Prescriptive Analytics

Dr Shakila Yasmin

Institute of Business Administration

University of Dhaka

Prescriptive Analytics

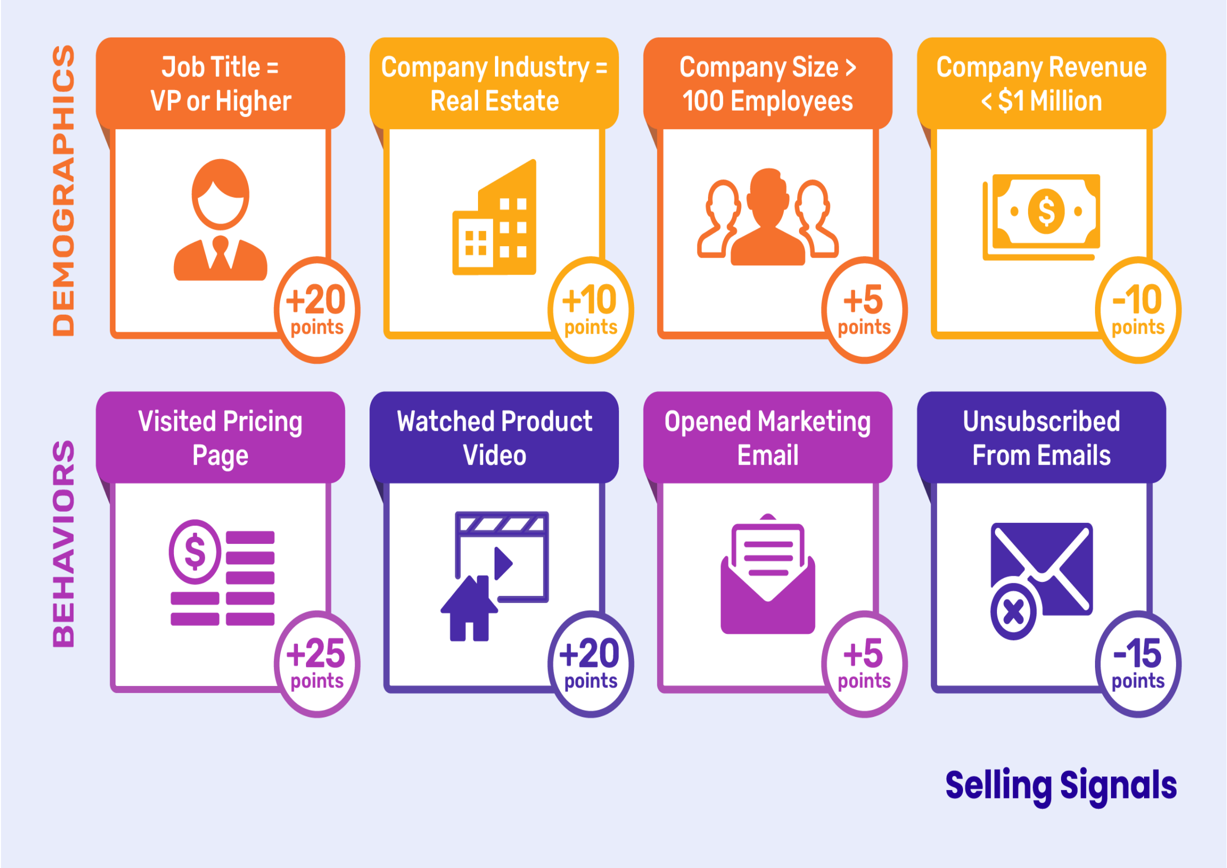
What is prescriptive analytics

- Prescriptive analytics involves analyzing the results of the predictive analytics and “prescribes” the best category to target and minimize or maximize the objective(s).
- The tools of prescriptive analytics are now used with big data to make data-driven decisions by selecting the best course of actions involving multi-criteria decision variables.
- Some examples of prescriptive analytics models are linear and nonlinear optimization models, different types of simulations, and others.
- Many of the operations management tools that are derived from management science and industrial engineering, including the simulation tools, are also part of prescriptive analytics.

Sales Lead Scoring

Lead scoring is the process of assigning a point value to various actions along the sales funnel (*visual representation of the customer journey)*, enabling you, or an algorithm, to rank leads based on how likely they are to convert into customers.

When assigning each action a point value, assign the highest number of points to those that imply purchase intent (for instance, visiting a product page) and negative points to those that reveal non-purchase intent (for instance, viewing job postings on your site).

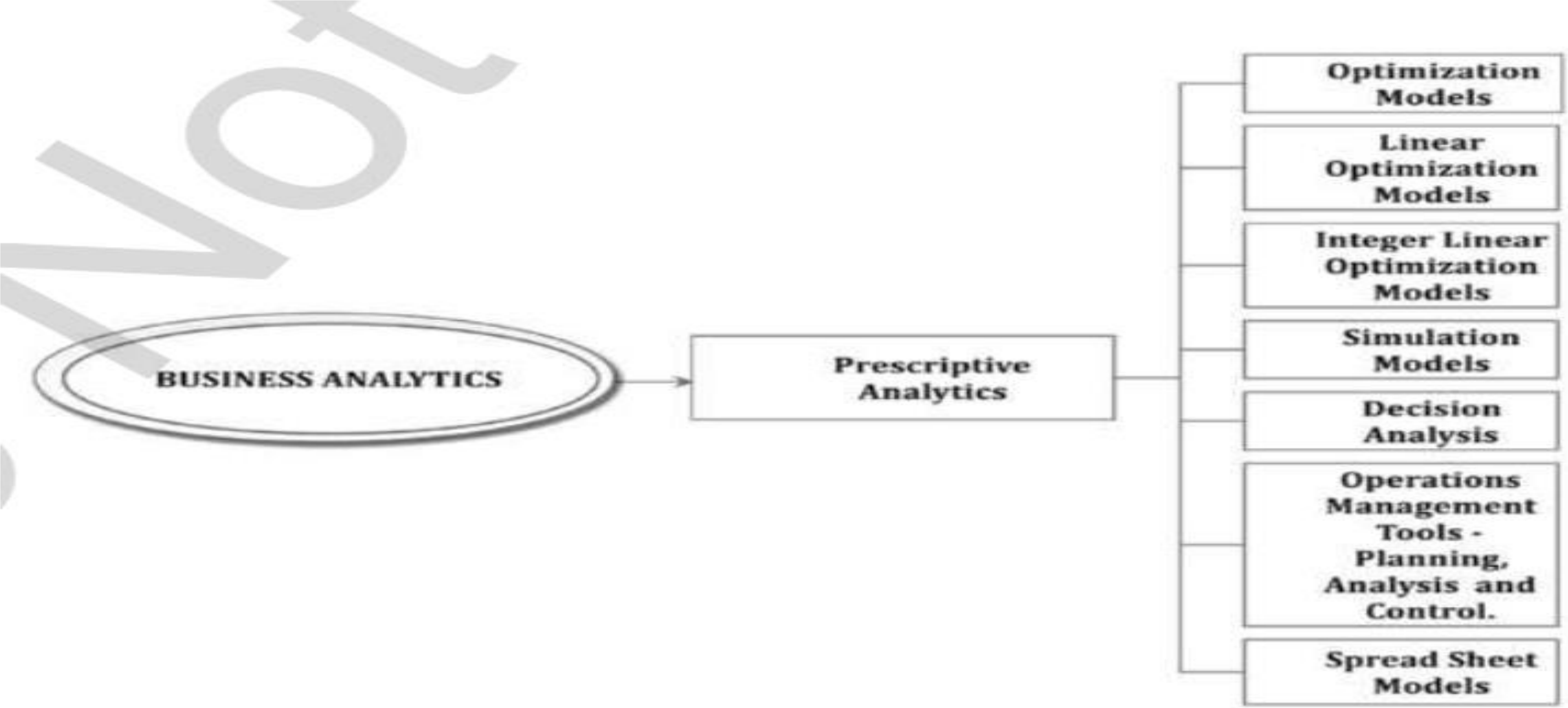


Banking Fraud Detection

An algorithm—trained using customers' historical transaction data—analyzes and scans new transactional data for anomalies. For instance, perhaps you typically spend $3,000 per month, but this month, there's a $30,000 charge on your credit card.

The algorithm analyzes patterns in your transactional data, alerts the bank, and provides a recommended course of action. In this example, the course of action may be to cancel the credit card, as it could have been stolen.

Prescriptive Analytic Tools



Multi-criteria decision making

Optimization models

A firm manufactures wood screws and metal screws. All the screws have to pass through a threading machine and a slotting machine. A box of wood screws requires 3 minutes on the slotting machine and 2 minutes on the threading machine. A box of metal screws requires 2 minutes on the slotting machine and 8 minutes on the threading machine. In a week, each machine is available for 60 hours. There is a profit of Tk1000 per box on wood screws and Tk1700 per box on metal screws.

Sensitivity Report

how much your objective function value will change for a one unit increase in that decision variable.

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$3	x	1080	0	1000	1550	575
$C$3	y	180	0	1700	2300	1033.333333

how much the objective coefficient of a decision variable can change before the recommended solution (decision variables) will change.

how much your objective function value will change for a one unit increase in that constraint.

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$D$6	slotting time	3600	230	3600	1800	2700
$D$7	threading time	3600	155	3600	10800	1200
$D$8	non-negative	1080	0	0	1080	1E+30
$D$9	non-negative	180	0	0	180	1E+30

how much the right-hand side constraint can change before the shadow price becomes unreliable (or changes)

Answer Report

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$3	x	0	1080	Contin
$C$3	y	0	180	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$D$6	slotting time	3600	$D$6<=$F$6	Binding	0
$D$7	threading time	3600	$D$7<=$F$7	Binding	0
$D$8	non-negative	1080	$D$8>=$F$8	Not Binding	1080
$D$9	non-negative	180	$D$9>=$F$9	Not Binding	180

indicates if each constraint was binding or not binding. This section also tells you if the constraint had "slack" – excess or unused quantities.

Limit Report

	Objective	
Cell	Name	Value
$D$4	objective	1386000

	Variable		Lower	Objective	Upper	Objective
Cell	Name	Value	Limit	Result	Limit	Result
$B$3	x	1080	0	306000	1080	1386000
$C$3	y	180	0	1080000	180	1386000

Objective results show what the corresponding profits will be at the lower and upper limits of the decision variables provided no other changes made.

Multi Criteria Decision Making

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), is a procedure designed to quantify managerial judgments regarding relative importance of each of several conflicting criteria used in the decision making process.

- It is popular and widely used method for multi-criteria decision making.
- Allows the use of qualitative, as well as quantitative criteria in evaluation.
- Wide range of applications exists:
  - Vendor Selection
  - Product Selection
  - Project Selection
  - Life Partner Selection

AHP-General Idea

- Develop an hierarchy of decision criteria and define the alternative courses of actions.
- AHP algorithm is basically composed of two steps:
  1. Determine the relative weights of the decision criteria
  2. Determine the relative rankings (priority) of alternatives
- Both qualitative and quantitative information can be compared using informed judgments to derive weights and priorities.

Analytic Hierarchy Process

- Step 1: List the Overall Goal, Criteria, and Decision Alternatives

- Step 2: Develop a Pair-wise Comparison Matrix

  Rate the relative importance between each pair of decision criteria and alternatives. The matrix lists the alternatives horizontally and vertically and has the numerical ratings comparing the horizontal (first) alternative with the vertical (second) alternative.

  Ratings are given as follows:

. . . continued

Analytic Hierarchy Process

- Step 2: Pair-wise Comparison Matrix (continued)

Compared to the second alternative, the first alternative is:	Numerical rating
extremely preferred	9
very strongly preferred	7
strongly preferred	5
moderately preferred	3
equally preferred	1

Intermediate numeric ratings of 8, 6, 4, 2 can be assigned. A reciprocal rating (i.e. 1/9, 1/8, etc.) is assigned when the second alternative is preferred to the first. The value of 1 is always assigned when comparing an alternative with itself.

Example

- Suppose the manager has identified the following pair-wise comparison matrix for the four objectives

$$A = \begin{bmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & 1/2 & 1/2 \\ 1/2 & 2 & 1 & 2 \\ 1/4 & 2 & 1/2 & 1 \end{bmatrix}$$

Analytic Hierarchy Process

- Step 3: Develop a Normalized Matrix
  - Divide each number in a column of the pair-wise comparison matrix by its column sum.
- Example:

$$A_{norm} = \begin{bmatrix} 0.5108 & 0.5000 & 0.5000 & 0.5333 \\ 0.1026 & 0.1000 & 0.1250 & 0.0667 \\ 0.2564 & 0.2000 & 0.2500 & 0.2667 \\ 0.1282 & 0.2000 & 0.1250 & 0.1333 \end{bmatrix}$$

Analytic Hierarchy Process

- Step 4: Develop the Priority Vector
  - Average each row of the normalized matrix. These row averages form the weights for each of the objectives. The values in this vector sum to 1.
- Example:

$$w_1 = \frac{0.5128 + 0.5000 + 0.5000 + 0.5333}{4} = 0.5115$$

$$w_2 = 0.0986, w_3 = 0.2433, w_4 = 0.1466$$

Analytic Hierarchy Process

- Step 5: Determine the score of each alternative on each objective
  - Construct pair-wise comparison matrix for each objective
  - Construct a normalized matrix for the alternatives for each objective
  - Construct a vector of scores for the alternatives for each objective

- Example: Suppose the manager assesses the following pair-wise comparison matrix for the 3 suppliers for the cost objective, then the normalized matrix and the vector scores for the three suppliers on cost are given as follows:

$$A_1 = \begin{bmatrix} 1 & 2 & 4 \\ 1/2 & 1 & 2 \\ 1/4 & 1/2 & 1 \end{bmatrix}, A_{1,norm} = \begin{bmatrix} 0.5714 & 0.5714 & 0.5714 \\ 0.2857 & 0.2857 & 0.2857 \\ 0.1429 & 0.1429 & 0.1429 \end{bmatrix}$$

$$S_1 = \begin{bmatrix} 0.5714 \\ 0.2857 \\ 0.1429 \end{bmatrix}$$

Analytic Hierarchy Process

- Step 6: Determine the best alternative
  - Combine the scores of the alternatives with the weights of the objective to determine the best alternative
- Example: Suppose the vector scores of the jobs for the objectives are as follows:

$$S_1 = \begin{bmatrix} 0.5714 \\ 0.2857 \\ 0.1429 \end{bmatrix} \quad S_2 = \begin{bmatrix} 0.1593 \\ 0.2519 \\ 0.5889 \end{bmatrix} \quad S_3 = \begin{bmatrix} 0.0882 \\ 0.6687 \\ 0.2431 \end{bmatrix} \quad S_4 = \begin{bmatrix} 0.0824 \\ 0.3151 \\ 0.6025 \end{bmatrix}$$

$$Sw = \begin{bmatrix} 0.5714 & 0.1593 & 0.0882 & 0.0824 \\ 0.2857 & 0.2519 & 0.6687 & 0.3151 \\ 0.1429 & 0.5889 & 0.2431 & 0.6025 \end{bmatrix} * \begin{bmatrix} 05115 \\ 0.0986 \\ 0.2433 \\ 0.1466 \end{bmatrix} = \begin{bmatrix} 0.3415 \\ 0.3799 \\ 0.2786 \end{bmatrix}$$

The manager should select supplier 2

Analytic Hierarchy Process

- Step 7: Check for Consistency
  - The consistency of the subjective input in the pair-wise comparison matrix can be measured by calculating a consistency ratio. A consistency ratio of less than .1 is good. For ratios which are greater than .1, the subjective input should be re-evaluated.

Determining the Consistency Ratio

- Step 1:

  For each row of the pair-wise comparison matrix, determine a weighted sum of the entries and the vector of weights.

- Example: Checking consistency of the *A* matrix
  - Compute *Aw*:

$$Aw = \begin{bmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & 1/2 & 1/2 \\ 1/2 & 2 & 1 & 2 \\ 1/4 & 2 & 1/2 & 1 \end{bmatrix} * \begin{bmatrix} 0.5115 \\ 0.0986 \\ 0.2433 \\ 0.1466 \end{bmatrix} = \begin{bmatrix} 2.0774 \\ 0.3958 \\ 0.9894 \\ 0.5933 \end{bmatrix}$$

Determining the Consistency Ratio

- Step 2:

  Find the ratio of each element of the weighted matrix to the corresponding weights in the vector of weights and average these ratios

$$\frac{\frac{2.0774}{0.5115}+\frac{0.3958}{0.0986}+\frac{0.9894}{0.2433}+\frac{0.5933}{0.1466}}{4}=4.0477$$

- Step 3:

  Compute the consistency index (*CI*) as:

CI=[(Step 2 result)-n]/(n-1), n=# objectives

$$CI=\frac{4.4077-4}{4-1}=0.0159$$

Determining the Consistency Ratio

- Step 4: Determine the random index, RI, as follows:

n	*RI*
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.51

- The values of *RI* give the average value of *CI* if the entries in *A* were chosen at random

- Step 5: Compute the consistency ratio: *CR = CI/RI*

$$CR = \frac{0.0159}{0.9} = 0.0177$$