Fig. 3: Optimum sample size versus the magnitude of the shift in process average (δ).

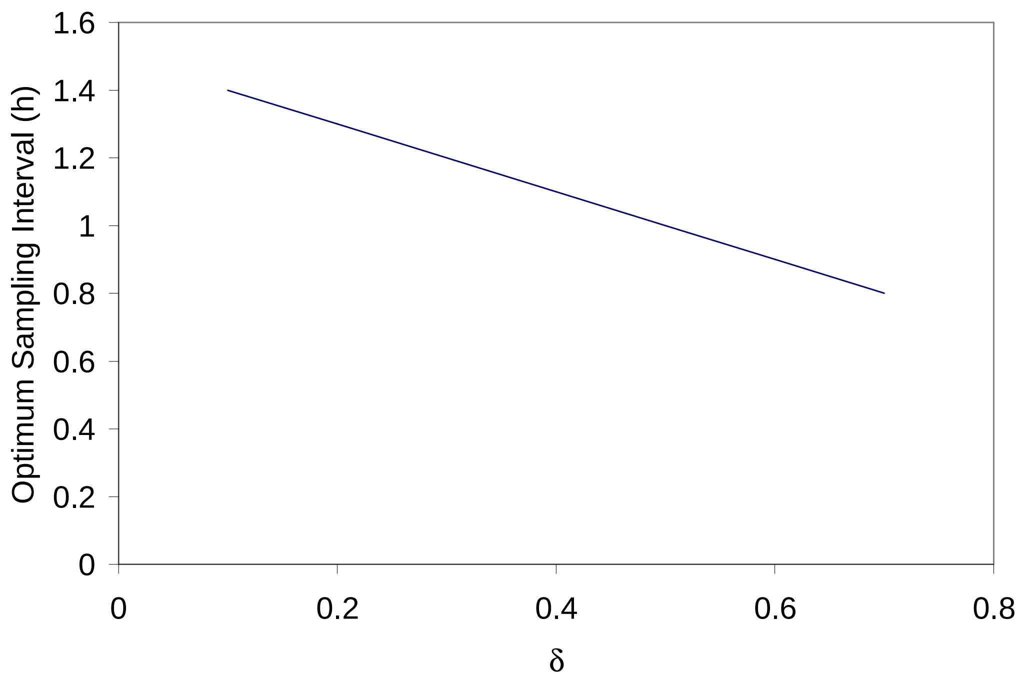

Fig. 4: Optimum sample size versus the magnitude of the shift in process average (δ).

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APPENDIX

Computer program for calculating the optimum values of the $\overline{X}$ - Control Chart Parameters

```
10 REM PARAMETER SELECTIONS FOR XBAR CHARTS
20 CLS
30 INPUT "FIXD SAMPLING COST PER SUBGROUP = "; A1
40 INPUT "VARIABLE SAMPLE COST PER = "; A2
50 INPUT "COST OF FINDING AN ASSIGNABLE CAUSE = "; A3
60 INPUT "COST OF INVESTING A FALSE ALARM = "; A3P
70 INPUT "PRODUCTION RATE (PCS/HR) = ";P
80INPUT "COST (SCRAP OR REWORK) FOR A PART OUTSIDE
SPECIFICATION LIMITS = "; A
90 INPUT "VARIANCE THE PRODUCT ="; V1
100 INPUT "TOLERANCE OF THE PRODUCT (+/- ) = ";TOL
110 INPUT "MEAN TIME PROCESS REMAINS IN CONTROL (HOURS) = ";
LAMDA
120 INPUT "TIME TO TAKE A SAMPLE AND INTERRET RESULTS (HOURS) =
"; G
130 INPUT "TIME TO FIND AN ASSIGNAABLE CAUSE (HOURS = "; D
140 INPUT "SIZE OF THE SHIFT YOU WISH TO DETECT (ABOVE/BELOW
NOMINAL) = "; DELTA
150 REM LISTS OF INPUTS
160 CLS: PRINT "      PARAMETER SELECTION INPUTS"; PRINT: PRINT
170 PRINT "DFIXED SAMPLING COST PER SUBGROUP = "; TAB (70):A1
180 PRINT "2) VARIABLE SAMPLE COST PER SAMPLE = "; TAB (70); A2
190 PRINT "3) COST OF FINDING AN ASSIGNABLE CAUSE = "; TAB (70); A3
200 PRINT "4) COST OF INVESTIGATING A FALSE ALSE ALARM = "; TAB
(70); A3P
210 PRINT "5) PRODUCTION RATE (PCS/HR) = "; TAB (70); P
220 PRINT "6) COST (SCRAP OR REWORK) FOR APART OUTSIDE
SPECIFICATION
LIMITS = "; TAB (70); A
230 PRINT "7) VARIANCE OF THE PRODUCT = "; TAB (70); V1
240 PRINT "8) TOLERANCE OF THE PRODUCT (+/-) = "; TAB (70); TOL
250 PRINT "9) MEAN TIME PROCESS REMAINS IN CONTROL (HOURS) = ";
TAB (70); LAMDA
260 PRINT "10) TIME TO TAKE A SAMPLE AND INTERPRET RESULTS
(HOURS) = "; TAB (70); G
270 PRINT "11) TIME TO FIND AN ASSIGNABLE CAUSE (HOURS) = "TAB
(70); D
280 PRINT "12) SIZE OF THE SHIFT YOU WISH TO DETECT (ABOVE/BELOW
NOMI-
NAL) = "TAB (70); DELTA
290 REM ROUTINE TO MAKE CHANGES
300 PRINT: PRINT: PRINT
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```
310 "INPUT     IF YOU WISH TO CHANCE A VALUE ENTER THE NUMER OR
ENTER 99 IF ALL THE VALUES ARE CORRECT"; E
320 IF E = 1 GOTO 450
330 IF E = 2 GOTO 470
340 IF E = 3 GOTO 490
350 IF E = 4 GOTO 510
360 IF E = 5 GOTO 530
370 IF E = 6 GOTO 550
380 IF E = 7 GOTO 570
390 IF E = 8 GOTO 590
400 IF E = 9 GOTO 610
410 IF E = 10 GOTO 630
420 IF E = 11 GOTO 650
430 IF E = 12 GOTO 670
440 GOTO 490
450 INPUT "FIXED SAMPLING COST PER SUBGRUOP = "; A1
460 GOTO 160
470 INPUT "VARIABLE SAMPLE PER SAMPLE = "; A2
480 GOTO 160
490 INPUT "COST OF FINDING AN ASSIGNABLE CAUSE = "; A3
500 GOTO 160
510 INPUT "COST OF INVESTIGATINC A FALSE ALARM = "; A3P
520 GOTO 160
530 INPUT "PRODUCTION RATE (PCS/HR) = "; P
540 GOTO 160
550 INPUT "COST (SCRAP OR REWORK) FOR A PART OUTSIDE
SPECIFICATION LIMITS = "; A
560 GOTO 160
570 INPUT "VARIANCE OF THE PRODUCT = "; V1
580 GOTO 160
590 INPUT "TOLERANCE OF THE PRODUCT (+/-) = "; TOL
600 GOTO 160
610 INPUT "MEAN TIME PROCESS REMAINS IN CONTROL = "; LAMDA
620 GOTO 160
630 INPUT "TIME TO TA;E A SAMPLE AND INTERPRET RESULTS = ";G
640 GOTO 160
650 INPUT "TIME TO FIND AN ASSIGNABLE CAUSE (HOURS) = "; D
660 GOTO 160
670 INPUT "SIZE OF THE SHIFT YOU WISH TO DETECT (ABOVE/BELOW
NOMINAL) = "; DELTA
680 GOTO 160
690 LPRINT: LPRINT: LPRINT
700 LPRINT: LPRINT: LPRINT TAB (15): "VARIABLES AND PARAMETER
SELECTION FOR XBAR CHART"
710 LPRINT: LPRINT
720 LPRINT TAB (14); "1) FIXED SAMPLING COST PER SUBGROUP = ";
LPRINT TAB (67)
```

```
USING" # #. # # "; A1
730 LPRINT TAB (14) VARABLE SAMPLE COST PER SAMPLE"; LPRINT
TAB (67) USING" # # #. # # "; A2
740 LPRINT TAB (14); "3) COST OF FINDING AN ASSIGNABLE CAUSE";
LPRINT
TAB (67) USING" # # #. # # "; A3
750 LPRINT TAB (14); "4) COST OF INVESTIGATING A FALSE ALARM";:
LPRINT TAB(67)USING "* * * . # # "; A3P
760 LPRINT TAB (14); "5) PRODUCTION RATE (PCS/HR) ";: LPRINT
TAB (67) USING" # # # # # # "; P
770 LPRINT TAB (14): "6) COST (SCRAP/REWORK) FOR A PART OUTSIDE
SPEC LIMITS = "; LPRINT
TAB (67) USING "# # #. # # "; A
780 LPRINT TAB (14); "7) VARIANCE OF THE PRODUCT"; LPRINT
TAB (64) USING "#. # # # # # # # "; V1
790 LPRINT TAB (14); "8) TOLERANCE OF THE PRODUCT (+ / -)"; LPRINT
TAB (67) USING
"# . # # # # "; TO;
800 LPRINT TAB (14); "9) MEAN TIME PROCESS REMAINS IN CONTROL
(HOURS) "; LPRINT
TAB (67) USING "# # # # # . # "; LAMDA
810 LPRINT TAB (14); "10) TIME TO TAKE A SMPLE AND INTERPRET
RESULTS (HRS) "; LPRINT
TAB (68) USING "#. # # # "; G
820 LPRINT TAB (14) TIME TO FIND AN ASSIGNABLE CAUSE (HOURS )
";:LPRINT
TAB (69) USING "# #. # ";D
830 LPRINT TAB(14); "12)SIZE OF THE SHIFT YOU WISH TO DETECT ( + / - )
";:LPRINT TAB(67)USING "# . # # # # "; DELTA
840 LPRINT: LPRINT
850 LPRINT TABS (19): "N –UP SIZE"
860 LPRINT TABS (19): "K –OEFFICIENT TO DETERMINE CONTROL LIMITS"
870 LPRINT TAB (19); "H–SAMPLING INTERVAL (HOURS)"
880 LPRINT"LPRINT
890 LPRINT TAB(13); "N"; TAB(24); "K"; TAB(32);"H" TAB(42);"ALPHA";
TAB(54);"POWER";
TAB (67);"COST"
900 LPRINT TAB (13);"—";TAB(23);:-.–";TAB(31);"- —";TAB(67);"– –"
910 FOR N = 2 TO 12
920 E    CMIN = 9999999!
930 FOR H = .1to 2 step .1
940 for k = 1! To 4! STEP .1
950 REM DETERMINE ALPHA
960 X = -K
970 Y = 2*(K)
980 C= Y/8
```

```
990 S = C/(3*SQR(2*3.14159))*(EXP(-.5X^2)+4*EXP(-.5*(X+Y/8^)2+2*EXP(-
.5*(X+Y/4)^2)+4*EXP(-.5*(X+3*Y/8)^2)+2*EXP(-.5(X+Y/2)^2)+4*EXP(-
.5*(X+5*Y/8^2)+2*EXP(-.5(X+6*Y/8)^2)+4*EXP(-.5*(X+7*Y/8)^2)+EXP(-
.5*(X+Y)^2))
1000 ALPHA = 1– S
1010 IFALPHA < 0 THEN ALPHA = 0
1020 L1= A/TOL ^2*V1
1030 V2 = V1 + DELTA^2)
1040 L2 = A/TOL^2*V2
1050 REM DETERMINE (1– BETA)
1060 NDELTA = DELTA/SQR (V1)
1070 T1 = NDELTA*SQR (N) – K
1080 T2 = – NDELTA*SQR (N)– K
1090 X = - 3.5
1100 Y1 = T1 – X
1110 C = Y1/8
11120 S1 = C/(3*SQR(2*3.14159))*(EXP(–.5X^2)+4*EXP(–.5*(X + Y1/8 )^2) +
2*EXP(–.5*(X + Y1/4)^2) +4*EXP(–.5*(X+ 3*Y1/8)^2) + 2*EXP(–.5*(X + Y1/2)^2)
+ 4*EXP(–.5*(X 5*Y18)^2) + 2*EXP(–.5*(X + 6*Y1/8)^ + 4*EXP–.5*(X
+7*Y1/8)^2) + EXP(–.5*(X +Y1)^2))
1130 X = –5
1140 Y2 = T2– X
1150 C2 Y2/8
1160 S2 = C2/(3*SQR(2*3.14159))*(EXP(–.5X^2)+4*EXP(–.5*(X + Y2/8 )^2) +
2*EXP(–.5*(X + Y2/4)^2) +4*EXP(–.5*(X+ 3*Y2/8)^2) + 2*EXP(–.5*(X + Y2/2)^2)
+ 4*EXP(–.5*(X 5*Y2/8)^2) + 2*EXP(–.5*(X + 6*Y2/8)^ + 4*EXP–.5*(X
+7*Y2/8)^2) + EXP(–.5*(X +Y2)^2))
1170 REM BETA IS 1 – BETA
1180 BETA = S1 + S2
1190 EC = (A1 + A2*N)/H + (A3 + A3P*ALPHA*LAMDA/H +
A*VI*P/TOL^2*LAMDA + A*V2*P/TOL^2*(H/BETA- (H*(.5 – 1/LAMDA*H/12))
+ G*N + D))/(LAMDA + H/BETA – H*(.5 – H/12/LAMDA) + G*N + D)
1200 IF EC > ECMIN THEN GOTO 1260
1210 HBEST = H
1230 KBEST = K
1240 ALPHAB = ALPHA
1250 BETABEST = BETA
1260 NEXT K
1270 NEXT H
1280 LPRINT TAB (14) USING" # # "; N; LPRINT TAB (23) USING " #. # ";
KBEST; LPRINT TAB (31) USING " #. # "; HBEST; LPRINT TAB (41) USING " #.
# # # # "; ALPRINT TAB (54) USING " # . # # # # "; BETABEST; LPRINT TAB (65)
USING " # # # #. # # "; ECMIN
1290 NEXT N
1300 LPRINT CHR$ (12)
1310 INPUT "make a change and run again (Y/N)?"; N$
1320 IF N$ = "Y" GOTO 160
```

تأثير التغيريه في متوسط عملية الإنتاج على القيم الاقتصادية لمتغيرات خرائط الضبط للمتوسطات

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عند استخدام خرائط ضبط الجودة للمتوسطات لمراقبة التغير في متوسطات صفة الجودة للمنتجات أثناء عمليات التصنيع يجب تحديد ثلاثة متغيرات وهم :-

1. حجم العينة التي يجب سحبها من خط الإنتاج.
2. الفترة الزمنية بين سحب العينات.
3. حد الضبط العلوي وحد الضبط السفلى لخريطة ضبط الجودة.

وقد أجريت هذه الدراسة بهدف دراسة تأثير التغيريه في متوسط عملية الإنتاج الناتجة من الأسباب العادية والمحددة على القيم المثلى (الاقتصادية) لمتغيرات خرائط الضبط للمتوسطات. تم اشتقاق نموذج رياضي والذي بواسطته أمكن تحديد القيم المثلى (الاقتصادية) لمتغيرات خرائط الضبط للمتوسطات وذلك باستخدام برنامج حاسب إلى. تم تطبيق النموذج الرياضي المقترح في هذه الدراسة على مثال رقمي بهدف توضيح كيفية تطبيق النموذج الرياضي المقترح أثناء عمليات التصنيع. تم عرض المنحنيات التي توضيح مدى حساسية قيم متغيرات خريطة ضبط الجودة للمتوسطات لكل من الفترات الزمنية لحدوث الانحرافات وقيم هذه الانحرافات في متوسط صفة الجودة للمنتجات أثناء عمليات التصنيع. وقد خلص البحث إلى النتائج التالية:-

1. يجب زيادة حجم العينة المسحوبة من خط الإنتاج عند زيادة تكرار حدوث الانحرافات في متوسط صفة الجودة للمنتجات.
2. يجب نقص حجم العينة المسحوبة من خط الإنتاج عند زيادة قيمة الانحرافات في متوسط صفة الجودة للمنتجات.