Solutions To Chapter 3 Problems

3-1 One square meter converts to 10.764 square feet. So the area of the office building in square feet is 107,640. Therefore the average annual cost of heating and cooling this area is (107,640 ft^2)($3.50/$ft^2$) = $376,740.

3-2 A representative cost and revenue structure for construction, 10-years of ownership and use, and the sale of a home is:

Cost or Revenue Category	Typical Cost and Revenue Elements
Captial Investment	Real estate (lot) cost; architect/engineering fees; construction costs (labor,material, other); working capital (tools, initial operating supplies, etc.); landscaping costs.
Annual Operating and Maintenance Costs	Utilities (electricity, water, gas, telephone, garbage); cable TV; painting (interior and exterior); yard upkeep (labor and materials); routine maintenance (furnace, air conditioner, hot water heater, etc.); insurance; taxes.
Major Repair or Replacement Costs	Roof; furnace; air conditioner; plumbing fixtures; garage door opener; driveway and sidewalks; patio; and so on.
Real Estate Fees	Acquisition; selling.
Asset Sales	Sale of home (year 10).

3-3 The estimated cost is \$12,000 + (\$10/ft^2)(8.5 ft)(15 ft)(500)(1.8) = \$1,159,500

3-4 **(a)** (62 million tons per year) (0.05) = 3.1 million tons of greenhouse gas per year

$$\frac{\$1.2 \text{ billion}}{3.1 \text{ million tons per year}} = \$387.10 \text{ per ton}$$

(b) (3 billion tons per year) (0.03) = 90 million tons per year

$$\frac{\$1.2 \text{ billion}}{3.1 \text{ million tons/year}} = \frac{\$X \text{ billion}}{90 \text{ million tons}}$$

$$X = \$34.84 \text{ billion}$$

3-5 $(24{,}000\ ft^2)(60{,}000\ Btu/ft^2)$ = 1,440 million Btu during the heating season. This is 1,440 thousand cubic feet of natural gas, and the cost would be $(1{,}440{,}000\ ft^3)(\$10.50/1000\ ft^3)$ = \$15,120 for the heating season.

Side note: The building uses 0.3 million kWhr of electricity × \$0.10 per kWhr = \$30,000 to cool the area. The total bill will be about \$45,000. The owner must take this into account when she decides on a price to charge per square foot of leased space.

3-6 **(a)** Standard electric bill = (400 kWhr)(12 months/year)($0.10/kWhr) = $480 per year.
Green power bill = (12 months/year)($4/month) = $48 per year.
Total electric bill = $528 per year.

(b) $528 / 4,800 kWhr = $0.11 per kWhr (a 10% increase due to green power usage)

(c) The technology used to capture energy from solar, wind power and methane is more expensive than traditional power generation methods (coal, natural gas, and so on).

3-7 The replacement cost in late 2017 can be estimated as follows:

$$C_{2017} = C_{2006}\,(I_{2017}/I_{2006})$$

$$= \$30{,}000\,(265/149)$$

$$= \$53{,}356$$

3-8 The cost of the water filtration system in 2019 is:

$C_{2019} = C_{2014} (\bar{I}_{2019}/ \bar{I}_{2014}) = \$250{,}000\ (298/220) = \$338{,}636$

3-9

$$\bar{I}_{2014} = \frac{0.70\left(\frac{62}{41}\right) + 0.05\left(\frac{57}{38}\right) + 0.25\left(\frac{53}{33}\right)}{0.70 + 0.05 + 0.25} \times 100 = 153.5$$

3-10 $(C_A / C_B) = (S_A / S_B)^x$

$C_A = \$800{,}000\ (30{,}000 / 20{,}000)^{0.83} = 800{,}000(1.4)$

C_A = \$1,120,000 for the larger warehouse

3-11 Let C_A = cost of new boiler, $S_A = 1.42X$
C_B = cost of old boiler, today $S_B = X$

$$C_B = \$181{,}000\left(\frac{221}{162}\right) = \$246{,}920$$

$$C_A = \$246{,}920\left(\frac{1.42X}{X}\right)^{0.8} = \$326{,}879$$

Total cost with options = \$326,879 + \$28,000 = <u>\$354,879</u>

3-12 The estimated capital investment of the seven MW solar farm in four years is:

$$\$14 \text{ million } (F/P, 8\%, 4) = \$14 \text{ million } (1.3605) = \$19.047 \text{ million}$$

Next, the capital investment (C) for the six MW solar farm in four years can be estimated by using Equation 3-4:

$$C = \$19.047 \text{ million } (6/7)^{0.85} = \$16.708 \text{ million}$$

3-13 **(a)** $C_{now}(80\text{-kW}) = \$160{,}000\left(\frac{194}{187}\right) = \$165{,}989$

$C_{now}(120\text{-kW}) = \$165{,}989\left(\frac{120}{80}\right)^{0.6} = \$211{,}707$

Total Cost = \$211,707 + \$18,000 = <u>\$229,707</u>

(b) $C_{now}(40\text{-kW}) = \$165{,}989\left(\frac{40}{80}\right)^{0.6} = \$109{,}512$

Total Cost = \$109,512 + \$18,000 = <u>\$127,512</u>

3-14 Let C_A = cost of new plant S_A = 450,000 gal/yr

C_B = cost of similar plant S_B = 250,000 gal/yr

= $6,000,000 X = 0.59

$$C_A = \$6{,}000{,}000\left(\frac{450{,}000}{250{,}000}\right)^{0.59} = \$8{,}487{,}153$$

3-15 $\$600{,}000 = \$300{,}000\,(100{,}000/40{,}000)^x$

$2 = 2.5^x$

$\log 2 = x \log 2.5$

$x = 0.756$

This is the cost-capacity factor for this technology.

3-16 **(a)** (500-425) / 500 = 0.15

85% learning curve

(b) $n = \log 0.85 / \log 2 = -0.234$

$Z_4 = 500(4)^{-0.234}$

$= 361.5$ hours

(c) $Z_1 = 500$hrs

$Z_2 = 425$hrs

$Z_3 = 500(3)^{-0.234} = 387$ hrs

$Z_4 = 361.5$hrs

$\Sigma Z_i = 1,673.5$

Average \$ = (1673.5/4)(\$15) = \$6,275.63

3-17 $n = \log(0.9) / \log 2 = -0.152$

$Z_6 = 10\,(6)^n$

$= 10\,[(6)^{-0.152}]$

$= 7.6$ hours

3-18 $n = \log(0.85) / \log 2 = -0.2345$

$C_x = T_x / x$ so $(x)\, C_x = T_x$, or $T_x = 5(15.882 \text{ hrs.}) = 79.41$ hours

We know that $T_x = K\, [1^{-0.2345} + 2^{-0.2345} + 3^{-0.2345} + 4^{-0.2345} + 5^{-0.2345}]$

so $79.41 = 4.031\, K$, or $K = 19.70$ hours

Now with equation 3-5 we can determine Z_{20}:

$$Z_{20} = 19.70\, (20^{-0.2345}) = 9.76 \text{ hours}$$

3-19 **(a)** $\sum x = 687$

$\sum y = 2{,}559$

$\sum xy = 442{,}844$

$\sum x^2 = 118{,}831$

$\bar{x} = 687/4 = 171.75$

$\bar{y} = 2{,}559/4 = 639.75$

$\hat{b} = [4(442{,}844) – 687(2{,}559)] / [4(118{,}831) – 687^2] = 3.977$

$\hat{a} = [2{,}559 – 3.977(687)] / 4 = -43.308$

$\therefore \hat{y} = -43.308 + 3.977(x)$

(b) $\hat{y} = -43.308 + 3.977(170)$

$\hat{y} = \$632.78$

3-20 $\sum x = 1{,}732$

$\sum y = 3{,}532$

$\sum xy = 644{,}176$

$\sum x^2 = 325{,}586$

$b = [644{,}176 – 173.2(3{,}532)] / [325{,}586 – 173.2(1{,}732)] = 1.2668$

$a = 353.2 – 1.2668(173.2) = 133.79$

So $y = 133.79 + 1.2668x$

When $x = 198$,

$y = 133.79 + 1.2668(198) = 384.6$ (call it 385 units per quarter)

3-21 The following table facilitates the intermediate calculations needed to compute the values of b_0 and b_1 using Equations (3-8) and (3-9).

I	x_i	y_i	x_i^2	$x_i y_i$
1	14,500	800,000	210,250,000	11,600,000,000
2	15,000	825,000	225,000,000	12,375,000,000
3	17,000	875,000	289,000,000	14,875,000,000
4	18,500	972,000	342,250,000	17,982,000,000
5	20,400	1,074,000	416,160,000	21,909,600,000
6	21,000	1,250,000	441,000,000	26,250,000,000
7	25,000	1,307,000	625,000,000	32,675,000,000
8	26,750	1,534,000	715,562,500	41,034,500,000
9	28,000	1,475,500	784,000,000	41,314,000,000
10	30,000	1,525,000	900,000,000	45,750,000,000
Totals	216,150	11,637,500	4,948,222,500	265,765,100,000

$$b_1 = \frac{(10)(265{,}765{,}100{,}000) - (216{,}150)(11{,}637{,}500)}{(10)(4{,}948{,}222{,}500) - (216{,}150)^2} = 51.5$$

$$b_0 = \frac{11{,}637{,}500 - (51.5)(216{,}150)}{10} = 50{,}631$$

(a) The resulting CER relating supermarket building cost to building area (x) is:

$$\underline{\text{Cost} = 50{,}631 + 51.5x}$$

So the estimated cost for the 23,000 ft^2 store is:

$$\text{Cost} = \$50{,}631 + (\$51.5/\text{ft}^2)(23{,}000\ \text{ft}^2) = \underline{\$1{,}235{,}131}$$

(b) The CER developed in part (a) relates the cost of building a supermarket to its planned area using the following equation:

$$\text{Cost} = 50{,}631 + 51.5x$$

Using this equation, we can predict the cost of the ten buildings given their areas.

3-21 ***continued***

i	x_i	y_i	$Cost_i$	$(y_i - Cost_i)^2$	$(x_i - \bar{x})(y_i - \bar{y})$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$
1	14,500	800,000	797,345	7,048,179	2,588,081,250	50,623,225	132,314,062,500
2	15,000	825,000	823,094	3,633,147	2,240,831,250	43,758,225	114,751,562,500
3	17,000	875,000	926,089	2,610,081,256	1,332,581,250	21,298,225	83,376,562,500
4	18,500	972,000	1,003,335	981,896,725	597,301,250	9,703,225	36,768,062,500
5	20,400	1,074,000	1,101,181	738,780,429	109,046,250	1,476,225	8,055,062,500
6	21,000	1,250,000	1,132,079	13,905,356,010	-53,043,750	378,225	7,439,062,500
7	25,000	1,307,000	1,338,069	965,288,881	484,901,250	11,458,225	20,520,562,500
8	26,750	1,534,000	1,428,190	11,195,807,942	1,901,233,750	26,368,225	137,085,062,500
9	28,000	1,475,500	1,492,562	291,099,988	1,990,523,750	40,768,225	97,188,062,500
10	30,000	1,525,000	1,595,557	4,978,246,304	3,029,081,250	70,308,225	130,501,562,500
Totals	216,150	11,637,500	11,637,500	35,677,238,861	14,220,537,500	276,140,250	767,999,625,000

$$\bar{x} = \frac{1}{10}(216{,}150) = 21{,}615 \qquad \bar{y} = \frac{1}{10}(11{,}637{,}500) = 1{,}163{,}750$$

Using Equations (3-10) and (3-11), we can compute the standard error and correlation coefficient for the CER.

$$SE = \sqrt{\frac{35{,}677{,}238{,}861}{10-2}} = \underline{66{,}780}$$

$$R = \frac{14{,}220{,}537{,}500}{\sqrt{(276{,}140{,}250)(767{,}999{,}625{,}000)}} = \underline{0.9765}$$

3-22 x_i = weight of order (lbs)
y_i = packaging and processing costs ($)

(a) $y = b_0 + b_1x$

$\sum x_i = 2530$ $\bar{x} = 253$ $\sum x_i^2 = 658{,}900$

$\sum y_i = 1024$ $\bar{y} = 102.4$ $\sum y_i^2 = 106{,}348$

$\sum x_i y_i = 264{,}320$

$$b_1 = \frac{264{,}320 - (253)(1024)}{658{,}900 - (253)(2530)} = 0.279$$

$b_0 = 102.4 - (0.279)(253) = 31.813$; $y = \underline{31.813 + 0.279x}$

(b) $$R = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}}$$

$S_{xy} = 264{,}320 - (2530)(1024)/10 = 5{,}248$

$S_{xx} = 658{,}900 - (2530)^2/10 = 18{,}810$

$S_{yy} = 106{,}348 - (1024)^2/10 = 1{,}490.4$

$$R = \frac{5248}{\sqrt{(18{,}810)(1490.4)}} = \underline{0.99}$$

(c) $y = 31.813 + (0.279)(250) = \underline{\$101.56}$

3-23 $\text{Cost}_{150\text{ ft}} = \$15{,}250\left(\frac{150}{250}\right)^{0.6}\left(\frac{1029}{830}\right) = \$13{,}915$

3-24 $127(1.19)^5 = $303 per square foot in five years. The total estimated cost in five years is (320,000 ft^2)($303/$ft^2$) = $96,960,000. It’s a good idea to build this facility today and then, if needed, add on the additional space five years later.

3-25 The amount of the FICO score affected is (0.35)(720) = 252. If this drops by 10%, the payment history score will be (0.90)(252) = 227 and the overall FICO score will be 695. This lower value could adversely affect the interest rate you'll be quoted on your next loan.

3-26 Boiler Cost = \$300,000 $\left(\frac{10mW}{6mW}\right)^{0.8}$ = \$451,440

Generator Cost = \$400,000 $\left(\frac{9mW}{6mW}\right)^{0.6}$ = \$510,170

Tank Cost = \$106,000 $\left(\frac{91{,}500gal}{80{,}000gal}\right)^{0.66}$ = \$115,826

Total Cost = (2)(\$451,440) + (2)(\$510,170) + \$115,826 + \$200,000 = <u>\$2,239,046</u>

3-27 The following spreadsheet was used to calculate a 2019 estimate of $320,274,240 for the plant.

Element Code	Units/Factors	Price/Unit	Subtotal	Totals
1.1.1-2	600	$2,000	$ 1,200,000	
1.1.3			$ 3,000,000	
1.1				$ 4,200,000
1.2-3	2.3969 [a]	$ 110,000,000	$ 263,659,000	$ 263,659,000
1.4	4.4727 [b]	$ 5,000,000	$ 22,363,500	$ 22,363,500
1.5.1-3				
labor	80,390 [c]	$ 60	$ 4,823,400	
materials			$ 15,000,000	
1.5.4	600	$ 1,500	$ 900,000	
1.5				$ 20,723,400
1.9	3%	$ 310,944,672		$ 9,328,340
TOTAL ESTIMATED COST IN 1996				$ 320,274,240

[a] Factor value for boiler and support system (WBS elements 1.2 and 1.3):

$$\left(\frac{492}{110}\right)\left(\frac{1}{2}\right)^{0.9} = 2.3969$$

[b] Factor value for the coal storage facility (WBS element 1.4):

$$\left(\frac{492}{110}\right) = 4.4727$$

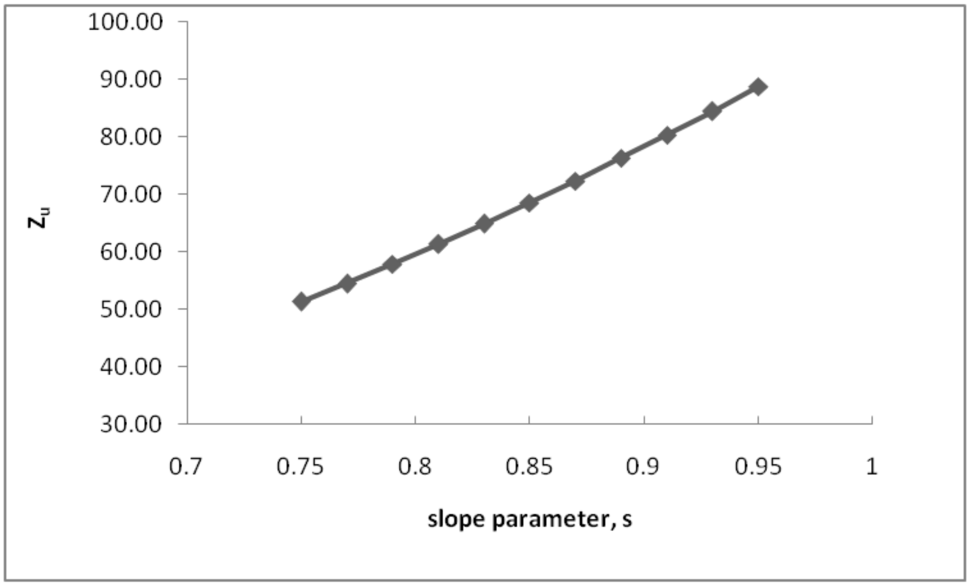
[c] Labor time estimate for the 3rd facility (WBS elements 1.5.1, 1.5.2, and 1.5.3):

$K = 95{,}000$ hours, $s = 0.9$, $n = \log(0.9)/\log(2) = -0.152$

$Z_3 = 95{,}000(3)^{-0.152} = 80{,}390$ hours

3-28

K	100
u	5
s	Z_u
0.75	51.27
0.77	54.51
0.79	57.85
0.81	61.31
0.83	64.88
0.85	68.57
0.87	72.37
0.89	76.29
0.91	80.33
0.93	84.49
0.95	88.77



3-29 **(a)** Based on the constant reduction rate of 8% each time the number of homes constructed doubles, a 92% leanring curve applies to the situation. The cumulative average material cost per square foot for the first five homes is $24.12.

(b) The estimated material cost per square foot for the 16th home is $19.34.

S	0.92		
K	$27		
	Material	Cumulative	Cumulative
Home	Cost per ft^2	Sum	Average
1	$ 27.00	$ 27.00	$ 27.00
2	$ 24.84	$ 51.84	$ 25.92
3	$ 23.66	$ 75.50	$ 25.17
4	$ 22.85	$ 98.35	$ 24.59
5	$ 22.25	$ 120.60	$ 24.12
6	$ 21.76	$ 142.36	$ 23.73
7	$ 21.37	$ 163.73	$ 23.39
8	$ 21.02	$ 184.75	$ 23.09
9	$ 20.73	$ 205.48	$ 22.83
10	$ 20.47	$ 225.95	$ 22.59
11	$ 20.23	$ 246.18	$ 22.38
12	$ 20.02	$ 266.21	$ 22.18
13	$ 19.83	$ 286.04	$ 22.00
14	$ 19.66	$ 305.69	$ 21.84
15	$ 19.49	$ 325.19	$ 21.68
16	$ 19.34	$ 344.53	$ 21.53

Spacecraft	Weight	Cost (millions)
0	100	$ 600
1	400	$ 278
2	530	$ 414
3	750	$ 557
4	900	$ 689
5	1,130	$ 740
6	1,200	$ 851

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.705850276
R Square	0.498224612
Adjusted R Square	0.397869535
Standard Error	151.9036833
Observations	7

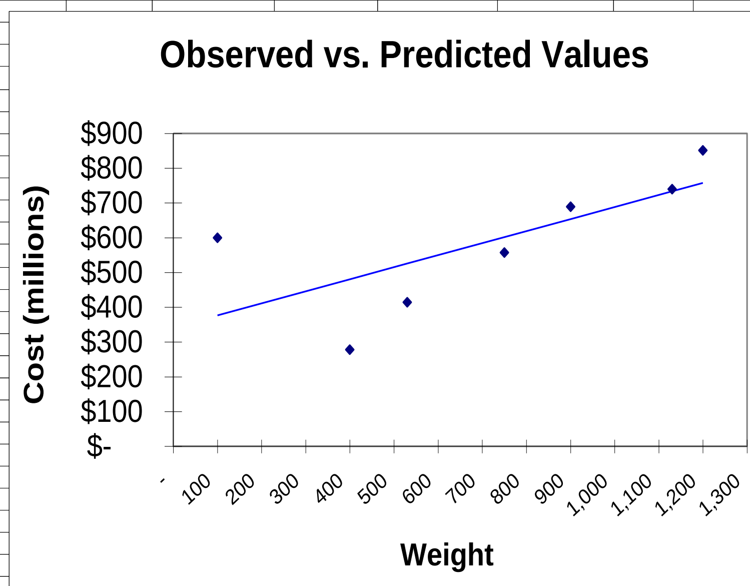
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	114557.2121	114557.212	4.9646179	0.076342997
Residual	5	115373.645	23074.729		
Total	6	229930.8571			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	341.9170907	125.2152843	2.73063383	0.0412491	20.04148132	663.7927001	20.04148132	663.7927001
Weight	0.346423227	0.155476261	2.22814225	0.076343	-0.053240574	0.746087027	-0.053240574	0.746087027

RESIDUAL OUTPUT

Observation	*Predicted Cost*	*Residuals*
1	376.5594133	223.4405867
2	480.4863813	-202.4863813
3	525.5214008	-111.5214008
4	601.7345106	-44.73451063
5	653.6979946	35.30200539
6	733.3753367	6.624663274
7	757.6249626	93.37503741



3-31 Other cost factors include maintenance, packaging, supervision, materials, among others. Also, the case solution presents a before-tax economic analysis.

3-32 Left as an exercise for the student. However, by observation, it appears that the factory overhead and factory labor are good candidates since they comprise the largest percentage contributions to the per unit demanufacuring cost.

3-33 A 50% increase in labor costs equates to a factor of 15%; a 90% increase in Transportation equates to a factor of 38%. The corresponding demnaufacturing cost per unit is $5.19. The per unit cost of using the outside contractor (i.e., the target cost) is $11.70. Should the proposed demanufacturing method be adopted, the revised per unit cost savings is $6.51 for a 55.6% reduction over the per unit cost for the outside contractor.

		Unit Elements		Factor Estimates		Row
	DE-MANUFACTURING COST ELEMENTS	Units	Cost/Unit	Factor	of Row	Total
A:	Factory Labor	24.5 hrs	$ 12.00/hr			$ 294.00
B:	Quality Costs - Training			15%	A	$ 44.10
C:	TOTAL LABOR					$ 338.10
D:	Factory Overhead - Set up Costs			150%	C	$ 507.15
E:	Transportation Cost			38%	C	$ 192.72
F:	TOTAL DIRECT CHARGE					$ 699.87
G:	Facitily Rental					-
H:	TOTAL DE-MANUFACTURING COST					$ 1,037.97
I:	Quantity - Lot Size					200
J:	De-manufacturing Cost/Unit					$ 5.19
	Outside Cost/Unit - Target Cost	$11.70				

3-34 The estimate of direct labor hours is based on the time to produce the 50th unit.

K = 1.76 hours
s = 0.8 (80% learning curve)
n = (log 0.80)/(log 2) = -0.322
$Z_{50} = 1.76(50)^{-0.322} = 0.5$ hours

Factory Labor	= ($15/hr)(0.5 hr/widget)	= $7.50 / widget
Production Material	= $375 / 100 widgets	= $3.75 / widget
Factory Overhead	= (1.25)($7.50 / widget)	= $9.375 / widget
Packing Costs	= (0.75)($7.50 / widget)	= $5.625 / widget
Total Manufacturing Cost		= $26.25 / widget
Desired Profit	= (0.20)($26.25 / widget)	= $5.25 / widget
Unit Selling Price		= $31.50 / widget

3-35 Profit = Revenue – Cost

$$\$25,000 = (\$20.00/\text{unit})(x) – [(\$21.00/\text{unit})(.2 \text{ hours/unit})(x) + (\$4.00/\text{unit})(x) + (1.2)(\$21.00/\text{unit})(.2 \text{ hours/unit})(x) + (\$1.20/\text{unit})(x)]$$

$\$25,000 = 5.56x$; x = <u>4,497 units</u>

3-36 K = 460 hours; s = 0.92 (91% learning curve); n = (log 0.92)/(log 2) = -0.120

$C_{30} = T_{30}/30$; $T_{30} = 460 \sum_{u=1}^{30} u^{-0.120} = 10{,}419.63$ hrs;

$C_{30} = 10{,}419.63 / 30 = 347.3211$

Select (d)

3-37 $-1{,}500 + 800 + (0.07 - 0.05)(4.00)(10)x = 0$

$-700 + 0.80x = 0$

$x = 700/0.80 = 875$ miles/year

<u>Select (a)</u>

3-38 $AC_{current}$ = $4,000
Proposed: N = 13 years, SV = 11% of first cost

$4,000 = I (A/P,12%,13) – (0.11)I (A/F,12%,13)
$4,000 = I(0.1557) – (0.003927)I
$4,000 = I (0.1517)

I = $26,358

Select (c)

3-39 Let X = average time spent supervising the average employee. Then the time spent supervising employee A = 2X and the time spent supervising employee B = 0.5X. The total time units spent by the supervisor is then 2X + 0.5X + (8)X = 10.5X. The monthly cost of the supervisor is $3,800 and can be allocated among the employees in the following manner:

$3,800/10.5X = $361.90 / X time units.

Employee A (when compared to employee B) costs (2X – 0.5X)($361.90/X) = $542.85 more for the same units of production. If employee B is compensated accordingly, the monthly salary for employee B should be $3,000 + $542.85 = $3,542.85.

<u>Select (a)</u>

3-40 Type X filter: cost = \$5, changed every 7,000 miles along with 5 quarts oil
between each oil change 1 quart of oil must be added after each 1,000 miles

Type Y filter: cost = ?, changed every 5,000 miles along with 5 quarts of oil
no additional oil between filter changes

oil = \$1.08 / quart

Common multiple = 35,000 miles

For filter X = 5 oil changes: 5(\$5 + 5(\$1.08) + 6(\$1.08)) = (5)\$16.88 = \$84.40
For filter Y = 7 oil changes: $7C_Y$ + 7(5)(\$1.08) = 7X + \$37.8

$\$84.40 = 7C_Y + \$37.8$
$\$46.60 = 7C_Y$

$C_Y = \$6.66$

Select (d)

3-41 $C_{2008}(\text{new design}) = \$900{,}000\left(\frac{200}{150}\right)^{0.92} + \$1{,}125{,}000\left(\frac{450}{200}\right)^{0.87} + \$750{,}000\left(\frac{175}{100}\right)^{0.79} = \$4{,}617{,}660$

$C_{2018} = \$4{,}617{,}660(1.12)^{10} = \$14{,}341{,}751$

Select (c)