Corrigenda: On modelling poor quality costs in part manufacturing operation

In the original paper by Feiring *et al.*¹ of which I was co-author, the internal and external failure costs are modeled by a five-state Markov chain. Their State 0 and State 3 involve compound activities. As a consequence, the activity-based quality costs associated with inspection and reworking/repairing activities cannot be separately estimated. Similarly, the customer's inspection and field testing activity costs cannot be separated. In order to avoid this difficulty, we must define two additional states to de-couple the compound activities. Figure 1 below illustrates the corrected seven-state transition diagram. The revised state definitions for individual activities are given as follows. State 0 = factory's inspection, State 1 = factory's rework/repair, State 2 = customer's inspection, State 3 = field test, State 4 = passing customer acceptance, State 5 = scrapping, and State 6 = UAI/RAP.

For certain parts in a batch, some quality cost-driving activities may not be required at all, while other activities may be performed at least once. The proportion of a given batch of parts requiring a certain activity is the probability that a random part may reach the corresponding state for the first time. This first-passage probability is therefore important for finding the expected number of parts that require a given operation, for example, field test. The original paper, however, did not consider the first-passage probability for the transient states. As a consequence, the total number of parts rejected by the customer for a given batch (denoted by M) was much smaller than the true value.

Let r_{ij} be the probability that a part reaches State j for the first time, given that it is initially in transient State i . Such probability can be determined by

$$r_{ij} = p_{ij} + \sum_{k \neq j} p_{ik} r_{kj} \quad (1)$$

Solving for r_{01} , r_{02} , r_{20} , and r_{23} , and defining X = the total number of parts that are reworked/repared; Y = the total number of parts that are returned for factory's defect fixing; Z = the total number of parts that are shipped to the customer; and T = time to absorption for a part initially in

State i , the following results are obtained:

$$\begin{aligned} r_{01} &= \frac{p_{01}(1-p_{23})}{1-p_{23}-p_{02}p_{20}}; & r_{02} &= \frac{p_{02}}{1-p_{01}}; \\ r_{20} &= \frac{p_{20}}{1-p_{23}}; & r_{23} &= \frac{p_{23}(1-p_{01})}{1-p_{01}-p_{02}p_{20}} \end{aligned} \quad (2)$$

$$\begin{aligned} X &= r_{01}M; & Z &= r_{02}M; & Y &= r_{20}Z = r_{02}r_{20}M; \\ T &= r_{23}Z = r_{02}r_{23}M \end{aligned} \quad (3)$$

$$\begin{aligned} F_1 &= w_{01}r_{01}MD_1; & F_2 &= u_{05}MV; & F_3 &= u_{06}MW; \\ F_4 &= w_{20}r_{02}r_{20}MR; & F_5 &= w_{20}r_{02}r_{20}MS; \\ F_6 &= w_{23}TD_2; & F_7 &= v_0MU, \end{aligned} \quad (4)$$

where the seven failure costs, in \$ per batch, for the quality system are defined as follows: F_1 = factory's rework/repair cost, F_2 = factory's scrapping cost, F_3 = UAI/RAP AP cost, F_4 = warranty, claims, and compensation cost, F_5 = factory's shipping and handling cost for returned parts, F_6 = customer's field testing cost for parts that failed the inspection, and F_7 = factory's record updating cost.

In this case study it is assumed that the total number of acceptable parts (G) to be delivered to the customer is 139 000. The absorption probability (u_{04} for both studies) is 0.925 when the factory's quality level is equal to 90%. The batch size $M = G/u_{04} = 150\,270$ parts for both studies. The number of parts that require rework/repair operation in the previous study¹ was given by $M - G = 11\,270$ parts. However, the result using (3) shows that the correct

Figure 1

reworked/repaired quantity is $X = r_{01}M = 4861$, which is much smaller. Furthermore, the correct rework/repair cost per batch is only 0.06% of the total failure costs, while the previous study reports that such percentage of the total failure costs is 5.51%.

In reference 1 the quantity Y equals the difference between the total number of parts shipped from the factory and the total number of good parts in the shipped batch, which is $(1/u_{34} - 1)G = 417$. The correct value is $r_{02}r_{20}M = 5722$. This is a big difference because some of the shipped parts are returned to the factory first, before they are finally accepted. Furthermore, observe that the correct

estimate of the total failure costs (\$13 351.4) is about 22% higher than the previous reported value (\$10 954.5). I apologise for these errors and the incorrect spelling of Tep Sastri's name in the original paper.

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References

- 1 Feiring BR *et al* (1998). Modeling the cost of poor quality in a five-state part manufacturing operation: a case study. *J Opl Res Soc* **49**: 1249–1253.

On the nature of distribution and delay (D&D) in major projects

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This paper¹ was published with an incorrect title. The above is the correct version. Apologies to all concerned.
John Ranyard *Editor*

References

- 1 Eden C, Williams T, Ackermann F and Howick S (2000). *J Opl Res Soc* **51**: 291–300.