

## IE 361 Exam Keys/ Fall 2000

### Exam 1

1. Use

$$\hat{x}_{n+1} = \text{estimated "truth" corresponding to measurement } y_{n+1} = \frac{1}{b_1}(y_{n+1} - b_0)$$

and

$$\hat{x}_{n+1} \pm t_{n-2} \frac{\sqrt{MSE}}{|b_1|} \sqrt{1 + \frac{1}{n} + \frac{(\hat{x}_{n+1} - \bar{x}_n)^2}{\sum_{i=1}^n (x_i - \bar{x}_n)^2}}$$

i.e.

$$3061.1 \pm 1.746 \frac{56.4}{|.975|} \sqrt{1 + \frac{1}{18} + \frac{(3061.1 - 2165)^2}{5,024,850}}$$

2.

(a) Testing here is almost surely destructive. There is likely no way to make the repeated measurements on a single part necessary to honestly assess "repeatability" variation.

(b) Since the bottles were tested in a random order, I would not expect any trend on such a plot to correspond to a manufacturing change. That leaves only the possibility that the *tester* (or perhaps its environment) is "drifting" or changing in some way over time.

$$(c) \sigma_x = \sqrt{\sigma_y^2 - \sigma^2} \approx \sqrt{(.56)^2 - (.10)^2} = .55\%$$

3.

(a) Use display (3.15).  $UCL_R = D_2\sigma = 4.6981(.00021) = .00099$  inch and there is no lower control limit.

$$(b) \text{ Use display (3.5). } UCL_{\bar{x}} = .3765 + 3\frac{.00021}{\sqrt{4}} = .37682 \text{ and}$$
$$LCL_{\bar{x}} = .3765 - 3\frac{.00021}{\sqrt{4}} = .37619$$

(c) Control limits for  $\bar{x}$  have nothing to do with specifications for individual  $x$  values (with the exception that in this "standards given" context they have the same "middle value" of .3765). Spec.s deal with the functionality of individual items and engineering requirements. Control limits (for means) deal with process stability and apply to means, not to individuals.

(d) We want  $1.282 = \frac{.3770 - \mu}{.00021}$ . This implies that  $\mu = .37673$ . Then we need two  $z$ -values.  $z_1 = \frac{.37682 - .37673}{.00021/\sqrt{4}} = .8571$  and  $z_2 = \frac{.37619 - .37673}{.00021/\sqrt{4}} = -5.1429$ . Then  $q = P[\text{the first sample mean plots outside limits}] = P[Z < -5.1429 \text{ or } Z > .8571] \approx 1 - .8051 = .1949$ . So  $ARL = 1/q \approx 1/.1949 = 5.13$ .

4. This is a  $u$  chart problem with a standard rate  $\lambda = .0111$  jams/second. For the first job  $k = 490$ ,  $\hat{u} = 11/490 = .0224$  with  $UCL_{\hat{u}} = .0111 + 3\sqrt{\frac{.0111}{490}} = .0254$  and no LCL since  $.0111 + 3\sqrt{\frac{.0111}{490}} < 0$ . This first job doesn't provide convincing evidence of a change, but the second does. This is because for the second job  $k = 474$ ,  $\hat{u} = 15/474 = .0316$  with  $UCL_{\hat{u}} = .0111 + 3\sqrt{\frac{.0111}{474}} = .0256$  (and no LCL since  $.0111 + 3\sqrt{\frac{.0111}{474}} < 0$ ).

5. This computer control is NOT SPC/statistical process monitoring. It is a form automated compensation/process tweaking/adjustment. (It's not really even EFC since it's not even driven by a feedback mechanism.) SPC intends to watch/monitor a process looking for change.

6. The purpose of Shewhart control charting is to detect process change/variation that can potentially be eliminated.

7. Without good measurement one is "blind"! One can't know what is really going on. Good measurement allows one to clearly see what is happening, allowing appropriate interventions and verification that measured individuals are acceptable. It must be a high priority to see that our company knows what its processes are doing and what its products look like. I've got to have resources for this activity.

## Exam 2

1.

(a)  $\text{Var}u = (1)^2\text{Var}x_2 + (-1)^2\text{Var}x_1 = (.01)^2 + (.01)^2$  so

$$\sigma_u = \sqrt{\text{Var}u} = \sqrt{2(.01)^2} = .0141$$

(b)  $\frac{\partial D}{\partial u} = \frac{(\frac{1}{5})2(5+u)}{\sqrt{(5+u)^2+v^2}}$  and  $\frac{\partial D}{\partial v} = \frac{(\frac{1}{5})2v}{\sqrt{(5+u)^2+v^2}}$ , so at  $(u, v) = (0, 0)$   $\frac{\partial D}{\partial u} = 1$  and  $\frac{\partial D}{\partial v} = 0$ .

Thus  $\sigma_D^2 \approx (1)^2(.02)^2 + (0)^2(.02)^2$  and  $\sigma_D \approx .02$

(c) YES. The plot is very linear, indicating that the data set has a shape equivalent to that of the normal distribution. Then  $\frac{1-.5}{20} = .025$  and  $\frac{2-.5}{20} = .075$ . So the first plotting position is  $Q_z(.025) = -1.96$  and  $Q_z(.075) = -1.44$ .

(d) Use display (5.11), i.e.  $5.0017 \pm 1.729(.0437)\sqrt{1 + \frac{1}{20}}$ . This is  $5.0017 \pm .0774$

(e) Use display (5.7), i.e.  $\left(\frac{.2}{6(.0437)}\sqrt{\frac{10.117}{19}}, \frac{.2}{6(.0437)}\sqrt{\frac{30.143}{19}}\right)$ . This is  $(.557, .961)$

(f) Use displays (5.9) and (5.10).  $\hat{C}_{pk} = \min\left(\frac{5.1-5.0017}{3(.0437)}, \frac{5.0017-4.9}{3(.0437)}\right) = .7498$  and the lower confidence bound is thus  $.7498 - 1.282\sqrt{\frac{1}{9(20)} + \frac{(.7498)^2}{2(20)-2}} = .567$ .

2.

(a)  $s \approx \overline{MR}/d_2$  when there is no trend or pattern in the measurements and they therefore "look like" a random sample from a fixed universe. (In this case these two quantities estimate the same parameter " $\sigma$ " of a normal universe.)  $s \gg \overline{MR}/d_2$  when there is an obvious trend in the measurements that causes the "overall variability" in the observations to exceed the kind of variability seen looking only at consecutive observations.

(b) Use displays (4.24) and (4.26). That is,

$$\begin{aligned} X^2 &= 4(2-0, 2-0) \begin{pmatrix} (1)^2 & .2(1)(1) \\ .2(1)(1) & (1)^2 \end{pmatrix}^{-1} \begin{pmatrix} 2-0 \\ 2-0 \end{pmatrix} \\ &= 4(2, 2) \left(\frac{1}{1-.04}\right) \begin{pmatrix} 1 & -.2 \\ -.2 & 1 \end{pmatrix} \begin{pmatrix} 2 \\ 2 \end{pmatrix} = \frac{4}{.96}(1.6, 1.6) \begin{pmatrix} 2 \\ 2 \end{pmatrix} = 26.67 \end{aligned}$$

And  $UCL_{X^2} = 2 + 3\sqrt{2(2)} = 8$ . Yes, there is an out-of-control signal.

3.

(a) Benchmarking should not only detail what "best in class performance" is, but also how that performance is achieved. What are the engineering/business processes that produce that best in class performance?

(b) As a performance goal, "six sigma" amounts to a  $C_{pk} = 2$  goal for all processes. as a problem-solving/process improvement strategy, it refers to something very much like the

6-step QA cycle described in Chapter 1 of the textbook. As a training/recognition system, it involves a "belt system" (like that of the martial arts) as one progresses in expertise and company responsibility for implementing the problem-solving strategy.

(c) "CQE" certification is a program of the American Society for Quality. An applicant for certification must have a degree from an accredited institution, 8 years of on-the-job experience in the field (3 in a decision-making position) and "proof of professionalism" (in the form of ASQ membership, PE registration or signatures from 2 "recognized professional societies.") Applicants must also pass an exam set by ASQ.

(d) Correct. ISO 9000 certification is NOT about a particular batch of widgets you send me. It is about consistency of how the certified organization does things. Having ISO 9000 certification supposedly guarantees that a company is doing things rationally and methodically, that it has in place clear and universally understood and adhered to processes for doing its work. I care about this because I need to know what to expect from you on a consistent basis, and I believe that if you take this seriously I can expect you to be continually better and more efficient, a continually better business partner.

### Exam 3

1. c
2. a
3. d
4. a
5. d (the plus or minus value for a difference in means is  $\sqrt{2}$  times that for a single mean)
6. b
7. a
8. e (you must find  $a_3$  and  $b_3$  and for each factor pick the level with the smallest, i.e. most negative, main effect)
9. a
10. c
11. d
12. b
13. c
14. d
15. b
16. a
17. e (responses i) and iii) are true while ii) is not)
18. d
19. d
20. e
21. b ( $A \leftrightarrow BCDG \leftrightarrow ACDEFH \leftrightarrow BEFGH$ )
22. c