# Engineering Economy Review

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Industrial Engineering

## Main concepts
- Models are approximations of reality (THINK)
- Time value of money, cash flow diagrams, and equivalence
- Comparison of alternatives
- Depreciation, inflation, and interest rates

## Suggestions for solving problems
- Look up unfamiliar terms in the index
- Draw cash flow diagrams
- Identify P, A, F, i
- Be flexible in using equations and tables
- Check with alternate methods

## Cash flows
- Cash flows describe income and outflow of money over time
- Disbursements = outflows “−”
- Receipts = inflows “+”
- Beginning of first year is traditionally defined as “Time 0”

## Equivalence
- Translating cashflows over time into common units
- Present values of future payments
- Future value of present payments
- Present value of continuous uniform payments
- Continuous payments equivalent to present payment

## Single Payment Compound Interest
- $P$: Present sum of money
- $i$: Interest per time period (usually years)
- MARR: Minimal Acceptable Rate of Return
- $n$: Number of time periods (usually years)
- $F$: Future sum of money that is equivalent to $P$ given an interest rate $i$ for $n$ periods

- $F = P(1+i)^n$
- $P = F(1+i)^{-n}$
- $F = P(F/P, i, n)$
- $P = F(F/P, i, n)$
Bank example
- You deposit 1000.
- 12% per year.
- 5 years.
- How much do you have at end if compounded yearly?
- How much do you have at end if compounded monthly?

5.47 Income from savings
- $25,000 deposited.
- Account pays 5% compounded semiannually.
- Withdrawals in one year and continuing forever.
- Maximum equal annual withdrawal equals?

5.47 Capitalized cost problem
- \( P = 25,000 \)
- \( A = \)?
- \( r = 5\% \)
- \( i = ? \)
- \( A = iP \)

Key points to remember
- Time value of money:
  - $1000 today is not the same as $1000 one hundred years from now.
  - Money in the future is worth less than present sums.
- Cash flow diagrams:
  - Starts at year zero.
  - Superposition to convert to standard forms.
- Equivalence:
  - Functional notation, \( F = P(F/P, i, n) \)
  - \( i \) and \( n \) must match units.
  - Capitalized cost, \( A = iP, P = A/i \)

Comparison of alternatives
- Present/Future worth.
- Cash flow.
- Rate of return.
- Cost benefit.
- Payback period.
- Breakeven analysis.

Present/Future worth
- Determine time period for analysis, least common multiple.
- Calculate present value for each alternative:
  - Draw cash flow diagram.
  - Identify/calculate \( A, i, P, F, n \).
  - Use present value equations to determine \( P \).
- Compare costs.
Tomato peeling machines

<table>
<thead>
<tr>
<th></th>
<th>Machine A</th>
<th>Machine B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase cost</td>
<td>$52,000</td>
<td>$63,000</td>
</tr>
<tr>
<td>Annual cost</td>
<td>$15,000/year</td>
<td>$9,000/year</td>
</tr>
<tr>
<td>Annual benefit</td>
<td>$38,000/year</td>
<td>$31,000/year</td>
</tr>
<tr>
<td>Salvage value</td>
<td>$13,000</td>
<td>$19,000</td>
</tr>
<tr>
<td>Useful life</td>
<td>4 years</td>
<td>6 years</td>
</tr>
</tbody>
</table>

Present cost of A

\[
P_1 = -52,000 + (38,000 - 15,000) (P/A, 12\%, 4) + 13,000 (P/F, 12\%, 4)
\]

\[P_{12} = P_4 + P_4 (P/F, 12\%, 4) + P_4 (P/F, 12\%, 8)
\]

\[P_{12} = 53,255
\]

Present cost of B

\[
P_6 = -63,000 + (31,000 - 9,000) (P/A, 12\%, 6) + 19,000 (P/F, 12\%, 6)
\]

\[P_{12} = P_6 + P_6 (P/F, 12\%, 6)
\]

\[P_{12} = 55,846
\]

Cash flow analysis

- Determine time period for analysis: common multiple OR continuing operation then doesn’t require least common multiple
- Calculate annual cost/benefit/profit for each alternative
  - Draw cashflow diagram
  - Identify/calculate A, S, i, P, F, n
  - Use uniform payment equations to determine A
- Compare annual costs

Rate of return analysis

- Draw cash flow diagram of each alternative
- Draw combined cash flow diagram
  (higher initial cost - lower initial cost)
- Convert to Present worth and Present costs
- OR
  Convert to EUAB and EUAC
- Write equation
- Solve for i
- If \( ROR \geq MARR \), choose higher-cost alternative
### 7-52: Purchase vs. Lease

- **Purchase machine:**
  - $12,000 initial cost
  - $1,200 salvage value

- **Lease machine**
  - $3,000 annual payment
  - 15% MARR, 8 year useful life

#### PW of Benefits - PW of Costs = 0

\[
\text{PW of Benefits} - \text{PW of Costs} = 0
\]

\[
3000(P/A, i, 7) + 4200(P/F, i, 8) - 12,000 = 0
\]

- **i=17%**
  \[
  3000(3.922) + 4200(0.2848) - 12,000 = 962
  \]

- **i=18%**
  \[
  3000(3.812) + 4200(0.2660) - 12,000 = 553
  \]

- **i=20%**
  \[
  3000(3.605) + 4200(0.2326) - 12,000 = -208
  \]

#### Internal rate of return = 17.6%

- **17.6% > 15% therefore choose purchase option**

### Evaluation of multiple alternatives

- Identify all alternatives
- Compute rate of return of all alternatives
  - Delete alternatives with a return < MARR
- Arrange remaining alternatives in order of increasing investment (find alternative where investing component dominates)
- Evaluate first two alternatives
- Repeat evaluation until all alternatives have been evaluated

### Repeated evaluation of alternatives

- Multiple comparisons of return on incremental investment
General suggestions

- Think about alternatives
  - \( i=0 \)
  - \( i=0 \)
  - \( A=P_i \) when salvage value equals initial cost
  - \( P=A_i = \) Capitalized cost
  - Infinite analysis period: \( EUAB-EUAC=NPWi \)
- Consider using Present Worth AND EUAB to frame rate of return calculation

Payback period analysis

- Approximate rather than exact calculation
- All costs and profits are included without considering their timing
- Economic consequence beyond payback period are ignored (salvage value, gradient cash flow)
- May select a different alternative than other methods
- Focus is speed versus efficiency

Benefit cost ratio

- Benefit cost ratio analysis
  - \( (PW \text{ of benefit}/PW \text{ of cost} \geq 1) \)
  - Compare incremental investment, similar to rate of return analysis

9.9 Three alternatives

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost</td>
<td>50</td>
<td>150</td>
<td>110</td>
</tr>
<tr>
<td>AB first</td>
<td>28.8</td>
<td>39.6</td>
<td>39.6</td>
</tr>
<tr>
<td>Useful life</td>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Rate of Return</td>
<td>10%</td>
<td>15%</td>
<td>16.4%</td>
</tr>
</tbody>
</table>
- Compare using MARR=12%
  - Future worth
  - Benefit cost
  - Payback period

Future worth: Option C

\[
F = 110(F/P, 12, 4) - 100(F/P, 12, 8) - 110(F/P, 12, 12) + 39.6(F/A, 12, 12) + 81.61
\]

Future worth analysis

<table>
<thead>
<tr>
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<td>Rate of Return</td>
<td>10%</td>
<td>15%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Future worth</td>
<td>-18.94</td>
<td>75.17</td>
<td>81.61</td>
</tr>
</tbody>
</table>
- Benefit costs
- Payback period
**Benefit-cost ratio analysis**

<table>
<thead>
<tr>
<th>Year</th>
<th>C</th>
<th>A</th>
<th>C-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-110</td>
<td>-50</td>
<td>-60</td>
</tr>
<tr>
<td>1</td>
<td>39.6</td>
<td>28.8</td>
<td>10.8</td>
</tr>
<tr>
<td>2</td>
<td>39.6</td>
<td>28.8-50</td>
<td>60.8</td>
</tr>
<tr>
<td>3</td>
<td>39.6</td>
<td>28.8</td>
<td>10.8</td>
</tr>
<tr>
<td>4</td>
<td>39.6</td>
<td>28.8</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Present worth of Cost=60
Present work of benefit=10.8(P/A,12,4)+50(P/F,12,2)
B/C=72.66/60>1
Reject A

**Benefit-cost ratio analysis**

<table>
<thead>
<tr>
<th>Year</th>
<th>B</th>
<th>C</th>
<th>B-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-150</td>
<td>-110</td>
<td>-60</td>
</tr>
<tr>
<td>1-4</td>
<td>39.6</td>
<td>39.6</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>-110</td>
<td>110</td>
</tr>
<tr>
<td>5-6</td>
<td>39.6</td>
<td>39.6</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>-150</td>
<td>0</td>
<td>-150</td>
</tr>
<tr>
<td>7-8</td>
<td>39.6</td>
<td>39.6</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>-110</td>
<td>110</td>
</tr>
<tr>
<td>9-12</td>
<td>39.6</td>
<td>39.6</td>
<td>0</td>
</tr>
</tbody>
</table>

**Payback period**

- A 50/28.8 = 1.74 years
- B 150/39.6= 3.79 years
- C 110/39.6= 2.78 years
Select A

**Summary**

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<td>81.61</td>
</tr>
<tr>
<td>Benefit cost</td>
<td>C-A=1.21</td>
<td>B-C=0.98</td>
<td></td>
</tr>
<tr>
<td>Payback period</td>
<td>1.74</td>
<td>3.79</td>
<td>2.78</td>
</tr>
</tbody>
</table>

**Motor comparison**

<table>
<thead>
<tr>
<th></th>
<th>Graybar</th>
<th>Blueball</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost</td>
<td>$7,000</td>
<td>$6,000</td>
</tr>
<tr>
<td>Efficiency</td>
<td>89%</td>
<td>85%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>300/year</td>
<td>300/year</td>
</tr>
<tr>
<td>Electricity cost $0.072/kW-hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 hp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 year useful life, No salvage value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate =10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hours used to justify expense</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Motor comparison

- Graybar-Blueball > 0
- NPC of Graybar-Blueball = 1000 + (300-300) + (P/A, 10%, 20) * 0.746 kW/hp * 0.072 $/kWhr * HRS (1/0.89) - (P/A, 10%, 20) * 0.746 kW/hp * 0.072 $/kWhr * HRS (1/0.85)

\[ 1000 = 8.514 * 0.568 * HRS \]

\[ 206.7 \text{ hrs} \]

Key points to remember

- Present/Future worth
  - Use least common multiple
- Cash flow
  - Useful for infinite analysis periods
- Rate of return
  - Do not use rate of return, but incremental rate of return as criterion
- Cost benefits
  - Use incremental comparison similar to rate of return analysis
- Payback period
  - Approximate method that makes huge assumptions
- Breakeven analysis

Interest rates, depreciation, and inflation

- Concepts that allow more precise modeling of economic decisions
- Nominal vs effective
- Depreciation
  - Straight line
  - MACRS (Modified Accelerated Cost Recovery System)
  - Book value
- Inflation moderates value of rate of returns

Nominal and effective interest rates

Effective interest rate, \( i_p \), (period of compounding=period of interest) is used in formulas:

\[ i_p = (1 + i_s)^{\frac{1}{m}} - 1 \]

\[ i_p = (1 + r_p/m)^{\frac{m}{m}} - 1 \]

\( r_p \) = interest per subperiod
\( m \) = number of subperiods in period \( P \)

Nominal interest rate, \( r_p = m \times i_s \)

Continuous compounding:

\[ F = P(1 + i_p)^n = P e^{rn} \]

Depreciation

- Depreciation basis=
  - Initial cost (C) - Salvage value (S)
- Book value = C - Accumulated depreciation

- Straight line depreciation
  - \( D_i = (C-S)/n \)
  - \( n \) = service life
- MACRS
  - \( D_i = C \times \text{Factor from table} \)

Methods for depreciation

- Book value = cost - depreciation charges
- Straight line (SL)
  - Same amount each year
  - Proportional to years of useful life and (initial cost - salvage)
- Sum-of-years (SOYD)
  - Initial rate is faster than SL
  - Proportional to sum of digits in useful life and (initial cost - salvage)
Methods for depreciation

- Declining balance, double declining balance (DDB)
  - Double declining = 200% of straight line
  - Proportional to years of useful life and book value
  - Salvage value not considered
- Declining balance/conversion to straight line (DDB/SL)
  - Optimal switch year CANNOT be determined from a simple comparison of depreciation schedules
- Unit of production (UOP)
- Modified Accelerated Cost Recovery System (MARCS)

Depreciation calculations

<table>
<thead>
<tr>
<th>Method</th>
<th>Annual</th>
<th>Book value (year J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight line</td>
<td>( \frac{(P-S)}{N} )</td>
<td>( P \cdot \frac{(P-S)}{JN} )</td>
</tr>
<tr>
<td>SOYD</td>
<td>( (P-S)(N+J+1)/(N(N+1/2)) )</td>
<td>P-sum of dep.</td>
</tr>
<tr>
<td>DDB</td>
<td>( 2 \cdot \frac{\text{Book value}}{N} )</td>
<td>( 2PN(1-2/N)^{1/2} )</td>
</tr>
<tr>
<td>UOP</td>
<td>( (P-S) \cdot \text{Prod. in year}/\text{Total prod.} )</td>
<td>P-sum of dep.</td>
</tr>
<tr>
<td>MARCS</td>
<td>Table lookup (Property class, year)</td>
<td>P-sum of dep.</td>
</tr>
</tbody>
</table>

Depreciation of machine

- Initial cost of $50,000
- Salvage value of $10,000
- Service life of 10 years
- Straight line depreciation=
  - \( d_n = \frac{(P-S)}{N} \)
  - \( d_n = (50,000-10,000)/10 \)
  - \( d_n = 4,000/\text{year} \)

10.3 Capsulating machine

- Initial cost= $76,000
- Five year useful life
- No salvage value
- Find depreciation schedule
  - Straight line
  - Sum of years digits
  - Double declining balance
  - DDB with conversion

10.3 Straight line

<table>
<thead>
<tr>
<th>Year</th>
<th>Dep/year</th>
<th>Cumulative Dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>76,000/5=15,200</td>
<td>15,200</td>
</tr>
<tr>
<td>2</td>
<td>15,200</td>
<td>30,400</td>
</tr>
<tr>
<td>3</td>
<td>15,200</td>
<td>45,600</td>
</tr>
<tr>
<td>4</td>
<td>15,200</td>
<td>60,800</td>
</tr>
<tr>
<td>5</td>
<td>15,200</td>
<td>76,000</td>
</tr>
</tbody>
</table>

10.3 Sum of year digits

<table>
<thead>
<tr>
<th>Year</th>
<th>Dep/year</th>
<th>Cumulative Dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>76,000(5)/15 =25,333</td>
<td>25,333</td>
</tr>
<tr>
<td>2</td>
<td>20,267</td>
<td>45,600</td>
</tr>
<tr>
<td>3</td>
<td>15,200</td>
<td>60,800</td>
</tr>
<tr>
<td>4</td>
<td>10,133</td>
<td>70,933</td>
</tr>
<tr>
<td>5</td>
<td>5,067</td>
<td>76,000</td>
</tr>
</tbody>
</table>
### 10.3 Double declining balance

<table>
<thead>
<tr>
<th>Year</th>
<th>Dep/year</th>
<th>Cumulative Dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>76,000(2/5)=30,400</td>
<td>30,400</td>
</tr>
<tr>
<td>2</td>
<td>(76,000 - 30,400)(2/5)=18,240</td>
<td>48,640</td>
</tr>
<tr>
<td>3</td>
<td>10,944</td>
<td>59,584</td>
</tr>
<tr>
<td>4</td>
<td>6,566</td>
<td>66,150</td>
</tr>
<tr>
<td>5</td>
<td>3,940</td>
<td>70,090</td>
</tr>
</tbody>
</table>

**Summary of depreciation schedules**

<table>
<thead>
<tr>
<th>Year</th>
<th>SL</th>
<th>SOYD</th>
<th>DDB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15,200</td>
<td>25,333</td>
<td>30,400</td>
</tr>
<tr>
<td>2</td>
<td>15,200</td>
<td>20,267</td>
<td>18,240</td>
</tr>
<tr>
<td>3</td>
<td>15,200</td>
<td>15,200</td>
<td>10,944</td>
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<tr>
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<td>10,133</td>
<td>6,566</td>
</tr>
<tr>
<td>5</td>
<td>15,200</td>
<td>5,067</td>
<td>3,940</td>
</tr>
</tbody>
</table>

What is best year to switch from DDB to SL depreciation?

### Straight line depreciation if DDB has been used in previous years

- Book value in year three for DDB = \(76,000 - 30,400 - 18,240 = 27,360\)
- SL depreciation = Book value / remaining useful life

<table>
<thead>
<tr>
<th>Switch year</th>
<th>BV</th>
<th>SL dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>27,360</td>
<td>27,360/3= 9,120&lt;10,940 from DDB</td>
</tr>
<tr>
<td>4</td>
<td>16,416</td>
<td>8,208&gt; 6,566</td>
</tr>
<tr>
<td>5</td>
<td>9,850</td>
<td>9,850</td>
</tr>
</tbody>
</table>

### Inflation

- Interest rate adjusted for computing present worth and other values
- Increases the value of the MARR to account for loss in value of future dollars due to inflation
- Inflation adjusted interest rate = \(i + f + if\)
- \(f\) = rate of inflation

### 13.33 Value of a 10,000 investment

- Interest rate 10%
- General price inflation is projected to be:
  - 3% for next 5 years
  - 5% for five years after that
  - 8% for following five years
- Calculate future worth of investment:
  - in terms of actual dollars
  - in terms of real dollars at that time
  - real growth in purchasing power

**A)** Future value of actual $ = 10,000 \( (F/P,10\%,15) \) = $41,770

**B)** Future value in real $, constant value = $41,770 \( (P/F,8\%,5)(P/F,5\%,5)(P/F,3\%,5) \)

\( 0.6806 \times 0.7835 \times 0.8626 \)

\( = 19,213 \)

**C)** Real growth rate of investment = \(19,213 ÷ 10,000(1+i)^{15} \) = 4.45%
Alternate solution solving for real dollars

- Use real rather than market interest rate
- Real interest rates: \( i' = \frac{i - f}{1 + f} \)
  - First five years: 6.796%
  - Second five years: 4.762%
  - Third five years: 1.9608%
- Real dollar value in 15 years
  \[ 10,000 \times (1.06796)^5 \times (1.04762)^5 \times (1.019608)^5 \]
  \[ = 19,318 \]

13.30 Comparison of alternatives with inflation

- 3 year lives with no salvage value
- Inflation = 5%
- Income tax rate of 25%
- Straight line depreciation
- MARR = 7%
- Using rate of return analysis which is preferable?

13.30 Cash flow

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
</tr>
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<tbody>
<tr>
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Cash flow for option A

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<th>ATCF Y0$</th>
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Cash flow for option B

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Incremental ROR analysis A-B

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Guessing 7%

\[ NPW = -120 + 47(P/F, 7\%, 1) + 46.7(P/F, 7\%, 2) + 46.1(P/F, 7\%, 3) \]
\[ = 2.3, \text{therefor ROR} > 7\% \text{ choose more expensive alternative} \]