

# Appendix VII: Adjusting Safety Stock to Account for Yield Loss

Procurement may wish to account for part *yield loss* in some situations. Here we use yield loss in a general sense to include additional part consumption either because of literal losses resulting from failures or damage or because of additional use of the part for unplanned reasons.

Let  $Y_i$  denote the weekly yield of an arbitrary part. We will assume that  $Y_i$  is distributed according to the binomial distribution.

The actual demand on a part per week is given by:

$$D'_i = \frac{D_i}{Y_i}$$

for week  $i = 1, 2, 3, \dots$ . The expected value of the actual demand is:<sup>1</sup>

$$E(D'_i) = E\left(\frac{D_i}{Y_i}\right) \cong \frac{\mu_D}{\mu_Y} - \frac{1}{\mu_Y^2} \text{cov}(D_i, Y_i) + \frac{\mu_D}{\mu_Y^3} V(Y_i).$$

We will assume that yield loss each week is not correlated with the demand each week. Then:

$$E(D'_i) \cong \frac{\mu_D}{\mu_Y} + \frac{\mu_D}{\mu_Y^3} V(Y_i).$$

$$V(Y_i) = \frac{\mu_Y(1 - \mu_Y)}{n} \cong \frac{\mu_Y(1 - \mu_Y)}{\mu_D/\mu_Y} = \frac{\mu_Y^2(1 - \mu_Y)}{\mu_D}$$

where  $n$  is the average number of parts used per week and we have approximated  $n$  by the average weekly demand divided by the average yield. Thus,

$$E(D'_i) \cong \frac{\mu_D}{\mu_Y} + \frac{\mu_D}{\mu_Y^3} \left( \frac{\mu_Y^2(1 - \mu_Y)}{\mu_D} \right) = \frac{\mu_D}{\mu_Y} + \frac{(1 - \mu_Y)}{\mu_Y}.$$

When  $\mu_Y \leq 50\%$ , the term  $\frac{(1 - \mu_Y)}{\mu_Y}$  is less than or equal to one and has little effect on expected demand. Therefore:

$$E(D'_i) \cong \frac{\mu_D}{\mu_Y}.$$

The variance of the actual demand is:<sup>1</sup>

$$V(D'_i) = V\left(\frac{D_i}{Y_i}\right) \cong \left(\frac{\mu_D}{\mu_Y}\right)^2 \left( \frac{\sigma_D^2}{\mu_D^2} + \frac{\sigma_Y^2}{\mu_Y^2} - \frac{2\text{cov}(D_i, Y_i)}{\mu_D\mu_Y} \right).$$

As before, we will assume that yield loss is not correlated with the demand each week:

$$V(D'_i) \cong \left(\frac{\mu_D}{\mu_Y}\right)^2 \left( \frac{\sigma_D^2}{\mu_D^2} + \frac{\sigma_Y^2}{\mu_Y^2} \right).$$

Again we will approximate  $\sigma_Y^2$  by  $\frac{\mu_Y^2(1 - \mu_Y)}{\mu_D}$ :

$$V(D'_i) \cong \left(\frac{\mu_D}{\mu_Y}\right)^2 \left( \frac{\sigma_D^2}{\mu_D^2} + \frac{1 - \mu_Y}{\mu_D} \right) = \frac{\sigma_D^2}{\mu_Y^2} + \frac{\mu_D(1 - \mu_Y)}{\mu_Y^2}.$$

Therefore, by adjusting the expected weekly average demand by dividing by the average yield and adjusting the variance of the weekly demand uncertainty as indicated above, we can obtain approximate values for safety stock, average expected on-hand inventory, and the standard deviation of on-hand inventory using the results obtained earlier in this paper.

However, while we have adjusted the expected weekly demand by the yield loss, our in-house system, POPLAN, will not. Therefore, we must pass the impact of the yield adjustment to POPLAN via the safety stock parameter.

Let  $SS'$  denote the safety stock obtained when using the yield-adjusted average demand and standard deviation of demand uncertainty as derived here. The objective is to pass a safety stock value to POPLAN that results in the appropriate order-up-to level.

The safety stock to pass to POPLAN is given by:

$$SS^* = \left[ \frac{\mu_D}{\mu_Y}(L + R) + SS' \right] - \mu_D(L + R).$$

In words, calculate the safety stock and the order-up-to level using the yield-adjusted average weekly demand and the yield-adjusted standard deviation of weekly demand uncertainty, then subtract the product of the average weekly demand without yield adjustment and  $L + R$ .

### Reference

1. A.M. Mood, F.A. Graybill, and D.C. Boes, *Introduction to the Theory of Statistics, Third Edition*, McGraw-Hill, 1974, p. 181, theorem 4.

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