Predictive Modeling and Analysis

Business Analytics, 1st edition
James R. Evans

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

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
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)

Example 8.2  A Profit Model

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

\[ P = \text{profit} \]
\[ R = \text{revenue} \]
\[ C = \text{cost} \]

\[ p = \text{unit price} \]
\[ c = \text{unit cost} \]
\[ F = \text{fixed cost} \]
\[ S = \text{quantity sold} \]
\[ D = \text{demand} \]
\[ Q = \text{quantity produced} \]
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
  \[ P = p*\min\{D, Q\} − (F + cQ) \]

Example 8.2 (continued) A Profit Model

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

Compute:
- \( R = p*\min\{D,Q\} \)
  \[ = 40(40,000) = 1,600,000 \]
- \( C = F + cQ = 1,360,000 \)
  \[ = 400,000 + 24(40,000) \]
- \( P = R − C = 1,600,000 − 1,360,000 = \$240,000 \)
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
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.
Logic-Driven Modeling

Example 8.3 (continued) New-Product Development

![Figure 8.3a](image)

**Profitable in 4th year**

NPV = $185 million

### 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

\[
\text{Net profit} = R(\min\{Q,D\}) + S(\max\{0,Q-D\}) - CQ
\]
Logic-Driven Modeling

Example 8.4  A Single-Period Purchase Decision Model

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

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 = \( P(\min\{300,D\}) − C(\max\{0,D−Q\}) \)
  = \( 120(\min\{300,D\})−100(\max\{0,D−300\}) \)
Example 8.5 (continued)

A Hotel Overbooking Model

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

---

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.
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

Value at 22 years old = $5,400

Value at 50 years old = $751,757
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 4th, the price is marked down 70% to sell off remaining inventory.
- Determine total revenue from the bathing suits.

Assume a linear trend model between sales and price:

\[
\text{daily sales} = a - b(\text{price})
\]

\[
7 = a - b(70)
\]

\[
32.2 = a - b(49)
\]

\[
\text{Daily sales} = 91 - 1.2(\text{price})
\]
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

Total revenue = $43,736
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.

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.*
Data-Driven Modeling

Example 8.8 Modeling a Price-Demand Function

Linear demand function:
Sales = -9.5116(price) + 20512

Data-Driven Modeling

Example 8.9 Predicting Crude Oil Prices

• Line chart of historical crude oil prices
Example 8.9 (continued) Predicting Crude Oil Prices

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

Logarithmic \( y = 13 \ln(x) + 39 \quad R^2 = 0.382 \)

Power \( y = 45.96x^{0.0169} \quad R^2 = 0.397 \)

Exponential \( y = 50.5e^{0.021x} \quad R^2 = 0.664 \)
  Polynomial 2° \( y = 0.13x^2 - 2.4x + 68 \quad R^2 = 0.905 \)
  Polynomial 3° \( y = 0.005x^3 - 0.111x^2 \)
    + 0.648x + 59.5 \quad R^2 = 0.928 * \n
Data-Driven Modeling

Example 8.9 (continued) Predicting Crude Oil Prices

- Third Order Polynomial Trendline fit to the data
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.

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
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)

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

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.

Enter B6 for Row input cell.
Enter B5 for Column input cell.
Analyzing Uncertainty and Model Assumptions

Example 8.13 (continued)

A Two-Way Data Table for the Profit Model

![Two-Way Data Table](image)

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.
Example 8.15 Finding the Break-even 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.

The break-even volume is 1000 units.

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.
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).