Engineering Economic Analysis

FOURTEENTH EDITION

Chapter 2

Estimating Engineering Costs & Benefits

Donald G. Newnan
San Jose State University

Ted G. Eschenbach
University of Alaska Anchorage

Jerome P. Lavelle
North Carolina State University

Neal A. Lewis
Fairfield University

OXFORD
UNIVERSITY PRESS

Chapter Outline

- Fixed, variable, marginal, & average costs
- Considering all costs
- Estimating benefits
- The estimating process
- Estimating models
- Cash flow diagrams

Learning Objectives

- Understand cost & benefit concepts
- Understand cost estimation models
- Estimate engineering costs
- Understand relationship between *cost* & *benefit* estimating
- Draw cash flow diagrams

Vignette: Automated Metering Information System

- Tullahoma Utilities Board (TUB) installed a $3.1 M automated metering system
- Usage information is relayed using LightTUBe, a fiber optics network
- After system justified & built, it had unused bandwidth
- LightTUBe now provides high quality video, high speed Internet, telephone services
- "Hybrid" business model crosses traditional boundaries with public utilities, phone companies, & Internet/cable TV providers

Vignette: Automated Metering Information System

Questions to Consider:

1. How to estimate cost & benefits of “hybrid” operation (max profit) with traditional utility business (min cost)?
2. Ethical issues in using public funds in what could be seen as a for-profit venture competing with private sector firms
3. LightTUBe would be able to consider both what it collects & consumer surplus value. How should this be handled?
4. When analyzing economics of “hybrid” projects, what tools would be appropriate?

Types of Costs

- Fixed costs & variable costs
- Marginal costs & average costs
- Sunk costs & opportunity costs
- Recurring & non-recurring costs
- Incremental costs
- Cash costs & book costs
- Life-cycle costs

Fixed Costs & Variable Costs

- Fixed costs: constant, unchanging regardless of the level of output or activity
  - Property taxes, insurance
  - Management & administrative salaries
  - License fees
  - Rent or lease
- Variable costs: vary with output or activity level
  - Direct labor cost
  - Direct materials

Marginal Costs & Average Costs

1 Lb $2
5 Lb $9
10 Lb $17
20 Lb $35

- Marginal costs: variable cost for 1 more unit
  - Capacity Planning: Cost of excess capacity
  - Basis for last-minute pricing
- Average costs: total cost / # units
  - Basis for normal pricing

Example 2-1

EXAMPLE 2-1

The Federation of Student Societies of Engineering (FeSSE) wants to offer a one-day training course to help students in job hunting and to raise funds. The organizing committee is sure that they can find alumni, local business people, and faculty to provide the training at no charge. Thus the main costs will be for space, meals, handouts, and advertising.

The organizers have classified the costs for room rental, room setup, and advertising as fixed costs. They also have included the meals for the speakers as a fixed cost. Their total of $225 is pegged to a room that will hold 40 people. So if demand is higher, the fixed costs will also increase.

The variable costs for food and bound handouts will be $20 per student. The organizing committee believes that $35 is about the right price to match value to students with their budgets. Since FeSSE has not offered training courses before, they are unsure how many students will reserve seats.

Develop equations for FeSSE's total cost and total revenue, and determine the number of registrations that would be needed for revenue to equal cost.

Example 2-1

let S be the number of students needed for revenue to equal cost

Revenue x number of students = fixed cost + Variable Cost x number of students

Fixed costs: $225

Variable costs: $20 / student

Revenue: $35 / student

Total cost = $225 + $20x

Total revenue = $35x

$35S = 225 + 20S$

$35S - 20S = 225$

$15S = 225$

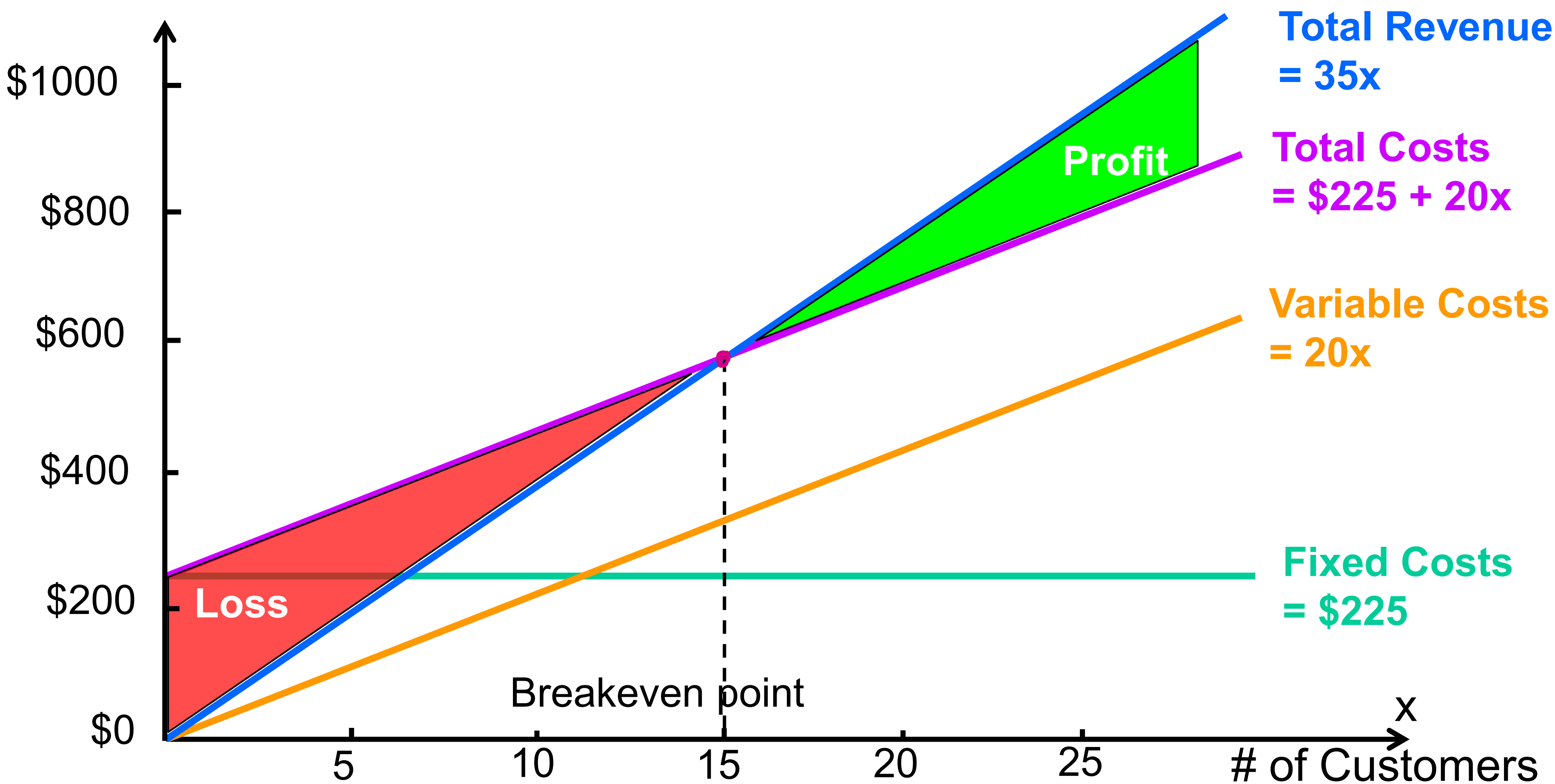
$\boxed{S = \frac{225}{15} = 15}$

At breakeven, Total cost = Total revenue

$225 + $20x = $35x

x = 15 students

Example 2-1

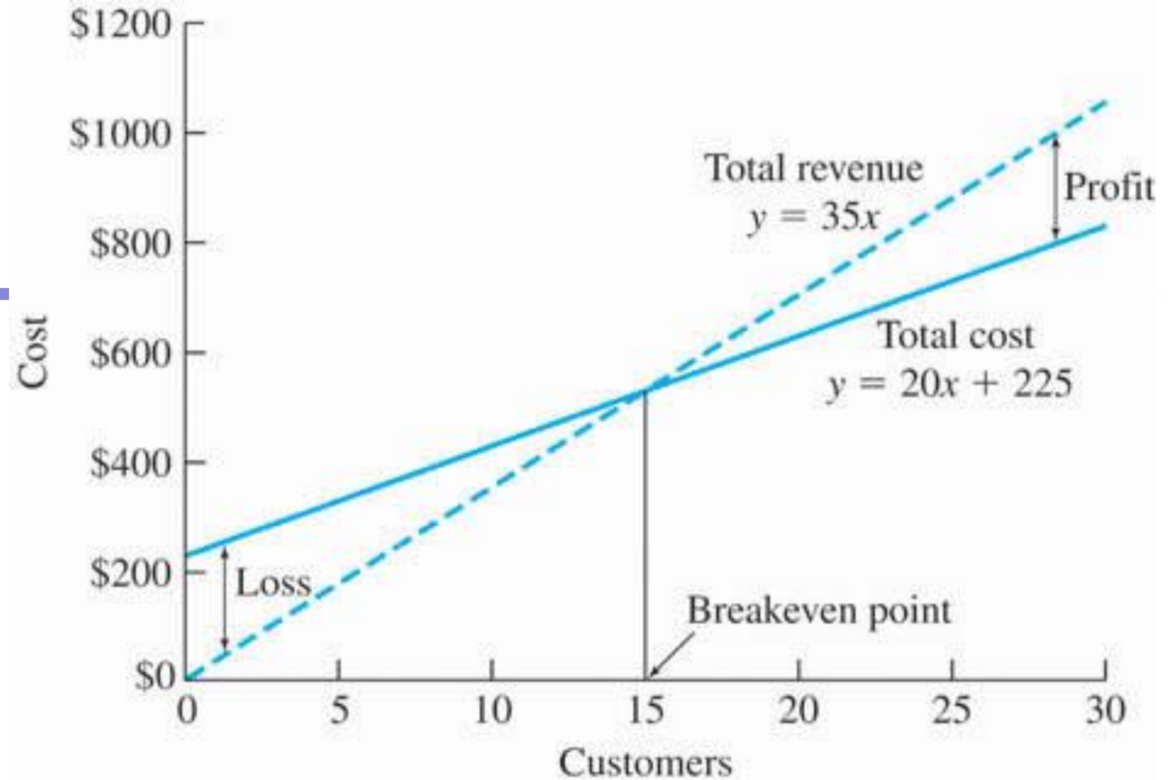


$1000
$800
$600
$400
$200
$0
Total Revenue
= 35x
Total Costs
= $225 + 20x
Variable Costs
= 20x
Fixed Costs
= $225
Profit
Loss
Breakeven point
x
5
10
15
20
25
# of Customers

Example 2-1

You have 15 Customers. Your profit is:

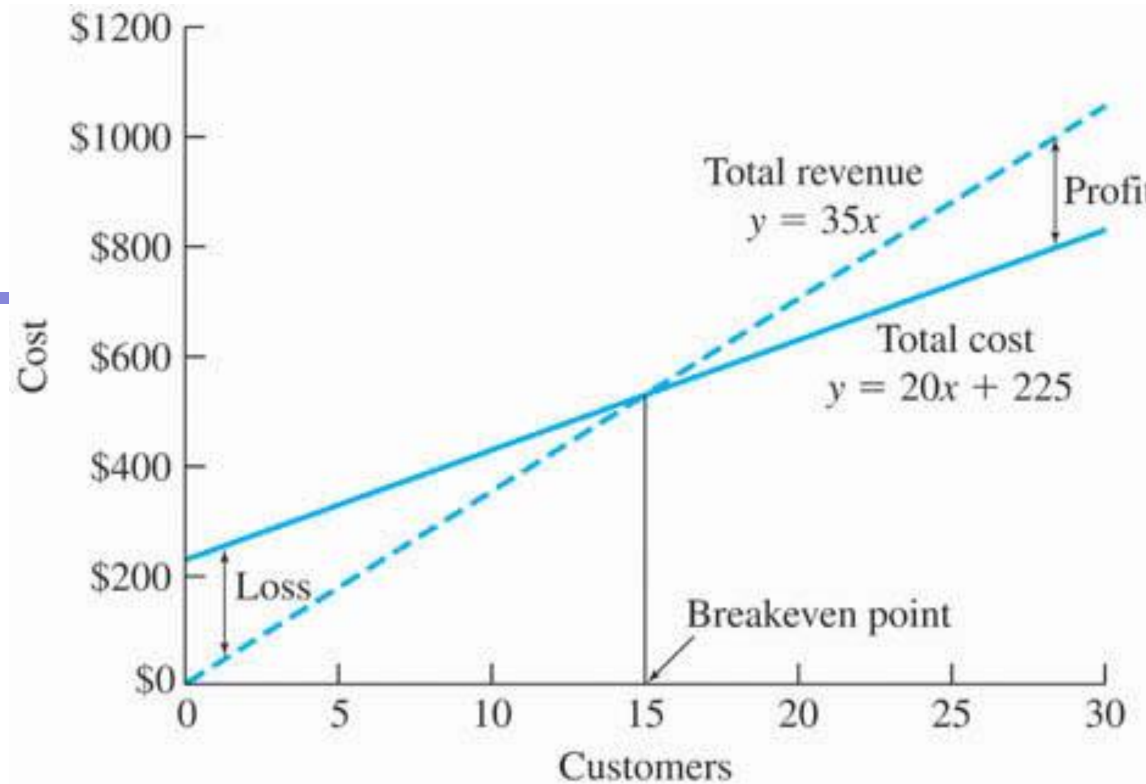
A. Negative
B. Positive
C. Small
D. $\boxed{\text{Zero}}$
E. I don't know



Example 2-1

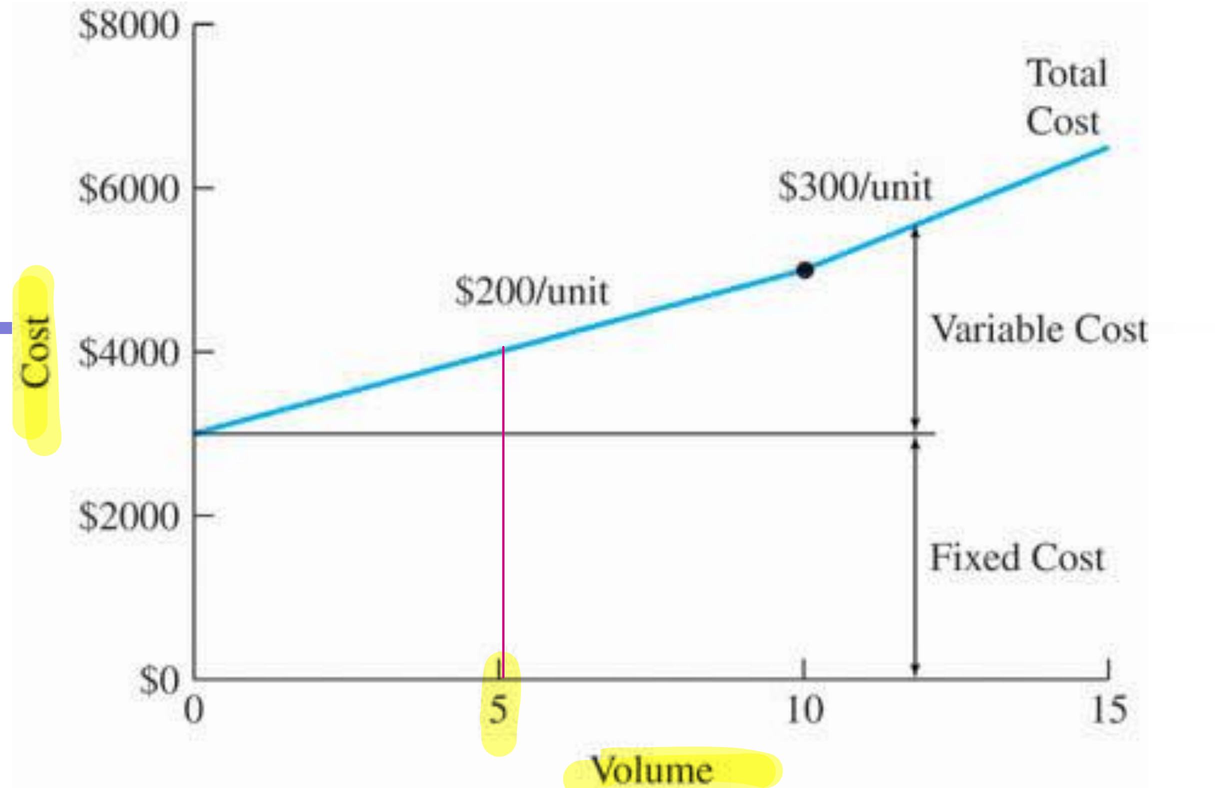
You have 15 Customers. Your profit is:

A. Negative
B. Positive
C. Small
D. Zero
E. I don't know



At breakeven, profit is zero.

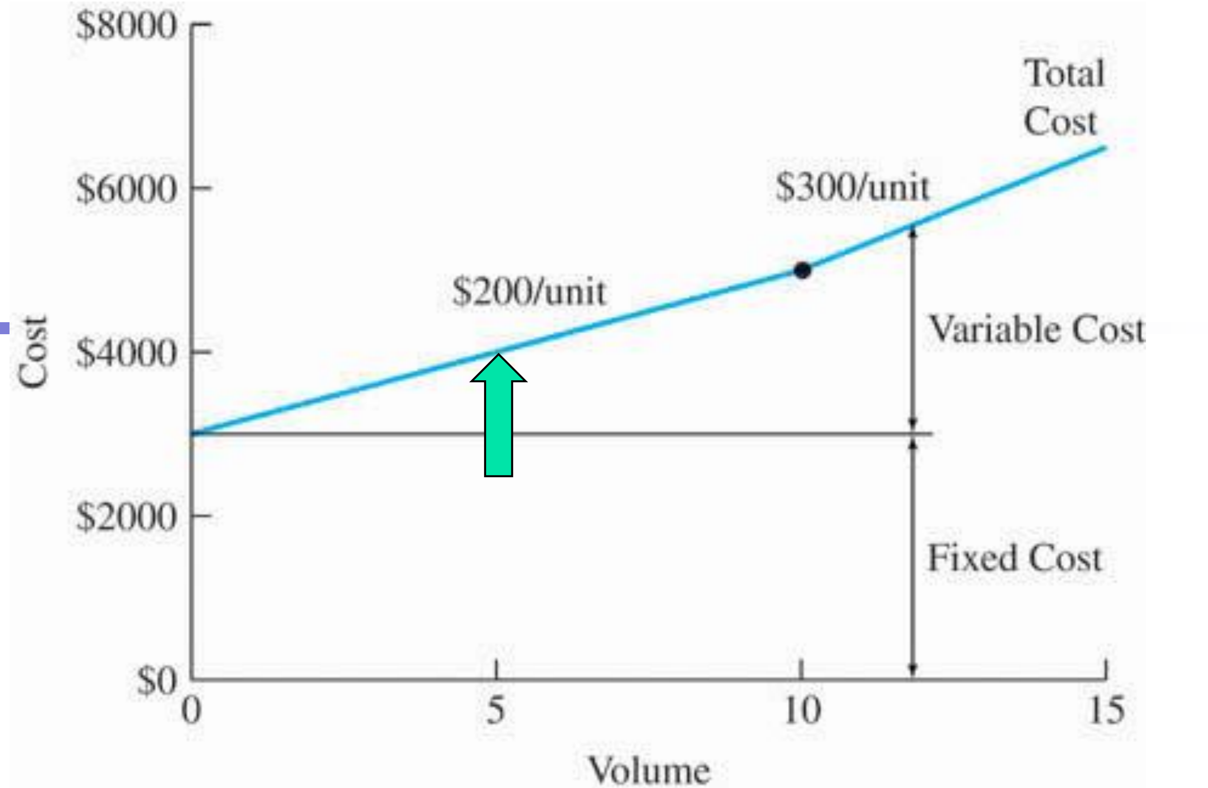
Figure 2-2



If volume = 5,

A. Fixed cost is \$3000, variable cost is \$200/unit.
B. Fixed cost is \$3000, variable cost is \$1000/unit.
C. Fixed cost is \$300/unit, variable cost is \$200/unit.
D. Total cost is \$3000 + \$300x
E. I'm confused.

Figure 2-2



If volume = 5,

A. Fixed cost is $3000, variable cost is $200/unit.
B. Fixed cost is $3000, variable cost is $1000/unit.
C. Fixed cost is $300/unit, variable cost is $200/unit.
D. Total cost is $3000 + $300x
E. I'm confused.

Profit & Loss Terms

Breakeven: activity level where

total revenue = total costs

- Just getting by

Profit region: total revenue > total costs

- Putting money in the bank

Loss region: total revenue < total costs

- Losing money

Sunk Costs & Opportunity Costs

- Sunk costs: money already spent due to past decision
  - Purchase price paid for a car 2 years ago

- Opportunity costs: cost of the foregone opportunity, often hidden or implied
  - Existing equipment in replacement analysis
  - Income not received from the job you turn down
  - Paying the mortgage instead of going out for dinner

Example 2-2 Pricing of Old Pumps

EXAMPLE 2-2

A distributor of electric pumps must decide what to do with a "lot" of old electric pumps purchased 3 years ago. Soon after the distributor purchased the lot, technology advances made the old pumps less desirable to customers. The pumps are becoming obsolescent as they sit in inventory. The pricing manager has the following information.

Distributor's purchase price 3 years ago	$ 7,000
Distributor's storage costs to date	1,000
Distributor's list price 3 years ago	9,500
Current list price of the same number of new pumps	12,000
Amount offered for the old pumps from a buyer 2 years ago	5,000
Current price the lot of old pumps would bring	3,000

Sunk Cost

Sunk Cost

irrelevant

Opportunity Cost

Looking at the data, the pricing manager has concluded that the price should be set at $8000. This is the money that the firm has "tied up" in the lot of old pumps ($7000 purchase and $1000 storage), and it was reasoned that the company should at least recover this cost. Furthermore, the pricing manager has argued that an $8000 price would be $1500 less than the list price from 3 years ago, and it would be $4000 less than what a lot of new pumps would cost ($12,000 – $8000). What would be your advice on price?

Example 2-2 Pricing of Old Pumps

Purchase Price of Old Pumps	$7,000	(Sunk)
Storage Costs of Old Pumps	$1,000	(Sunk)
List Price of Old Pumps (3yrs)	$9,500	(Irrelevant)
List Price of New Pumps	$12,000	(Irrelevant)
Offer of Old Pumps (2 yrs ago)	$5,000	(Irrelevant)
Current Price of Old Pumps	$3,000	

Recurring Costs & Non-recurring Costs

- Recurring costs: repetitive to produce similar goods & services
  - Office space rental
  - Material cost for a product
- Non-recurring costs: not repetitive; one time
  - Purchase cost for real estate,
  - Construction costs of the plant
- Some large non-recurring costs can be planned for by buying insurance, turning this into a recurring cost

Incremental Costs

- Incremental costs: difference in costs between two alternatives.
  - Suppose that A & B are mutually exclusive
  - A has an initial cost of \$10,000
  - B has an initial cost of \$14,000
  - Incremental initial cost of (B – A) = \$4000

Example 2-3
Choosing between Models A & B

EXAMPLE 2-3

Philip is choosing between model *A* (a budget model) and model *B* (with more features and a higher purchase price). What *incremental costs* would Philip incur if he chose model *B* instead of the less expensive model *A*?

Cost Items	Model *A*	Model *B*
Purchase price	$10,000	$17,500
Installation costs	3,500	5,000
Annual maintenance costs	2,500	750
Annual utility expenses	1,200	2,000
Disposal costs after useful life	700	500

Example 2-3
Choosing between Models A & B

Cost Items	Model A	Model B	Incremental Cost
Purchase Price	$10,000	$17,500	$7,500
Installation Costs	3,500	5,000	1,500
Annual Maintenance	2,500	750	−1,750
Annual Utility	1,200	2,000	800
Disposal Cost	700	500	−200

Example 2-3
Choosing between Model A & B

Incremental cost = Cost of B – Cost of A

A positive incremental cost means

A. A costs more than B
B. B costs more than A
C. The incremental cost is a good thing
D. We save money if we buy A
E. I don't know

Example 2-3
Choosing between Model A & B

Incremental cost = cost of B – cost of A

A positive incremental cost means

A. A costs more than B
B. B costs more than A
C. The incremental cost is a good thing
D. We save money if we buy A
E. I don't know

Cash vs. Book Costs

Cash costs: money from one owner to another: cash flow

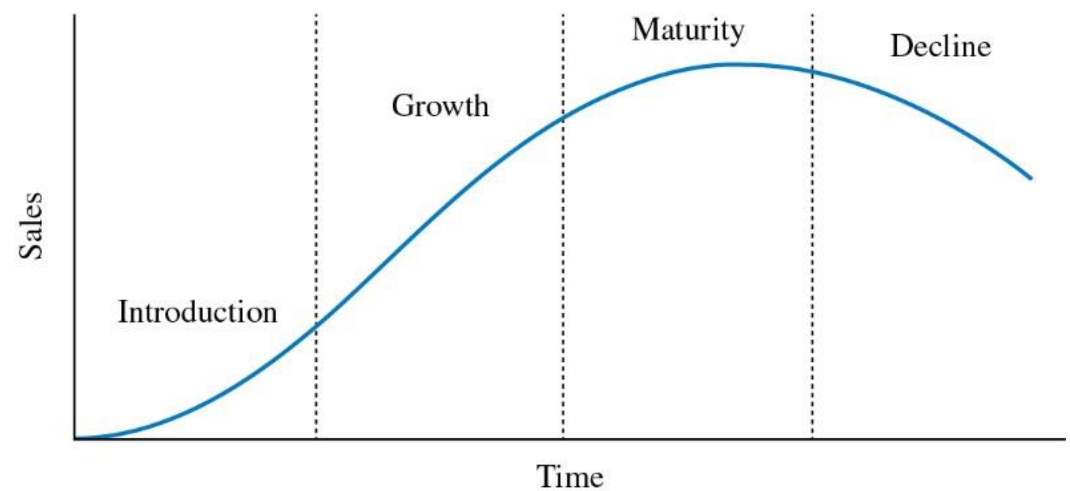
- This month's loan payment

Book cost: transaction cost as recorded in an accounting book

- Depreciation cost calculated this year for an existing asset, per accounting department

Life-Cycle Costs

- Life-cycle costs: all costs over its entire life of a product, structure, system, or service
- Life cycle costing: design products, projects, & services recognizing all costs & benefits over the entire life cycle



Life-Cycle Costs

Which is true?

A. Life-cycle: time from conception to death of a product or process
B. Life-cycle costs: all costs incurred during life cycle
C. Life-cycle costing: proper basis for economic choices
D. All of the above
E. None of the above

Life-Cycle Costs

Which is true?

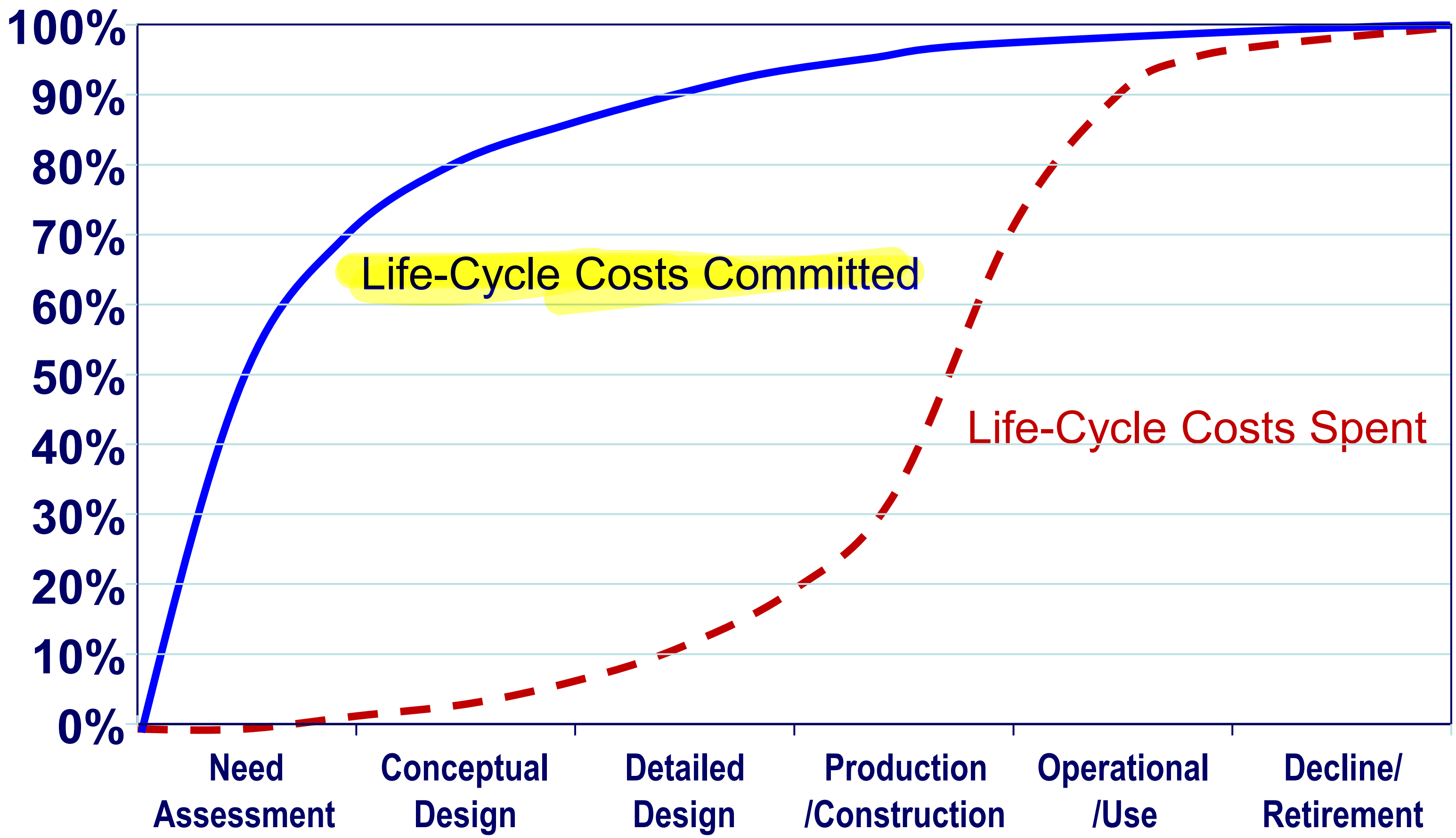
A. Life-cycle: time from conception to death of a product or process
B. Life-cycle costs: all costs incurred during life cycle
C. Life-cycle costing: proper basis for economic choices
D. All of the above
E. None of the above

All of the above are true.

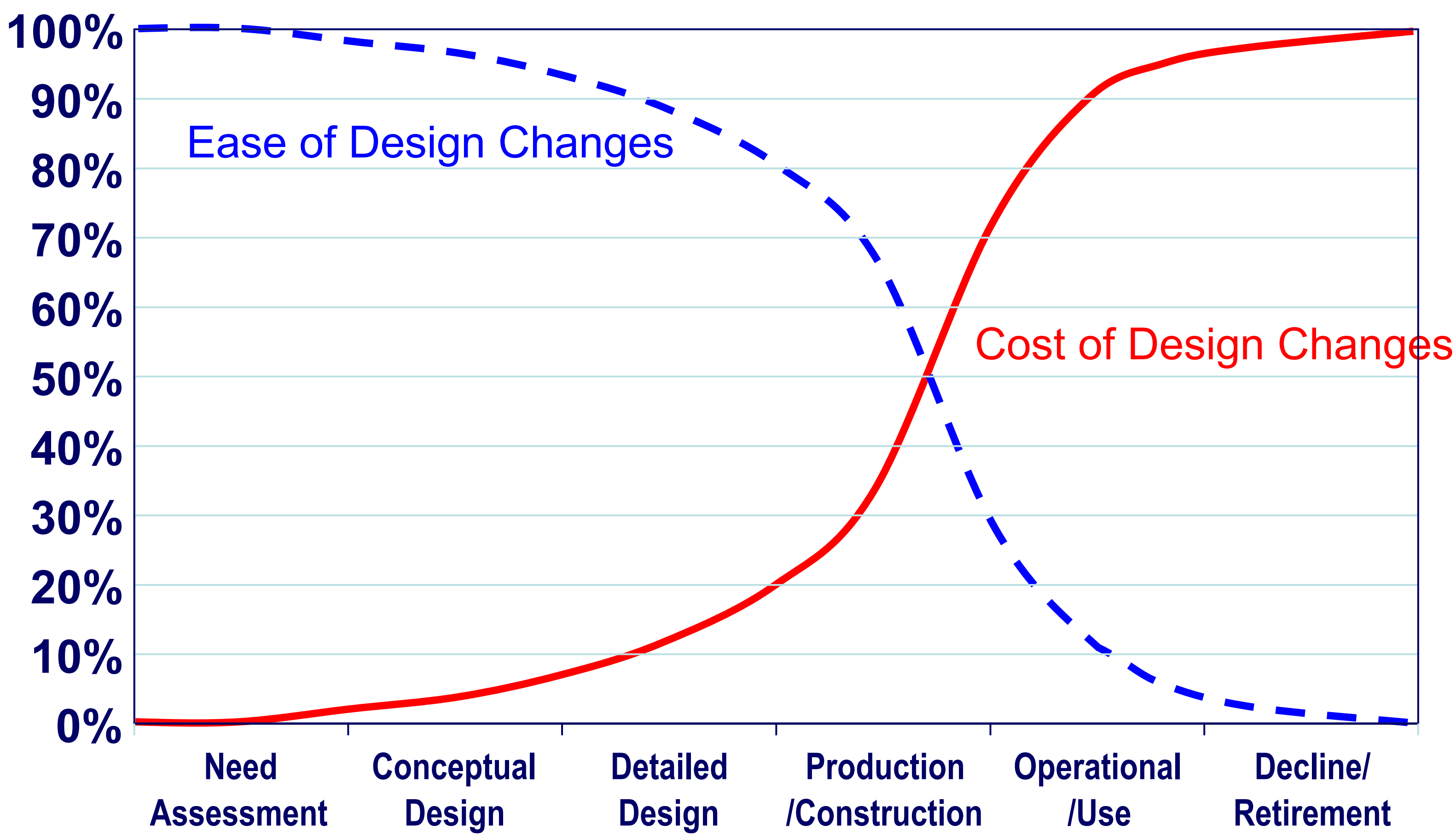
Phases of Life-Cycle

1. Needs Assessment	2. Conceptual Design	3. Detailed Design	4. Production /Construction	5.Operational Use	6. Decline/ Retirement
Requirements Analysis	Impact Analysis	Allocation of Resources	Production of Goods/ Services	Distribution of Goods/ Services	Phase Out
Overall Feasibility Study	Proof of Concept	Detailed Specifications	Building of Supporting Facilities	Maintenance/ Support	Disposal
Conceptual Design Planning	Prototype/ Breadboard	Component/ Supplier Selection	Quality Control/ Assurance	Retirement Planning	
	Development/ Testing	Production Planning	Operational Planning		
	Detailed Design Planning				

Cumulative Life-Cycle Costs Committed & Spent



Cost/Ease of Design Changes in Product Life-Cycle



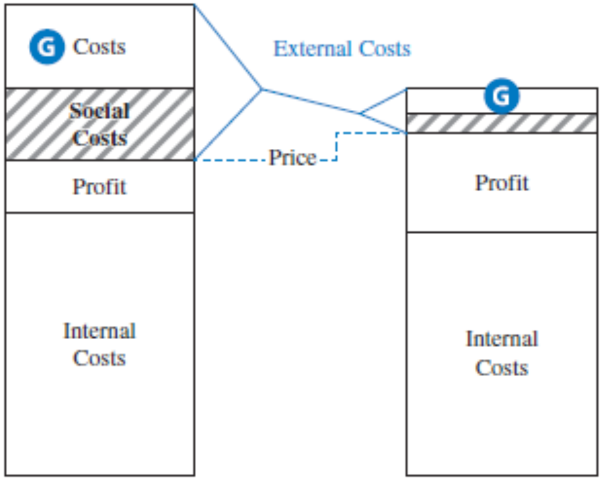
Why is there a gap between money committed & money spent?

A. Materials ordered & work done before vendors & workers paid
B. Design decisions largely determine costs to build, operate, & close-out
C. There is a time lag while funds are recorded & published by Accounting
D. All of the above
E. None of the above

Why is there a gap between money committed & money spent?

A. Materials ordered & work done before vendors & workers paid
B. Design decisions largely determine costs to build, operate, … & benefits from product & project performance
C. There is a time lag while funds are recorded & published by Accounting
D. All of the above   All are true, but B is the most important.
E. None of the above

Internal & External Costs



- Internal costs (materials, labor, overhead, etc.) used to calculate product/service cost

- External costs are not directly incurred by the firm
  - Cost of disposal, decommissioning, landfill
  - Effects on wildlife & environment
  - Effects on air & water quality

Example 2-4 Identify internal & external costs for new mountaintop ski resort project

- Site costs – I
- Land costs – I
- Water quality costs – E
- Legal costs – I
- Community costs – E
- Design costs – I
- Habitat costs – E
- Viewshed costs – E
- Recreational costs – E
- Administrative costs – I
- Roadway costs – E
- Labor costs – I
- Materials costs – I
- Equipment costs – I
- Overhead costs – I
- Construction costs – I

Example 2-4 Identify internal & external costs for new mountaintop ski resort project

Internal costs | External costs

- Site costs
- Land costs
- Water quality costs
- Legal costs
- Community costs
- Design costs
- Habitat costs
- Viewshed costs
- Recreational costs
- Administrative costs
- Roadway costs
- Labor costs
- Materials costs
- Equipment costs
- Overhead costs
- Construction costs

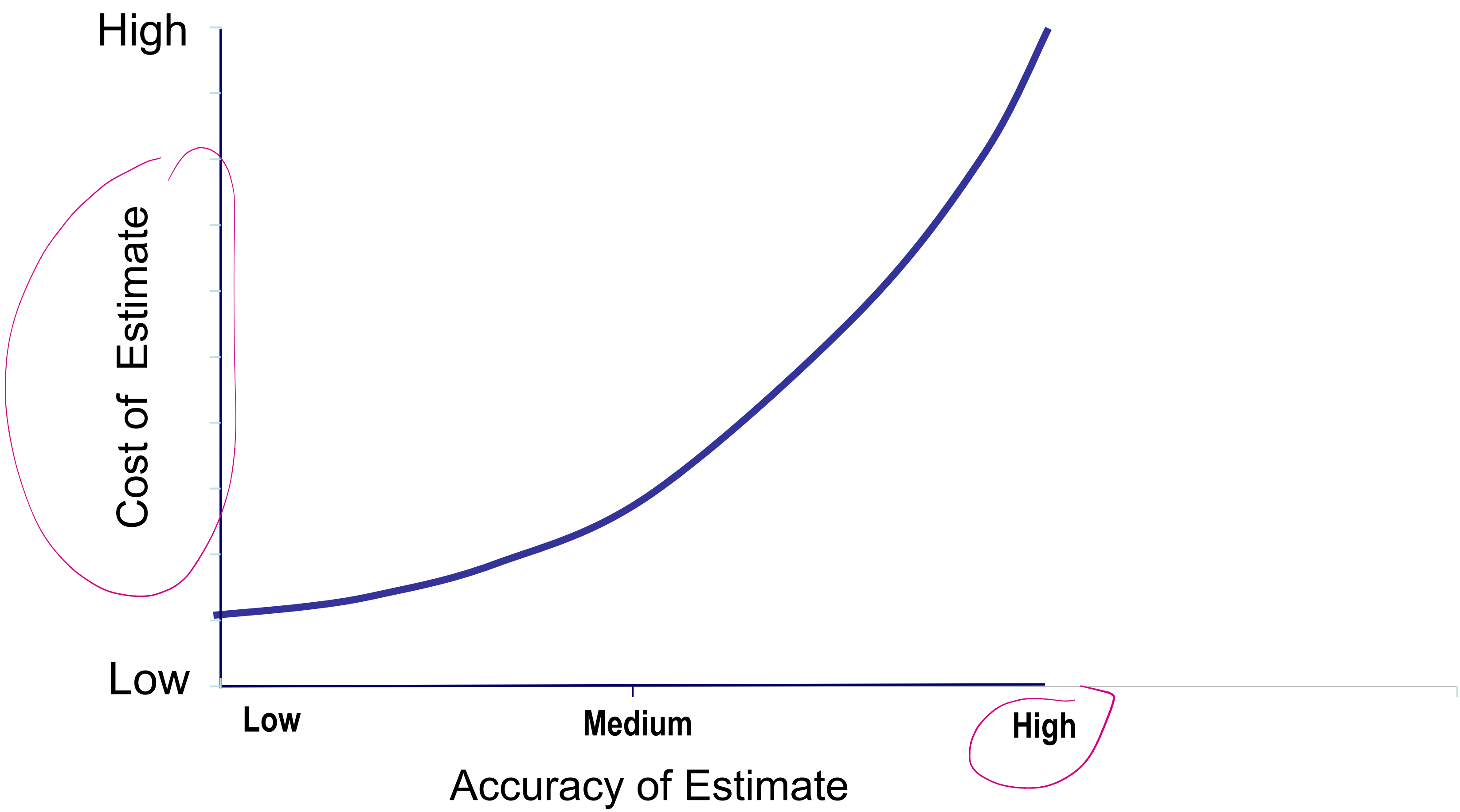
Estimating Benefits

- Benefits examples
  - Sales of products
  - Revenues from bridge tolls & electric power sales
  - Cost reduction from reduced material or labor costs
  - Reduced risk of flooding
- Cost concepts & models apply to economic benefits
- Like for costs uncertainty in benefit estimating is usually asymmetric; optimism is common
- Benefits are often more difficult to estimate than costs

Cost Estimating

- Economic analysis is future based
- Future is not known with certainty
- Types of cost estimating
  - Rough estimates −30% to +60%
  - Semi-detailed estimates −15% to +20%
  - Detailed estimates −3% to +5%

Cost Estimating—Trade-off between Accuracy & Cost



Difficulties in Estimation

- One-of-a-kind estimates
- Time & effort available
- Estimator expertise

Cost Estimating Models

- Per-unit model
- Segmenting model
- Cost & price indexes
- Power-sizing model
- Triangulation
- Improvement & the learning curve

Cost Estimating Models
Per-Unit Model

- Per-Unit Model
  - Construction cost per square foot (building)
  - Capital cost of power plant per kW of capacity
  - Revenue / maintenance cost per mile (hwy)
  - Utility cost per square foot of floor space
  - Fuel cost per kWh generated
  - Revenue per customer served

A 1600 ft^2 clean manufacturing area recently cost \$8 M. Use a per unit model to estimate cost of a new 2000 ft^2 area.

A. \$0.8 million

B. \$6.4 million

C. \$8.0 million

D. $\boxed{\text{\$10.0 million}}$

E. I don't know

$$\frac{1600\,ft^2}{\$8M} = \frac{2000\,ft^2}{X}$$

$$X = \frac{\overset{5}{\cancel{2000}}\,ft^2}{\underset{4}{\cancel{1600}}\,ft^2} \times \$\overset{2}{\cancel{8}}M$$

$$X = \$10M$$

A 1600 ft^2 clean manufacturing area recently cost \$8 M. Use a per unit model to estimate cost of a new 2000 ft^2 area.

A. \$0.8 million
B. \$6.4 million
C. \$8.0 million
D. \$10.0 million
E. I don't know

$$\frac{\$8M}{1600} = \frac{x}{2000}$$

Example 2-5 Cost Estimating using Per-Unit Model

EXAMPLE 2-5

Gaber Land Corp. is evaluating a 4-acre waterfront property for development into rental condominiums. The front 2-acre lot is more expensive to purchase than the rear 2-acre lot, and condo leases closer to the waterfront can be more expensive than those units in the rear. Gaber is considering a design that includes a 32-unit building on each lot. Data includes the following:

Initial Costs

Lot purchase prices: $400,000/acre front lot, $100,000/acre back lot

Legal fees, applications, permits, etc.: $80,000

Site clearing and preparation: $3000/acre

Paving roadways, parking, curbs, and sidewalks: 25% of total lot at $40,000/acre

Construction costs: $3,000,000 per building

Example 2-5 Cost Estimating using Per-Unit Model

Recurring Costs

Taxes and insurance: $5000/month per building

Landscaping: 25% of lot at $1000/acre/month

Security: $1000/building + $1500/month

Other costs: $2000/month

Revenue (assume 90% annual occupancy)

Front lot units: $2500/unit/month

Rear lot units: $1750/unit/month

Other revenue: $5000/month

Answer the following: (1) Use the concept of the per-unit model to estimate the total initial cost, annual cost, and annual revenue of this prospective project, and (2) If you made the simplifying assumption of no changes to costs and revenues for 10 years, estimate the profitability of this prospective investment ignoring the effects of money's value over time.

Example 2-5 Cost Estimating using Per-Unit Model

Evaluate 4-acre (front 2-acre + rear 2-acre) waterfront lots for rental condominiums (32-unit building on each lot)

Initial Costs

- Purchase prices: $400,000/acre front, $200,000/acre back
- Legal fees, applications, permits, etc.: $80,000
- Site clearing & preparation: $3000/acre
- Paving roadways, parking, curbs, & sidewalks: 25% of each lot at $40,000/acre
- Construction costs: $3,000,000 per building

Example 2-5 continued

- Recurring costs
  - Taxes & insurance: $5000/month per building
  - Landscaping: 25% of lot at $1000/acre/month
  - Security: $1000/building + $1500/month
  - Other costs: $2000/month
- Revenue (assume 90% annual occupancy)
  - Front lot units: $2500/unit/month
  - Rear lot units: $1750/unit/month
  - Other revenue: $5000/month
- Estimate
  - Initial cost, annual cost, & annual revenue
  - Ignoring time value of money estimate profitability

Example 2-5 continued

Solution:

Initial cost

Purchase price: (400,000×2) + (200,000×2) =	$1,000,000
Legal costs =	80,000
Site clearing & preparation: 3000×4 =	12,000
Roadways, etc.: (.25×4)×40,000 =	40,000
Construction: 3,000,000×2 =	6,000,000
	$7,132,000

Annual cost

Taxes & insurance: 10,000×12 =	$120,000
Landscaping: (.25×4)×1000×12 =	12,000
Security: (1000×2) + (1500×12) =	20,000
Other costs: 2000×12 =	24,000
	$176,000

Example 2-5 continued

Solution:

Annual revenue

Front lot leases: $(32\times2500\times12)\times.90 =$	$864,000
Rear lot leases: $(32\times1750\times12)\times.90 =$	604,800
Other revenue: $5000\times12 =$	60,000
	$1,528,800

Net profit over 10 years

$$= [1{,}528{,}800 \times 10] - [7{,}132{,}000 + (176{,}000 \times 10)]$$

$$= \$6{,}396{,}000$$

Item	Units	Intial Cost		Total
Intial Cost		**Front**	**Back**	
Lot Purchase Price	2	$400,000	$100,000	$1,000,000
Legal Fee				$80,000
Site Clearing and Preparation	2	$3,000	$3,000	$12,000
Paving roadways, Parking, Curbs and Sidewalks	2	$40,000	$40,000	$40,000
Construction Costs	1	$3,000,000	$3,000,000	$6,000,000
				$7,132,000
Annual Cost				
Taxes and Insurance	1	$5,000	$5,000	$120,000
Landscaping	2	$1,000	$1,000	$12,000
Security	1	$1,000	$1,000	$20,000
Other Costs				24000
				$176,000
Revenue				
Front Lot Units	32	2500	0	$864,000
Rear Lot Units	32	0	1750	$604,800
Other Revenue				60000
				$1,528,800

Profitability after 10 years =

$\$1.529M \times 10 - (\$7.132M + \$176k \times 10)$

Profitability after 10 years = $6,396,000

Cost Estimating Models – Segmenting Model

- Estimate is decomposed into individual components
- Estimates are made at component level
- Individual estimates are aggregated back together

Example 2-6 Cost Estimating using Segmenting Model

Clean Lawn Corp., a manufacturer of yard equipment, is planning to introduce a new high-end industrial-use lawn mower called the Grass Grabber. The Grass Grabber is designed as a walk-behind, self-propelled mower. Clean Lawn engineers have been asked by the accounting department to estimate the material costs for the new mower. The material cost estimate will be used, along with estimates for labor and overhead to evaluate the potential of this new model.

Example 2-6 Cost Estimating using Segmenting Model

Cost estimate of lawn mower

A. Chassis

Cost Item	Estimate
A.1 Deck	$7.40
A.2 Wheels	10.20
A.3 Axles	4.85
Subtotal	$22.45

B. Drive Train

Cost Item	Estimate
B.1 Engine	$38.50
B.2 Starter assembly	5.90
B.3 Transmission	5.45
B.4 Drive disc assembly	10.00
B.5 Clutch linkage	5.15
B.6 Belt assemblies	7.70
Subtotal	$72.70

Example 2-6 Cost Estimating using Segmenting Model

Cost estimate of lawn mower

C. Controls

Cost Item	Estimate
C.1 Handle assembly	$3.85
C.2 Engine linkage	8.55
C.3 Blade linkage	4.70
C.4 Speed control linkage	21.50
C.5 Drive control assembly	6.70
C.6 Cutting height adjuster	7.40
Subtotal	$\boxed{\$52.70}$

D. Cutting/Collection system

Cost Item	Estimate
D.1 Blade assembly	$10.80
D.2 Side chute	7.05
D.3 Grass bag & adapter	7.75
Subtotal	$\boxed{\$25.60}$

Total material cost = $22.45 + $72.70 + $52.70 + $25.60 = $\boxed{\$173.45}$

Cost Estimating Models – Cost Indexes

- Cost indexes reflect historical change in cost
- Cost index could be individual cost items (labor, material, utilities), or group of costs (consumer prices, producer prices)
- Indexes can be used to update historical costs

$$\frac{Cost_A}{Cost_B} = \frac{Index_A}{Index_B} \qquad \text{(Eq. 2-2)}$$

Example 2-7 Cost Estimating using Cost Indexes

Miriam is interested in estimating the annual labor and material costs for a new production facility. She was able to obtain the following cost data:

Labor Costs

- Labor cost index value was at 124 ten years ago and is 188 today.
- Annual labor costs for a similar facility were $575,500 ten years ago.

Material Costs

- Material cost index value was at 544 three years ago and is 715 today.
- Annual material costs for a similar facility were $2,455,000 three years ago.

Labor Cost

	Present	10 years ago
Cost index	188	124
Cost	C_x	\$575,500

$$\boxed{\frac{Cost_A}{Cost_B} = \frac{Index_A}{Index_B}}$$

$$\frac{C_x}{575{,}500} = \frac{188}{124}$$

$$C_x = \frac{575{,}500 \times 188}{124} = 872{,}532$$

Materia Cost

	Present	three years ago
Cost index	715	544
Cost	M_x	\$2,455,000

$$\frac{Cost_A}{Cost_B} = \frac{Index_A}{Index_B}$$

$$\frac{M_x}{\$2,455,000} = \frac{715}{544}$$

$$M_x = \frac{715 \times 2,455,000}{544}$$

$$\boxed{M_x = \$3,226,700}$$

Example 2-7 Cost Estimating using Cost Indexes

$$Labor\ Cost_{now} = Labor\ Cost_{10\ yrs}\left(\frac{Index_{now}}{Index_{10\ yrs}}\right)$$

$$= \$575{,}500\left(\frac{188}{124}\right) = \$872{,}500$$

$$Material\ Cost_{now} = Material\ Cost_{3\ yrs}\left(\frac{Index_{now}}{Index_{3\ yrs}}\right)$$

$$= \$2{,}455{,}000\left(\frac{715}{544}\right) = \$3{,}227{,}000$$

Cost Estimating Models
Power-Sizing Model

$$\frac{Cost_A}{Cost_B} = \left(\frac{Size_A}{Size_B}\right)^x \qquad \text{(Eq. 2-3)}$$

x = Power-sizing exponent

Equipment/Facility	x
Blower, centrifugal	0.9
Compressor	1.0
Crusher	0.8
Dryer, drum	0.6
Electrostatic precipitators	0.8

Equipment/Facility	x
Fan, 10^3-10^4 cfm	0.4
Fan, $2\text{x}10^4$-$7\text{x}10^4$ cfm	1.2
Filter, plate & frame	0.75
Jacketed vessels	0.6
Motor	0.9
Tank, Horizontal	0.6

Example 2-8 Cost Estimating using Power-Sizing & Cost Indexes

Based on her work in Example 2-7, Miriam has been asked to estimate the cost today of a 2500-ft^2 heat exchange system for the new plant being analyzed. She has the following data.

- Her company paid \$50,000 for a 1000-ft^2 heat exchanger 5 years ago.
- Heat exchangers within this range of capacity have a power-sizing exponent (x) of 0.55.
- Five years ago the Heat Exchanger Cost Index (HECI) was 1306; it is 1487 today.

$$\frac{Cost_A}{Cost_B} = \left(\frac{Size_A}{Size_B}\right)^x$$

5 years ago

heat exchange system Size	cost
$2500\ ft^2$	X
$1000\ ft^2$	\$50,000

Assumming five years ago Price of $2500\text{-}ft^2$ heat exchange System was \$X

Given: Power-Sizing exponent (x) for a heat exchange system is 0.55

$$\frac{X}{50{,}000} = \left(\frac{2500}{1000}\right)^{0.55}$$

$$X = 50{,}000 \times 1.65526$$

$X = \$82,763$

	HECI	Cost
Present	1487	Y
Five year ago	1306	$82,763

$$\frac{Cost_A}{Cost_B} = \frac{Index_A}{Index_B}$$

$$\frac{Y}{82763} = \frac{1487}{1306}$$

$$Y = \frac{1487 \times 82763}{1306}$$

$$\boxed{Y = \$\,94,233}$$

Example 2-8 Cost Estimating using Power-Sizing & Cost Indexes

A. Considering power-sizing index change

$$Cost_{2500\,ft^2} = Cost_{1000\,ft^2}\left(\frac{2500ft^2}{1000ft^2}\right)^{0.55}$$

$$= \$50{,}000\left(\frac{2500ft^2}{1000ft^2}\right)^{0.55} = \$82{,}800$$

B. Considering cost index change

$$Cost_{now} = Cost_{5\ yrs}\left(\frac{Index_{now}}{Index_{5\ yrs}}\right) = \$82{,}800\left(\frac{1487}{1306}\right)$$

$$= \$94{,}300$$

Cost Estimating Models – Triangulation

- Surveying technique: to map points of interest using fixed points, angles, & distances
  - Extra points provide accuracy checks
- Economic analysis: estimate from different perspectives, such as different source of data or different quantitative models

Cost Estimating Models – Improvement & Learning Curve

- Learning phenomenon: as # of repetitions increase performance is faster
  - People learn, unneeded steps are dropped, methods & tools improve
- Learning curve captures relationship between task performance & task repetition.
- As output doubles the unit production time is reduced to some fixed percentage, the learning curve % or learning curve rate

Cost Estimating Models – Improvement & Learning Curve

Learning curve

Let T_1 = Time to perform the 1st unit

T_N = Time to perform the Nth unit

b = Learning-curve exponent

N = Number of completed units

$$T_N = T_1 \times N^b \qquad \text{(Eq. 2-4)}$$

$$b = \frac{\log(\text{learning curve expressed as a decimal})}{\log 2}$$

(Eq. 2-5)

Example 2-9 Cost Estimating using Learning Curve

EXAMPLE 2-9

Calculate the time required to produce the hundredth unit of a production run if the first unit took 32.0 minutes to produce and the learning-curve rate for production is 80%.

$$b = \frac{\log(\text{learning curve expressed as a decimal})}{\log 2}$$

$$b = \frac{\log(0.80)}{\log 2}$$

$$b = \frac{-0.09691}{0.30103} = -0.32193$$

$$T_N = T_1 \times N^b \Rightarrow T_{100} = T_1 \times 100^b = 32 \times 100^{-0.32193}$$

$$\boxed{T_{100} = 7.27 \text{ minutes}}$$

Example 2-9 Cost Estimating using Learning Curve

Let T_1 = 32.0 min
N = 100
Learning-curve rate = 80%

Solution:

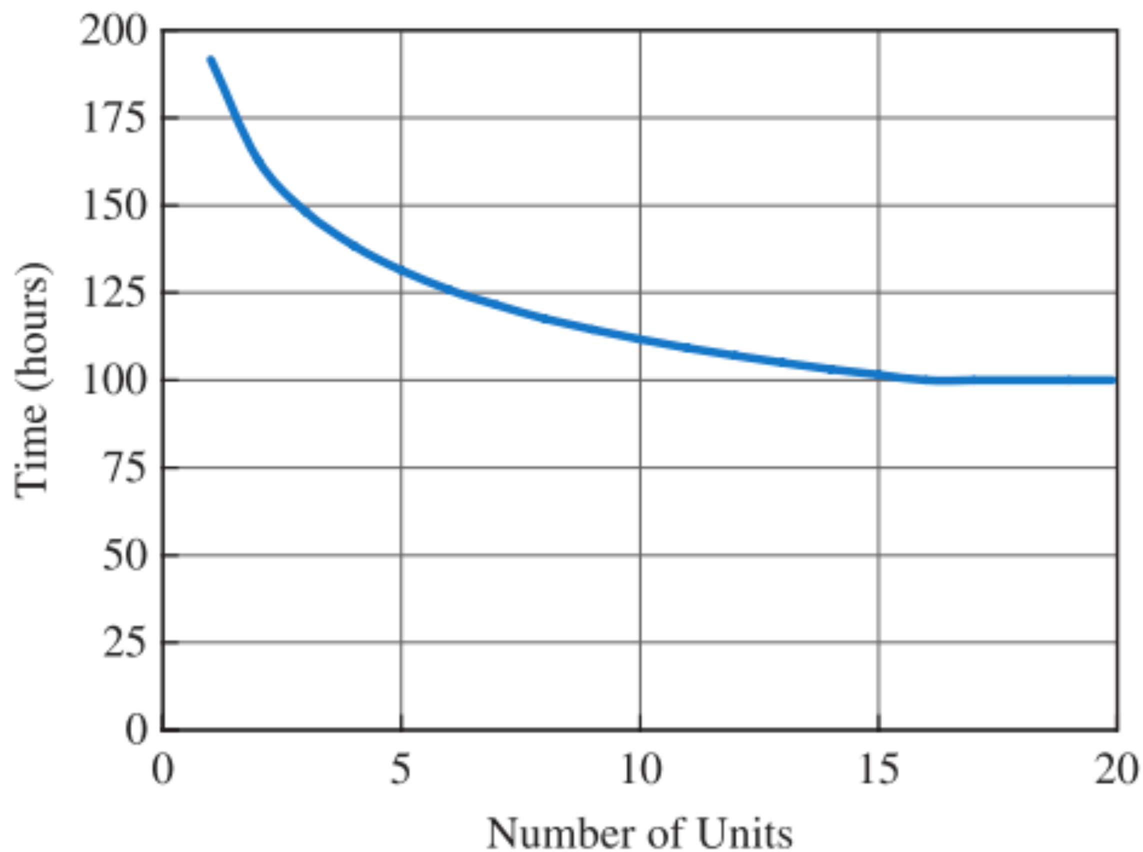
$$b = \frac{log(0.80)}{log\ 2} = -0.3219$$

$$T_{100} = T_1 \times 100^b = 32.0 \times 100^{-0.3219} = 7.27\ min$$

Example 2-9 Cost Estimating using Learning Curve

N	T_N
1	191.6
2	162.8
3	148.1
4	138.4
5	131.4
6	125.9
7	121.4
8	117.6
9	114.4
10	111.7

N	T_N
11	109.2
12	107.0
13	105.0
14	103.2
15	101.5
16	100.0
17	100.0
18	100.0
19	100.0
20	100.0



Example 2-10 Cost Estimating using Learning Curve

Known: T_{16} = 100 hrs.

Learning-curve rate = 85%

Solution:

$$b = \frac{\log(0.85)}{\log 2} = -0.2345$$

$$T_{16} = T_1 \times 16^b = 100$$

$$T_1 = \frac{100}{16^{-0.2345}} = 191.6\ hrs.$$

$$T_N = T_1 \times N^b = 191.6 \times N^{-0.2345}$$

$T_1 = ?$

$b = \frac{\log(85\%)}{\log(2)} = -0.234$

$T_N = T_1 N^b$

$T_{16} = T_1 \times 16^{-0.234}$

$100 = T_1 \times 16^{-0.234}$

$T_1 = 100 \times 16^{0.234}$

$\boxed{T_1 = 191.5686}$

The 1st unit is made in 50 hours. With an 80% learning curve, how long for 10th?

$\boxed{b = -0.3219}$

$T_{10} = T_1 \times 10^{-0.3219}$

$T_{10} = 50 \times 10^{-0.3219}$

$\boxed{T_{10} = 23.82 \text{ hours}}$

A. 85.8 hours
B. 39.7 hours
C. 29.1 hours
D. 23.8 hours
E. I don't know

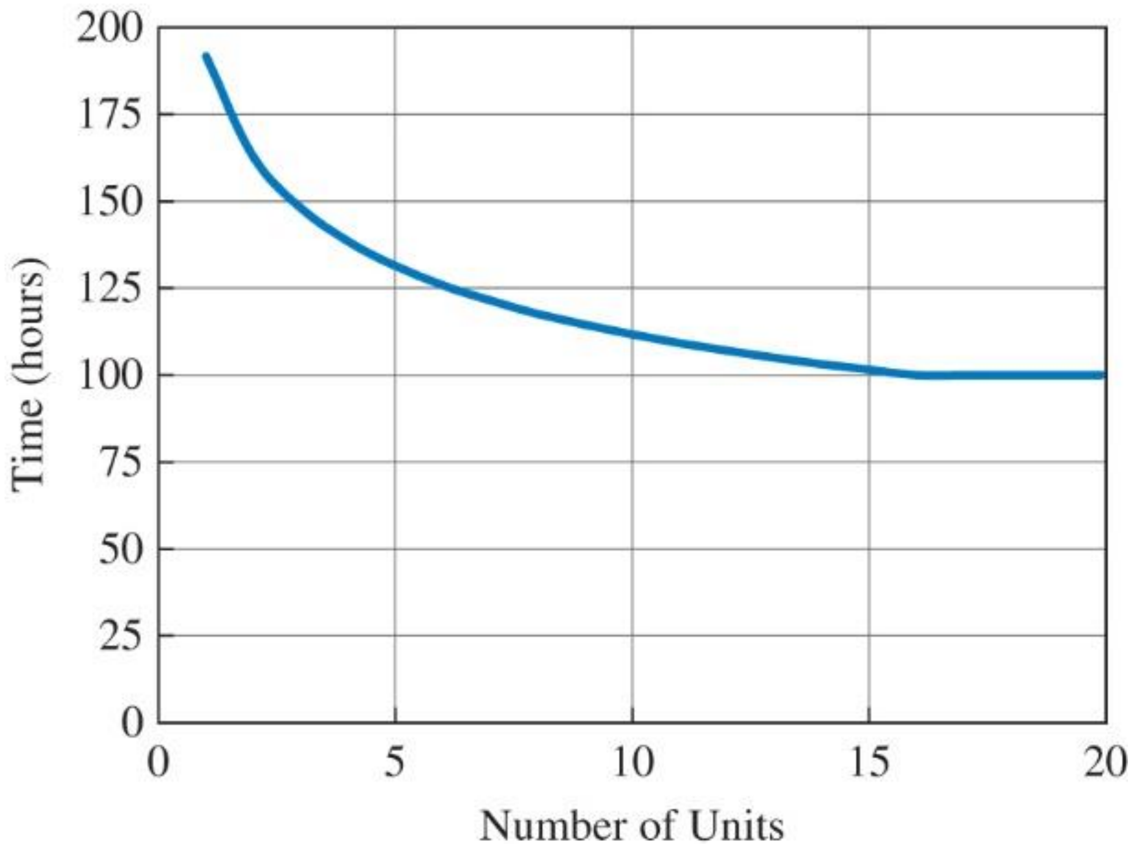
The 1st unit is made in 50 hours. With an 80% learning curve, how long for 10th?

A. 85.8 hours
B. 39.7 hours
C. 29.1 hours
D. 23.8 hours
E. I don't know

$b=\log(0.80)/\log(2) = -0.322$

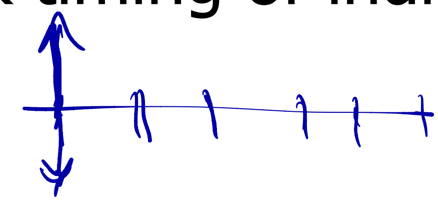
$T_{10} = 50 \times (10)^{-0.3219} = 23.8$

Figure 2-9 Learning curve of time vs. number of units



Cash Flow Diagrams (CFD)

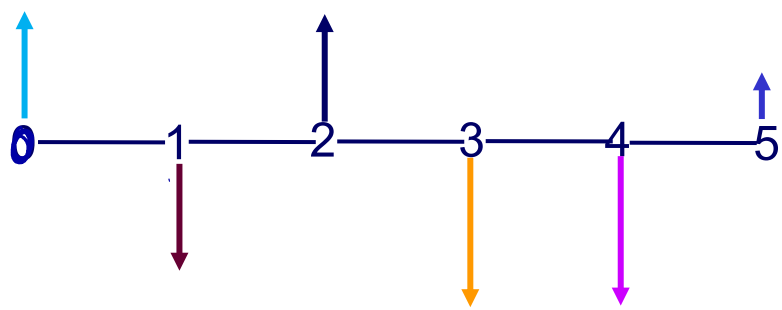
- CFD summarize costs & benefits occurring over time
- CFD illustrate the size, sign, & timing of individual cash flows



- Components of CFD
  - A horizontal line divided into time units
  - A vertical arrow for each cash flow when it occurs
  - Arrows point down for costs & up for benefits

Cash Flow Diagrams (CFD) Example

Timing of Cash Flow	Size of Cash Flow
At time zero (now)	Positive $100
1 time period from today	Negative $100
2 time periods from today	Positive $100
3 time periods from today	Negative $150
4 time periods from today	Negative $150
5 time periods from today	Positive $50



Categories of Cash Flows

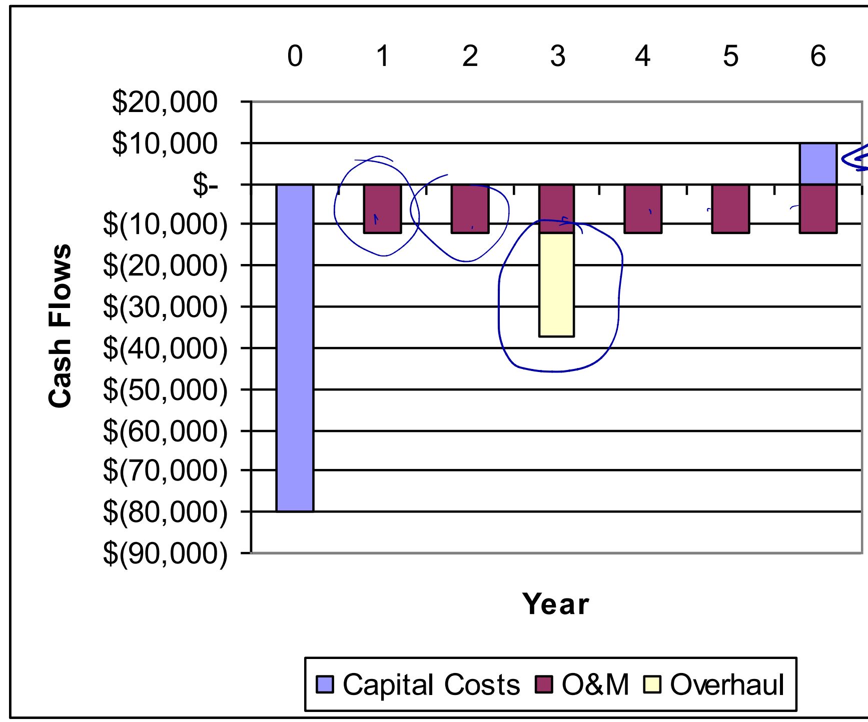
- First cost: expenses to build or to buy & install
- Operations & maintenance (O&M): annual expense, such as electricity, labor, & minor repairs
- Salvage value: money received at project termination for sale or transfer of the equipment
- Revenues: annual receipts due to sale of products or services
- Overhaul: major capital expenditure that occurs during the asset's life

Drawing a Cash Flow Diagram

- Shows when all cash flows occur
- End of period *t* is same time as beginning of period *t+1*
- Rent, lease, insurance payments usually treated as beginning-of-period cash flows
- O&M, salvage, revenues, & overhauls are assumed to be end-of-period cash flows
- Choice of time 0 is arbitrary

Drawing Cash Flow Diagrams with Spreadsheet

Year	Capital Costs	O&M	Overhaul
0	-$80,000		
1		$(12,000)	
2		$(12,000)	
3		$(12,000)	$(25,000)
4		$(12,000)	
5		$(12,000)	
6	$ 10,000	$(12,000)	



Engineering Economic Analysis

FOURTEENTH EDITION

Chapter 3

Interest & Equivalence

Donald G. Newnan
San Jose State University

Ted G. Eschenbach
University of Alaska Anchorage

Jerome P. Lavelle
North Carolina State University

Neal A. Lewis
Fairfield University

OXFORD UNIVERSITY PRESS

Chapter Outline

- Computing Cash Flows
- Time Value of Money
- Equivalence
- Single Payment Compound Interest Formulas
- Nominal & Effective Interest Rates

Learning Objectives

- Understand time value of money
- Distinguish between simple & compound interest
- Understand cash flow equivalence
- Solve problems using single payment compound interest formulas
- Solve problems using spreadsheet factors

Vignette: A Prescription for Success

- Complex tablet press operation
- Significant scrap & tablet press downtime
- Equipment modification to 3 presses cost $90,000
- Impact of modifications:
  - Each batch finished in 16 hrs (⇔24 hrs)
  - Product yield increased to 96.6% (⇔92.4%)
  - Production was reduced to 2 shifts (⇔3)
  - 240 batches processed in one year
  - First year savings of $10 million

Vignette: A Prescription for Success

- Product value = \$240 M /yr; what is value of one batch?
- How many batches for breakeven on initial \$27 K investment? (assume 4.2% yield improvement)
- What is project's present value?
  - Assume interest rate is 15%,
  - Savings are a single end-of-year cash flow, &
  - \$90,000 investment is at time 0.
- If 1 batch produced per day, how often are savings actually compounded?

Computing Cash Flows

- Would you rather
  - Receive $1000 today; or
  - Receive $1000 10 years from today?
- Answer: Today!
- Why?
  - I could invest $1000 today to make more money
  - I could buy a lot of stuff today with $1000
  - Who knows what will happen in 10 years

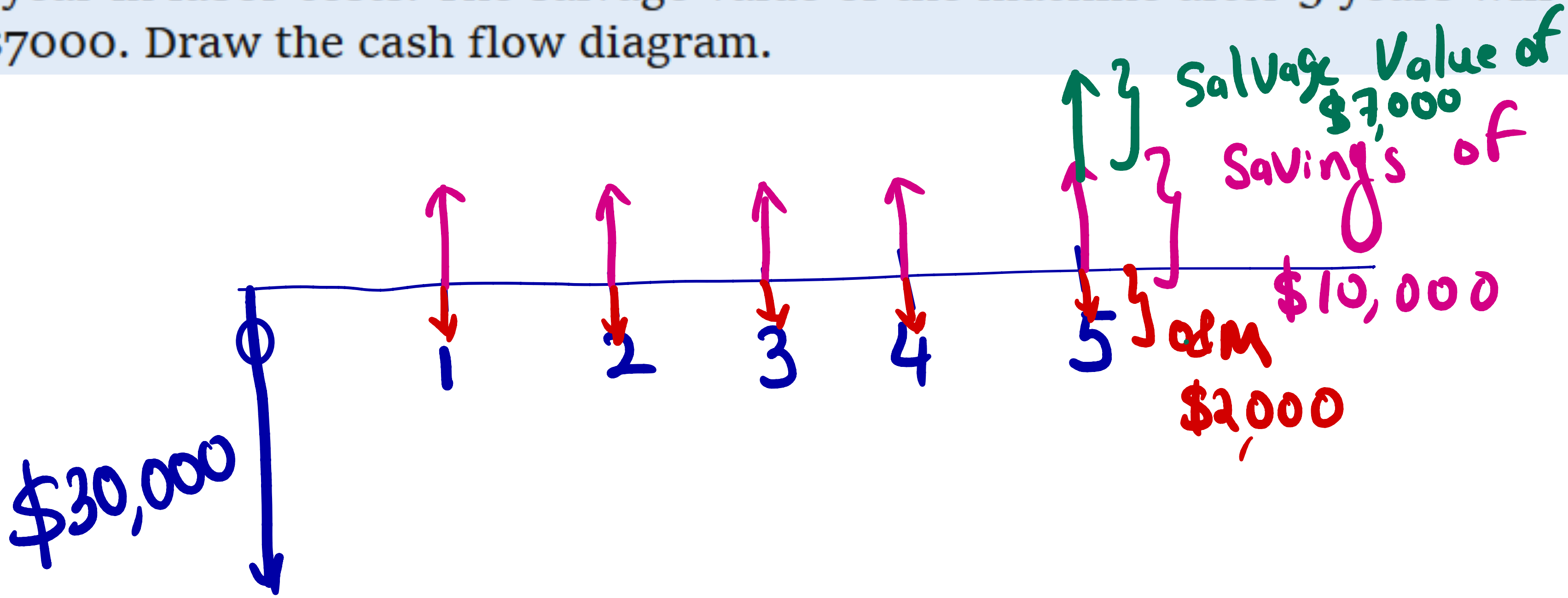
Computing Cash Flows

- Cash flows are
  - Costs (disbursements) = a negative number
  - Benefits (receipts) = a positive number
- Because money is more valuable today than in the future, we need to describe cash receipts & disbursements at time they occur.

Example 3-1
Cash flows of 2 payment options

EXAMPLE 3-1

A machine will cost $30,000 to purchase. Annual operating and maintenance costs (O&M) will be $2000. The machine will save $10,000 per year in labor costs. The salvage value of the machine after 5 years will be $7000. Draw the cash flow diagram.



Example 3-1
Cash flows of 2 payment options

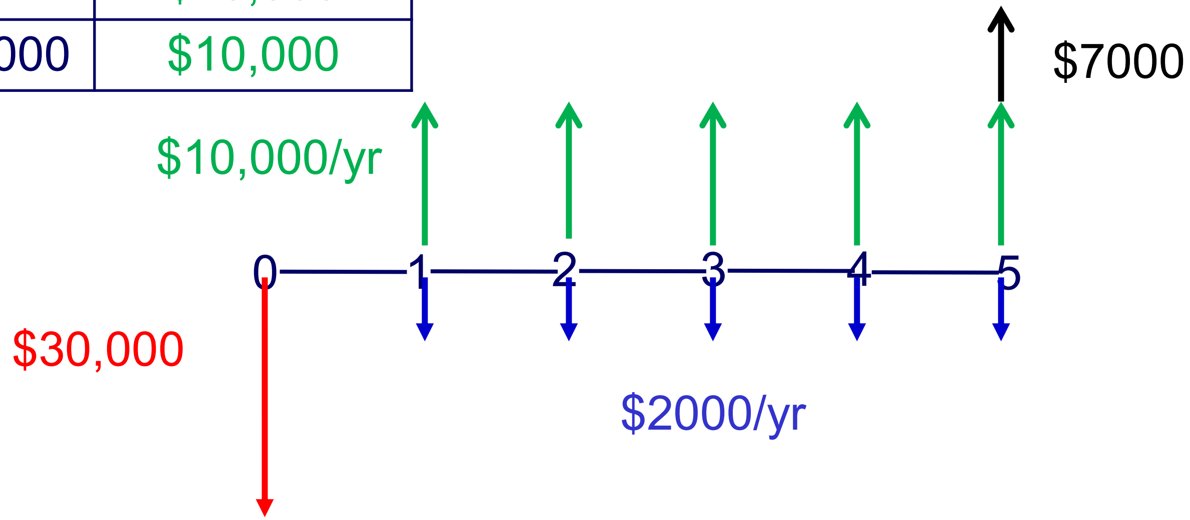
Purchase a new $30,000 machine,

- O&M costs = $2000/yr
- Savings = $10,000/yr
- Salvage value at Yr 5 = $7000

Draw the cash flow diagram

Example 3-1, Cash flows

End of Year	Costs & SV	Savings
0 (now)	−$30,000	$10,000
1	−2000	$10,000
2	−2000	$10,000
3	−2000	$10,000
4	−2000	$10,000
5	−2000+7000	$10,000

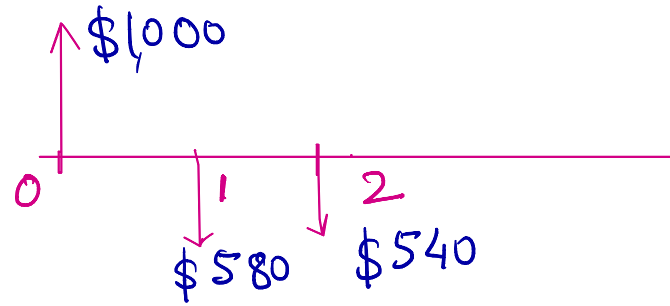


Example 3-2
Cash flow for repayment of a loan

EXAMPLE 3-2

A man borrowed $1000 from a bank at 8% interest. He agreed to repay the loan in two end-of-year payments. At the end of each year, he will repay half of the $1000 principal amount plus the interest that is due. Compute the borrower's cash flow.

Year	Principal	interest	Payment
0	\$1000		
1	\$1000	$\frac{8}{100} \times 1000 = 80$	$\frac{1000}{2} + 80 = 500 + 80 = \$580$
2	\$500	$\frac{8}{100} \times 500 = 40$	$500 + 40 = \$540$

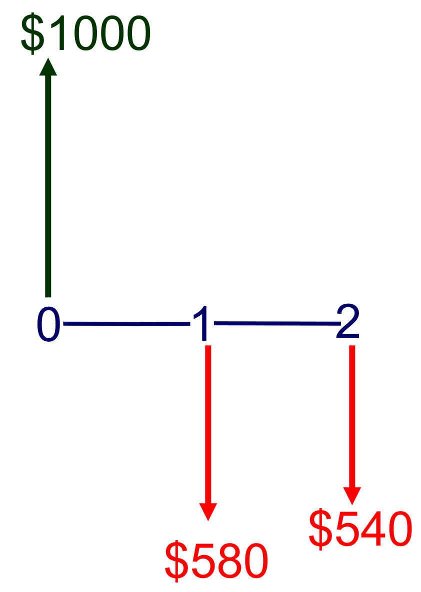


Example 3-2
Cash flow for repayment of a loan

To repay a loan of $1000 at 8% interest in 2 years

- Repay half of $1000 plus interest at the end of each year

Yr	Interest	Balance	Repayment	Cash Flow
0		1000		1000
1	80	500	500	−580
2	40	0	500	−540



Time Value of Money

Money has value

- Money can be leased or rented
- Payment is called interest
- If you put $1000 in a bank at 4% interest for one time period you will receive back your original $1000 plus $40

$1000 \times \frac{4}{100} = \$40$

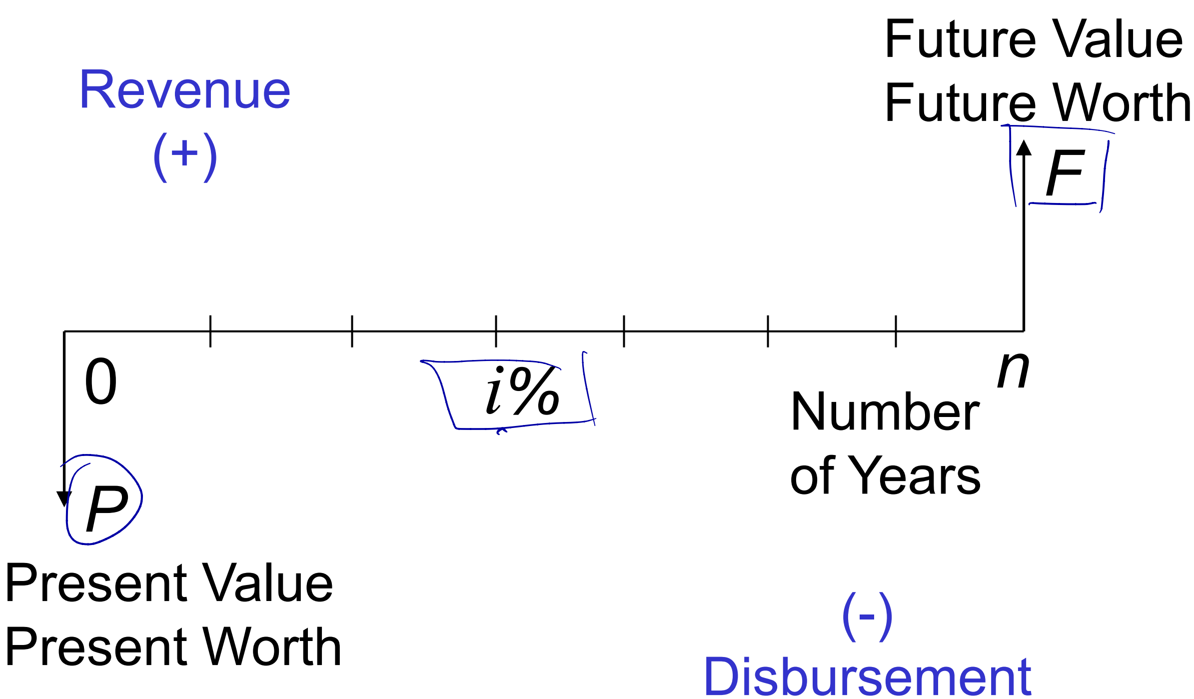
Original amount to be returned = $1000
Interest to be returned = $1000 x .04 = $40

Cash Flow Diagram

Invest P dollars at i% interest & receive F dollars after n years

$F = f(P, i\%, n)$

$P = f(F, i\%, n)$



Simple Interest on Loan

Is computed only on original sum—does not include interest earned or owed

P borrowed for n years

Total interest owed = $P \times i \times n$

- P = present sum of money
- i = interest rate
- n = number of periods (years)

Simple interest = $1000 x .04/period x 2 periods = $80