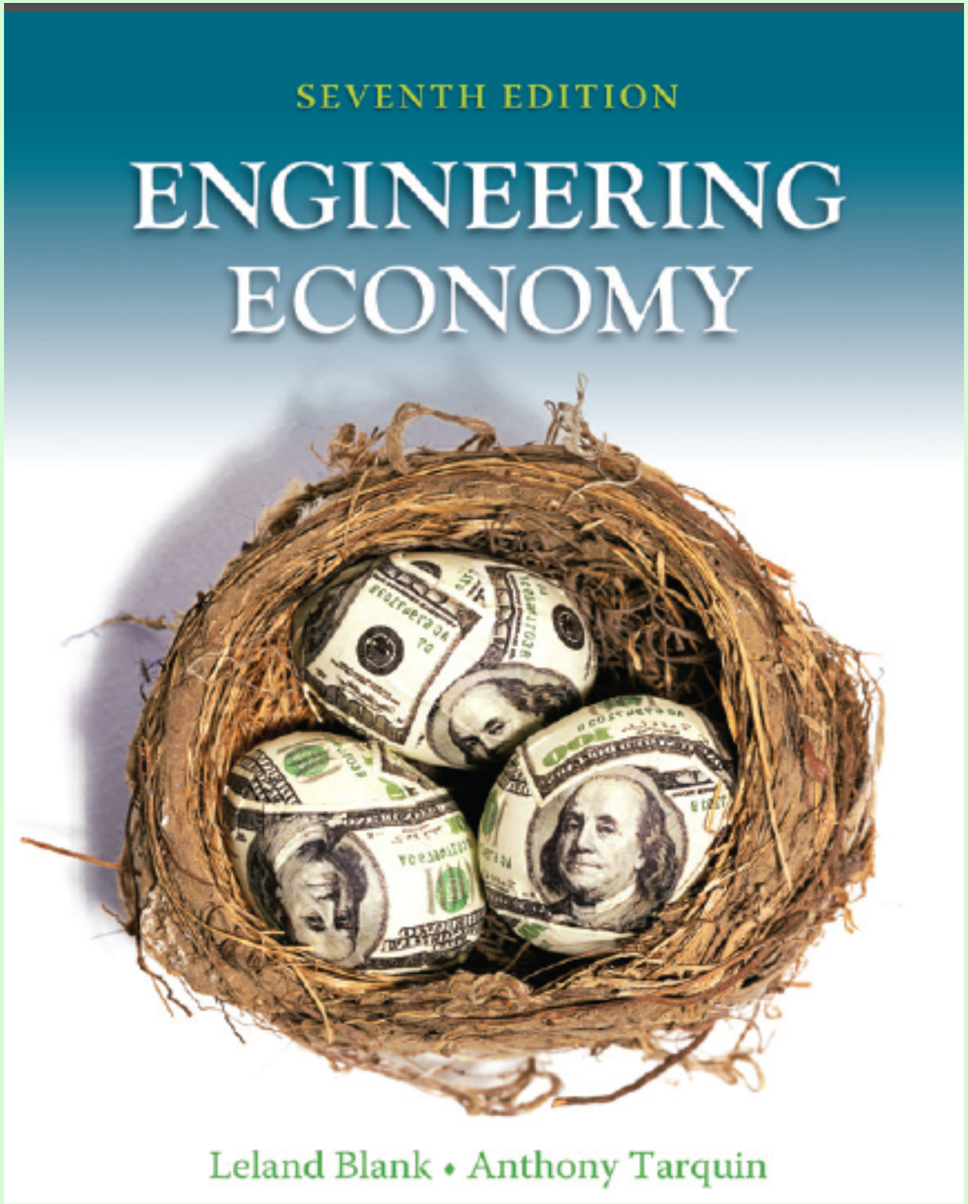

Chapter 8

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

- **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, e.g., buildings, fixed overhead, insurance, minimum workforce cost

Variable cost, VC — Costs that **change with parameters** such as production level and workforce size. These are labor, material and marketing costs. 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)

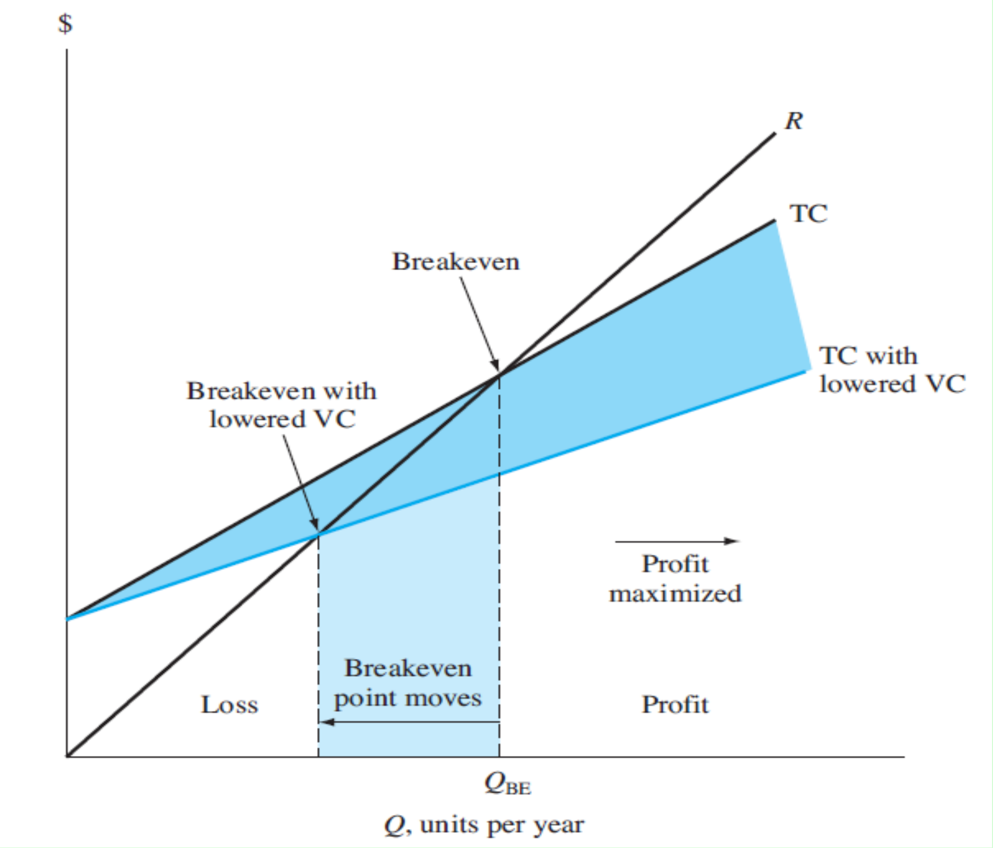
BREAKEVEN FOR LINEAR R AND TC

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 1: 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; calculate Profit

$$Q_{BE} = 75{,}000 / (8.00-2.50) = 13{,}636 \text{ units/month}$$

Production level is above breakeven → Profit

Profit = R – (FC + VC)

= rQ – (FC + vQ) = (r-v)Q – FC

= (8.00 – 2.50)(15,000) – 75,000

= $ 7500/month

EXAMPLE 2

Indira Industries is a major producer of diverter dampers used in the gas turbine power industry to divert gas exhausts from the turbine to a side stack, thus reducing the noise to acceptable levels for human environments. Normal production level is 60 diverter systems per month, but due to significantly improved economic conditions in Asia, production is at 72 per month. The following information is available.

Fixed costs

FC = $2.4 million per month

Variable cost per unit

***v* = $35,000**

- **Revenue per unit**

***r*= $75,000**

(*a*) What is the current profit level per month for the facility?

(*c*) What is the revenue per unit cost per damper that is necessary if the production level significantly reduced to 45 units. Note : the fixed costs is remaining constant.

BREAKEVEN BETWEEN TWO ALTERNATIVES

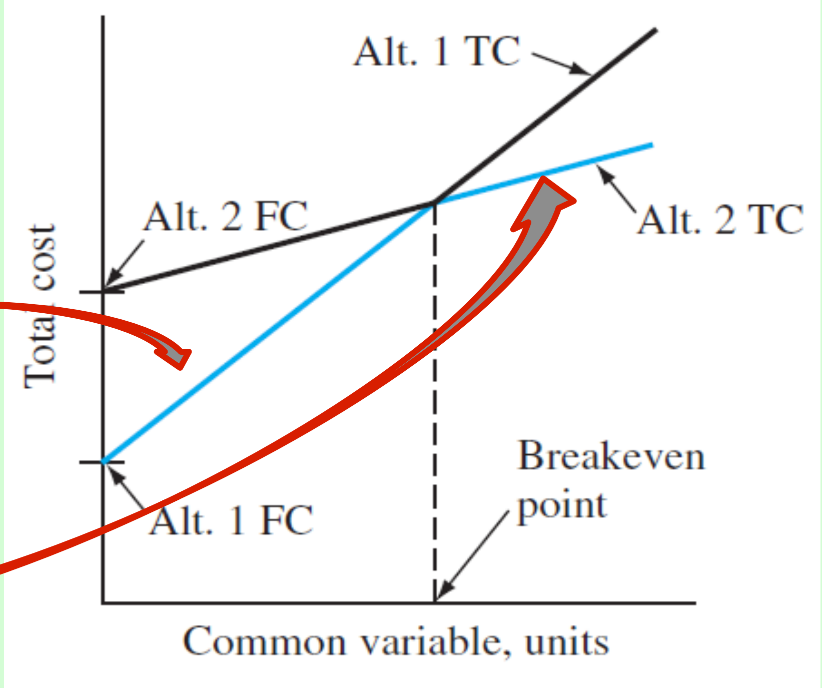
To determine value of common variable between 2 alternatives, do the following:

1. **Define the common variable**
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 are:

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

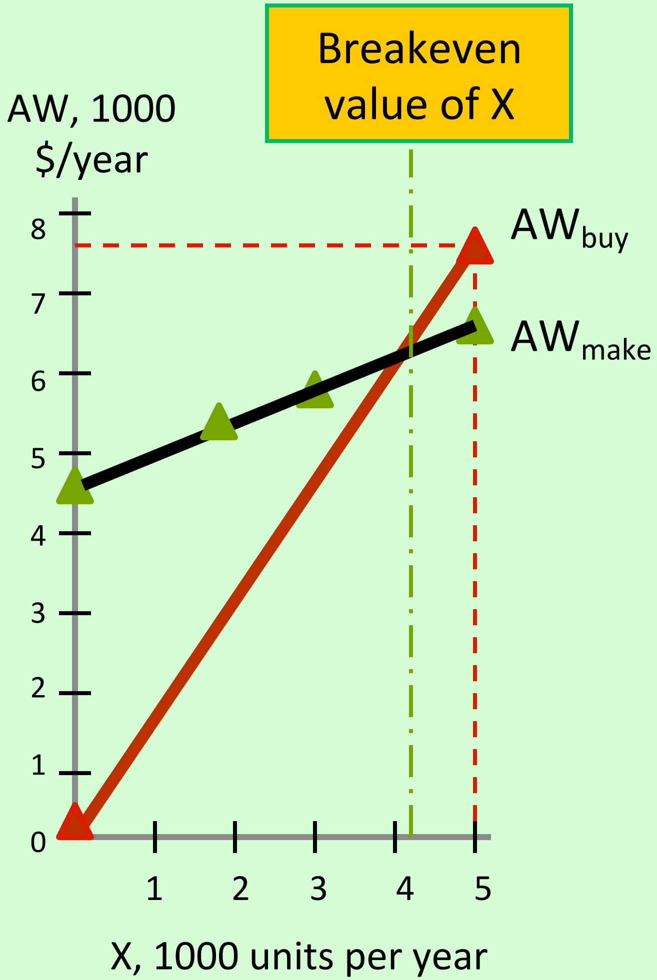
$$AW_{buy} = -1.5X$$

Solution: Equate AW relations, solve for X

$$-1.5X = -4528 - 0.4X$$

$$X = 4116 \text{ per year}$$

If anticipated production > 4116, select make alternative (lower variable cost)



EXAMPLE 3: MAKE OR BUY

Guardian is a national manufacturing company of home health care appliances. It is faced with a make-or-buy decision. A newly engineered lift can be installed in a car trunk to raise and lower a wheelchair. The steel arm of the lift can be purchased internationally for $3.50 per unit or made in-house. If manufactured on site, two machines will be required. Machine A is estimated to cost $18,000, have a life of 6 years, and have a $2000 salvage value; machine B will cost $12,000, have a life of 4 years, and have a $ 500 salvage value (carry-away cost). Ma- chine A will require an overhaul after 3 years costing $3000. The annual operating cost for machine A is expected to be $6000 per year and for machine B is $5000 per year. A total of four operators will be required for the two machines at a rate of $12.50 per hour per operator. In a normal 8-hour period, the operators and two machines can produce parts sufficient to manufacture 1000 units. Use a MARR of 15% per year to determine the following.

(*a*) Number of units to manufacture each year to justify the in-house (make) option.

(*b*) The maximum capital expense justifiable to purchase machine A, assuming all other estimates for machines A and B are as stated. The company expects to produce 10,000 units per year.

a) Use steps 1 to 3 stated previously to determine the breakeven point.

1.Define x as the number of lifts produced per year.

2. There are variable costs for the operators and fixed costs for the two machines for the make option.

Annual VC=cost per unit x unit per year

$$= \frac{4 \text{ operators}}{1000 \text{ units}} \times \frac{\$12.50}{\text{hour}} (8 \text{ hours})x$$

$$= 0.4x$$

The annual fixed costs for machines A and B are the AW amounts.

$$AW_A = 18{,}000(A/P,15\%,6) + 2000(A/F,15\%,6) - 6000 - 3000(P/F,15\%,3)(A/P,15\%,6)$$
$$AW_B = -12{,}000(A/P,15\%,4) - 500(A/F,15\%,4) - 5000$$

Total cost is the sum of AW_A, AW_B, and VC.

3. Equating the annual costs of the buy option ($3.50x$) and the make option yields

$$-3.50x = AW_A + AW_B - VC$$
$$= 18{,}000(A/P,15\%,6) + 2000(A/F,15\%,6) - 6000 - 3000(P/F,15\%,3)(A/P,15\%,6) - 12{,}000(A/P,15\%,4) - 500(A/F,15\%,4) - 5000 - 0.4x$$

$$-3.10x = -20{,}352$$

$$x = 6565 \text{ units per year}$$

b) Substitute 10,000 for x and P_A for the to-be-determined first cost of machine A (currently \$18,000) in Equation [13.5]. Solution yields P_A \$58,295. This is approximately three times the estimated first cost of \$18,000, because the production of 10,000 per year is considerably larger than the breakeven amount of 6565.

BREAKEVEN ANALYSIS USING GOAL SEEK TOOL

Spreadsheet tool Goal Seek finds breakeven value for the common variable between two alternatives

Problem: Two machines (1 and 2) have following estimates.
a) Use spreadsheet and AW analysis to select one at MARR = 10%.
b) Use Goal Seek to find the breakeven first cost.

Machine	1	2
P, $	-80,000	-110,000
NCF, $/year	25,000	22,000
S, $	2,000	3,000
n, years	4	6

	A	B	C	D
1	MARR =	10%		
2		Net cash flows, $/year		
3	Year	Machine 1	Machine 2	
4	0	-80,000	-110,000	
5	1	25,000	22,000	
6	2	25,000	22,000	
7	3	25,000	22,000	
8	4	27,000	22,000	
9	5		22,000	
10	6		25,000	
11	AW @ MARR	193	-2,868	
12				
13				
14				

= -PMT(B1,4,NPV($B1,B5:B8)+B4)

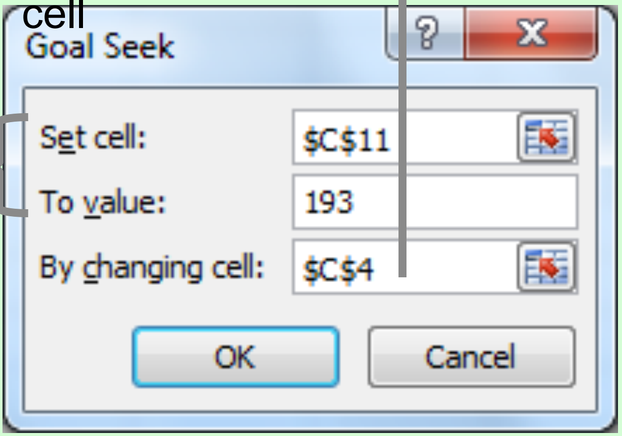
Solution: a) Select machine A with AW_A = $193

BREAKEVEN ANALYSIS USING GOAL SEEK TOOL

Solution: b) Goal Seek finds a first-cost breakeven of $96,669 to make machine B economically equivalent to A

	A	B	C
1	MARR =	10%	
2		Net cash flows, $/year	
3	Year	Machine 1	Machine 2
4	0	-80,000	-96,669
5	1	25,000	22,000
6	2	25,000	22,000
7	3	25,000	22,000
8	4	27,000	22,000
9	5		22,000
10	6		25,000
11	AW @ MARR	193	193

Changing cell



Spreadsheet after Goal Seek is applied

Target cell

PAYBACK PERIOD ANALYSIS

Payback period: **Estimated amount of time (n_p) for cash inflows to recover an initial investment (P) plus 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

- No-return payback neglects time value of money, so no return is expected for the investment made
- No cash flows after the payback period are considered in the analysis. Return may be higher if these cash flows are expected to be positive.

- Approach of payback analysis is different from PW, AW, ROR and B/C analysis. A different alternative may be selected using payback.
- Rely on payback as a supplemental tool; use PW or AW at the MARR for a reliable decision
- Discounted payback (i > 0%) gives a good sense of the risk involved

EXAMPLE: PAYBACK ANALYSIS

	System 1	System 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

Problem: Use (a) no-return payback, (b) discounted payback at 15%, and (c) PW analysis at 15% to select a system. Comment on the results.

Solution: (a) Use Eqns. 1 and 2

n_{p1} = 12,000 / 3,000 = **4 years**

n_{p2} = -8,000 + 5(1,000) + 1(3,000) = **6 years**

EXAMPLE: PAYBACK ANALYSIS (CONTINUED)

	System 1	System 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) Use Eqns. 3 and 4

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

$n_{p1} =$ **6.6 years**

System 2: $0 = -8{,}000 + 1{,}000(P/A,15\%,5) + 3{,}000(P/A,15\%,n_{p2} - 5)(P/F,15\%,5)$

$n_{p1} =$ 9.5 years

Select system 1

(c) Find PW over LCM of 14 years

$PW_1 = \$663$

$PW_2 = \$2470$

Select system 2

Comment: PW method considers cash flows after payback period. Selection changes from system 1 to 2

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** ***level > 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**
- ***Payback*** **is useful to sense the** ***economic risk*** **in a project**