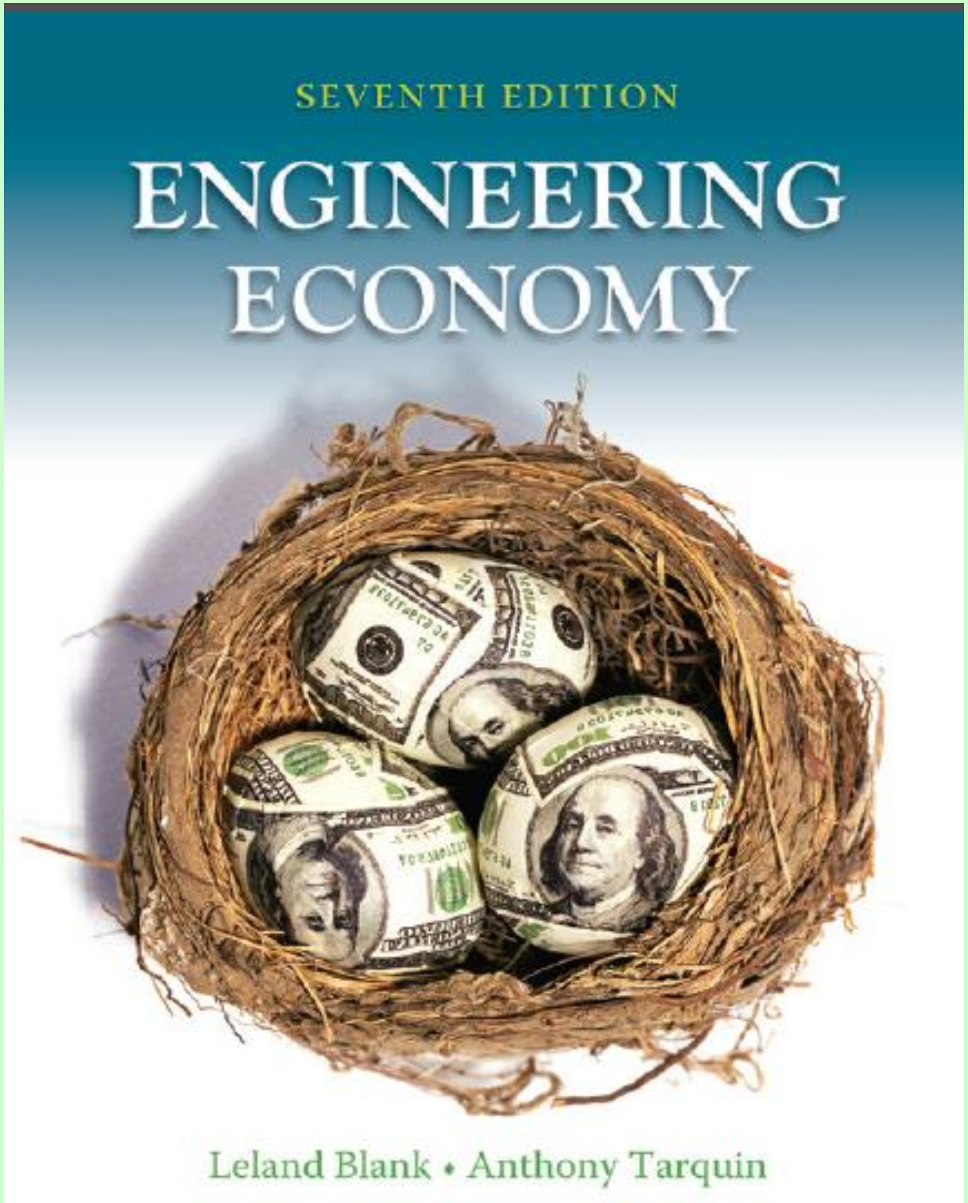

Chapter 13

Breakeven and Payback Analysis

Lecture slides to accompany

Engineering Economy

7th edition

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McGraw Hill Higher Education

LEARNING OUTCOMES

1. **Breakeven point – one parameter**
2. **Breakeven point – two alternatives**
3. **Payback period analysis**

Breakeven Point

Value of a parameter that makes two elements equal

The parameter (or variable) can be an **amount of** revenue, cost, supply, demand, *etc*. for **one project or between two alternatives**

Barber shop?

- **One project** - Breakeven point is identified as Q_{BE}. Determined using linear or non-linear math relations for revenue and cost
- **Between two alternatives** - Determine one of the parameters ***P***, ***A***, ***F***, ***i***, or ***n*** with others constant.

Solution is by one of three methods:

- **Direct solution of relations**
- **Trial and Error**
- **Spreadsheet functions or tools (Goal Seek or Solver)**

Cost-Revenue Model — One Project

Quantity, Q — An amount of the variable in question, *e.g.*, units/year, hours/month

Breakeven value is Q_{BE}

Fixed cost, FC — Costs not directly dependent on the variable

Variable cost, VC — Costs that change with parameters such as production level and workforce size. Variable cost per unit is v

Total cost, TC — Sum of fixed and variable costs, TC = FC + VC

Revenue, R — Amount is dependent on quantity sold

Revenue per unit is r

Profit, P — Amount of revenue remaining after costs

P = R – TC = R – (FC+VC)

Breakeven for linear R and TC

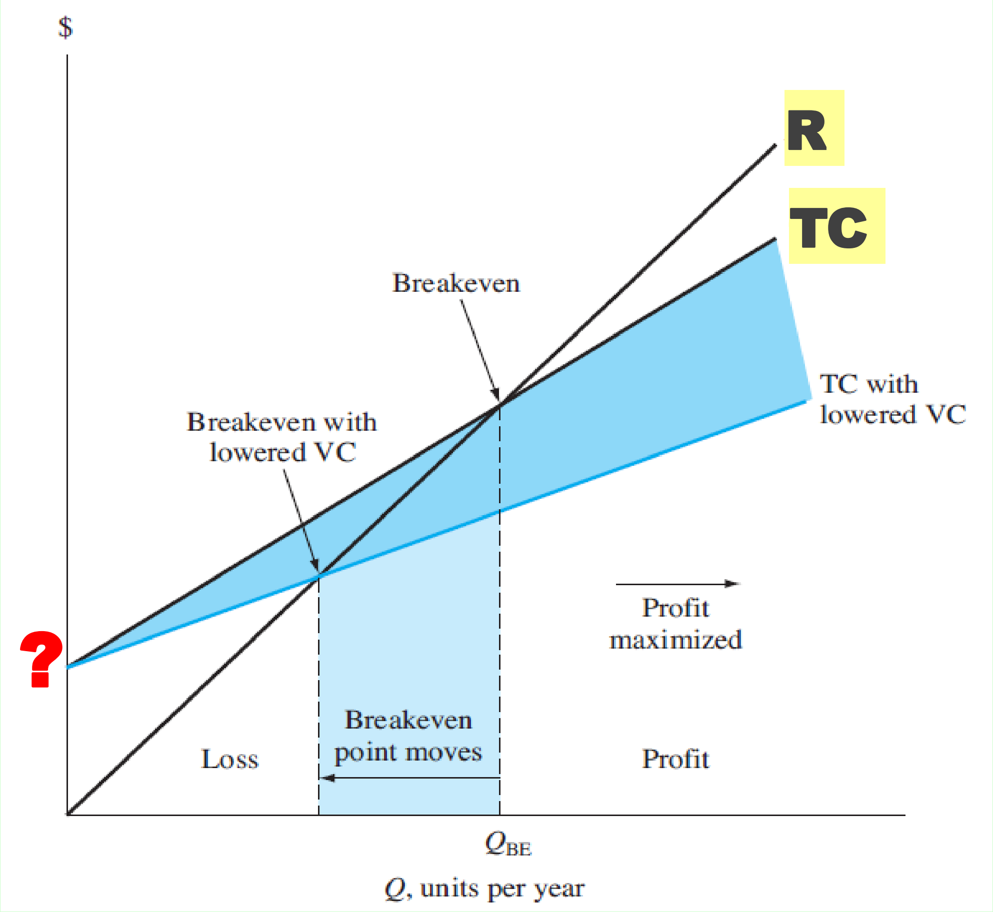
Set R = TC and solve for Q (Q_{BE})

$$R = TC$$

$$rQ = FC + vQ$$

$$Q_{BE} = \frac{FC}{r - v}$$

When variable cost, v, is lowered, Q_{BE} decreases (moves to left)



Example: One Project Breakeven Point

A plant produces 15,000 units/month. Find **breakeven** level if FC = $75,000/month, **revenue** is $8/unit and **variable cost** is $2.50/unit. Determine expected monthly **profit or loss.**

Solution: Find Q_{BE} and compare to 15,000 units; calculate **Profit**

$$Q_{BE} = 75{,}000/(8-2.5) = 13{,}636 \text{ units/month}$$

Production level (15,000) is **above** breakeven → **Profit**

$$\begin{aligned} \text{Profit} &= R - (FC + VC) \\ &= rQ - (FC + vQ) \\ &= (r - v)Q - FC \\ &= (8 - 2.5)(15{,}000) - 75{,}000 \\ &= \$7{,}500/\text{month} \end{aligned}$$

Breakeven Between Two Alternatives

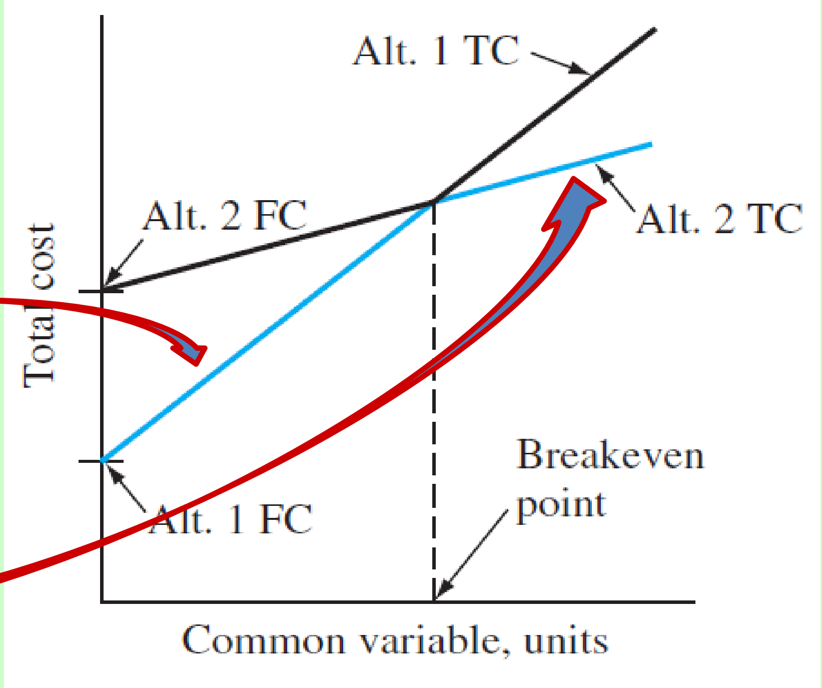
To determine value of common variable between 2 alternatives, do the following:

1. Define the common variable (usually *units of production*)
2. Develop equivalence **PW**, **AW** or **FW** relations as function of common variable for each alternative
3. Equate the relations; solve for variable. This is **breakeven value**

Selection of alternative is based on anticipated value of common variable:

✓ **Value BELOW breakeven;**
  select higher variable cost

✓ **Value ABOVE breakeven;**
  select lower variable cost



Example: Two Alternative Breakeven Analysis

Perform a **make/buy** analysis where the common variable is X, *the number of units produced each year*. AW relations:

$$AW_{make} = -18{,}000(A/P,15\%,6) + 2{,}000(A/F,15\%,6) - 0.4X$$

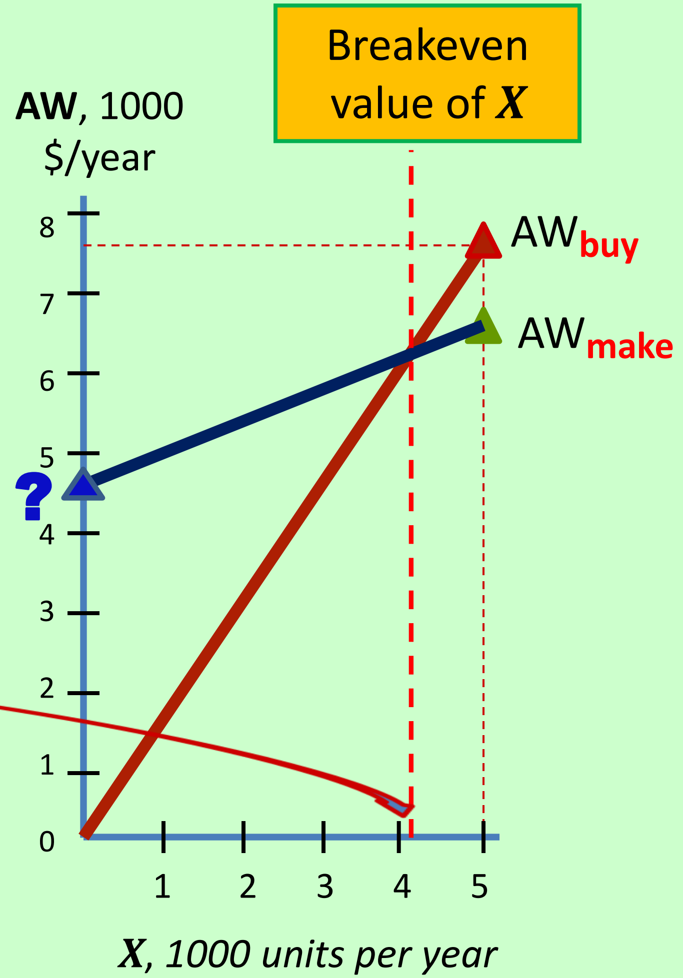
$$AW_{buy} = -1.5X$$

Solution: Equate AW relations, solve for X.

$$-1.5X = -4{,}528 - 0.4X$$

$$X = 4{,}116 \text{ per year}$$

If anticipated production > 4,116 units select make alternative (lower variable cost)



Example: Two Alternatives (Breakeven Analysis)

	Automatic	Manual
First cost, *$*	23,000	8,000
AOC, *$/year*	3,500	1,500
SV, *$*	4,000	-
Life, *years*	10	5
Output, *tons/hr*	8	6
Operator needed	1	3
Operator cost, *$/hr*	12	8

2 alternative machines are under evaluation. Both machines are expected to generate a return of 10% *p.a.*. How many *tons per year* must be finished in order to justify the higher purchase cost of the *Automatic* machine?

a typical breakeven question

SOLUTION:

$$AW_A = -23{,}000(A/P,10,10) - 3{,}500 + 4{,}000(A/F,10,10) - \textit{annual}\ VC_A$$

$$AW_M = -8{,}000(A/P,10,5) - 1{,}500 - \textit{annual}\ VC_M$$

where, $\textit{annual}\ VC_A \equiv 1.(12)\ (\$/hr).1/8\ (hr/ton).X\ (ton/year) \equiv 1.5X\ (\$/yr)$

$\textit{annual}\ VC_M \equiv 3.(8)\ (\$/hr).1/6\ (hr/ton).X\ (ton/year) \equiv 4X\ (\$/yr)$

set $AW_A \equiv AW_M$ *and solve for X* → $X_{BE} \equiv$ ***1,353 tons/yr***

comments?

Payback Period Analysis

Payback period: Estimated time (n_p) it will take for revenues to recover the initial investment (P) and a stated *return of return* ($i\%$)

Types of **payback** analysis: **No-return** and **Discounted payback**

1. **No-return payback** means rate of return is **zero** (i **= 0**%)
2. **Discounted payback considers** time value of money (i **> 0**%)

Caution: Payback period analysis is a good initial screening tool, rather than the primary method to justify a project or select an alternative (discussed later).

Payback Period Computation

Formula to determine payback period (n_p) varies with type of analysis.

NCF = Net Cash Flow per period *t*

No return, $i = 0\%$; NCF_t varies annually:	$0 = -P + \sum_{t=1}^{t=n_p} NCF_t$	Eqn. 1
No return, $i = 0\%$; annual uniform NCF:	$n_p = \frac{P}{NCF}$	Eqn. 2
Discounted, $i > 0\%$; NCF_t varies annually:	$0 = -P + \sum_{t=1}^{t=n_p} NCF_t(P/F,i,t)$	Eqn. 3
Discounted, $i > 0\%$; annual uniform NCF:	$0 = -P + NCF(P/A,i,n_p)$	Eqn. 4

Points to remember about Payback Analysis

- **Cash flows <u>after</u> the payback period are NOT considered** in **payback analysis**. Return may be higher if these cash flows are expected to be positive.
- **No-return payback <u>neglects</u> time value of money**, so **no return** is expected for the investment made.

- Approach of payback analysis is **different** from ***PW***, ***AW***, ***ROR*** and **B/C** analysis. <u>A different alternative may be selected</u> using payback. Therefore **Payback period** is only a **supplemental tool (initial screening)**; Use ***PW*** or ***AW*** or ***incremental ROR*** at the MARR for a reliable decision.

Example: Payback Analysis

	Machine1	Machine2
First cost, *$*	12,000	8,000
NCF, *$ per year*	3,000	1,000 (year 1-5)
		3,000 (year 6-14)
Max. **life**, *years*	7	14

Taking i at 15% *p.a.*, **evaluate**

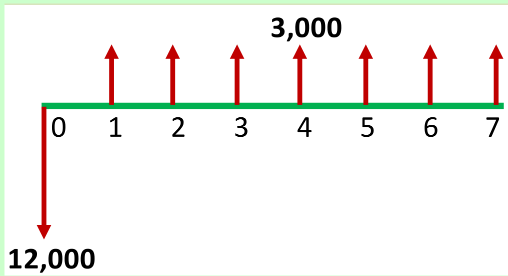
(a) Discounted payback at 15%, **and**

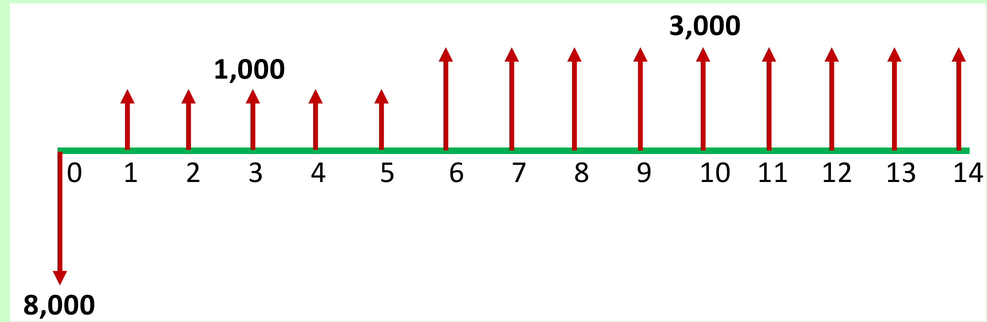
(b) *PW* analysis

Comment on the results.

Example: **Payback Analysis** (*continued*)

	Machine 1	Machine 2
First cost, *$*	12,000	8,000
NCF, *$ per year*	3,000	1,000 (year 1-5) 3,000 (year 6-14)
Maximum **life**, *years*	7	14





Solution:

(a) Using Equation 4:

Machine 1: $0 = -12{,}000 + 3{,}000(P/A, 15\%, n_{p1})$

$n_{p1} = 6.6$ years *(by interpolation)*

Machine 2: $0 = -8{,}000 + 1{,}000\overset{3.3522}{(P/A, 15\%, 5)} +$

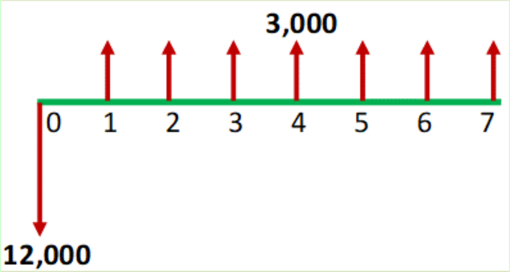
$3{,}000(P/A, 15\%, n_{p2} - 5)(P/F, 15\%, 5)$

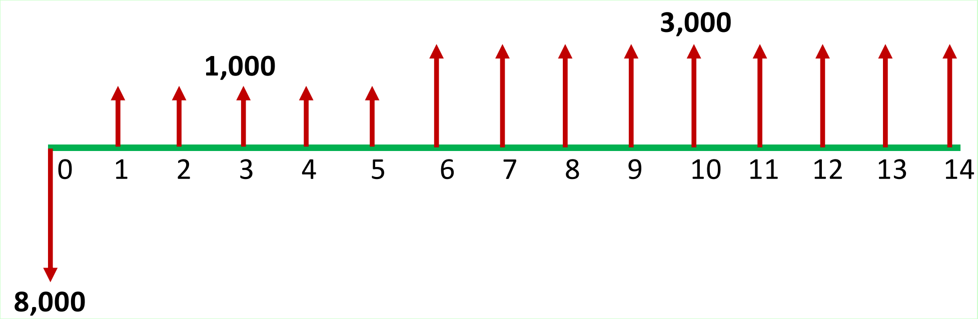
$n_{p2} = 9.5$ years *(by interpolation)*

Machine 1 has shorter payback period, should we select it?

Example: **Payback Analysis** (continued)

	Machine 1	Machine 2
First cost, *$*	12,000	8,000
NCF, *$ per year*	3,000	1,000 (year 1-5) 3,000 (year 6-14)
Maximum **life**, *years*	7	14





Solution:

(b) Find **PW** over LCM of 14 years

PW_1 = -12,000 - 12,000(P/F,15,7) + 3,000(P/A,15,14) = **$663**

PW_2 = -8,000 + 1,000(P/A,15,5) + 3,000(P/A,15,9)(P/F,15,5) = **$2,470**

Select Machine 2

Comment: ***PW*** **method considers all cash flows (after payback period too). Selecting Machine 2 is economically better.**

Summary of Important Points

- ***Breakeven*** **amount is a** ***point of indifference*** **to accept or reject a project**
- **One project breakeven:** ***accept if quantity is > Q_{BE}***
- **Two alternative breakeven: if** ***quantity > breakeven*****, select lower variable cost alternative** ***(smaller slope)***
- **Payback estimates time to recover investment. Return can be i = 0% or i > 0%**
- **Use** ***payback as supplemental*** **to PW or other analyses, because n_p neglects cash flows after payback, and if i = 0%, it neglects time value of money too**
- ***Payback*** **is useful to sense the** ***economic risk*** **in a project**