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NPTEL ONLINE CERTIFICATION COURSES

Business Analytics for Management Decision

Predictive Modeling and Analysis

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Predictive Modeling and Analysis

- Logic-Driven Modeling
- Data-Driven Modeling
- Analyzing Uncertainty and Model Assumptions
- Model Analysis Using *Risk Solver Platform*

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Logic-Driven Modeling

- Predictive modeling is the heart and soul of business decisions.
- Building decision models is more of an art than a science.
- Creating good decision models requires:
  - solid understanding of business functional areas
  - knowledge of business practice and research
  - logical skills
- It is best to start simple and enrich models as necessary.

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Logic-Driven Modeling

Example 8.1 The Economic Value of a Customer

- A restaurant customer dines 6 times a year and spends an average of $50 per visit.
- The restaurant realizes a 40% margin on the average bill for food and drinks.
- Annual gross profit on a customer = $50(6)(0.40)
  = $120
- 30% of customers do not return each year.
- Average lifetime of a customer = 1/.3 = 3.33 years
- Average gross profit for a customer = $120(3.33)
  = $400

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Logic-Driven Modeling

Example 8.1 (continued)
The Economic Value of a Customer

$$V = \frac{R \times F \times M}{D}$$

- V = value of a loyal customer
- R = revenue per purchase
- F = purchase frequency (number visits per year)
- M = gross profit margin
- D = defection rate (proportion customers not returning each year)

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Logic-Driven Modeling

Example 8.2 A Profit Model

- Develop a decision model for predicting profit in face of uncertain demand.

P = profit
R = revenue
C = cost

p = unit price
c = unit cost
F = fixed cost
S = quantity sold
D = demand
Q = quantity produced

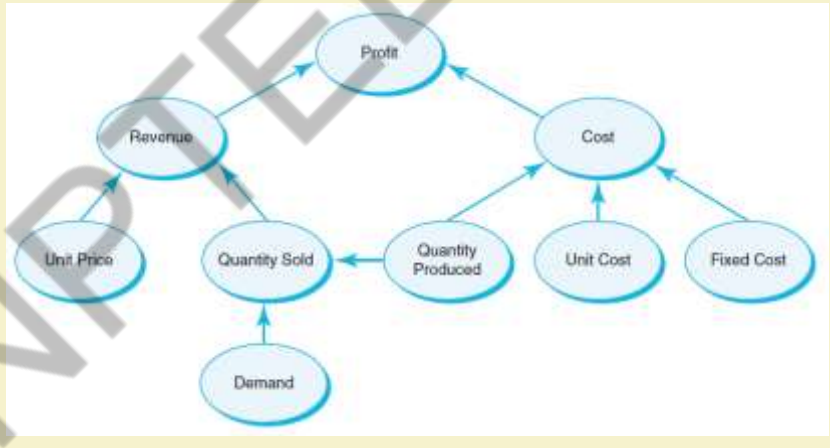


Figure 8.1

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Logic-Driven Modeling

Example 8.2 (continued) A Profit Model

- Cost = fixed cost + variable cost

  $C = F + cQ$

- Revenue = price times quantity sold

  $R = pS$

- Quantity sold = Minimum{demand, quantity sold}

  $S = \min\{D, Q\}$

- Profit = Revenue — Cost

  $P = p^*\min\{D, Q\} - (F + cQ)$

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Logic-Driven Modeling

Example 8.2 (continued) A Profit Model

- p = \$40
- c = \$24
- F = \$400,000
- D = 50,000
- Q = 40,000

	A	B	C
1	**Profit Model**		
2			
3	**Data**		
4			
5	**Unit Price**	\$40.00	
6	**Unit Cost**	\$24.00	
7	**Fixed Cost**	\$400,000.00	
8	**Demand**	50000	
9			
10			
11	**Model**		
12			
13	**Unit Price**	\$40.00	
14	**Quantity Sold**	40000	
15	**Revenue**		\$1,600,000.00
16			
17	**Unit Cost**	\$24.00	
18	**Quantity Produced**	40000	
19	**Variable Cost**		\$960,000.00
20	**Fixed Cost**		\$400,000.00
21			
22	**Profit**		\$240,000.00

Figure 8.2a

Compute:

- $R = p^* \min\{D,Q\}$
  $= 40(40,000) = 1,600,000$
- $C = F + cQ = 1,360,000$
- $= 400,000 + 24(40,000)$
- $P = R - C = 1,600,000 - 1,360,000 = \$240,000$

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Logic-Driven Modeling

Example 8.2 (continued) A Profit Model

	A	B	C
1	Profit Model		
2			
3	Data		
4			
5	Unit Price	$40.00	
6	Unit Cost	$24.00	
7	Fixed Cost	$400,000.00	
8	Demand	50000	
9			
10			
11	Model		
12			
13	Unit Price	$40.00	
14	Quantity Sold	40000	
15	Revenue		$1,600,000.00
16			
17	Unit Cost	$24.00	
18	Quantity Produced	40000	
19	Variable Cost		$960,000.00
20	Fixed Cost		$400,000.00
21			
22	Profit		$240,000.00

Figure 8.2a

	A	B	C
1	Profit Model		
2			
3	Data		
4			
5	Unit Price	40	
6	Unit Cost	24	
7	Fixed Cost	400000	
8	Demand	50000	
9			
10			
11	Model		
12			
13	Unit Price	=B5	
14	Quantity Sold	=MIN(B8,B18)	
15	Revenue		=B13*B14
16			
17	Unit Cost	=B6	
18	Quantity Produced	40000	
19	Variable Cost		=B17*B18
20	Fixed Cost		=B7
21			
22	Profit		=C15-C19-C20

Figure 8.2b

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Logic-Driven Modeling

Example 8.3 New-Product Development

- Moore Pharmaceuticals needs to decide whether to conduct clinical trials and seek FDA approval for a newly developed drug.

Estimated figures:

- R&D cost = $700 million
- Clinical trials cost = $150 million
- Market size = 2 million people
- Market size growth = 3% per year

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Logic-Driven Modeling

Example 8.3 (continued) New-Product Development

Additional estimated figures

- Market share = 8%
- Market share growth = 20% per year (for 5 years)
- Revenue from a monthly prescription = $130
- Variable cost for a monthly prescription = $40
- Discount rate for net present value = 9%

Moore Pharmaceuticals wants to determine net present value for the next 5 years and to determine how long it will take to recover fixed costs.

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Logic-Driven Modeling

Example 8.3 (continued) New-Product Development

	A	B	C	D	E	F
1	Moore Pharmaceuticals					
2						
3	Data					
4						
5	Market size	2000000				
6	Unit (monthly Rx) revenue	130				
7	Unit (monthly Rx) cost	40				
8	Discount rate	0.09				
9						
10	Project Costs					
11	R&D	700000000				
12	Clinical Trials	150000000				
13	Total Project Costs	=B11+B12				
14						
15	Model					
16						
17	Year	1	2	3	4	5
18	Market growth factor		0.03	0.03	0.03	0.03
19	Market size	=B5	=B19*(1+C18)	=C19*(1+D18)	=D19*(1+E18)	=E19*(1+F18)
20	Market share growth rate		0.2	0.2	0.2	0.2
21	Market share	0.08	=B21*(1+C20)	=C21*(1+D20)	=D21*(1+E20)	=E21*(1+F20)
22	Sales	=B19*B21	=C19*C21	=D19*D21	=E19*E21	=F19*F21
23						
24	Annual Revenue	=B22*$B$6*12	=C22*$B$6*12	=D22*$B$6*12	=E22*$B$6*12	=F22*$B$6*12
25	Annual Costs	=B22*$B$7*12	=C22*$B$7*12	=D22*$B$7*12	=E22*$B$7*12	=F22*$B$7*12
26	Profit	=B24-B25	=C24-C25	=D24-D25	=E24-E25	=F24-F25
27						
28	Cumulative Net Profit	=B26-B13	=B28+C26	=C28+D26	=D28+E26	=E28+F26
29						
30	Net Present Value	=NPV(B8,B26:F26)-B13				

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Figure 8.3b

Logic-Driven Modeling

Example 8.3 (continued) New-Product Development

	A	B	C	D	E	F
1	Moore Pharmaceuticals					
2						
3	Data					
4						
5	Market size	2,000,000				
6	Unit (monthly Rx) revenue	$ 130.00				
7	Unit (monthly Rx) cost	$ 40.00				
8	Discount rate	9%				
9						
10	Project Costs					
11	R&D	$ 700,000,000				
12	Clinical Trials	$ 150,000,000				
13	Total Project Costs	$ 850,000,000				
14						
15	Model					
16						
17	Year	1	2	3	4	5
18	Market growth factor		3.00%	3.00%	3.00%	3.00%
19	Market size	2,000,000	2,060,000	2,121,800	2,185,454	2,251,018
20	Market share growth rate		20.00%	20.00%	20.00%	20.00%
21	Market share	8.00%	9.60%	11.52%	13.82%	16.59%
22	Sales	160,000	197,760	244,431	302,117	373,417
23						
24	Annual Revenue	$ 249,600,000	$ 308,505,600	$ 381,312,922	$ 471,302,771	$ 582,530,225
25	Annual Costs	$ 76,800,000	$ 94,924,800	$ 117,327,053	$ 145,016,237	$ 179,240,069
26	Profit	$ 172,800,000	$ 213,580,800	$ 263,985,869	$ 326,286,534	$ 403,290,156
27						
28	Cumulative Net Profit	$ (677,200,000)	$ (463,619,200)	$ (199,633,331)	$ 126,653,203	$ 529,943,358
29						
30	Net Present Value	$ 185,404,860				

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NPV = $185 million

Profitable in 4th year

Figure 8.3a

Logic-Driven Modeling

Single-Period Purchase Decisions

- One-time purchase decisions often must be made in the face of uncertain demand.

Newsvendor Problem:

How many newspapers to purchase each day?

- C = cost to purchase a newspaper
- Q = number of newspapers the vendor purchases
- D = number of newspapers demanded
- R = revenue from selling a newspaper
- S = salvage value of unsold newspapers
- Net profit = $R(\min\{Q,D\}) + S(\max\{0,Q-D\}) - CQ$

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Logic-Driven Modeling

Example 8.4

A Single-Period Purchase Decision Model

- A small candy store makes Valentine's Day gift boxes that cost $12 and sell for $18.
- In the past, at least 40 boxes have sold by Valentine's Day but the actual amount is unknown.
- After the holiday, boxes are discounted 50%.

Determine net profit on the gift boxes.

- $C = 12$, $R = 18$, $S = 9$
- Net profit = $R(\min\{Q,D\}) + S(\max\{0,Q-D\}) - CQ$

  $= 18(\min\{Q,D\}) + 9(\max\{0,Q-D\}) - 12Q$

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Logic-Driven Modeling

Example 8.4

A Single-Period Purchase Decision Model

- Net profit $= 18(\min\{Q, D\}) + 9(\max\{0, Q - D\}) - 12Q$

	A	B
1	Newsvendor Model	
2		
3	Data	
4		
5	Selling price	$ 18.00
6	Cost	$ 12.00
7	Discount price	$ 9.00
8		
9	Model	
10		
11	Demand	41
12	Purchase Quantity	44
13		
14	Quantity Sold	41
15	Surplus Quantity	3
16		
17	Profit	$ 237.00

	A	B
1	Newsvendor Model	
2		
3	Data	
4		
5	Selling price	18
6	Cost	12
7	Discount price	9
8		
9	Model	
10		
11	Demand	41
12	Purchase Quantity	44
13		
14	Quantity Sold	=MIN(B11,B12)
15	Surplus Quantity	=MAX(0,B12-B11)
16		
17	Profit	=B14*B5+B15*B7-B12*B6

Figure 8.4

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Logic-Driven Modeling

Example 8.5 A Hotel Overbooking Model

- A popular resort hotel has 300 rooms.
- The room rate is $120 per night.
- Reservations can be cancelled by 6:00 p.m.
- Cost of overbooking is $100 per occurrence.

Determine net revenue on the rooms.

- $Q = 300$, $P = 120$, $C = 100$
- D = Reservations — Cancellations
- Net revenue = $P(\min\{300, D\}) - C(\max\{0, D-Q\})$
  $= 120(\min\{300, D\}) - 100(\max\{0, D-300\})$

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Logic-Driven Modeling

Example 8.5 (continued)

A Hotel Overbooking Model

Net revenue = $120(\min\{300, D\}) - 100(\max\{0, D - 300\})$

	A	B
1	Hotel Overbooking Model	
2		
3	Data	
4		
5	Rooms available	300
6	Price	$120
7	Overbooking cost	$100
8		
9	Model	
10		
11	Reservation limit	300
12	Customer demand	290
13	Reservations made	290
14	Cancellations	15
15	Customer arrivals	275
16	Overbooked customers	0
17		
18	Net revenue	$33,000

	A	B
1	Hotel Overbooking Model	
2		
3	Data	
4		
5	Rooms available	300
6	Price	120
7	Overbooking cost	100
8		
9	Model	
10		
11	Reservation limit	300
12	Customer demand	290
13	Reservations made	=MIN(B11,B12)
14	Cancellations	15
15	Customer arrivals	=B13-B14
16	Overbooked customers	=MAX(0,B15-B5)
17		
18	Net revenue	=MIN(B15,B5)*B6-B16*B7

Figure 8.5

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Logic-Driven Modeling



Analytics in Practice:
Using an Overbooking Model
at a Student Health Clinic

- East Carolina University's health clinic experiences a large number of no-shows.
- A quality improvement team analyzed an overbooking option.
- Analytic models developed suggested that an overbooking rate of 7.3% would result in savings of $95,000 per semester.

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Logic-Driven Modeling

Example 8.6 A Retirement-Planning Model

- Start work at age 22, earning $50,000 per year.
- Expect a salary increase of 3% per year.
- Required to contribute 8% to retirement.
- Employer contributes 35% of that amount.
- Expect an annual return of 8% on the portfolio.

Determine the value of the retirement account when the employee is 50 years old.

Logic-Driven Modeling

Example 8.6 (continued) Retirement-Planning Model

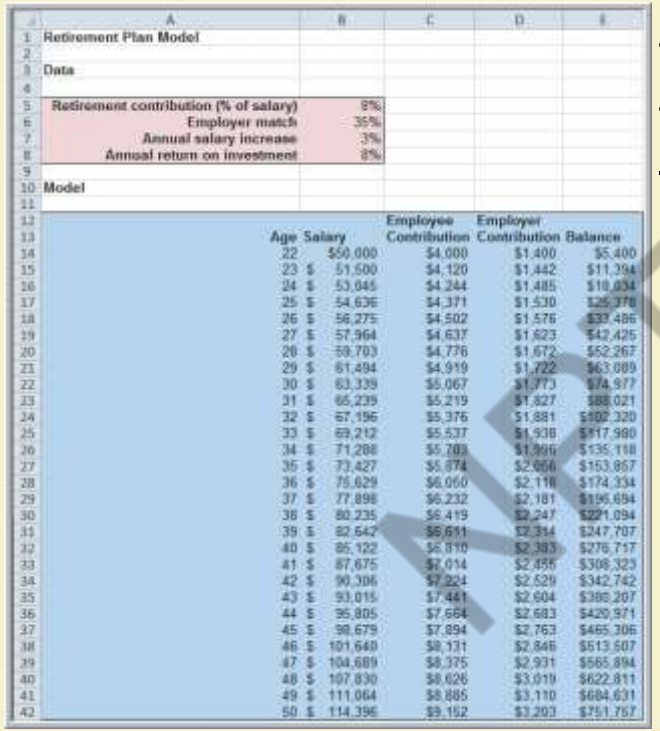
- Salary = 1.03(previous year's salary)
- Employee contribution = 0.08(salary)
- Employer contribution = 0.35(employee contrib.)
- Value of account = 1.08(previous value) + employee contribution + employer contribution

	A	B	C	D	E
1	Retirement Plan Model				
2					
3	Data				
4					
5	Retirement contribution (% of salary)	0.08			
6	Employer match	0.35			
7	Annual salary increase	0.03			
8	Annual return on investment	0.08			
9					
10	Model				
11					
12			Employee	Employer	
13	Age	Salary	Contribution	Contribution	Balance
14	22	50000	=B14*$B$5	=$B$6*C14	=C14+D14
15	23	= B14*(1+$B$7)	=B15*$B$5	=$B$6*C15	=E14*(1+$B$8) + C15+D15
16	24	= B15*(1+$B$7)	=B16*$B$5	=$B$6*C16	=E15*(1+$B$8) + C16+D16
17	25	= B16*(1+$B$7)	=B17*$B$5	=$B$6*C17	=E16*(1+$B$8) + C17+D17

Figure 8.6a

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Logic-Driven Modeling



	A	B	C	D	E
1	Retirement Plan Model				
2					
3	Data				
4					
5	Retirement contribution (% of salary)	8%			
6	Employer match	35%			
7	Annual salary increase	3%			
8	Annual return on investment	8%			
9					
10	Model				
11					
12			Employee	Employer	
13	Age	Salary	Contribution	Contribution	Balance
14	22	$50,000	$4,000	$1,400	$5,400
15	23	$ 51,500	$4,120	$1,442	$11,394
16	24	$ 53,045	$4,244	$1,485	$18,034
17	25	$ 54,636	$4,371	$1,530	$25,378
18	26	$ 56,275	$4,502	$1,576	$33,486
19	27	$ 57,964	$4,637	$1,623	$42,425
20	28	$ 59,703	$4,776	$1,672	$52,267
21	29	$ 61,494	$4,919	$1,722	$63,089
22	30	$ 63,339	$5,067	$1,773	$74,977
23	31	$ 65,239	$5,219	$1,827	$88,021
24	32	$ 67,196	$5,376	$1,881	$102,320
25	33	$ 69,212	$5,537	$1,938	$117,980
26	34	$ 71,288	$5,703	$1,996	$135,118
27	35	$ 73,427	$5,874	$2,056	$153,857
28	36	$ 75,629	$6,050	$2,118	$174,334
29	37	$ 77,898	$6,232	$2,181	$196,694
30	38	$ 80,235	$6,419	$2,247	$221,094
31	39	$ 82,642	$6,611	$2,314	$247,707
32	40	$ 85,122	$6,810	$2,383	$276,717
33	41	$ 87,675	$7,014	$2,455	$308,323
34	42	$ 90,306	$7,224	$2,529	$342,742
35	43	$ 93,015	$7,441	$2,604	$380,207
36	44	$ 95,805	$7,664	$2,683	$420,971
37	45	$ 98,679	$7,894	$2,763	$465,306
38	46	$ 101,640	$8,131	$2,846	$513,507
39	47	$ 104,689	$8,375	$2,931	$565,894
40	48	$ 107,830	$8,626	$3,019	$622,811
41	49	$ 111,064	$8,885	$3,110	$684,631
42	50	$ 114,396	$9,152	$3,203	$751,757

Example 8.6 (continued) Retirement Planning Model

Value at 22 years old = $5,400

Value at 50 years old = $751,757

Figure 8.6b

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Data-Driven Modeling

Example 8.7: Modeling Retail Markdown Pricing Decisions

- In the spring, a department store introduces a new line of bathing suits that sells for $70.
- The store purchases 1000 of these bathing suits.
- During the prime selling season, the store sells an average of 7 units per day at full price (40 days).
- On 10 sale days, the price is discounted 30% and sales increase to 32.2 units per day.
- Around July 4^{th}, the price is marked down 70% to sell off remaining inventory.
- Determine total revenue from the bathing suits.

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Data-Driven Modeling

Example 8.7 (continued) Modeling Retail Markdown Pricing Decisions

Assume a linear trend model between sales and price:

daily sales = $a - b$(price)

$7 = a - b(70)$

$32.2 = a - b(49)$

Daily sales = 91 – 1.2(price)

	A	B	C
1	Markdown Pricing Model		
2			
3	Data		
4	Retail price	70	
5	Inventory	1000	
6	Selling season (days)	50	
7	Days at full retail	40	
8	Intermediate markdown	0.3	
9	Clearance markdown	0.7	
10	Demand function		
11	a	91	
12	b	1.2	
13			
14	Model		
15			
16	Full Retail Sales		
17	Retail price	=B4	
18	Daily sales	=B11-B12*B17	
19	Days at retail price	=B7	
20	Units sold at retail	=B18*B19	
21	Retail revenue	=B20*B17	
22	Discount Sales		
23	Discount	=B6	
24	Discount price	=B17*(1-B23)	
25	Daily sales	=B11 - B12*B24	
26	Unit sold	=MIN(B25*(B6-B19),B5-B20)	
27	Discount revenue	=B26*B24	
28	Clearance Sales		
29	Clearance price	=B4*(1-B9)	
30	Units sold at clearance	=MAX(0,B5-B20-B26)	
31	Clearance revenue	=B29*B30	
32			
33	Total revenue	=C21+C27+C31	

Figure 8.7

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Data-Driven Modeling

Example 8.7 (continued)

Revenue from full retail sales

= units sold * days * price

= (7)*(40)*(70)

= $19,600

Revenue from sale weekends

= (32.2)*(10)*(49)

= $15,778

Revenue from clearance sales

= leftovers * price

= (1000−7(40) − 32.2(10))*(21)

= (398)(21)

= $8,358

	A	B	C
1	Markdown Pricing Model		
2			
3	Data		
4	Retail price	70	
5	Inventory	1000	
6	Selling season (days)	50	
7	Days at full retail	40	
8	Intermediate markdown	0.3	
9	Clearance markdown	0.7	
10	Demand function		
11	a	91	
12	b	1.2	
13			
14	Model		
15			
16	Full Retail Sales		
17	Retail price	=B4	
18	Daily sales	=B11-B12*B17	
19	Days at retail price	=B7	
20	Units sold at retail	=B18*B19	
21	Retail revenue	=B20*B17	
22	Discount Sales		
23	Discount	=B6	
24	Discount price	=B17*(1-B23)	
25	Daily sales	=B11 - B12*B24	
26	Unit sold	=MIN(B25*(B6-B19),B5-B20)	
27	Discount revenue	=B26*B24	
28	Clearance Sales		
29	Clearance price	=B4*(1-B9)	
30	Units sold at clearance	=MAX(0,B5-B20-B26)	
31	Clearance revenue	=B29*B30	
32			
33	Total revenue	=C21+C27+C31	

Figure 8.7

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Data-Driven Modeling

Example 8.7 (continued)

Modeling Retail Markdown Pricing Decisions

	A	B	C
1	Markdown Pricing Model		
2			
3	Data		
4	Retail price	70	
5	Inventory	1000	
6	Selling season (days)	50	
7	Days at full retail	40	
8	Intermediate markdown	0.3	
9	Clearance markdown	0.7	
10	Demand function		
11	a	91	
12	b	1.2	
13			
14	Model		
15			
16	Full Retail Sales		
17	Retail price	=B4	
18	Daily sales	=B11-B12*B17	
19	Days at retail price	=B7	
20	Units sold at retail	=B18*B19	
21		Retail revenue	=B20*B17
22	Discount Sales		
23	Discount	=B8	
24	Discount price	=B17*(1-B23)	
25	Daily sales	=B11 - B12*B24	
26	Unit sold	=MIN(B25*(B6-B19),B5-B20)	
27		Discount revenue	=B26*B24
28	Clearance Sales		
29	Clearance price	=B4*(1-B9)	
30	Units sold at clearance	=MAX(0,B5-B20-B26)	
31		Clearance revenue	=B29*B30
32			
33		Total revenue	=C21+C27+C31

	A	B	C
1	Markdown Pricing Model		
2			
3	Data		
4	Retail price	$70.00	
5	Inventory	1000	
6	Selling season (days)	50	
7	Days at full retail	40	
8	Intermediate markdown	30%	
9	Clearance markdown	70%	
10	Demand function		
11	a	91	
12	b	1.2	
13			
14	Model		
15			
16	Full Retail Sales		
17	Retail price	$70.00	
18	Daily sales	7.00	
19	Days at retail price	40	
20	Units sold at retail	280	
21		Retail revenue	$19,600.00
22	Discount Sales		
23	Discount	30%	
24	Discount price	$49.00	
25	Daily sales	32.20	
26	Unit sold	322	
27		Discount revenue	$15,778.00
28	Clearance Sales		
29	Clearance price	$21.00	
30	Units sold at clearance	398	
31		Clearance revenue	$8,358.00
32			
33		Total revenue	$43,736.00

Total revenue = $43,736

Figure 8.7

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Data-Driven Modeling

Modeling Relationships and Trends in Data

- Create charts to better understand data sets.
- For cross-sectional data, use a scatter chart.
- For time series data, use a line chart.
- Consider using mathematical functions to model relationships.

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Data-Driven Modeling

- Common mathematical functions used to model relationships in data:

Linear	$y = a + bx$
Logarithmic	$y = ln(x)$
Polynomial (2nd order)	$y = ax^2 + bx + c$
Polynomial (3rd order)	$y = ax^3 + bx^2 + dx + e$
Power	$y = ax^b$
Exponential	$y = ab^x$

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Data-Driven Modeling

Excel *Trendline* tool

Click on a chart
- *Chart tools*
- *Layout*
- *Trendline*

Choose a Trendline.
Choose whether to display equation and *R*-squared.

R-squared values closer to 1 indicate better fit of the Trendline to the data.

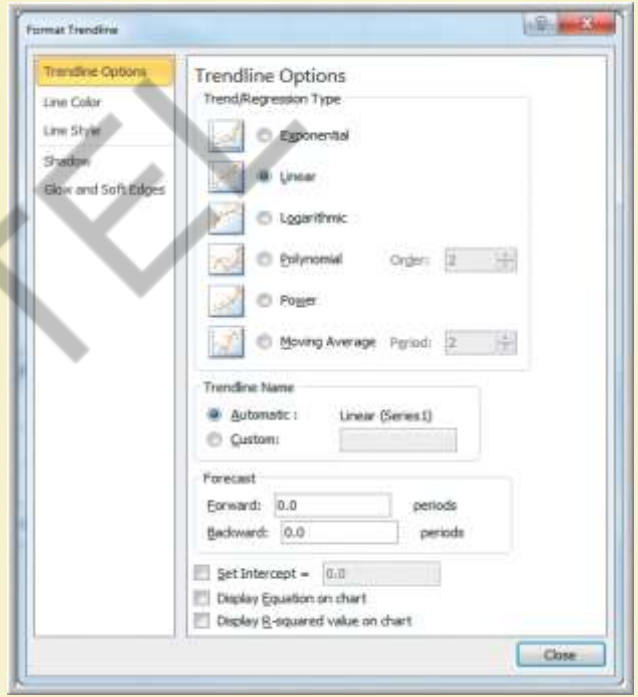


Figure 8.8

NPTEL

Data-Driven Modeling

Example 8.8 Modeling a Price-Demand Function

Linear demand function:

Sales = -9.5116(price) + 20512

	A	B
1	Price-Sales Data	
2		
3	Price	Demand
4	$50.00	19964.085
5	$60.00	19706.855
6	$70.00	20240.83
7	$80.00	19698.807
8	$90.00	20095.808
9	$100.00	19390.994
10	$110.00	19430.071
11	$120.00	19273.695
12	$130.00	18716.381
13	$140.00	18925.364
14	$150.00	19484.776
15	$160.00	18934.879
16	$170.00	18915.765
17	$180.00	18893.373
18	$190.00	18961.622
19	$200.00	18443.294
20	$210.00	18811.981
21	$220.00	18561.917
22	$230.00	18158.619
23	$240.00	18412.56
24	$250.00	17771.387



Figure 8.9

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Data-Driven Modeling

Example 8.9 Predicting Crude Oil Prices

- Line chart of historical crude oil prices

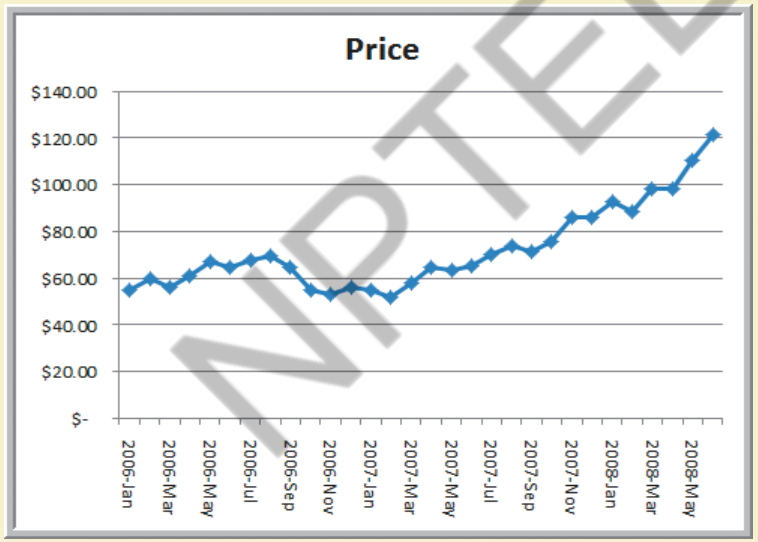


Figure 8.10

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Data-Driven Modeling

Example 8.9 (continued) Predicting Crude Oil Prices

- Excel's *Trendline* tool is used to fit various functions to the data.

Logarithmic	$y = 13 \ln(x) + 39$	$R^2 = 0.382$
Power	$y = 45.96x^{0.0169}$	$R^2 = 0.397$
Exponential	$y = 50.5e^{0.021x}$	$R^2 = 0.664$
Polynomial 2°	$y = 0.13x^2 - 2.4x + 68$	$R^2 = 0.905$
Polynomial 3°	$y = 0.005x^3 - 0.111x^2 + 0.648x + 59.5$	$R^2 = 0.928$ *

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Data-Driven Modeling

Example 8.9 (continued) Predicting Crude Oil Prices

- Third Order Polynomial Trendline fit to the data

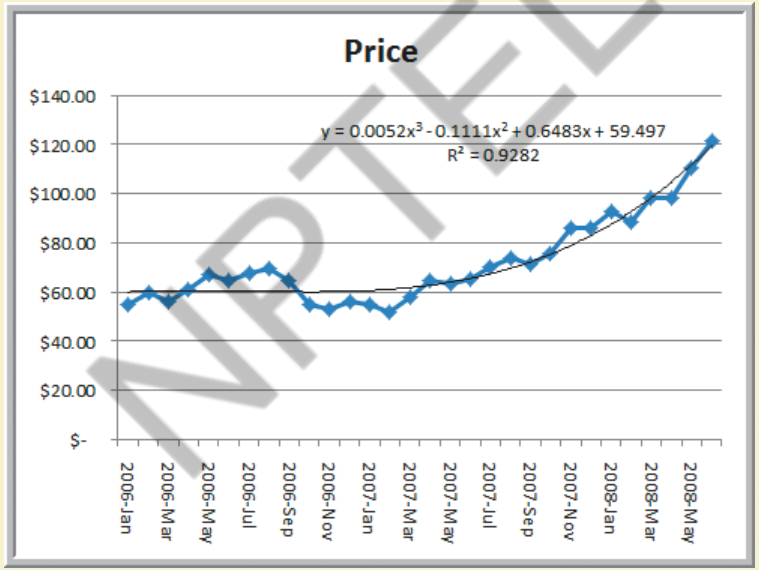


Figure 8.11

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Analyzing Uncertainty and Model Assumptions

What-If Analysis

- Spreadsheet models allow you to easily evaluate what-if questions.
- How do changes in model inputs (that reflect key assumptions) affect model outputs?
- Systematic approaches to what-if analysis make the process easier and more useful.

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Analyzing Uncertainty and Model Assumptions

Example 8.10 Using Excel for What-If Analysis

- Uncertain demand in the *Profit Model*.

	A	B	C	D	E	F	G	H	I
1	**Profit Model**								
2									
3	**Data**				**Demand**	**Qty. Sold**	**Revenue**	**Cost**	**Profit**
4					25000	=MIN(E4,$B$18)	=$B$13*F4	=$C$19+$C$20	=G4-H4
5	**Unit Price**	40			30000	=MIN(E5,$B$18)	=$B$13*F5	=$C$19+$C$20	=G5-H5
6	**Unit Cost**	24			35000	=MIN(E6,$B$18)	=$B$13*F6	=$C$19+$C$20	=G6-H6
7	**Fixed Cost**	400000			40000	=MIN(E7,$B$18)	=$B$13*F7	=$C$19+$C$20	=G7-H7
8	**Demand**	50000			45000	=MIN(E8,$B$18)	=$B$13*F8	=$C$19+$C$20	=G8-H8
9					50000	=MIN(E9,$B$18)	=$B$13*F9	=$C$19+$C$20	=G9-H9
10					55000	=MIN(E10,$B$18)	=$B$13*F10	=$C$19+$C$20	=G10-H10
11	**Model**				60000	=MIN(E11,$B$18)	=$B$13*F11	=$C$19+$C$20	=G11-H11
12									
13	**Unit Price**	=B5							
14	**Quantity Sold**	=MIN(B8,B18)							
15	**Revenue**		=B13*B14						
16									
17	**Unit Cost**	=B6							
18	**Quantity Produced**	40000							
19	**Variable Cost**		=B17*B18						
20	**Fixed Cost**		=B7						
21									
22	**Profit**		=C15-C19-C20						

Figure 8.12a

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Analyzing Uncertainty and Model Assumptions

Example 8.10 (continued)

Using Excel for What-If Analysis

	A	B	C	D	E	F	G	H	I
1	Profit Model								
2									
3	Data				Demand	Qty. Sold	Revenue	Cost	Profit
4					25000	25000	$1,000,000	$1,360,000	$(360,000)
5	Unit Price	$40.00			30000	30000	$1,200,000	$1,360,000	$(160,000)
6	Unit Cost	$24.00			35000	35000	$1,400,000	$1,360,000	$ 40,000
7	Fixed Cost	$400,000.00			40000	40000	$1,600,000	$1,360,000	$ 240,000
8	Demand	50000			45000	40000	$1,600,000	$1,360,000	$ 240,000
9					50000	40000	$1,600,000	$1,360,000	$ 240,000
10					55000	40000	$1,600,000	$1,360,000	$ 240,000
11	Model				60000	40000	$1,600,000	$1,360,000	$ 240,000
12									
13	Unit Price	$40.00							
14	Quantity Sold	40000							
15	Revenue		$1,600,000.00						
16									
17	Unit Cost	$24.00							
18	Quantity Produced	40000							
19	Variable Cost		$960,000.00						
20	Fixed Cost		$400,000.00						
21									
22	Profit		$240,000.00						

Profit increases until demand equals the quantity produced.

Figure 8.12b

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Analyzing Uncertainty and Model Assumptions

Example 8.10 (continued)

Using Excel for What-If Analysis

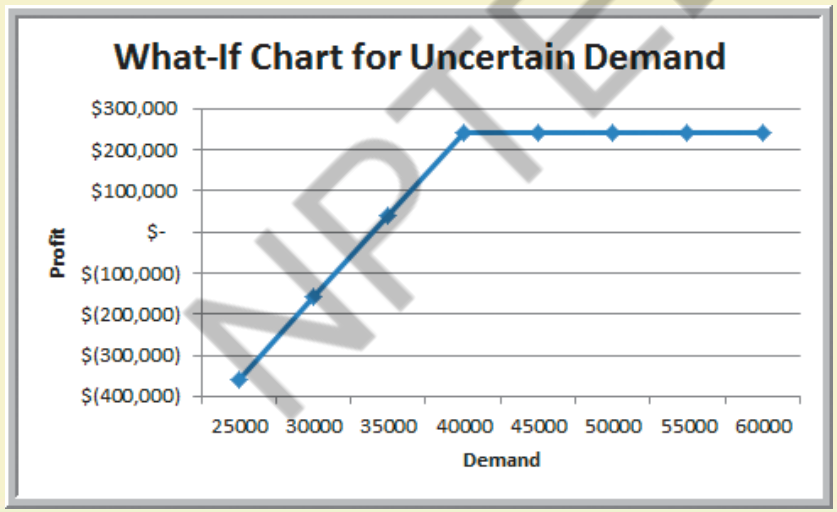


Figure 8.13

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Analyzing Uncertainty and Model Assumptions

Data Tables

- Data Tables summarize the impact of one or two inputs on a specified output.
- Excel data table types:
  - One-way data tables – for one input variable
  - Two-way data table – for two input variables

To construct a data table:

- *Data*
- *What-If Analysis*
- *Data Table*

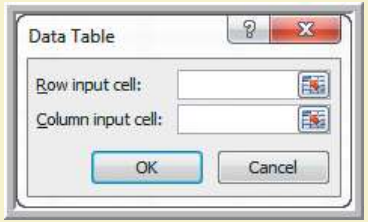


Figure 8.14

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Analyzing Uncertainty and Model Assumptions

Example 8.11

A One-Way Data Table for Uncertain Demand

Create a column of demand values (column E).

Enter =C22 in cell F3 (to reference the output cell).

Highlight the range E3:F11.

Choose *Data Table*.

Enter B8 for *Column input cell.* *(tells Excel that column E is demand values)*

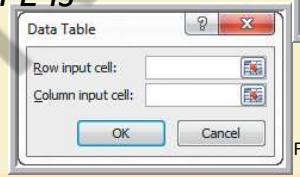


Figure 8.14

	A	B	C	D	E	F
1	Profit Model					
2						
3	Data				Demand	$240,000.00
4					25000	
5	Unit Price	$40.00			30000	
6	Unit Cost	$24.00			35000	*Data Table tool* computes these values
7	Fixed Cost	$400,000.00			40000	
8	Demand	50000			45000	
9					50000	
10					55000	
11	Model				60000	
12						
13	Unit Price	$40.00				
14	Quantity Sold	40000				
15	Revenue		$1,600,000.00			
16						
17	Unit Cost	$24.00				
18	Quantity Produced	40000				
19	Variable Cost		$960,000.00			
20	Fixed Cost		$400,000.00			
21						
22	Profit		$240,000.00			

Figure 8.15a

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Analyzing Uncertainty and Model Assumptions

Example 8.11 (continued)

A One-Way Data Table for Uncertain Demand

The Data Table tool computes the profit values in column F (below $240,000).

	A	B	C	D	E	F
1	Profit Model					
2						
3	Data				Demand	$240,000.00
4					25000	$(360,000.00)
5	Unit Price	$40.00			30000	$(160,000.00)
6	Unit Cost	$24.00			35000	$ 40,000.00
7	Fixed Cost	$400,000.00			40000	$ 240,000.00
8	Demand	50000			45000	$ 240,000.00
9					50000	$ 240,000.00
10					55000	$ 240,000.00
11	Model				60000	$ 240,000.00
12						
13	Unit Price	$40.00				
14	Quantity Sold	40000				
15	Revenue		$1,600,000.00			
16						
17	Unit Cost	$24.00				
18	Quantity Produced	40000				
19	Variable Cost		$960,000.00			
20	Fixed Cost		$400,000.00			
21						
22	Profit		$240,000.00			

Figure 8.15b

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Analyzing Uncertainty and Model Assumptions

Example 8.12

One-Way Data Tables with Multiple Outputs

- Create a second output, revenue.

Enter =C15 in cell G3.
Highlight E3:G11.
Choose *Data Table*
Proceed as in the previous example.
Excel computes the revenues values.

	A	B	C	D	E	F	G
1	Profit Model						
2						Profit	Revenue
3	Data				Demand	$240,000.00	$1,600,000.00
4					25000	$(360,000.00)	$ 1,000,000.00
5	Unit Price	$40.00			30000	$(160,000.00)	$ 1,200,000.00
6	Unit Cost	$24.00			35000	$ 40,000.00	$ 1,400,000.00
7	Fixed Cost	$400,000.00			40000	$ 240,000.00	$ 1,600,000.00
8	Demand	50000			45000	$ 240,000.00	$ 1,600,000.00
9					50000	$ 240,000.00	$ 1,600,000.00
10					55000	$ 240,000.00	$ 1,600,000.00
11	Model				60000	$ 240,000.00	$ 1,600,000.00
12							
13	Unit Price	$40.00					
14	Quantity Sold	40000					
15	Revenue		$1,600,000.00				
16							
17	Unit Cost	$24.00					
18	Quantity Produced	40000					
19	Variable Cost		$960,000.00				
20	Fixed Cost		$400,000.00				
21							
22	Profit		$240,000.00				

Figure 8.15

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Analyzing Uncertainty and Model Assumptions

Example 8.13

A Two-Way Data Table for the Profit Model

- Evaluate the impact of both unit price and unit cost

Create a column of unit prices (F5:F15).
Create a row of unit costs (G4:J4).
Enter =C22 in cell F4.
Select F4:J15.
Choose *Data Table*.

	A	B	C	D	E	F	G	H	I	J
1	Profit Model									
2										
3	Data						Unit Cost			
4						Unit	$240,000.00	$22.00	$23.00	$24.00	$25.00
5	Unit Price	$40.00				Price	$35.00				
6	Unit Cost	$24.00					$36.00				
7	Fixed Cost	$400,000.00					$37.00				
8	Demand	50000					$38.00				
9							$39.00				
10							$40.00				
11	Model						$41.00				
12							$42.00				
13	Unit Price	$40.00					$43.00				
14	Quantity Sold	40000					$44.00				
15	Revenue		$1,600,000.00				$45.00				
16											
17	Unit Cost	$24.00									
18	Quantity Produced	40000									
19	Variable Cost		$960,000.00								
20	Fixed Cost		$400,000.00								
21											
22	Profit		$240,000.00								

Data Table tool computes these cell values.

Figure 8.17a

Enter B6 for *Row input cell*.
Enter B5 for *Column input cell*.

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Analyzing Uncertainty and Model Assumptions

Example 8.13 (continued)

A Two-Way Data Table for the Profit Model

	A	B	C
1	**Profit Model**		
2			
3	**Data**		
4			
5	Unit Price	$40.00	
6	Unit Cost	$24.00	
7	Fixed Cost	$400,000.00	
8	Demand	50000	
9			
10			
11	**Model**		
12			
13	Unit Price	$40.00	
14	Quantity Sold	40000	
15	Revenue		$1,600,000.00
16			
17	Unit Cost	$24.00	
18	Quantity Produced	40000	
19	Variable Cost		$960,000.00
20	Fixed Cost		$400,000.00
21			
22	Profit		$240,000.00

		Unit Cost				
	Unit	$240,000.00	$22.00	$23.00	$24.00	$25.00
	Price	$35.00	$120,000.00	$80,000.00	$40,000.00	$0.00
		$36.00	$160,000.00	$120,000.00	$80,000.00	$40,000.00
		$37.00	$200,000.00	$160,000.00	$120,000.00	$80,000.00
		$38.00	$240,000.00	$200,000.00	$160,000.00	$120,000.00
		$39.00	$280,000.00	$240,000.00	$200,000.00	$160,000.00
		$40.00	$320,000.00	$280,000.00	$240,000.00	$200,000.00
		$41.00	$360,000.00	$320,000.00	$280,000.00	$240,000.00
		$42.00	$400,000.00	$360,000.00	$320,000.00	$280,000.00
		$43.00	$440,000.00	$400,000.00	$360,000.00	$320,000.00
		$44.00	$480,000.00	$440,000.00	$400,000.00	$360,000.00
		$45.00	$520,000.00	$480,000.00	$440,000.00	$400,000.00

Figure 8.17b

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Analyzing Uncertainty and Model Assumptions

Excel's *Scenario Manager*

- Allows creation of scenarios – sets of values that are saved and can be substituted in worksheets.

Data
What-If Analysis
Scenario Manager
Add
Enter a *Scenario Name*
Changing Cells:
Enter cell references to include in scenario.

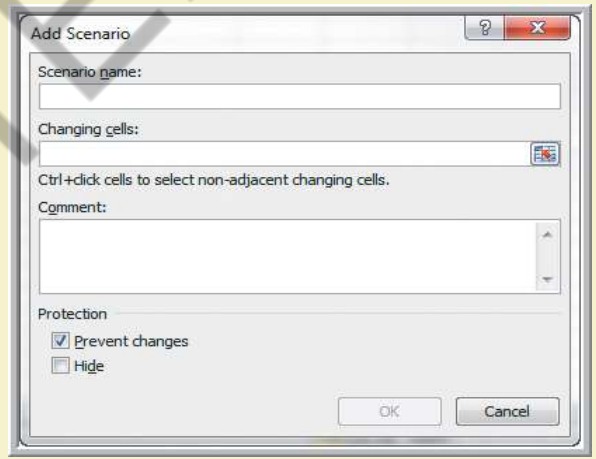


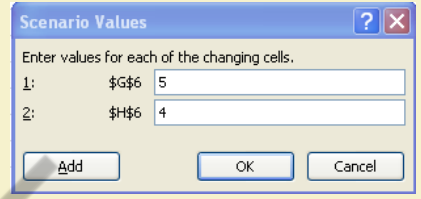
Figure 8.18

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Analyzing Uncertainty and Model Assumptions

Scenario Manager (continued)

- After entering *Changing Cells*, a *Scenario Values* dialog box appears.
- Enter values for each of the changing cells.
- From the *Scenario Manager*, choose *Summary.*
- Choose a *PivotTable* or *Summary.* Enter *Results cells* for the output computations.







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Analyzing Uncertainty and Model Assumptions

Example 8.14 Using the Scenario Manager for the Markdown Pricing Model

- Evaluate 4 strategies for pricing and discounts on the bathing suits in the *Markdown Pricing Model*.
- Days at full price — Price discount on sale days

Days at full price	Price discount on sale days
10	10%
20	20%
30	30%
40	40%

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Analyzing Uncertainty and Model Assumptions

Example 8.14 (continued)

	A	B	C	D	E	F	G	H
1	Markdown Pricing Model			Scenarios	Ten/ten	Twenty/twenty	Thirty/thirty	Forty/forty
2				Days at full retail price	10	20	30	40
3	Data			Intermediate markdown	10%	20%	30%	40%
4	Retail price	$70.00						
5	Inventory	1000						
6	Selling season (days)	50						
7	Days at full retail	40						
8	Intermediate markdown	40%						
9	Clearance markdown	70%						
10	Demand function							
11	a	91						
12	b	1.2						
13								
14	Model							
15								
16	Full Retail Sales							
17	Retail price	$70.00						
18	Daily sales	7.00						
19	Days at retail price	40						
20	Units sold at retail	280						
21	Retail revenue	$19,600.00						
22	Discount Sales							
23	Discount	40%						
24	Discount price	$42.00						
25	Daily sales	40.60						
26	Unit sold	406						
27	Discount revenue	$17,052.00						
28	Clearance Sales							
29	Clearance price	$21.00						
30	Units sold at clearance	314						
31	Clearance revenue	$6,594.00						
32								
33	Total revenue	$43,246.00						

In the *Add Scenario d*ialog box
Scenario Name:
Ten/ten
In the *Scenario Values* dialog;
=E2 for changing cell B7
=E3 for changing cell B8
Repeat for the other scenarios.
Choose *Summary*.
Enter C33 (total revenue) for the *Result cell*.
A Summary table is generated.

Figure 8.19

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Analyzing Uncertainty and Model Assumptions

Example 8.14 (continued) Using the Scenario Manager for the Markdown Pricing Model

	B	C	D	E	F	G	H
2	**Scenario Summary**						
3			Current Values:	Ten/ten	Twenty/twenty	Thirty/thirty	Forty/forty
5	**Changing Cells:**						
6		**$B$7**	40	10	20	30	40
7		**$B$8**	40%	10%	20%	30%	40%
8	**Result Cells:**						
9		**$C$33**	$41,188.00	$50,302.00	$47,264.00	$44,226.00	$41,188.00
10	Notes: Current Values column represents values of changing cells at						
11	time Scenario Summary Report was created. Changing cells for each						
12	scenario are highlighted in gray.						

Figure 8.20

The largest profit results from using the Ten/ten strategy.

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Analyzing Uncertainty and Model Assumptions

Goal Seek

Goal Seek allows you to alter the data used in a formula in order to find out what the results will be.

- *Set cell* contains the formula that will return the result you're seeking.
- *To value* is the target value you want the formula to return.
- *By changing cell* is the location of the input value that Excel can change to reach the target.

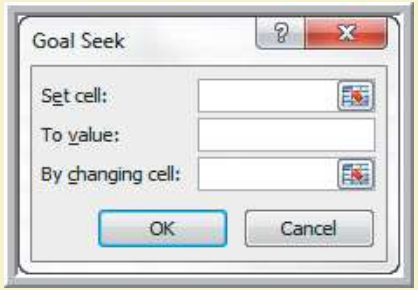


Figure 8.21

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Analyzing Uncertainty and Model Assumptions

Example 8.15 Finding the Breakeven Point in the Outsourcing Model (using *Goal Seek*)

- Find the value of demand at which manufacturing cost equals purchased cost
- *Set cell*: B19
- *To value*: 0
- *By changing cell*: B12.

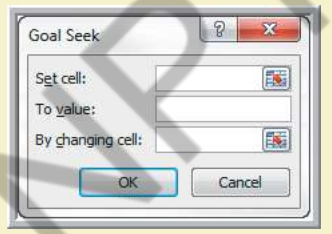


Figure 8.21

	A	B
1	Outsourcing Decision Model	
2		
3	Data	
4		
5	Manufactured in-house	
6	Fixed cost	$50,000
7	Unit variable cost	$125
8		
9	Purchased from supplier	
10	Unit cost	$175
11		
12	Production volume	1000
13		
14	Model	
15		
16	Total manufacturing cost	$175,000
17	Total purchased cost	$175,000
18		
19	Cost difference	$0
20	Decision	Manufacture

Figure 8.22

The breakeven volume is 1000 units.

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Model Analysis Using *Risk Solver* Platform

Example 8.16 Creating Data Tables with *Risk Solver Platform* (for *Profit Model)*

Create a one-way data table to evaluate profit as the unit price is varied between $35 and $45.

Risk Solver
Select cell B5.
Click *Parameters* in the ribbon.
Select *Sensitivity.*

	A	B	C
1	**Profit Model**		
2			
3	**Data**		
4			
5	**Unit Price**	$40.00	
6	**Unit Cost**	$24.00	
7	**Fixed Cost**	$400,000.00	
8	**Demand**	50000	
9			
10			
11	**Model**		
12			
13	**Unit Price**	$40.00	
14	**Quantity Sold**	40000	
15	**Revenue**		$1,600,000.00
16			
17	**Unit Cost**	$24.00	
18	**Quantity Produced**	40000	
19	**Variable Cost**		$960,000.00
20	**Fixed Cost**		$400,000.00
21			
22	**Profit**		$240,000.00

Figure 8.2



Figure 8.23

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Model Analysis Using *Risk Solver* Platform

Example 8.16 (continued) Creating Data Tables

Enter the *lower* (35) and *upper* (45) price values.

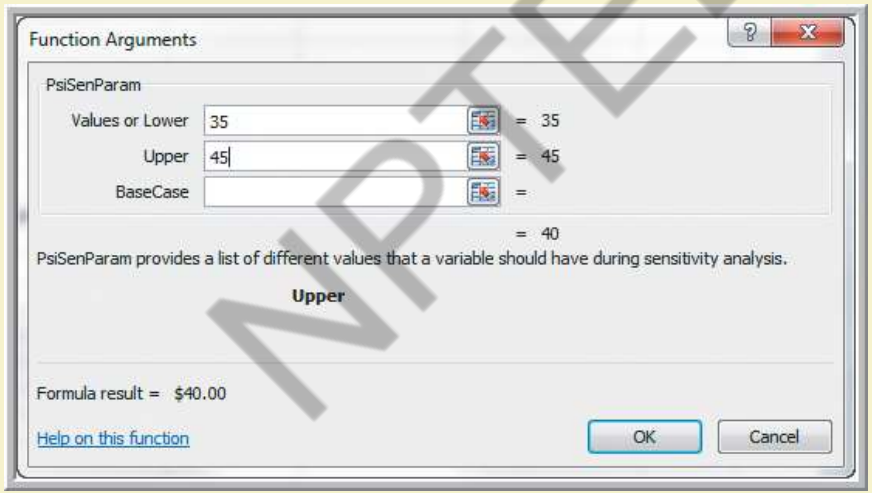


Figure 8.24

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Model Analysis Using *Risk Solver* Platform

Example 8.16 (continued) Creating Data Tables

Select cell C22.

Reports

Sensitivity

Parameter Analysis

	A	B	C
1	Profit Model		
2			
3	Data		
4			
5	Unit Price	$40.00	
6	Unit Cost	$24.00	
7	Fixed Cost	$400,000.00	
8	Demand	50000	
9			
10			
11	Model		
12			
13	Unit Price	$40.00	
14	Quantity Sold	40000	
15	Revenue		$1,600,000.00
16			
17	Unit Cost	$24.00	
18	Quantity Produced	40000	
19	Variable Cost		$960,000.00
20	Fixed Cost		$400,000.00
21			
22	Profit		$240,000.00

Figure 8.2

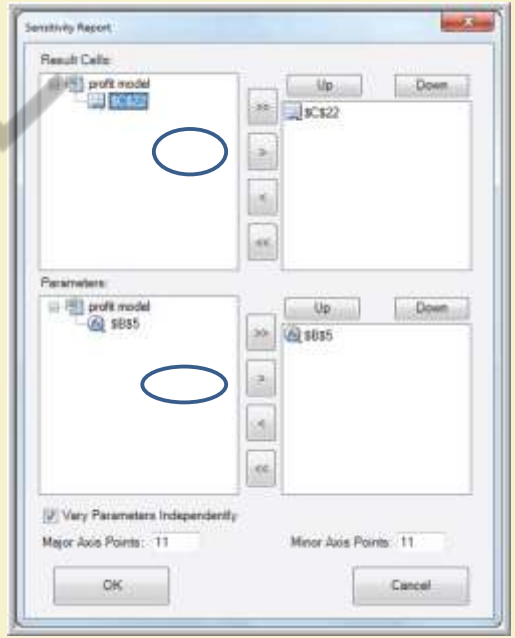


Figure 8.25

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Model Analysis Using *Risk Solver* Platform

Example 8.16 (continued) Creating Data

Data Table created by *Risk Solver*

Unit price versus profit when unit cost = $24

	A	B
1	$B$5	[profit model.xlsx]profit model'!$C$22
2	$35.00	$40,000.00
3	$36.00	$80,000.00
4	$37.00	$120,000.00
5	$38.00	$160,000.00
6	$39.00	$200,000.00
7	$40.00	$240,000.00
8	$41.00	$280,000.00
9	$42.00	$320,000.00
10	$43.00	$360,000.00
11	$44.00	$400,000.00
12	$45.00	$440,000.00

Figure 8.26

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Model Analysis Using *Risk Solver* Platform

Example 8.16 (continued) Creating Data Tables

- 3D Chart for a two-way data table when both unit price and unit cost are varied.
- *Charts*
- *Sensitivity Analysis*
- *Parameter Analysis*
- *Vary parameters independently*

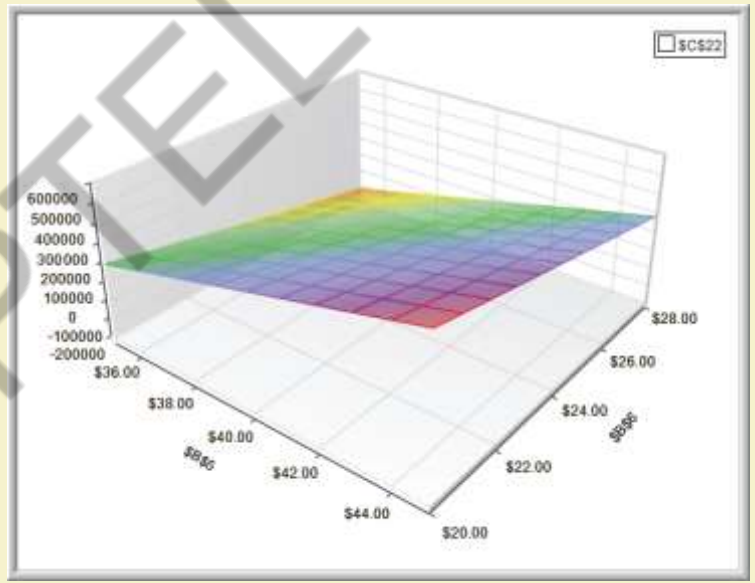


Figure 8.27

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Model Analysis Using *Risk Solver* Platform

Tornado Chart

- Shows the impact that variation in a model input has on some output while holding all other inputs constant.
- Shows which inputs are the least and most influential on the output.
- Helps you select the inputs that you would want to further analyze.

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Model Analysis Using *Risk Solver* Platform

Example 8.17

Creating a Tornado Chart in *Risk Solver Platform*

Profit Model

Select cell C22.
Parameters
Identify

A 10% change in unit price (B5) affects profit the most. Next is unit cost (B6).

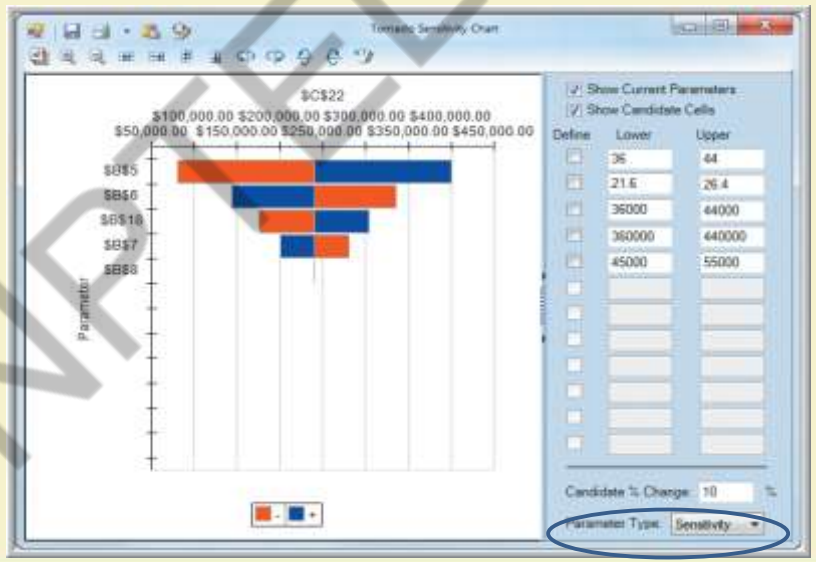


Figure 8.28

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Keywords

- Data table
- Exponential function
- Linear function
- Logarithmic function
- Newsvendor problem
- One-way data table
- Overbook
- Parametric sensitivity analysis
- Polynomial function
- Power function
- R^2 (R-squared)
- Scenarios
- Tornado chart
- Two-way data table
- Validity
- What-if analysis

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Case Study: Performance Lawn Equipment (8)

- Recall that PLE produces lawnmowers and a medium size diesel power lawn tractor.
- Predict net income for the next 3 years.
- Determine which variables are uncertain and might change in the future. Discuss any assumptions that you make.
- Perform what-if, scenario, and parametric sensitivity analysis on the 3 years of net income.
- Construct a tornado chart and write a formal report summarizing your results.





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Books to read

- Business Analytics by J R Evans
- Business Analytics for Managers by H N Laursen

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Thank You!!

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