Solution

1. $OR = ? \Rightarrow OP = OR - OC = ? \Rightarrow$ Payback, $NPV, NAV = ?$

2. $OR = \$2.50 \times 250,000 = \$625,000, \quad OC = \$1.95 \times 250,000 = \$487,500$

   $$\text{Payback period} = \frac{IV}{OP} = \frac{IV}{OR - OC} = \frac{1,000,000}{137,500} = 7.27 \text{ yr}$$

3. $IV^{\text{eff}} = IV - SV(1+i)^{-N} = IV - IV(0.5)(1+0.1)^{-20} = \$925,678$

   $$NPV = OP\left[\frac{1-(1+i)^{-N}}{i}\right] - IV^{\text{eff}} = 137,500\left[\frac{1-(1+0.1)^{-20}}{0.1}\right] - 925,678 = \$244,937$$

   $$K = IV^{\text{eff}}\left[\frac{i}{1-(1+i)^{-N}}\right] = \$108,730$$

   $$NAV = OP - K = 137,500 - 108,730 = \$28,770$$

4. $$AC = \frac{K + OC}{q} = \frac{108,730 + 487,500}{250,000} = \$2.38$$

5. (*a*) $$\frac{IV^{\text{eff}} + \text{PV of } OC}{N \times q} = \frac{IV^{\text{eff}} + OC\left[\frac{1-(1+i)^{-N}}{i}\right]}{20 \times 250,000} = \$1.02 \neq AC$$

   (*b*) Quantity over N years not discounted: $$AC = \frac{IV^{\text{eff}} + OC\left[\frac{1-(1+i)^{-N}}{i}\right]}{\left[\frac{1-(1+i)^{-N}}{i}\right] \times q} = \$2.38$$

6. $$q_B = \frac{F}{P-V} = \frac{K}{P-V} = \frac{108,730}{2.50-1.95} = 197,691 \text{ widgets}$$

7. $OP_{\text{auto}} = (2.50 - 1.10)250,000 = \$350,000$

   $$IV_{\text{auto}}^{\text{eff}} = IV_{\text{auto}} - SV(1+i)^{-N} = 3,000,000 - 1,500,000(1+0.1)^{-20} = \$2,777,035$$

   $$K_{\text{auto}} = IV_{\text{auto}}^{\text{eff}}\left[\frac{i}{1-(1+i)^{-N}}\right] = \$326,189$$

   $$NAV_{\text{auto}} = OP_{\text{auto}} - K_{\text{auto}} = 350,000 - 326,189 = \$23,811$$

   $$NAV_{\text{auto}} < NAV_{\text{man}} = \$28,770 \Rightarrow \text{Manual}$$

8. Can now use the net operating cost savings as operating profit.

9. $$q_I = \frac{F_1 - F_2}{V_2 - V_1} = \frac{F_{\text{auto}} - F_{\text{man}}}{V_{\text{man}} - V_{\text{auto}}} = \frac{K_{\text{auto}} - K_{\text{man}}}{V_{\text{man}} - V_{\text{auto}}} = \frac{326,189 - 108,730}{1.95 - 1.10} = 255,835 \text{ widgets}$$