Chapter 11

Replacement Analysis

In comparing various investment alternatives in Chapters 5 thru 10, we considered a single alternative (where the decision is between investing and not investing) and a set of mutually exclusive alternatives (where we recommended the alternative having the greatest economic worth). Both situations could involve a replacement of an existing asset.

In the case of the single alternative, a decision not to invest in a new asset could be a decision to continue using a current asset; likewise, a decision to invest could be a decision to replace a current asset. The same holds for mutually exclusive alternatives, since one alternative could be continued usage of an existing asset.

Because decisions to *replace* versus *continue using* an asset occur so frequently, a body of literature has evolved treating replacement decisions. We refer to the comparison of investment alternatives that involve the replacement of an asset as *replacement analysis*.

Replacement decisions occur all around us. Perhaps you have replaced a camera, car, cell phone, computer, printer, sound system, or television. If so, then your decision was probably influenced by economics, capacity concerns, deteriorating quality of service provided, changing requirements, prestige, fads, or a host of other reasons.

Replacement decisions occur for a variety of reasons, including:

1. the current asset, which we call the *defender*, has developed several deficiencies, including high set-up cost, excessive maintenance expense, declining productivity, high energy cost, limited capability, and physical impairment;
2. potential replacement assets, which we call the *challengers*, are available which have a number of advantages over the *defender*, including new technology that is quicker to set-up and easier to use, along with having lower labor cost, lower maintenance expense, lower energy cost, higher productivity, and additional capabilities; and
3. a changing external environment, including
   a) changing user and customer preferences and expectations,
   b) changing requirements,
   c) new, alternative ways of obtaining the functionality provided by the *defender*, including the availability of leased equipment and third-party suppliers, and
   d) increased demand that cannot be met with the current equipment – either supplementary equipment or replacement equipment is required to meet demand.

Although replacement of existing assets can offer considerable potential for increasing shareholder value, many firms fail to subject existing equipment to careful scrutiny on a periodic basis to ensure that capital is being used in the most effective manner. Why?

- **Currently making a profit**
- **Equipment is operational**
- **Risks associated with change**
- **Decision to change is a future commitment**
- **Limited investment capital**
- **Uncertainty regarding future**
- **Psychological impact of sunk costs**
- **Technological improvement trap**
- **Prefer to be a “technology follower”**
- **Taking a “financial hit” on financial statements by writing off assets not fully depreciated**

Principle #2

Make investments that are economically justified

"If you need a new machine and don't buy it, you pay for it without ever getting it."

Henry Ford

Principal Reason for Replacing an Asset: Obsolescence

- ❖ Functional obsolescence
- ❖ Technological obsolescence
- ❖ Economic obsolescence

Replacement Analysis

Two approaches are commonly used in replacement analyses: the *cash flow approach* or *insider approach* and the *opportunity cost approach* or *outsider viewpoint approach*. If performed correctly, the two approaches will yield the same recommendation. (The essential difference in the two relates to how the salvage value of the *defender* is treated.)

We have not “made a big deal” out of replacement problems, since we prefer to treat them as just another investment alternative. Hence, we advocate using the same systematic approach when solving replacement problems.

Systematic Economic Analysis Technique

1. Identify the investment alternatives
2. Define the planning horizon
3. Specify the discount rate
4. Estimate the cash flows
5. Compare the alternatives
6. Perform supplementary analyses
7. Select the preferred investment

Cash Flow Approach

Before-Tax Analysis

Cash Flow Approach

The *cash flow approach* can be called the *insider viewpoint approach*. The cash flows used are those that are "seen" by the internal decision maker in answer to the question, "how much money will be spent and how much will be received if I adopt this alternative?" In sum, we are interested in knowing how much money will be spent and received/saved if the asset is replaced and how much money will be spent and received/saved if it is retained.

Caution

In performing replacement analyses, beware of sunk costs!

Example 11.1

A surface mount placement machine was acquired 10 years ago for $300,000. It can be kept for a maximum of 5 more years, at which time it will have a negligible salvage value. Annual O&M costs for the *defender* have been increasing by $5,000 a year since its acquisition. Next year, the O&M costs will total $120,000.

A new SMP machine (*challenger*) being considered as a replacement for the *defender* has a current market value of $50,000. The new SMP machine will cost $500,000 and have annual O&M costs of $10,000 the first year, increasing by $5,000 a year.

Based on the remaining useful life of the *defender*, a 5-year planning horizon is used. After 5 years, the *challenger* will have a market value of $200,000. With a *BTMARR* of 16.67%, should the *defender* be replaced?

Solution to Example 11.1

The cash flows for the *defender* (alternative 1) and *challenger* (alternative 2) are shown below. Based on the following incremental *EUAC* analysis, it is recommended that the *defender* continue to be used until a more attractive *challenger* is identified.

$$EUAC_{2-1}(16.67\%) = \$450{,}000(A/P\ 16.67\%,5) - \$200{,}000(A/F\ 16.67\%,5) - \$110{,}000 = \$890.00 > \$0^*$$

=PMT(16.67%,5,-450000,200000)-110000 = $889.06

EOY	CF(1)	CF(2)	CF(2) - CF(1)
0	$0.00	-$450,000.00	-$450,000.00
1	-$120,000.00	-$10,000.00	$110,000.00
2	-$125,000.00	-$15,000.00	$110,000.00
3	-$130,000.00	-$20,000.00	$110,000.00
4	-$135,000.00	-$25,000.00	$110,000.00
5	-$140,000.00	$170,000.00	$310,000.00

*** *EUAC* > $0 means *AW* < $0**

Solution to Example 11.1

The cash flows for the *defender* (alternative 1) and *challenger* (alternative 2) are shown below. Based on the following incremental *EUAC* analysis, it is recommended that the *defender* continue to be used until a more attractive *challenger* is identified.

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=PMT(16.67%,5,-450000,200000)-110000 = $889.06

Since $EUAC_{2\text{-}1}(16.67\%) > \$0$, Do Not Replace!

3	-$130,000.00	-$20,000.00	$110,000.00
4	-$135,000.00	-$25,000.00	$110,000.00
5	-$140,000.00	$170,000.00	$310,000.00

*** *EUAC* > $0 means *AW* < $0**

Example 11.2

A filter press was purchased 3 yrs ago for $30,000. O&M costs are expected to be $7,000 next year if the filter press is kept; they will increase by $1,000 per year, thereafter. In 5 yrs, the filter press can be sold for $2,000. Its book value is $21,000.

A new filter press can be purchased for $36,000. If purchased, the old filter press can be sold for $9,000. O&M costs will follow a $1,000 gradient series, with no cost in the first year. At the end of 5 yrs, the new press will have a $12,000 salvage value.

With a 15% *BTMARR*, what should be done?

Solution to Example 11.2

Alternative 1: keep the old press

AW(15%) = -\$7,000 - \$1,000(A|G 15%,5)
+ \$2,000(A|F 15%,5)

AW(15%) = -\$7,000 - \$1,000(1.72281)
+ \$2,000(0.14832)

AW(15%) = -\$8,426.17/yr

Alternative 2: replace old press

AW(15%) = -\$27,000(A|P 15%,5) - \$1,000(A|G 15%,5)
+ \$12,000(A|F 15%,5)

AW(15%) = -\$27,000(0.29832) - \$1,000(1.72281)
+ \$12,000(0.14832)

AW(15%) = -\$7,997.61/yr

$AW_{2-1}(15\%) = \$428.56$

Replace the filter press!

Example 11.3

In the previous example, what should be done if a 10-yr planning horizon is used, a replacement press will cost $31,000 in 5 yrs and have a salvage value of $15,000 after 5 yrs use, and O&M costs for the new press will be a $1,000 gradient series?

EOY	CF(1)	CF(2)
0	$0.00	-$27,000.00
1	-$7,000.00	$0.00
2	-$8,000.00	-$1,000.00
3	-$9,000.00	-$2,000.00
4	-$10,000.00	-$3,000.00
5	-$40,000.00	-$4,000.00
6	$0.00	-$5,000.00
7	-$1,000.00	-$6,000.00
8	-$2,000.00	-$7,000.00
9	-$3,000.00	-$8,000.00
10	$11,000.00	-$6,000.00

Example 11.3

In the previous example, what should be done if a 10-yr planning horizon is used, a replacement press will cost $31,000 in 5 yrs and have a salvage value of $15,000 after 5 yrs use, and O&M costs for the new press will be a $1,000 gradient series?

-$31,000 - $11,000 + $2,000 = -$40,000

EOY	CF(1)	CF(2)
0	$0.00	-$27,000.00
1	-$7,000.00	$0.00
2	-$8,000.00	-$1,000.00
3	-$9,000.00	-$2,000.00
4	-$10,000.00	-$3,000.00
5	-$40,000.00	-$4,000.00
[illegible]	$0.00	-$5,000.00
7	-$1,000.00	-$6,000.00
8	-$2,000.00	-$7,000.00
9	-$3,000.00	-$8,000.00
10	$11,000.00	-$6,000.00

Example 11.3

In the previous example, what should be done if a 10-yr planning horizon is used, a replacement press will cost $31,000 in 5 yrs and have a salvage value of $15,000 after 5 yrs use, and O&M costs for the new press will be a $1,000 gradient series?

EOY	CF(1)	CF(2)
0	$0.00	-$27,000.00
1	-$7,000.00	$0.00
2	-$8,000.00	-$1,000.00
3	-$9,000.00	-$2,000.00
4	-$10,000.00	-$3,000.00
5	-$40,000.00	-$4,000.00
6	$0.00	-$5,000.00
7	-$1,000.00	-$6,000.00
[illegible]	-$2,000.00	-$7,000.00
9	-$3,000.00	-$8,000.00
10	$11,000.00	-$6,000.00

-$4,000 + $15,000 = $11,000

Example 11.3

In the previous example, what should be done if a 10-yr planning horizon is used, a replacement press will cost $31,000 in 5 yrs and have a salvage value of $15,000 after 5 yrs use, and O&M costs for the new press will be a $1,000 gradient series?

EOY	CF(1)	CF(2)
0	$0.00	-$27,000.00
1	-$7,000.00	$0.00
2	-$8,000.00	-$1,000.00
3	-$9,000.00	-$2,000.00
4	-$10,000.00	-$3,000.00
5	-$40,000.00	-$4,000.00
6	$0.00	-$5,000.00
7	-$1,000.00	-$6,000.00
8	-$2,000.00	-$7,000.00
9	-$3,000.00	-$8,000.00
10	$11,000.00	-$6,000.00

-$9,000 + $3,000 = -$6,000

Table 11.2 shows $S_{2,10}$ = $3,000

Solution to Example 11.3

$$EUAC_1(15\%) = [\$7{,}000(P/A\ 15\%,5) + \$1{,}000(P/G\ 15\%,5) + \$29{,}000(P/F\ 15\%,5) + \$1{,}000(P/G\ 15\%,5)(P/F\ 15\%,5) - \$15{,}000(P/F\ 15\%,10)](A/P\ 15\%,10)$$

$$= [\$7{,}000(3.35216) + \$1{,}000(5.77514) + \$29{,}000(0.49718) + \$1{,}000(5.77514)(0.49718) - \$15{,}000(0.24718)](0.19925)$$

$$= \$8{,}532.30/\text{yr}$$

$$EUAC_2(15\%) = \$27{,}000(A/P\ 15\%,10) + \$1{,}000(A/G\ 15\%,10) - \$3{,}000(A/F\ 15\%,10)$$

$$= \$27{,}000(0.19925) + \$1{,}000(3.38320) - \$3{,}000(0.04925)$$

$$= \$8{,}615.20/\text{yr}$$

$$EUAC_{2\text{-}1}(15\%) = -\$82.90$$

Keep the Filter Press!

The technology forecast for filter presses reversed the recommendation.

Example 11.4

In Example 11.2, suppose the equipment supplier offers a $10,000 trade-in for the old press. Also, suppose two new alternatives are considered: a $40,000 filter press having a $13,000 salvage value in 5 yrs, O&M equal to a $500 gradient series on a $500 base, and a $12,000 trade-in for the old press; and a leased press, with $7,500 ***beginning-of-year*** **lease costs and end-of-year O&M costs given by an $800 gradient series. If leasing is pursued, the old press will be sold for $9,000.**

EOY	CF(1)	CF(2)	CF(3)	CF(4)
0	$0.00	-$26,000.00	-$28,000.00	$1,500.00
1	-$7,000.00	$0.00	-$500.00	-$7,500.00
2	-$8,000.00	-$1,000.00	-$1,000.00	-$8,300.00
3	-$9,000.00	-$2,000.00	-$1,500.00	-$9,100.00
4	-$10,000.00	-$3,000.00	-$2,000.00	-$9,900.00
5	-$9,000.00	$8,000.00	$10,500.00	-$3,200.00

Example 11.4

In Example 11.2, <u>suppose the equipment supplier offers a $10,000 trade-in for the old press</u>. Also, suppose two new alternatives are considered: a $40,000 filter press having a $13,000 salvage value in 5 yrs, O&M equal to a $500 gradient series on a $500 base, and a $12,000 trade-in for the old press; and a leased press, with $7,500 *beginning-of-year* lease costs and end-of-year O&M costs given by an $800 gradient series. If leasing is pursued, the old press will be sold for $9,000.

EOY	CF(1)	CF(2)	CF(3)	CF(4)
0	$0.00	-$26,000.00	-$28,000.00	$1,500.00
1	-$7,000.00	$0.00	-$500.[illegible]	-$7,500.00
2	-$8,000.00	-$1,000.00	-$1,000.[illegible]	-$8,300.00
3	-$9,000.00	-$2,000.[illegible]	[illegible]	-$9,100.00
4	-$10,000.00	-$3,000.[illegible]	[illegible]	-$9,900.00
5	-$9,000.00	$8,000.00	$10,500.00	-$3,200.00

-$36,000 + $10,000 = -$26,000

Example 11.4

In Example 11.2, suppose the equipment supplier offers a $10,000 trade-in for the old press. Also, suppose two new alternatives are considered: <u>a $40,000 filter press having a $13,000 salvage value in 5 yrs, O&M equal to a $500 gradient series on a $500 base, and a $12,000 trade-in for the old press</u>; and a leased press, with $7,500 *beginning-of-year* lease costs and end-of-year O&M costs given by an $800 gradient series. If leasing is pursued, the old press will be sold for $9,000.

EOY	CF(1)	CF(2)	CF(3)	CF(4)
0	$0.00	-$26,000.00	-$28,000.00	[illegible],500.00
1	-$7,000.00	$0.00	-$500.00	[illegible]500.00
2	-$8,000.00	-$1,000.00	-$1,000.00	-$8,[illegible]00.00
3	-$9,000.00	-$2,000.00	-$1,500.00	-$[illegible]00.00
4	-$10,000.00	-$3,000.00	[illegible]	[illegible]00.00
5	-$9,000.00	$8,000.00	[illegible]	[illegible]$3,200.00

-$40,000 + $12,000 = -$28,000

Example 11.4

In Example 11.2, suppose the equipment supplier offers a $10,000 trade-in for the old press. Also, suppose two new alternatives are considered: a $40,000 filter press having a $13,000 salvage value in 5 yrs, O&M equal to a $500 gradient series on a $500 base, and a $12,000 trade-in for the old press; and <u>a leased press, with $7,500 *beginning-of-year* lease costs and end-of-year O&M costs given by an $800 gradient series. If leasing is pursued, the old press will be sold for $9,000</u>.

EOY	CF(1)	CF(2)	CF(3)	CF(4)
0	$0.00	-$26,000.00	-$28,000[illegible]	$1,500.00
1	-$7,000.00	$0.00	-$500	-$7,500.00
2	-$8,000.00	-$1,000.00	-$1,000.00	-$8,300.00
3	-$9,000.00	-$2,000.00	-$1,500.00	-$9,100.00
4	-$10,000.00	-$3,000.00	-$2,000[illegible]	[illegible]
5	-$9,000.00	$8,000.00	$10,500.0[illegible]	[illegible]

$9,000 - $7,500 = $1,500

Solution to Example 11.4

$$\begin{aligned} EUAC_1(15\%) &= \$7{,}000 + \$1{,}000(A/G\ 15\%,5) - \$2{,}000(A/F\ 15\%,5) \\ &= \$7{,}000 + \$1{,}000(1.72281) - \$2{,}000(0.14832) \\ &= \$8{,}426.17/\text{yr}\ (\$8{,}426.18 \text{ with Excel®}) \end{aligned}$$

$$\begin{aligned} EUAC_2(15\%) &= \$26{,}000(A/P\ 15\%,5) + \$1{,}000(A/G\ 15\%,5) - \$12{,}000(A/F\ 15\%,5) \\ &= \$26{,}000(0.29832) + \$1{,}000(1.72281) - \$12{,}000(0.14832) \\ &= \$7{,}699.29/\text{yr}\ (\$7{,}699.23 \text{ with Excel®}) \end{aligned}$$

$$\begin{aligned} EUAC_3(15\%) &= \$28{,}000(A/P\ 15\%,5) + \$500 + \$500(A/G\ 15\%,5) \\ &= \$28{,}000(0.29832) + \$500 + \$500(1.72281) \\ &= \$7{,}786.21/\text{yr}\ (\$7{,}786.14 \text{ with Excel®}) \end{aligned}$$

$$\begin{aligned} EUAC_4(15\%) &= \$7{,}500(F/P\ 15\%,1) + \$800(A/G\ 15\%,5) - \$9{,}000(A/P\ 15\%,5) \\ &= \$7{,}500(1.15000) + \$800(1.72281) - \$9{,}000(0.29832) \\ &= \$7{,}318.37/\text{yr}\ (\$7{,}318.41 \text{ with Excel®}) \end{aligned}$$

Lease a New Filter Press!

Opportunity Cost Approach

Before-Tax Analysis

Opportunity Cost Approach

The *opportunity cost approach* views the transaction from the perspective of an "*outsider*" who does not own the existing asset. The *outsider* considers the salvage value of the existing asset to be its investment cost if it is retained in service. (Recall our opportunity cost discussion.)

The analogy of an *outsider* purchasing the *defender* on a used equipment market is likely to break down with respect to assumptions made regarding the planning horizon, depreciation allowances, and income tax rate used. If an *outsider* purchases the *defender*, is it reasonable to assume that the same planning horizon will be used? Likewise, is it reasonable to assume the new owner will use the depreciation allowances available to the previous owner, instead of starting anew and taking full depreciation allowances for the equipment? Finally, is it reasonable to assume that the new owner's tax bracket is the same as that of the previous owner? For these reasons, we prefer to call this approach the *opportunity cost approach*.

Example 11.9

A surface mount placement machine was acquired 10 years ago for $300,000. It can be kept for a maximum of 5 more years, at which time it will have a negligible salvage value. Annual O&M costs for the *defender* have been increasing by $5,000 a year since its acquisition. Next year, the O&M costs will total $120,000.

A new SMP machine (*challenger*) is being considered as a replacement for the *defender*, which has a current market value of $50,000. The *challenger* will cost $500,000 and have annual O&M costs of $10,000 the first year, increasing by $5,000 a year.

Based on the remaining useful life of the *defender*, a 5-year planning horizon is used. After 5 years, the *challenger* will have a market value of $200,000. With a ***BTMARR*** of 16.67%, using an *opportunity cost approach*, should the *defender* be replaced?

Solution to Example 11.9

Based on the incremental cash flows shown below and an *EUAC* analysis, the old SMP machine (*defender*) should be retained.

EOY	CF(1)	CF(2)	CF(2) - CF(1) *
0	-$50,000.00	-$500,000.00	-$450,000.00
1	-$120,000.00	-$10,000.00	$110,000.00
2	-$125,000.00	-$15,000.00	$110,000.00
3	-$130,000.00	-$20,000.00	$110,000.00
4	-$135,000.00	-$25,000.00	$110,000.00
5	-$140,000.00	$170,000.00	$310,000.00

$$EUAC_{2\text{-}1}(16.67\%) = \$450{,}000(A/P\ 16.67\%,5)$$

$$- \$200{,}000(A/F\ 16.67\%,5) - \$110{,}000$$

$$= \$890.00 > \$0^*$$

=PMT(16.67%,5,-450000,200000)-110000

= $889.06

*** CF(2) – CF(1) identical to cash flow approach**

Solution to Example 11.9

Based on the incremental cash flows shown below and an *EUAC* analysis, the old SMP machine (*defender*) should be retained.

EOY	CF(1)	CF(2)	CF(2) - CF(1) *
0	-$50,000.00	-$500,000.00	-$450,000.00
1	-$120,000.00	-$10,000.00	$110,000.00

Since $EUAC_{2-1}$(16.67%) > $0,
Do Not Replace!

$EUAC_{2-1}$(16.67%) = $450,000(*A/P* 16.67%,5)

- $200,000(*A/F* 16.67%,5) - $110,000

= $890.00 > $0*

=PMT(16.67%,5,-450000,200000)-110000

= $889.06

*** CF(2) – CF(1) identical to cash flow approach**

Example 11.10

A filter press was purchased 3 yrs ago for $30,000. O&M costs are expected to be $7,000 next year if the filter press is kept; they will increase by $1,000 per year. In 5 yrs, the filter press can be sold for $2,000. Its book value is $12,600.

A new press can be purchased for $36,000. If purchased, the old filter press can be sold for $9,000. O& M costs will follow a $1,000 gradient series, with no cost in the first year. At the end of 5 yrs, the new press will have a $12,000 salvage value.

With a 15% ***BTMARR***, using an *opportunity cost approach*, what should be done?

Solution to Example 11.10

Given the incremental cash flows shown below, based on an *EUAC* analysis, the old filter press should be replaced.

$$
\begin{aligned}
EUAC_{2-1}(15\%) &= \$27{,}000(A/P\ 15\%,5) - \$17{,}000(A/F\ 15\%,5) - \$7000 \\
&= \$27{,}000(0.29832) - \$10{,}000(0.14832) - \$7000 \\
&= -\$428.56/\text{yr} < \$0
\end{aligned}
$$

=PMT(15%,5,-27000,17000)-7000

$$= -\$428.64/\text{yr} < \$0$$

The *challenger* is preferred; replace the old filter press.

EOY	CF(1)	CF(2)	CF(2) - CF(1)
0	-$9,000.00	-$36,000.00	-$27,000.00
1	-$7,000.00	$0.00	$7,000.00
2	-$8,000.00	-$1,000.00	$7,000.00
3	-$9,000.00	-$2,000.00	$7,000.00
4	-$10,000.00	-$3,000.00	$7,000.00
5	-$9,000.00	$8,000.00	$17,000.00

Alternate Solution to Example 11.10

Alternative 1: keep the old press

$EUAC_1(15\%) = \$9{,}000(A|P\ 15\%,5) + \$7{,}000$
$\qquad + \$1{,}000(A|G\ 15\%,5) - \$2{,}000\ (A|F\ 15\%,5)$

$EUAC_1(15\%) = \$9{,}000(0.29832) + \$7{,}000 + \$1{,}000(1.72281)$
$\qquad - \$2{,}000(0.14832)$

$EUAC_1(15\%) = \$11{,}111.05/yr$

Alternative 2: replace the old press

$EUAC_2(15\%) = \$36{,}000(A|P\ 15\%,5) + \$1{,}000(A|G\ 15\%,5)$
$\qquad - \$12{,}000(A|F\ 15\%,5)$

$EUAC_2(15\%) = \$36{,}000(0.29832) + \$1{,}000(1.72281)$
$\qquad - \$12{,}000(0.14832)$

$EUAC_2(15\%) = \$10{,}682.49/yr$

$EUAC_2(15\%) < EUAC_1(15\%)$

Replace the Filter Press!

Example 11.11

In Example 11.10, suppose the equipment supplier offers a $10,000 trade-in for the old press. Also, suppose two new alternatives are considered: a $40,000 filter press having a $13,000 salvage value in 5 yrs, O&M equal to a $500 gradient series on a $500 base, and a $12,000 trade-in for the old press; and a leased press, with $7,500 beginning-of-year lease costs and end-of-year O%M cost given by an $800 gradient series. If leasing is pursued, the old press will be sold for $9,000.

EOY	CF(1)	CF(2)	CF(3)	CF(4)
0	-$9,000.00	-$35,000.00	-$37,000.00	-$7,500.00
1	-$7,000.00	$0.00	-$500.00	-$7,500.00
2	-$8,000.00	-$1,000.00	-$1,000.00	-$8,300.00
3	-$9,000.00	-$2,000.00	-$1,500.00	-$9,100.00
4	-$10,000.00	-$3,000.00	-$2,000.00	-$9,900.00
5	-$9,000.00	$8,000.00	$10,500.00	-$3,200.00

Solution to Example 11.11

$EUAC_1(15\%)$ = $9,000(A|P 15%,5) + $7,000 + $1,000(*A/G* 15%,5)
- $2,000(*A/F* 15%,5)
= $9,000(0.29832) + $7,000 + $1,000(1.72281) - $2,000(0.14832)
= $11,111.05/yr ($11,111.02 with Excel)

$EUAC_2(15\%)$ = $35,000(*A/P* 15%,5) + $1,000(*A/G* 15%,5) - $12,000(*A/F* 15%,5)
= $35,000(0.29832) + $1,000(1.72281) - $12,000(0.14832)
= $10,384.17/yr ($10,384.07 with Excel)

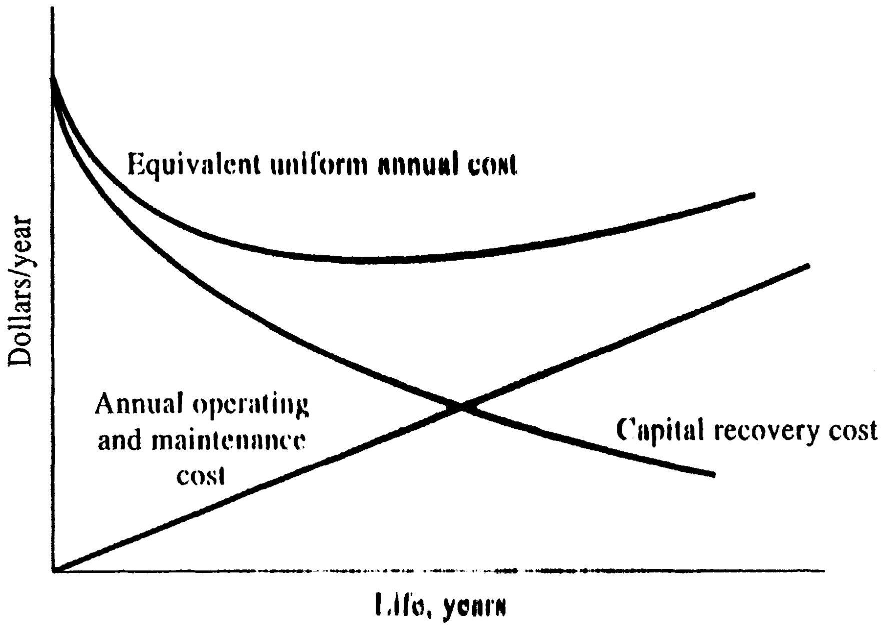
$EUAC_3(15\%)$ = $37,000(*A/P* 15%,5) + $500 +$500(*A/G* 15%,5)
= $37,000(0.29832) + $500 + $500(1.72281)
= $10,471.09/yr ($10,470.98 with Excel)

$EUAC_4(15\%)$ = $7,500(*F/P* 15%,1) + $800(*A/G* 15%,5)
= $7,500(1.15000) + $800(1.72281)
= $10,003.25/yr ($10,003.25 with Excel)

Lease a New Filter Press!

Optimum Replacement Interval

As equipment ages, O&M costs increase and CR cost decreases. As a result, the EUAC is often a convex function of the number of years the equipment is used. Under certain conditions, the optimum replacement interval can be determined, i.e., the frequency of replacements that will minimize EUAC.



Example 11.18

a) **A medium-sized industrial grade compressor can be purchased for $10,000. Its salvage value will be negligible, regardless of how long it is used. Annual O&M costs are expected to increase $1,500/yr, with a 1st year O&M cost of $2,500. Based on a 15% *MARR*, how frequently should the compressor be replaced?**

Chapter 11 tables and figures.rev [Compatibility Mode] - Microsoft Excel

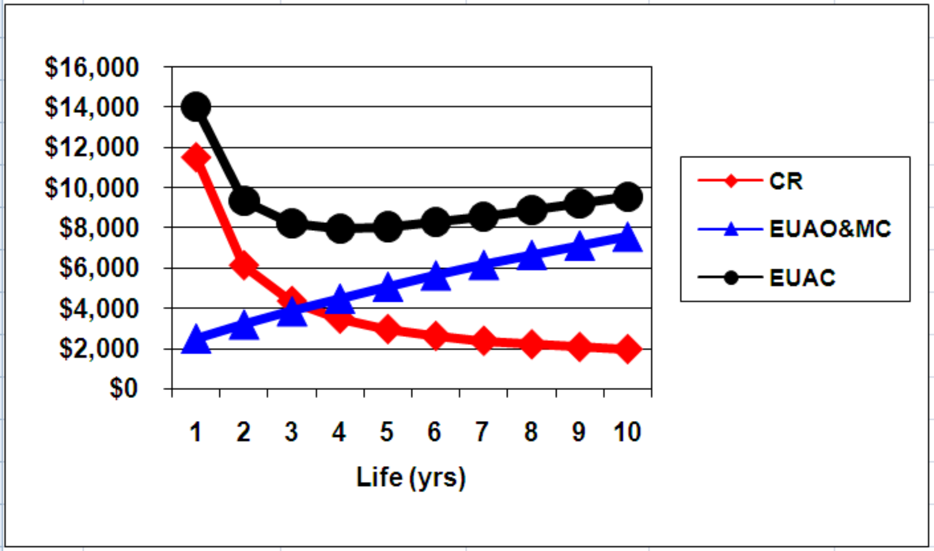
Life	CR	O&M	EUAO&MC	EUAC	
1	$11,500.00	$2,500.00	$2,500.00	$14,000.00	
2	$6,151.16	$4,000.00	$3,197.67	$9,348.84	
3	$4,379.77	$5,500.00	$3,860.69	$8,240.46	
4	$3,502.65	$7,000.00	$4,489.39	**$7,992.04**	**optimum**
5	$2,983.16	$8,500.00	$5,084.22	$8,067.38	
6	$2,642.37	$10,000.00	$5,645.79	$8,288.15	
7	$2,403.60	$11,500.00	$6,174.77	$8,578.38	
8	$2,228.50	$13,000.00	$6,671.99	$8,900.49	
9	$2,095.74	$14,500.00	$7,138.34	$9,234.08	
10	$1,992.52	$16,000.00	$7,574.79	$9,567.31	

=PMT(15%,A3,-NPV(15%,C2:C3))

=PMT(15%,A5,-10000)

=B7+D7

=C8+1500



n* = 4 yrs

P = $10,000

SV = $0

$O\&M_1$ = $2,500

G = $1,500

MARR = 15%

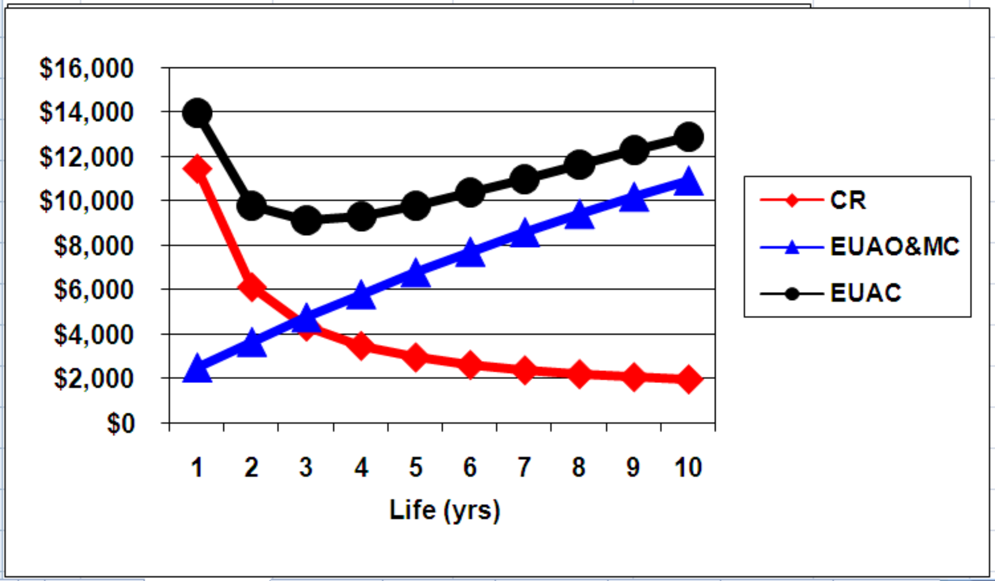
Table 11.15 | Table 11.16 | Table 11.17 | Table 11.18 | Table 11.19 | Figure 11.3 | Figure 11.4 | Figure 11.5

Example 11.18 (Continued)

b) **Now, suppose annual O&M costs increase $2,500/yr, with a 1st year O&M cost of $2,500. Based on a 15% *MARR*, how frequently should the compressor be replaced?**

E4 f_x =B4+D4

Life	CR	O&M	EUAO&MC	EUAC	
1	$11,500.00	$2,500.00	$2,500.00	$14,000.00	
2	$6,151.16	$5,000.00	$3,662.79	$9,813.95	
3	$4,379.77	$7,500.00	$4,767.82	**$9,147.59**	**optimum**
4	$3,502.65	$10,000.00	$5,815.64	$9,318.30	
5	$2,983.16	$12,500.00	$6,807.04	$9,790.19	
6	$2,642.37	$15,000.00	$7,742.98	$10,385.35	
7	$2,403.60	$17,500.00	$8,624.62	$11,028.23	
8	$2,228.50	$20,000.00	$9,453.32	$11,681.82	
9	$2,095.74	$22,500.00	$10,230.56	$12,326.30	
10	$1,992.52	$25,000.00	$10,957.99	$12,950.51	



n* = 3 yrs

P = $10,000

SV = $0

$O\&M_1$ = $2,500

G = $2,500

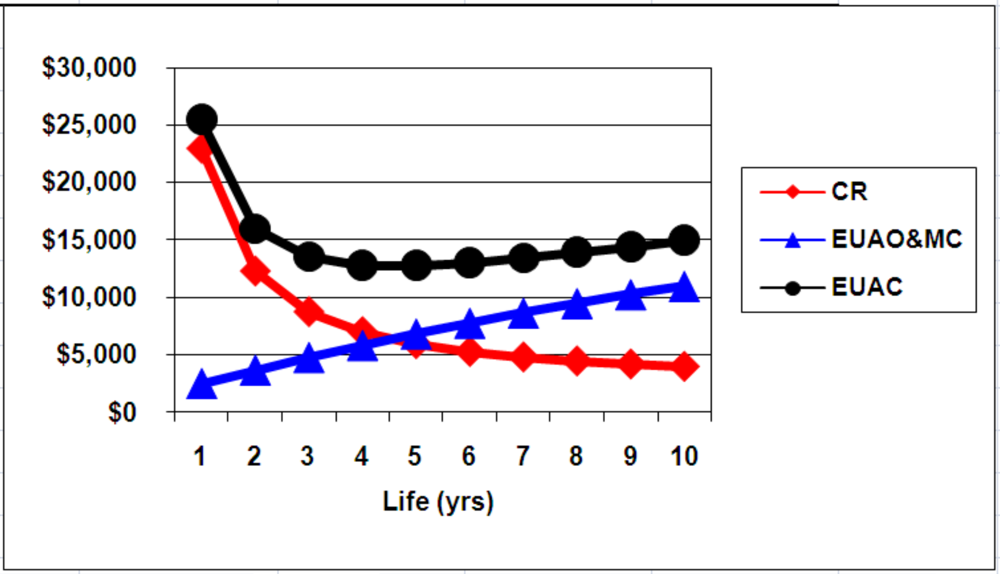
MARR = 15%

Figure 11.3 | Figure 11.4 | Figure 11.5 | Figure 11.6 | Figure 11.7 | Figure 11.8 | Figrue 11.9 | Figure 11.10

Example 11.18 (Continued)

c) **Now, suppose annual O&M costs increase $2,500/yr, with a 1st year O&M cost of $2,500 and the initial cost of the compressor increases from $10,000 to $20,000. Based on a 15% *MARR*, how frequently should the compressor be replaced?**

Life	CR	O&M	EUAO&MC	EUAC	
1	$23,000.00	$2,500.00	$2,500.00	$25,500.00	
2	$12,302.33	$5,000.00	$3,662.79	$15,965.12	
3	$8,759.54	$7,500.00	$4,767.82	$13,527.36	
4	$7,005.31	$10,000.00	$5,815.64	$12,820.95	
5	$5,966.31	$12,500.00	$6,807.04	**$12,773.35**	**optimum**
6	$5,284.74	$15,000.00	$7,742.98	$13,027.71	
7	$4,807.21	$17,500.00	$8,624.62	$13,431.83	
8	$4,457.00	$20,000.00	$9,453.32	$13,910.32	
9	$4,191.48	$22,500.00	$10,230.56	$14,422.04	
10	$3,985.04	$25,000.00	$10,957.99	$14,943.03	



$n^* = 5$ yrs

P = $20,000

SV = $0

$O\&M_1$ = $2,500

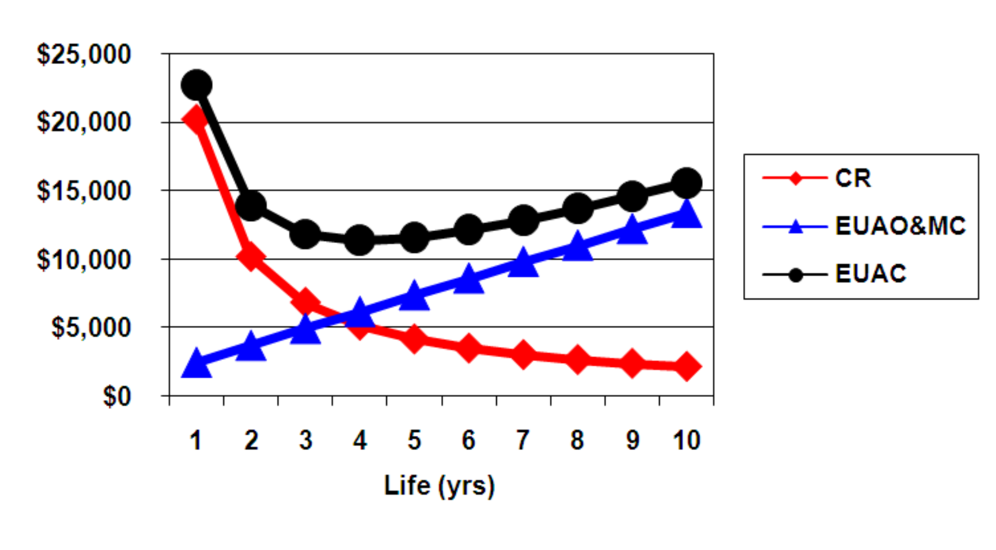
G = $2,500

MARR = 15%

Example 11.18 (Continued)

d) **Now, suppose annual O&M costs increase $2,500/yr, with a 1st year O&M cost of $2,500, the initial cost of the compressor is $20,000, and the *MARR* is decreased to 1.5%. How frequently should the compressor be replaced?**

Life	CR	O&M	EUAO&MC	EUAC	
1	$20,300.00	$2,500.00	$2,500.00	$22,800.00	
2	$10,225.56	$5,000.00	$3,740.69	$13,966.25	
3	$6,867.66	$7,500.00	$4,975.19	$11,842.85	
4	$5,188.90	$10,000.00	$6,203.48	**$11,392.37**	**optimum**
5	$4,181.79	$12,500.00	$7,425.56	$11,607.35	
6	$3,510.50	$15,000.00	$8,641.45	$12,151.96	
7	$3,031.12	$17,500.00	$9,851.14	$12,882.26	
8	$2,671.68	$20,000.00	$11,054.63	$13,726.31	
9	$2,392.20	$22,500.00	$12,251.93	$14,644.13	
10	$2,168.68	$25,000.00	$13,443.04	$15,611.72	



n* = 4 yrs

P = $20,000

SV = $0

$O\&M_1$ = $2,500

G = $2,500

MARR = 1.5%

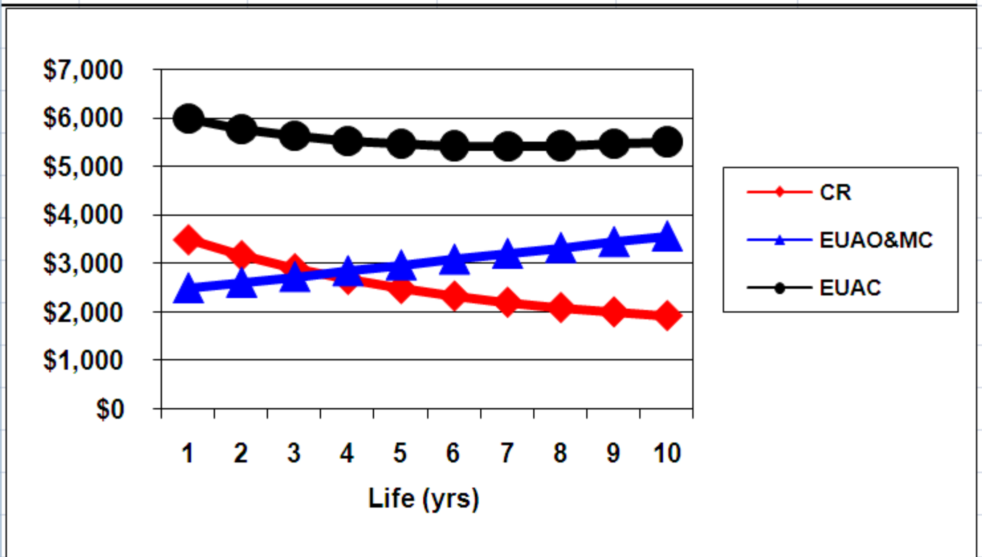
Example 11.18 (Continued)

e) **Now, suppose the compressor costs $10,000; annual O&M costs increase 10%/yr, with a 1st year O&M cost of $2,500; and salvage value is a decreasing geometric series, with a decrease of 20%/yr, i.e., the salvage value after 1-yr of use is $8,000, after 2 yrs use is $6,400, … Using a 15% *MARR*, how frequently should the compressor be replaced?**

Chapter 11 tables and figures [Compatibility Mode] - Microsoft Excel

F8 =C8+E8

Life	SV	CR	O&M	EUAO&MC	EUAC	
1	$8,000.00	$3,500.00	$2,500.00	$2,500.00	$6,000.00	
2	$6,400.00	$3,174.42	$2,750.00	$2,616.28	$5,790.70	
3	$5,120.00	$2,905.33	$3,025.00	$2,733.98	$5,639.31	
4	$4,096.00	$2,682.37	$3,327.50	$2,852.84	$5,535.21	
5	$3,276.80	$2,497.16	$3,660.25	$2,972.59	$5,469.75	
6	$2,621.44	$2,342.90	$4,026.28	$3,092.96	$5,435.87	
7	$2,097.15	$2,214.10	$4,428.90	$3,213.68	**$5,427.78**	**optimum**
8	$1,677.72	$2,106.28	$4,871.79	$3,334.47	$5,440.75	
9	$1,342.18	$2,015.78	$5,358.97	$3,455.08	$5,470.86	
10	$1,073.74	$1,939.64	$5,894.87	$3,575.24	$5,514.88	



n* = 7 yrs

P = $10,000

SV = $10,000(0.8)^n

O&M$_1$ = $2,500

j = 10%

MARR = 15%

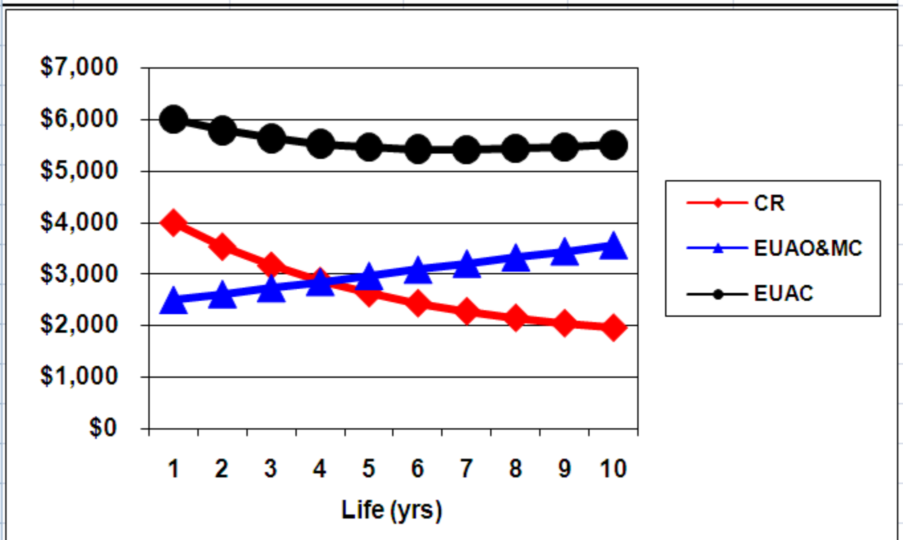
Figure 11.4 | Figure 11.5 | Figure 11.6 | Figure 11.7 | Figure 11.8 | Figrue 11.9 | Figure 11.10 | Figure 11.11

Example 11.18 (Continued)

f) **Now, suppose the compressor costs $10,000; annual O&M costs increase 10%/yr, with a 1st year O&M cost of $2,500; and salvage value is a decreasing geometric series, with a decrease of 25%/yr, i.e., the salvage value after 1-yr of use is $7,500, after 2 yrs use is $5,625, … Using a 15% *MARR*, how frequently should the compressor be replaced?**

F9 =C9+E9

Life	SV	CR	O&M	EUAO&MC	EUAC	
1	$7,500.00	$4,000.00	$2,500.00	$2,500.00	$6,500.00	
2	$5,625.00	$3,534.88	$2,750.00	$2,616.28	$6,151.16	
3	$4,218.75	$3,164.87	$3,025.00	$2,733.98	$5,898.85	
4	$3,164.06	$2,869.00	$3,327.50	$2,852.84	$5,721.84	
5	$2,373.05	$2,631.20	$3,660.25	$2,972.59	$5,603.79	
6	$1,779.79	$2,439.05	$4,026.28	$3,092.96	$5,532.01	
7	$1,334.84	$2,282.99	$4,428.90	$3,213.68	$5,496.67	
8	$1,001.13	$2,155.57	$4,871.79	$3,334.47	**$5,490.04**	**optimum**
9	$750.85	$2,051.01	$5,358.97	$3,455.08	$5,506.09	
10	$563.14	$1,964.79	$5,894.87	$3,575.24	$5,540.03	



$n^* = 8$ yrs

P = $10,000

SV = $10,000(0.75)^n

O&M$_1$ = $2,500

j = 10%

MARR = 15%

Sensitivity Analysis Conclusions

- **Increasing (*decreasing*) the rate of increase in annual operating and maintenance costs tends to decrease (*increase*) the optimum replacement interval**
- **Increasing (*decreasing*) the magnitude of the initial investment tends to increase (*decrease*) the optimum replacement interval**
- **Increasing (*decreasing*) the minimum attractive rate of return tends to increase (*decrease*) the optimum replacement interval**
- **Increasing (*decreasing*) the rate of decrease in salvage value tends to increase (*decrease*) the optimum replacement interval**

Question

Given the previous examples, with a $10,000 investment, zero salvage value, a 1st year O&M cost of $2,500, and a $1,500/yr increase in O&M costs.

Suppose the 1st year O&M doubles. What will happen to the optimum replacement interval? Will it increase or will it decrease?

Question

Given the previous examples, with a $10,000 investment, zero salvage value, a 1st year O&M cost of $2,500, and a $1,500/yr increase in O&M costs.

Suppose the 1st year O&M doubles. What will happen to the optimum replacement interval? Will it increase or will it decrease?

Changing the base for a gradient series does not change the optimum replacement interval, since the same change is made to each yearly O&M cost.

Question

Given the previous examples, with a $10,000 investment, zero salvage value, a 1st year O&M cost of $2,500, and a 15%/yr increase in O&M costs.

Suppose the 1st year O&M doubles. What will happen to the optimum replacement interval?

Question

Given the previous examples, with a $10,000 investment, zero salvage value, a 1st year O&M cost of $2,500, and a 15%/yr increase in O&M costs.

Suppose the 1st year O&M doubles. What will happen to the optimum replacement interval?

Increasing A_1 for a geometric series tends to decrease the optimum replacement interval, since subsequent O&M costs increase exponentially.

Optimum Replacement Interval Analysis Observations

1. Subsequent replacements are assumed to have identical CF profiles
2. For the replacement interval to be optimum, it must minimize ATPW over the planning horizon
3. Implicit assumption: the planning horizon is an integer-multiple of the optimum replacement interval

Example 11.20

Recall the initial conditions in Example 11.18, which, as shown below, produce an optimum replacement interval of 6 years. Suppose a 10-year planning horizon exists, instead of an integer multiple of 6 years.

Life	CR	O&M	EUAO&MC	EUAC
1	$11,500.00	$2,500.00	$2,500.00	$14,000.00
2	$6,151.16	$3,000.00	$2,732.56	$8,883.72
3	$4,379.77	$3,600.00	$2,982.36	$7,362.13
4	$3,502.65	$4,320.00	$3,250.24	$6,752.90
5	$2,983.16	$5,184.00	$3,537.05	$6,520.21
6	$2,642.37	$6,220.80	$3,843.63	$6,486.00
7	$2,403.60	$7,464.96	$4,170.86	$6,574.46
8	$2,228.50	$8,957.95	$4,519.60	$6,748.10
9	$2,095.74	$10,749.54	$4,890.74	$6,986.48
10	$1,992.52	$12,899.45	$5,285.19	$7,277.71

Example 11.20 (Continued)

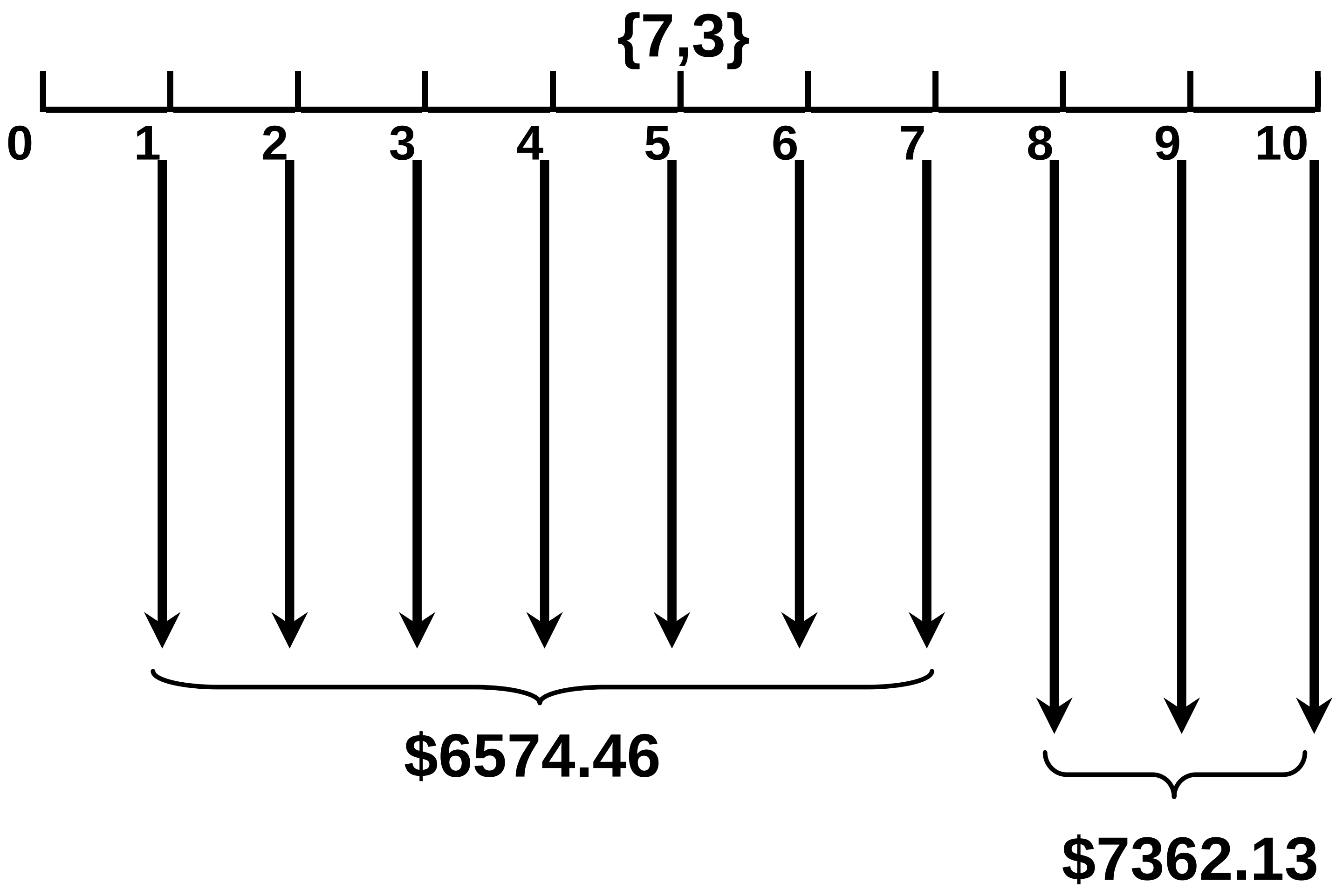
Assuming identical cash flows for replacements during the planning horizon, evaluate the following possible combinations of service lives: {5,5}, {6,4}, and {7,3}.

$$PW_{\{5,5\}}(15\%) = \$6{,}520.21(P|A\ 15\%,10)$$
$$= \$32{,}723.43$$

$$PW_{\{6,4\}}(15\%) = \$6{,}486.00(P|A\ 15\%,6)$$
$$+ \$6{,}752.90(P|A\ 15\%,4)(P|F\ 15\%,6)$$
$$= \$32{,}881.20$$

$$PW_{\{7,3\}}(15\%) = \$6{,}574.46(P|A\ 15\%,7)$$
$$+ \$7{,}362.13(P|A\ 15\%,3)(P|F\ 15\%,7)$$
$$= \$33{,}671.85$$

Why didn't we have to evaluate {3,7}? Recall the TVOM discussions in Ch. 2.



Pit Stop #11—Pick Up the Pace! Don't Get Replaced!

1. True or False: In performing engineering economic analyses of replacement alternatives, it is best to perform before-tax analyses, since incorporating income tax considerations in the analysis is difficult, due to the treatment of trade-in values not equaling book values.
2. True or False: The two approaches used in performing replacement analyses are the cash flow approach and the insider approach.
3. True or False: In determining the optimum replacement interval, it is necessary to assume negligible salvage values.
4. True or False: Before-tax replacement analyses and after-tax replacement analyses seldom yield the same recommendation.
5. True or False: Section 1031 exchanges of property can be performed for any real or personal property.
6. True or False: If the optimum replacement interval for an over-the-road tractor is 4 years and the initial cost of the tractor is increased by 20% then the optimum replacement interval for the next tractor might be less than 4 years.
7. True or False: If the optimum replacement interval for an over-the-road tractor is 4 years and the salvage value for used tractors is suddenly cut in half, then the optimum replacement interval for the next tractor might be greater than 4 years.
8. True or False: If the optimum replacement interval for an over-the-road tractor is 4 years and the *ATMARR* is increased from 9% to 12%, then the optimum replacement interval for the next tractor might be less than 4 years.
9. True or False: If the optimum replacement interval for an over-the-road tractor is 4 years and the rate of increase in O&M costs doubles, then the optimum replacement interval for the next tractor might be less than 4 years.
10. True or False: Section 1031 Property Exchanges are no longer permitted by the U.S. Internal Revenue Service.

Pit Stop #11—Pick Up the Pace! Don't Get Replaced!

1. True or False: In performing engineering economic analyses of replacement alternatives, it is best to perform before-tax analyses, since incorporating income tax considerations in the analysis is difficult, due to the treatment of trade-in values not equaling book values. False
2. True or False: The two approaches used in performing replacement analyses are the cash flow approach and the insider approach. False
3. True or False: In determining the optimum replacement interval, it is necessary to assume negligible salvage values. False
4. True or False: Before-tax replacement analyses and after-tax replacement analyses seldom yield the same recommendation. False
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10. True or False: Section 1031 Property Exchanges are no longer permitted by the U.S. Internal Revenue Service. False