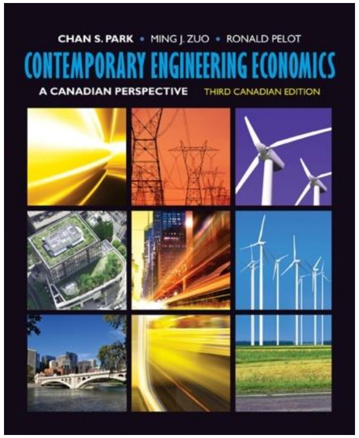
Make-or-Buy Decision, Life-Cycle Cost Analysis, and Design Economics



Lecture No.19
Chapter 6
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Lecture 19 Objectives

- How do firms decide whether to make a part in-house or to buy it?
- How do firms conduct a life-cycle cost analysis?
- How do firms optimize parameters in engineering design?

Make-or-Buy Decision

Analysis period

- Step 1: Determine the time span (planning horizon) for which part (or product) will be needed.
- Step 2: Determine the annual quantity of the part (or product).

"Units" is necessary info

- Step 3: Obtain the unit cost of purchasing the part (or product) from the outside firm.

Buying option

- Step 4: Determine the equipment, labour, and all other resources required to make the part (or product).

Making option

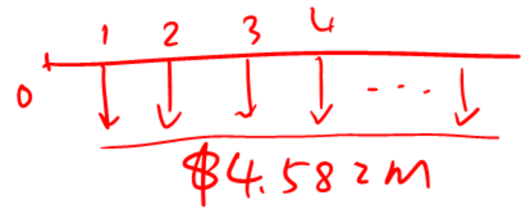
- Step 5: Estimate the net cash flows associated with the "make" option over the planning horizon.
- Step 6: Compute the annual equivalent cost of producing the part (or product).
- Step 7: Compute the unit cost of making the part (or product) by dividing the annual equivalent cost by the required annual volume.
- Step 8: Choose the option with the minimum unit cost.

Example 6.12: Equivalent Worth: Outsourcing the Manufacture of Hard Drive Cases

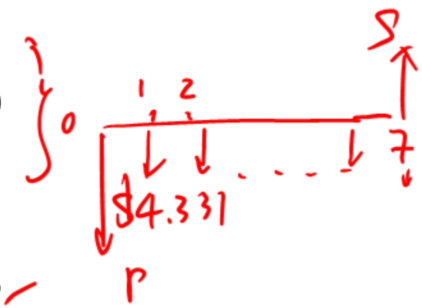
Seagate Ltd. currently produces both the electronic storage media for hard drives and the cases for commercial use. An increased demand for hard drives is projected, and Seagate is deciding between increasing the internal production of hard drive cases or purchasing empty cases from an outside vendor. If Seagate purchases the cases from a vendor, the company must also buy specialized equipment to insert the electronic media, since its current loading machine is not compatible with the cases produced by the vendor under consideration. The projected production rate of hard drives is 79,815 units per week for 48 weeks of operation per year. The planning horizon is seven years.

Example 6.12: Equivalent Worth: Outsourcing the Manufacture of Hard Drive Cases

- Make Option (annual costs):
  - Labour $1,445,633
  - Materials $2,048,511
  - Incremental overhead $1,088,110
  - Total annual cost $4,582,254

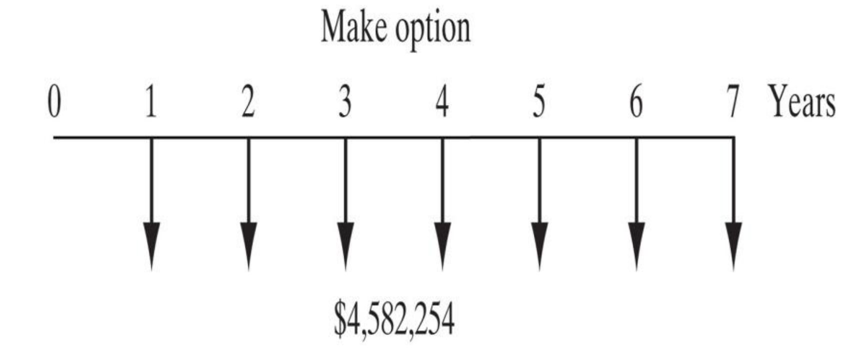


- Buy Option:
  - Capital expenditure:
    - Acquisition of a new loading machine P = $ 405,000
    - Salvage value at end of 7 years S = $ 45,000
  - Annual Operating Costs:
    - Labour $ 251,956
    - Purchasing empty cassette ($0.85/unit) $3,256,452
    - Incremental overhead $ 822,719
  - Total annual operating costs $4,331,127

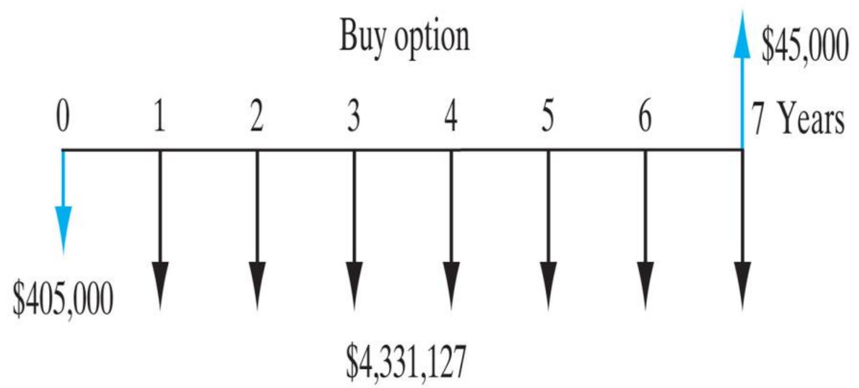


Example 6.12: Solution

- **Make Option**:
  - AEC(14%) = $4,582,254
  - Unit cost:
    $4,582,254/3,831,120
    = $1.20



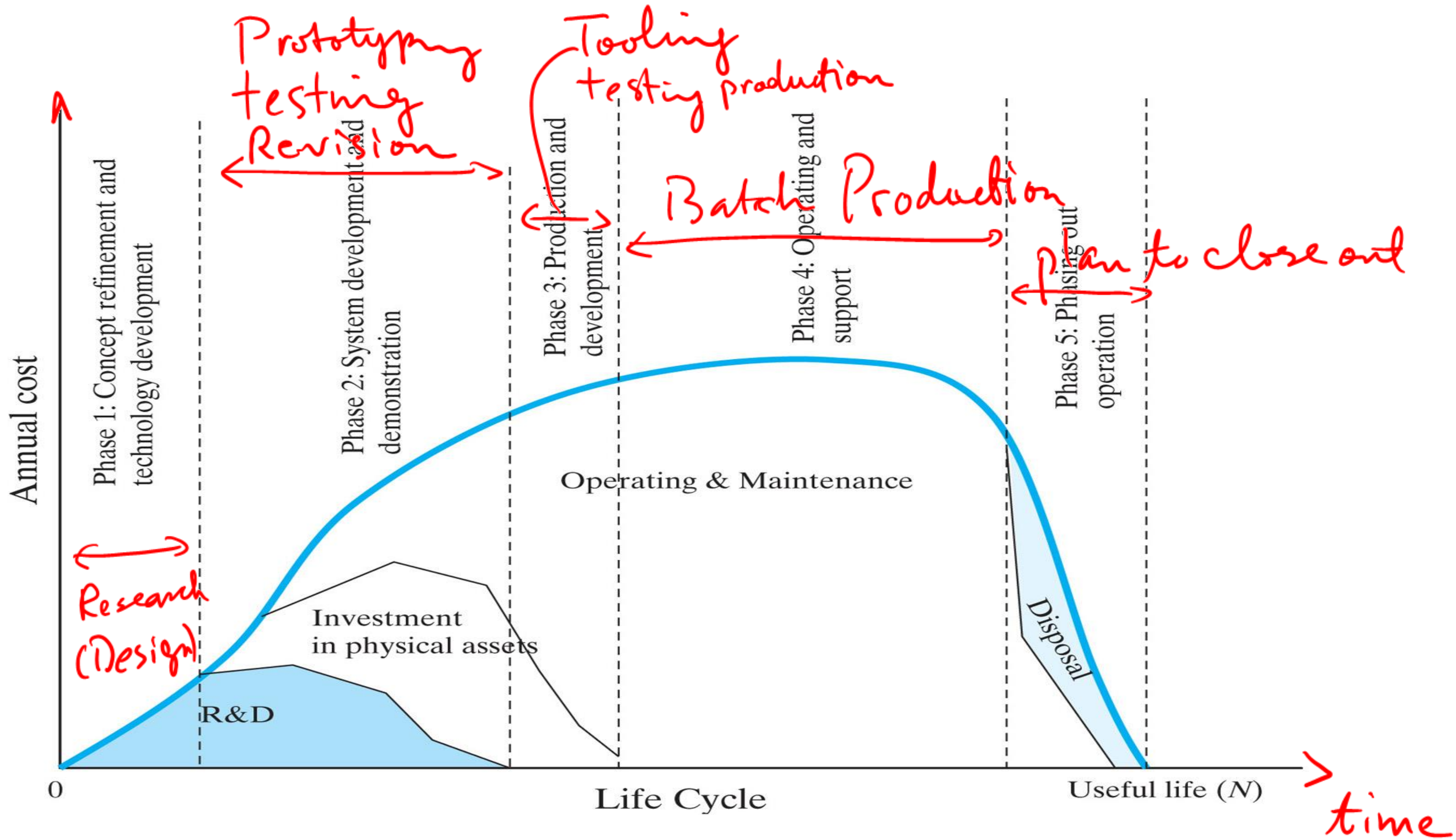
- **Buy Option**:
  - AEC(14%) = $4,421,376
  - Unit cost:
    $4,421,376/3,831,120
    = $1.15



Life-Cycle Cost Analysis

- Life-Cycle Cost Analysis (LCCA) is a way to predict the most cost-effective solution by allowing engineers to make a reasonable comparison among alternatives within the limit of the available data. — Dig into the raw data → derivation of cashflows (costs) is necessary.
- Makes sure the analyst examines both initial costs and operating costs over the project's useful life. P A.E.C
- Used to predict the most cost-effective solution.

Stages of Life-Cycle Cost



Example 6.13:

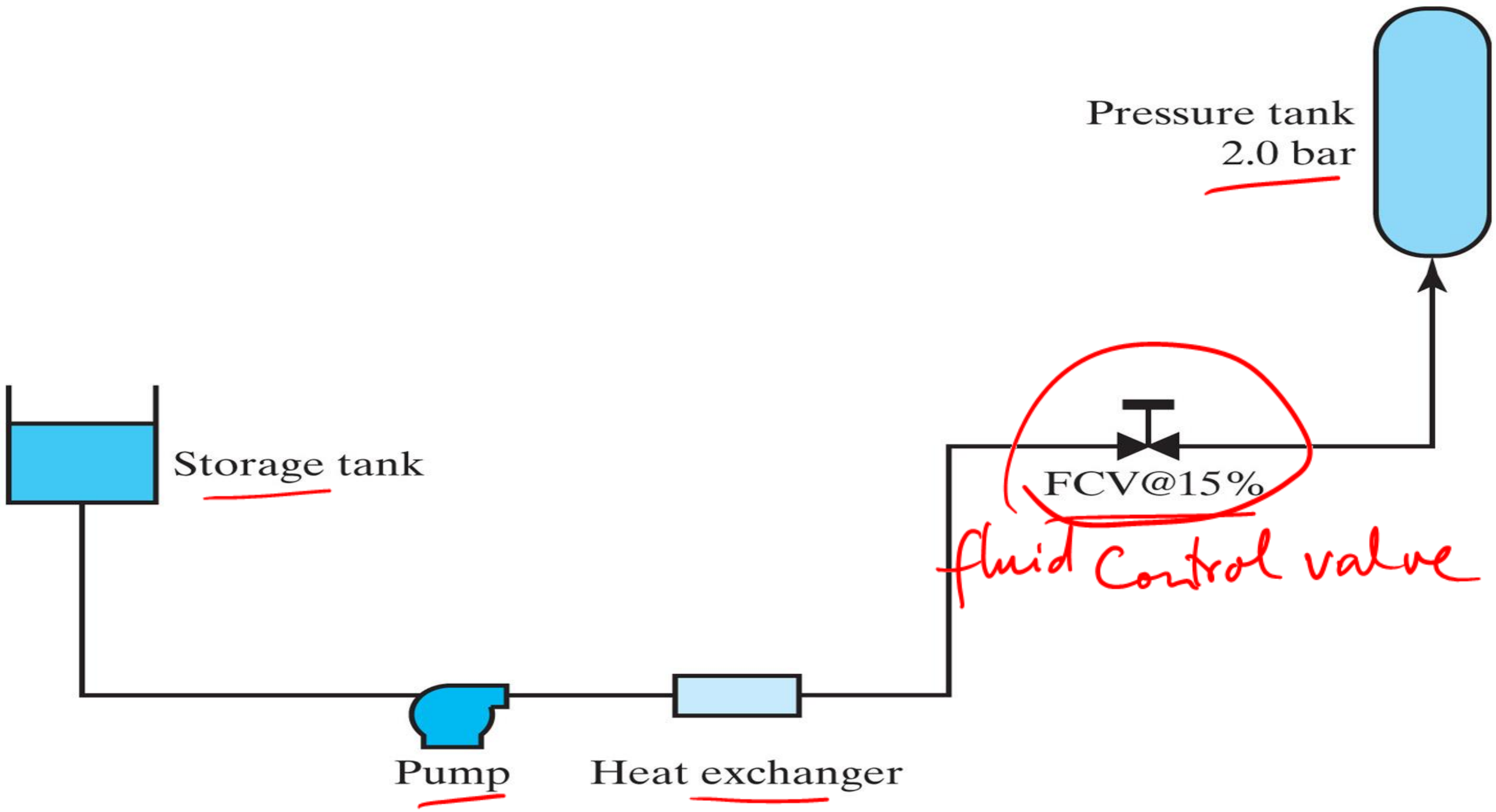
oilsands production

Consider a single-pump circuit that transports a process fluid containing some solids from a storage tank to a pressurized tank. A heat exchanger heats the fluid, and a control valve regulates the rate of flow into the pressurized tank to 80 cubic metres per hour . The process is depicted in Figure 6.14. The plant engineer is experiencing problems with a fluid control valve (FCV) that fails due to erosion caused by cavitations. The valve fails every 10 to 12 months at a cost of $4000 per repair. A change in the control valve is being considered: Replace the existing valve with one that can resist cavitations. Before the control valve is repaired again, the project engineer wants to look at other options and perform an LCCA on alternative solutions.

$80\ m^3/hr$

A small section of oilsands operation

Example 6.13: Pumping System With a Problem Valve



Example 6.13: Pumping System With a Problem Valve (continued)

- **Engineering Solution Alternatives**
  - **Option A**: A new control valve can be installed to accommodate the high-pressure differential.
  - **Option B**: The pump impeller can be trimmed so that the pump does not develop as much head, resulting in a lower pressure drop across the current valve.
  - **Option C**: A variable frequency drive (VFD) can be installed, and the flow control valve removed. The VFD can vary the pump speed and thus achieve the desired process flow.
  - **Option D: The system can be left as it is, with a yearly repair of the flow control valve to be expected.**

Example 6.13: Pumping System With a Problem Valve (continued)

P

Life-Cycle Cost Elements

$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$

LCC = life cycle cost

C_{ic} = initial costs, purchase price (pump, system, pipe, auxiliary services)

C_{in} = installation and commissioning cost (including training)

o p. C_e = energy costs (predicted cost for system operation, including pump driver, controls, and any auxiliary services)

C_o = operation costs (labor cost of normal system supervision)

C_m = maintenance and repair costs (routine and predicted repairs)

C_s = down time costs (loss of production) ← This needs more details

C_{env} = environmental costs (contamination from pumped liquid and auxiliary equipment)

C_d = decommissioning/disposal costs (including restoration of the local environment and disposal of auxiliary services).

Example 6.13: Pumping System With a Problem Valve (continued)

Cost Comparison for Options A Through D

Operation

Cost	Change Control Valve (A)	Trim Impeller (B)	VFD (C)	Repair Control Valve (D)
Pump Cost Data				
Impeller diameter	430 mm	375 mm	430 mm	430 mm
Pump head	71.7 m (235 ft)	42.0 m (138 ft)	34.5 m (113 ft) just as needed!	71.7 m (235 ft)
Pump efficiency	75.1%	72.1%	77%	75.1%
Rate of flow	80 m^3/h (350 gpm)	80 m^3/h (350 gpm)	80 m^3/h (350 gpm)	80 m^3/h (350 gpm)
Power consumed	23.1 kW	14.0 kW	11.6 kW	23.1 kW
Energy cost/year	$11,088	$6,720	$ 5,568	$11,088
New valve	$ 5,000	0	0	0
Modify impeller	0	$2,250	0	0
VFD	0	0	$20,000	0
Installation of VFD	0	0	$ 1,500	
Valve repair/year	0	0	0	$ 4,000

6000 hrs per year

Price of Electricity

/yr

Sample LCC Calculation for Option A

	A	B	C	D	E	F	G	H	I	J
1	**Calculation Chart for LCC: Option A**									
2										
3	Year No	0	1	2	3	4	5	6	7	8
4	Initial investment cost:	$5,000								
5	Installation and commissioning cost:	$0								
6										
7	Energy cost/year (calculated)		$11,532	$11,993	$12,472	$12,971	$13,490	$14,030	$14,591	$15,175
8	Routine maintenance		$520	$541	$562	$585	$608	$633	$658	$684
9	Repair cost every 2nd year			$2,704		$2,925		$3,163		$3,421
10	Operating costs		$0	$0	$0	$0	$0	$0	$0	$0
11	Other costs		$0	$0	$0	$0	$0	$0	$0	$0
12										
13	Downtime costs		$0	$0	$0	$0	$0	$0	$0	$0
14										
15	Decommissioning costs									$0
16	Environmental & disposal costs									$0
17										
18	**Sum costs**	$5,000	$12,052	$15,238	$13,035	$16,481	$14,099	$17,826	$15,249	$19,280
19										
20	**Present costs**	$5,000	$11,159	$13,064	$10,348	$12,114	$9,595	$11,233	$8,898	$10,417
21	Present costs, energy		$10,677	$10,282	$9,901	$9,534	$9,181	$8,841	$8,514	$8,198
22	Present costs, routine maintenance		$481	$464	$446	$430	$414	$399	$384	$370
23										
24	**Sum of present costs**	$\boxed{\$91{,}827}$								
25	Sum of energy costs	$75,129								
26	Sum of routine maintenance costs	$3,388								
27										
28	**Annual equivalent cost (8%)**	$\boxed{\$15{,}979}$								
29	Cost per operating hour	$2.66								

4% inflation rate has been considered

1.04 1.04 1.04

$(1.04)^2$ $(1.04)^2$ $(1.04)^2$

8 yrs

Will be given in assignment or exam

MARR => 8%

Discounting rate (interest rate) is based on MARR

Cost Cash flows

PV

AEC

(A/P, i, N)

$$\left(\frac{12{,}052}{1.08}\right) \quad \left(\frac{15{,}238}{1.08^2}\right) \quad \left(\frac{13{,}035}{1.08^3}\right)$$

Comparison of LCC for Options A-D

Calculate off line

	Option A Change Control Valve	Option B Trim Impeller	Option C VFD and Remove Control Valve	Option D Repair Control Valve
Input	P_A	P_B	P_C	
Initial investment cost:	$5,000	$2,250	$21,500	0
Energy price (present) per kWh:	0.080	0.080	0.080	0.080
Weighted average power of equipment in kW:	23.1	14.0	11.6	23.1
Average operating hours/year:	6,000	6,000	6,000	6,000
Energy cost/year (calculated) + energy price × weighted average power × average operating hours/year:	11,088	6,720	5,568	11,088
Maintenance cost (routine maintenance/year):	500	500	1,000	500
Repair every second year:	2,500	2,500	2,500	2,500
Other yearly costs:	0	0	0	4,000
Downtime cost/year:	0	0	0	0
Environmental cost:	0	0	0	0
Decommissioning/disposal (salvage) cost:	0	0	0	0
Lifetime in years:	8	8	8	8
Interest rate (%):	8.0%	8.0%	8.0%	8.0%
Inflation rate (%):	4.0%	4.0%	4.0%	4.0%
Output				
Present LCC value:	$91,827	$59,481	$74,313	$113,930
Cost per operating hour	**$2.66**	**$1.73**	**$2.16**	**$3.30**

Different

FCV repair

AEC throughout LC.

Selected

No action

Design Economics

- Concept: Annual equivalent analysis is used to determine optimal engineering designs.
- Goal: Find the optimal design parameter that minimizes annual equivalent costs.

Example 6.14: Optimal Cross-Sectional Area

A constant electric current of 5000 amps is to be transmitted a distance of 300 metres from a power plant to a substation for 24 hours a day, 365 days a year. A copper conductor can be installed for $16.50 per kilogram. The conductor will have an estimated life of 25 years and a salvage value of $1.65 per kilogram. The power loss from a conductor is inversely proportional to the cross-sectional area *A* of the conductor. What is the optimal diameter of this copper conductor?

Example 6.14: Optimal Cross-Sectional Area

- Necessary Service Requirements
  7
  - Conduct 5,000 amps over a distance of 300 metres for 24 hours a day, 365 days a year.
- Copper price: \$16.50/kg
- Resistance: 1.7241×10^{-8} Ω per metre -4 Constant for Copper
- Cost of energy: \$0.0375/kwh City rate for bulk use
- Density of copper: 8,894 kg/m^3
- Useful life: 25 years
- Salvage value: \$1.65/kg S = 10% of the P
- Interest rate: 9%
  MARR

A: a variable to be determined

Example 6.14: Optimal Cross-Sectional Area (continued)

<u>Step 1</u>: Energy loss in kilowatt-hour

$$\text{Energy loss} = \frac{I^2RT}{1000A} = \frac{I^2T}{1000} \times \frac{\rho L}{A}$$

R

$$= \frac{5000^2 \times 24 \times 365}{1000} \times \frac{1.7241 \times 10^{-4} \times 300}{A}$$

$$= \boxed{\frac{11{,}327{,}337}{A} kWh}$$

I = current flow in amperes
R = resistance in ohms
T = number of operating hours
A = cross-sectional area
ρ = resistivity of material
L = length of conductor

Example 6.14: Optimal Cross-Sectional Area

Step 2: Total cost of energy loss in dollars per year

Price

$$\text{Annual energy loss cost} = \frac{11{,}327{,}337}{A}(\phi)$$

$$= \frac{11{,}327{,}337}{A}(\$0.0375)$$

$$= \frac{\$424{,}775}{A}$$

where ϕ = cost of energy in dollars per kWh.

Example 6.14: Optimal Cross-Sectional Area (continued)

<u>Step 3</u>: Calculate total cost of conductor material

Material mass in kilograms

$$\frac{300(8894)A}{100^3} = \boxed{267A}$$

Material cost (required investment)

$$\text{Total material cost} = 267A(\$16.50)$$

$$= \$4406A$$

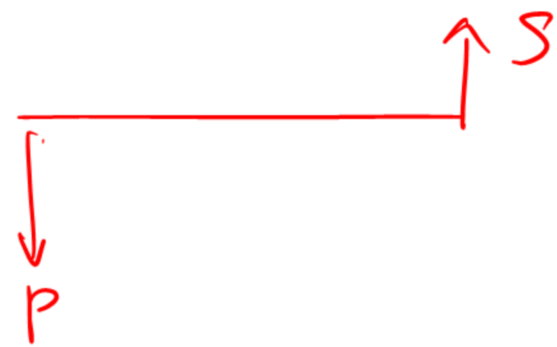
Example 6.14: Optimal Cross-Sectional Area (continued)

Step 4: Compute the capital recovery cost

$CR(i) = (P - S)(A/P, i, N) + S \cdot i$

$i = 9\%, \ N = 25$

$$CR(9\%) = \left[\$4406A - \$1.65(267A)\right](A/P, 9\%, 25)$$
$$+\$1.65(267A)(0.09)$$
$$= \$404A + \$40A$$
$$= \$444A$$



Example 6.14: Optimal Cross-Sectional Area (continued)

Step 5: Express the total annual equivalent cost (*AEC*) as a function of a design variable (*A*):

$$AEC(9\%) = \overbrace{\underbrace{\$444A}_{\text{cable material}}}^{\text{Capital cost}} + \underbrace{\frac{424{,}775}{A}}_{\text{Operating cost}} \Bigg\} \text{ Energy Cost}$$

Example 6.14: Optimal Cross-Sectional Area (continued)

Step 5 Continued: Find the minimum annual equivalent cost using the following formula

peak optimization

$$\frac{d\,AEC(9\%)}{dA} = 444 - \frac{424{,}755}{A^2} = 0$$

$$\frac{d\,f(x)}{dx} = 0$$

the x is the optimum input parameter.

$$A^* = \sqrt{\frac{424{,}755}{444}}$$

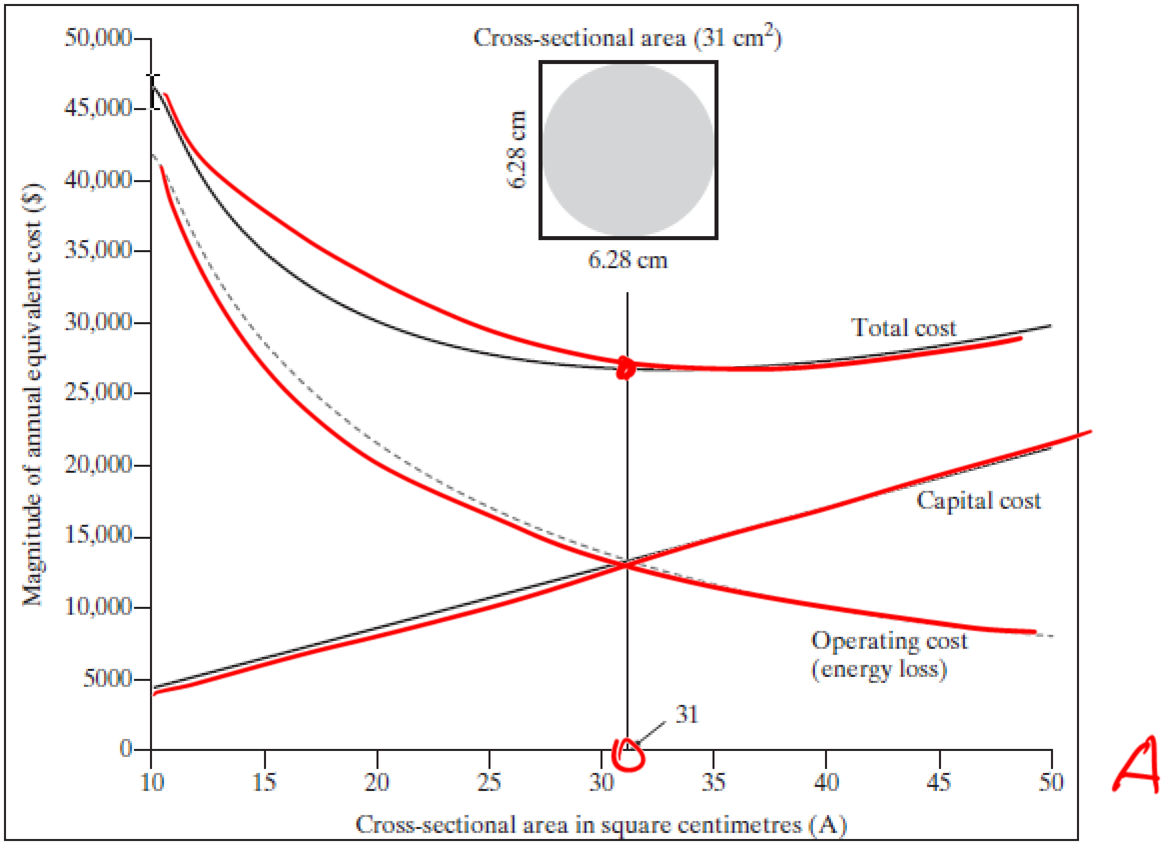
$$= 31 \text{ cm}^2$$

$$AEC(9\%) = 444(31) + \frac{424{,}755}{31}$$

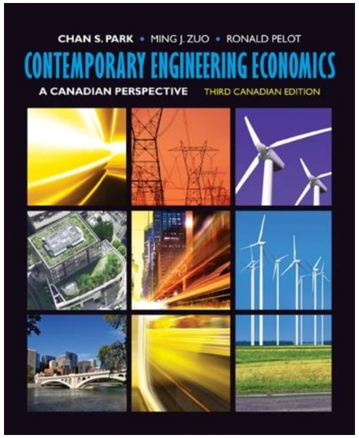
$$= \$27{,}466$$

Example 6.14: Optimal Cross-Sectional Area (continued)

Optimal Cross-Sectional Area



Summary



Life-cycle cost analysis is a way to predict the most cost-effective solution by allowing engineers to make a reasonable comparison among alternatives within the limit of the available data. Design economics can be used to determine a design parameter that minimizes annual equivalent costs.