Cost-volume-profit (CVP) Analysis

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Basic Formula

Revenue	-	Variable Costs	-	Fixed Costs	=	Operating Income

Where the following supporting equations hold:

Revenue	=	Selling Price	x	Quantity Sold

and

Variable Costs	=	Variable Cost per Unit	x	Quantity Sold

Basic Formula Derivation

- The Basic Formula may be further rearranged and decomposed as follows:

Contribution Margin

$$\text{Revenues - Variable costs} - \text{Fixed costs} = \text{Operating income}$$

$$\left[\begin{pmatrix}\text{Selling price}\\ \times \\ \text{Quantity sold}\end{pmatrix} - \begin{pmatrix}\text{Variable cost per unit}\\ \times \\ \text{Quantity sold}\end{pmatrix}\right] - \text{Fixed costs} = \text{Operating income}$$

$$\left[(\text{Selling price - Variable cost per unit}) \times \text{Quantity sold}\right] - \text{Fixed costs} = \text{Operating income}$$

$$(\text{Contribution margin per unit} \times \text{Quantity sold}) - \text{Fixed costs} = \text{Operating income}$$

Contribution Margin

- **Contribution Margin** is the difference between total revenues and total variable costs
- **Contribution Margin per Unit** equals unit selling price less variable cost per unit. It indicates why operating income changes as the number of units sold changes
- **Contribution Margin Percentage (Ratio)** equals contribution margin per unit divided by Selling Price
  - **Contribution margin percentage**

    =Contribution margin per unit ÷ Selling price
  - Contribution margin percentage indicates how many cents out of every sales dollar are represented by Contribution Margin

Alternative Income Statement Formats

Contribution Income Statement Emphasizing Contribution Margin (in 000s)		
Revenues		$1,000
Variable Manufacturing Costs	$ 250	
Variable Nonmanufacturing Costs	270	520
Contribution Margin		480
Fixed Manufacturing Costs	160	
Fixed Nonmanufacturing Costs	138	298
Operating Income		$182

Financial Accounting Income Statement Emphasizing Gross Margin (in 000s)	
Revenues	$1,000
Cost of Goods Sold ($250+160)	410
Gross Margin	590
Nonmanufacturing Costs ($270+138)	408
Operating Income	$182

Breakeven Point

- **Breakeven point (BEP)** is that quantity of output sold at which total revenues equal total costs – that is, the quantity of output sold that result in **$0 of operating income.**

$$\text{Breakeven number of units} = \frac{\text{Fixed costs}}{\text{Contribution margin per unit}}$$

$$\text{Breakeven revenues} = \frac{\text{Fixed costs}}{\text{Contribution margin percentage}}$$

Breakeven Point Illustration

- Mary Frost is considering selling Do-All Software, a home-office software package, at a computer convention in Chicago. Mary knows she can purchase this software from a computer software wholesaler at $120 per package, with the privilege of returning all unsold packages and receiving a full $120 refund per package. She also knows that she would pay $2,000 to Computer Conventions, Inc., for the booth rental at the convention. She will incur no other costs, and she predicts that she can charge a price of $200 for Do-All Software. She must decide whether she should rent a booth.

Breakeven Point Illustration

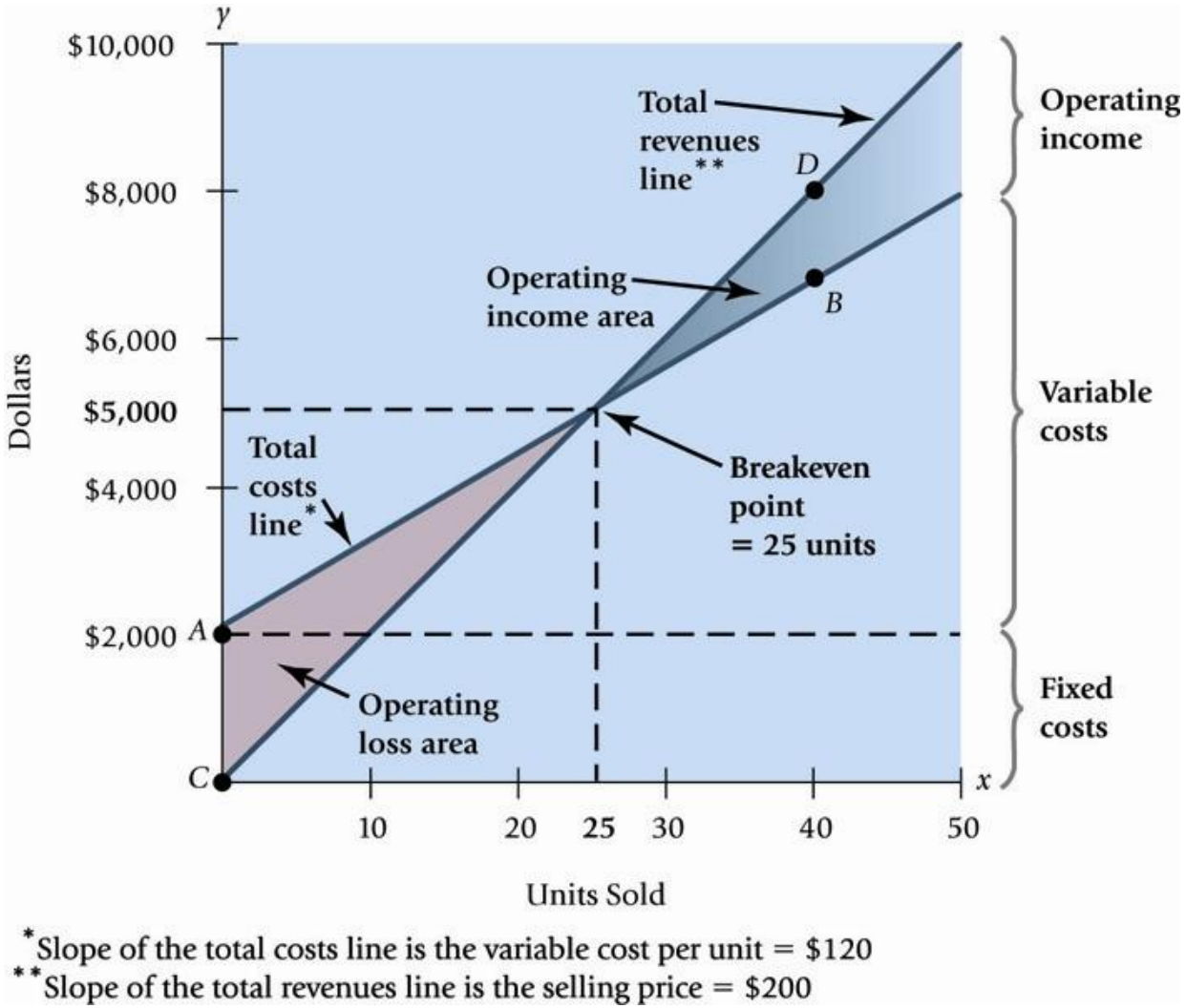
Contribution margin per unit = $200 - $120 = $80

Contribution margin ratio = $80/$200 = 40%

Breakeven number of units = $2,000 / $80 = 25 units

Breakeven revenues = $2,000/40% = $5,000

Breakeven Point: Graph Method



*Slope of the total costs line is the variable cost per unit = $120
**Slope of the total revenues line is the selling price = $200

Breakeven Point Extended: Profit Planning

- With a simple adjustment, the Breakeven Point formula can be modified to become a Profit Planning tool.

$$\text{Quantity of units required to be sold} = \frac{\text{Fixed costs} + \text{Target operating income}}{\text{Contribution margin per unit}}$$

Profit Planning Illustration

- How many units must Mary sell to earn an operating income of $1,200?

  ($1,200 + $2,000)/$80 = 40 units

- Revenues needed to earn operating income of $1,200

  ($1,200 + $2,000)/40% = $8,000

Using CVP Analysis for Decision Making, Illustration

- Suppose Mary anticipates selling 40 units at the convention, and Mary's operating income will be $1,200. Mary is considering placing an advertisement describing the product and its features in the convention brochure. The advertisement will cost $500. This cost is a fixed cost because it will not change regardless of the number of units Mary sells. She thinks that advertising will increase sales by 10% to 44 packages. Should Mary advertise?

Using CVP Analysis for Decision Making, Illustration

	40 Packages Sold without Advertisement (1)	44 Packages Sold with Advertisement (2)	Difference (3) = (2) – (1)
Revenues ($200 x 40, $200 x 44)	$8,000	$8,800	$800
Variable costs ($120 x 40, $120 x 44)	4,800	5,280	480
Contribution margin ($80 x 40, $80 x 44)	3,200	3,520	320
Fixed costs	2,000	2,500	500
Operating income	$1,200	$1,020	$(180)

Mary should not advertise!

Using CVP Analysis for Decision Making, Illustration

- Having decided not to advertise, Mary is contemplating whether to reduce the selling price to $175. At this price, she thinks she will sell 50 units. At this quantity, the software wholesaler who supplies Do-All Software will sell the packages to Mary for $115 per unit instead of $120. Should Mary reduce the selling price?

Using CVP Analysis for Decision Making, Illustration

Contribution margin from lowering price to $175: ($175 - $115) x 50 units	**$3,000**
Contribution margin from maintaining price at $200: ($200 - $120) x 40 units	**$3,200**
Change in contribution margin from lowering price	**$(200)**

Mary should not reduce the selling price!

Using CVP Analysis for Decision Making, Illustration

- Mary should also examine the effects of other decisions, such as simultaneously increasing advertising costs and lowering prices. In each case, Mary will compare the changes in contribution margin (through the effects on selling prices, variable costs, and quantities of units sold) to the changes in fixed costs, and she will choose the alternative that provides the highest operating income.

Product-Mix Decisions with Capacity Constraints

- The decisions made by a company about which products to sell and in what quantities.
- These decisions usually have only a short-run focus because the level of capacity can be expanded in the long run.
- **Decision Rule (with a constraint):** focus on the product that produces the highest contribution margin per unit of the constraining resource.

Product-Mix Decisions with Capacity Constraints Illustration

- Pandleton engineering makes cutting tools for metalworking operations. It makes two types of tools: R3, a regular cutting tool, and HP6, a high-precision cutting tool. R3 is manufactured on a regular machine, but HP6 must be manufactured on both the regular machine and a high-precision machine.

Product-Mix Decisions with Capacity Constraints Illustration

The following information is available:

	R3	HP6
Selling Price	$100	$150
Variable Manufacturing Cost per Unit	$60	$100
Variable Marketing Cost per Unit	$15	$35
Budgeted Total Fixed Overhead Cost	$350,000	$550,000
Hours Required to Produce One Unit on the Regular Machine	1.0	0.5

Additional Information Includes:

- Pendleton faces a capacity constraint on the regular machine of 50,000 hours per year.
- The capacity of the high precision machine is not a constraint.
- Of the 550,000 budgeted fixed overhead cost of HP6, $300,000 are lease payments for the high precision machine. This cost is charged entirely to HP6 because Pendleton uses the machine exclusively to produce HP6. The lease agreement for the high precision machine can be cancelled at any time without penalties.
- All other overhead costs are fixed and will not change.

Requirement 1: What product mix – that is, how many units of R3 and HP6 – will maximize Pendleton's operating income.

	R3	HP6
Selling price	$100	$150
Variable manufacturing c	60	100
Variable marketing cost p	15	35
Total variable costs per un	75	135
Contribution margin per unit	$ 25	$ 15
Contributi on margin per hour of the constraine d resource (the regular machine)	$\frac{\$25}{1} = \$25$	$\frac{\$15}{0.5} = \$30$
Total contribution m		
only R3 or only H		
R3: $25 × 50,000;	$1,250,000	$1,500,000
Less Lease costs of high-precision machine to produce and sell HP6	–	300,000
Net relevant benefit	$1,250,000	$1,200,000

First notice the contribution margin for product: R3 is higher

Next notice the CM per unit of scarce resource is higher for HP6

Finally, notice that R3 should be manufactured when all costs are considered

Product-Mix Decisions with Capacity Constraints Illustration

Requirement 2

Suppose that the capacity of the regular machines has been increased to 65,000 hours. Pendleton has been approached by Carter Corporation to supply 20,000 units of another cutting tool S3 for $120 per unit. Pendleton must either accept the order for all 20,000 units or reject it totally. S3 is exactly like R3 except that its variable manufacturing cost is $70 per unit. It takes one hour to produce one unit of S3 on the regular machine, and variable marketing cost equals $15 per unit.

What product mix should Pendleton choose to maximize operating income?

Product-Mix Decisions with Capacity Constraints Illustration

	R3	HP6	S3
Selling price	$100	$150	$120
Variable manufacturing costs per unit	60	100	70
Variable marketing costs per unit	15	35	15
Total variable costs per unit	75	135	85
Contribution margin per unit	$ 25	$ 15	$ 35
Contribution margin per hour of the constrained resource (the regular machine)	$\frac{\$25}{1} = \$25$	$\frac{\$15}{0.5} = \$30$	$\frac{\$35}{1} = \$35$

S3 has the highest contribution margin per hour on the regular machine and requires no additional investment such as leasing a high-precision machine.

To produce the 20,000 units of S3 requested by Carter Corporation, Pendleton would require 20,000 hours on the regular machine resulting in contribution margin of $35 × 20,000 = $700,000.

Pendleton now has 45,000 hours available on the regular machine to produce R3 or HP6.

	R3	HP6
Total contribution margin from selling only R3 or only HP6		
R3: $25 × 45,000; HP6: $30 × 45,000	$1,125,000	$1,350,000
Less Lease costs of high-precision machine to produce and sell HP 6	–	300,000
Net relevant benefit	$1,125,000	$1,050,000

Thus, the product mix that maximizes operating income is 20,000 units of S3, 45,000 units of R3, and zero units of HP6. This optimal mix results in a contribution margin of $1,825,000 ($700,000 from S3 and $1,125,000 from R3).

Pendleton should use all the 45,000 hours of available capacity to produce 45,000 units of R3.

Sensitivity Analysis

- **Sensitivity analysis** is a “what-if” technique that managers use to examine how an outcome will change if the original predicted data are not achieved or if an underlying assumption changes.

Sensitivity Analysis

- CVP Provides structure to answer a variety of "what-if" scenarios
- "What" happens to operating income "if":
  - Selling price changes
  - Quantity of units sold changes
  - Cost structure changes
    - Variable cost per unit changes
    - Fixed cost changes

Sensitivity Analysis Illustration

File Edit View Insert Format Tools Data Window Help

D5 fx =($A5+D$3)/(F1-$B5)

	A	B	C	D	E	F
1			Number of units required to be sold at $			200
2			Selling Price to Earn Target Operating Income of			
3		Variable Costs	$0	$1,200	$1,600	$2,000
4	Fixed Costs	per Unit	(Breakeven point)			
5	$2,000	$100	20	32[a]	36	40
6	$2,000	$120	25	40	45	50
7	$2,000	$150	40	64	72	80
8	$2,400	$100	24	36	40	44
9	$2,400	$120	30	45	50	55
10	$2,400	$150	48	72	80	88
11	$2,800	$100	28	40	44	48
12	$2,800	$120	35	50	55	60
13	$2,800	$150	56	80	88	96
14						
15	[a]Number of units required to be sold	$= \frac{\text{Fixed costs + Target operating income}}{\text{Contribution margin per unit}} = \frac{\$2,000 + \$1,200}{\$200 - \$100} = 32$				
16						

Margin of Safety

- One indicator of risk, the **Margin of Safety (MOS)** measures the amount by which budgeted (or actual) revenues exceeds breakeven revenues
  - Expressed in dollar amount, MOS = Budgeted revenues – Breakeven revenues
  - Expressed in units, MOS = Budgeted sales quantity – Breakeven quantity
  - MOS answers the "what-if" question: if budgeted revenues are above breakeven and drop, how far can they fall below budget before the breakeven point is reached
- The **MOS Percentage (Ratio)** removes the firm's size from the output, and expresses itself in the form of a percentage:
  - MOS Percentage = MOS in dollars ÷ Budgeted revenues

Margin of Safety Illustration

- Assume that Mary has fixed costs of $2,000, a selling price of $200, and variable cost per unit of $120. For 40 units sold, the budgeted revenues are $8,000 and the budgeted operating income is $1,200.

Margin of safety (in dollars)= $8,000 - $5,000 = $3,000

Margin of safety (in units) = 40 – 25 = 15 units

Margin of safety percentage = $3,000/$8,000 = 37.5%

Margin of Safety Illustration

- The high margin of safety gives Mary confidence that she is unlikely to suffer a loss
- A low margin of safety increases the risk of a loss. If Mary does not have the tolerance for high level of risk, she will prefer not to rent a booth at the convention

Cost Planning and CVP

- CVP-based sensitivity analysis highlights the risks and returns as fixed costs are substituted for variable costs in a company's cost structure.

			Number of units required to be sold at $200 selling price to earn target operating income of	
	Fixed Cost	**Variable Cost**	**$0 (Breakeven point)**	**$2,000**
Line 6	$2,000	$120	25	50
Line 11	$2,800	$100	28	48

Compared to Line 6, Line 11, with higher fixed costs, has more risk of loss but requires fewer units to be sold to earn operating income of $2,000.

Operating Leverage

- The risk-return trade-off across alternative cost structures can be measured as **operating leverage**, at *any given level of sales:*

$$\text{Degree of operating leverage} = \frac{\text{Contribution margin}}{\text{Operating income}}$$

- Operating leverage describes the effects that fixed costs have on changes in operating income as changes occur in units sold and contribution margin

Operating Leverage Illustration

- Suppose Computer Conventions, Inc. offers Mary three rental alternatives:

Option 1: $2,000 fixed fee

Option 2: $800 fixed fee plus 15% of convention revenues

Option 3: 25% of convention revenues with no fixed fee

Operating Leverage Illustration

- The following table shows the degree of operating leverage at sales of 40 units for the three rental options:

	Option 1	Option 2	Option 3
1. Contribution margin per unit	$80	$50	$30
2. Contribution margin (Row 1 x 40 units)	$3,200	$2,000	$1,200
3. Operating income	$1,200	$1,200	$1,200
4. Degree of operating leverage (Row 2 divided by Row 3)	2.67	1.67	1.00

When sales are 40 units, a percentage change in sales and contribution margin will result in 2.67 times that percentage change in operating income for Option 1, but the same percentage change in operating income for Option 3.

Operating Leverage

- Why must managers monitor operating leverage carefully?

  Consider companies such as US Airways, United Airlines, WorldCom, and Global Crossing. Their high operating leverage was a major reason for their financial problems. Anticipating high demand for their services, these companies borrowed money to acquire assets, resulting in high fixed costs. As sales declined in 2001 and 2002, these companies suffered losses and could not generate sufficient cash to service their interest and debt, causing them to seek bankruptcy protection.

Actions to Reduce Fixed Costs

- Move manufacturing facilities to lower-cost countries
- Purchase products from lower-cost suppliers instead of manufacturing products themselves

Effects of Sales-Mix on CVP

- The formulae presented to this point have assumed a single product is produced and sold
- A more realistic scenario involves multiple products sold, in different volumes, with different costs
- The same formulae are used, but instead use average contribution margins for bundles of products.

Effects of Sales-Mix on CVP, Illustration

- Suppose Mary is now budgeting for a subsequent computer convention in Boston. She plans to sell two different software products – Do-All and Superword – and budgets the following

	Do-All	Superword	Total
Expected Sales	60	40	100
Revenues, $200 and $100 per unit	12,000	4,000	16,000
Variable costs, $120 and $70 per unit	7,200	2,800	10,000
Contribution margin, $80 and $30 per unit	4,800	1,200	6,000
Fixed costs			4,500
Operating income			$1,500

Effects of Sales-Mix on CVP, Illustration

- In contrast to the single-product (service) situation, the number of total units that must be sold to break even in a multiproduct company depends on the sales mix - the combination of the number of units of Do-All sold and the number of units of Superword sold.
- We assume that the budgeted sales mix will not change at different levels of total unit sales. That is, we think of Mary selling a bundle of 3 units of Do-All and 2 units of Superword.

Effects of Sales-Mix on CVP, Illustration

- Each bundle yields a contribution margin of $300.

  ($80 x 3) + ($30 x 2) = $300

- Breakeven point in bundles:

  $4,500 / $300 = 15 bundles

Effects of Sales-Mix on CVP, Illustration

Breakeven point in units	
Do-All: 15 bundles x 3 units per bundle	45 units
Superword: 15 bundles x 2 units per bundle	30 units
Total number of units to breakeven	75 units

Assumptions in CVP Analysis

- Changes in production/sales volume are the sole cause for cost and revenue changes
- Total costs consist of fixed costs and variable costs
- Revenue and costs behave and can be graphed as a linear function (a straight line)
- Selling price, variable cost per unit and fixed costs are all known and constant
- In many cases only a single product will be analyzed. If multiple products are studied, their relative sales proportions are known and constant
- The time value of money (interest) is ignored

Thank You!
Q&A