Chapter 1
Introduction to Business Analytics
Contents

- Introduction to Analytics
- Tools
- Data
- Models
- Problem solving with analytics
Business Analytics

Analytics is the use of:

- data,
- information technology,
- statistical analysis,
- quantitative methods, and
- mathematical or computer-based models

to help managers gain improved insight about their business operations and make better, fact-based decisions.
Examples of Applications

- **Pricing**
  - setting prices for consumer and industrial goods, government contracts, and maintenance contracts

- **Customer segmentation**
  - identifying and targeting key customer groups in retail, insurance, and credit card industries

- **Merchandising**
  - determining brands to buy, quantities, and allocations

- **Location**
  - finding the best location for bank branches and ATMs, or where to service industrial equipment

- **Social Media**
  - understand trends and customer perceptions; assist marketing managers and product designers
A Visual Perspective of Business Analytics
Impacts and Challenges

¬ **Benefits**
  ◦ …reduced costs, better risk management, faster decisions, better productivity and enhanced bottom-line performance such as profitability and customer satisfaction.

¬ **Challenges**
  ◦ …lack of understanding of how to use analytics, competing business priorities, insufficient analytical skills, difficulty in getting good data and sharing information, and not understanding the benefits versus perceived costs of analytics studies.
Scope of Business Analytics

- **Descriptive analytics**: the use of data to understand past and current business performance and make informed decisions

- **Predictive analytics**: predict the future by examining historical data, detecting patterns or relationships in these data, and then extrapolating these relationships forward in time.

- **Prescriptive analytics**: identify the best alternatives to minimize or maximize some objective
Example 1.1: Retail Markdown Decisions

- Most department stores clear seasonal inventory by reducing prices.
- *Key question:* When to reduce the price and by how much to maximize revenue?

- Potential applications of analytics:
  - **Descriptive analytics:** examine historical data for similar products (prices, units sold, advertising, …)
  - **Predictive analytics:** predict sales based on price
  - **Prescriptive analytics:** find the best sets of pricing and advertising to maximize sales revenue
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Tools

- Database queries and analysis
- Spreadsheets
- Data visualization
- Dashboards to report key performance measures
- Data and Statistical methods
- Data Mining basics (predictive models)

- Simulation
- Forecasting
- Scenario and “what-if” analyses
- Optimization
- Text Mining
- Social media, web, and text analytics

In this course
Software Support

- **SQL** various databases
- **Excel** Spreadsheets
- **Tableau Software** Simple drag and drop tools for visualizing data from spreadsheets and other databases.
- **IBM Cognos Express** An integrated business intelligence and planning solution designed to meet the needs of midsize companies, provides reporting, analysis, dashboard, scorecard, planning, budgeting and forecasting capabilities.
- **SAS / SPSS / Rapid Miner** Predictive modeling and data mining, visualization, forecasting, optimization and model management, statistical analysis, text analytics, and more using visual workflows.
- **R / Python** Advanced programming-based data preparation, analytics and visualization.
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Data: numerical or textual facts and figures that are collected through some type of measurement process.

Information: result of analyzing data; that is, extracting *meaning* from data to support evaluation and decision making.
Examples of Data Sources and Uses

- **Internal**
  - Annual reports
  - Accounting audits
  - Financial profitability analysis
  - Operations management performance
  - Human resource measurements

- **External**
  - Economic trends
  - Marketing research

- **New developments: Web behavior – Social Media – Mobile - IOT**
  - page views, visitor’s country, time of view, length of time, origin and destination paths, products they searched for and viewed, products purchased, what reviews they read, and many others.
Big Data

- **Big data** to refer to massive amounts of business data from a wide variety of sources, much of which is available in real time, and much of which is uncertain or unpredictable. IBM calls these characteristics *volume, variety, velocity, and veracity*.

“The effective use of big data has the potential to transform economies, delivering a new wave of productivity growth and consumer surplus. Using big data will become a key basis of competition for existing companies, and will create new competitors who are able to attract employees that have the critical skills for a big data world.” - McKinsey Global Institute, 2011
Big Data

- Apache Hadoop Ecosystem for Big Data
Database - a collection of related tables containing records on people, places, or things.
- In a database table the columns correspond to each individual element of data (called *fields*, or *attributes*), and the rows represent records of related data elements.

Data set - a collection of data (often a single "spread sheet" or data mining table).
- Examples: Marketing survey responses, a table of historical stock prices, and a collection of measurements of dimensions of a manufactured item.
Metrics and Data Classification

- **Metric** - a unit of measurement that provides a way to objectively quantify performance.

- **Measurement** - the act of obtaining data associated with a metric.

- **Measures** - numerical values associated with a metric.
Types of Metrics

- **Discrete metric** - one that is derived from counting something.
  - For example, a delivery is either on time or not; an order is complete or incomplete; or an invoice can have one, two, three, or any number of errors. Some discrete metrics would be the proportion of on-time deliveries; the number of incomplete orders each day, and the number of errors per invoice.

- **Continuous metrics** are based on a continuous scale of measurement.
  - Any metrics involving dollars, length, time, volume, or weight, for example, are continuous.
Categorical (nominal) data - sorted into categories according to specified characteristics.

Ordinal data - can be ordered or ranked according to some relationship to one another.

Interval data - ordinal but have constant differences between observations and have arbitrary zero points.

Ratio data - continuous and have a natural zero.
Example 1.3: Classifying Data Elements

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
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<td></td>
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<td></td>
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<td>3</td>
<td>Supplier</td>
<td>Order No.</td>
<td>Item No.</td>
<td>Item Description</td>
<td>Item Cost</td>
<td>Quantity</td>
<td>Cost per order</td>
<td>A/P Terms (Months)</td>
<td>Order Date</td>
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<td>Hulkey Fasteners</td>
<td>Aug11001</td>
<td>1122</td>
<td>Airframe fasteners</td>
<td>$4.25</td>
<td>19,500</td>
<td>$82,875.00</td>
<td>30</td>
<td>08/05/11</td>
</tr>
<tr>
<td>5</td>
<td>Alum Sheeting</td>
<td>Aug11002</td>
<td>1243</td>
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<td>$42,500.00</td>
<td>30</td>
<td>08/08/11</td>
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<tr>
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<td>5462</td>
<td>Shielded Cable/ft.</td>
<td>$1.05</td>
<td>23,000</td>
<td>$24,150.00</td>
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<td>08/10/11</td>
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<td>Shielded Cable/ft.</td>
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<td>21,500</td>
<td>$22,575.00</td>
<td>30</td>
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<td>5319</td>
<td>Shielded Cable/ft.</td>
<td>$1.10</td>
<td>17,500</td>
<td>$19,250.00</td>
<td>30</td>
<td>08/20/11</td>
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<td>4312</td>
<td>Bolt-nut package</td>
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<td>4,250</td>
<td>$15,937.50</td>
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<td>11</td>
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<td>7258</td>
<td>Pressure Gauge</td>
<td>$90.00</td>
<td>100</td>
<td>$9,000.00</td>
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<td>O-Ring</td>
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<td>1,300</td>
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<td>$1.05</td>
<td>22,500</td>
<td>$23,625.00</td>
<td>30</td>
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<td>14</td>
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<td>Shielded Cable/ft.</td>
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<td>18,100</td>
<td>$19,910.00</td>
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<td>08/25/11</td>
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<tr>
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<td>3166</td>
<td>Electrical Connector</td>
<td>$1.25</td>
<td>5,600</td>
<td>$7,000.00</td>
<td>30</td>
<td>08/25/11</td>
</tr>
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</table>

Categorical, Ordinal, Categorical, Ratio, Ratio, Ratio, Ratio, Interval, Interval
Data Reliability and Validity

- **Reliability** - data are **accurate and consistent**.
- **Validity** - data **measures what it is supposed to measure**.

**Examples:**
- A tire pressure gage that consistently reads several pounds of pressure below the true value is **not reliable**, although it is valid because it does measure tire pressure.
- The number of calls to a customer service desk might be counted correctly each day (and thus is a reliable measure) but **not valid** if it is used to assess customer dissatisfaction, as many calls may be simple queries.
- A survey question that asks a customer to rate the quality of the food in a restaurant may be **neither reliable** (because different customers may have conflicting perceptions) **nor valid** (if the intent is to measure customer satisfaction, as satisfaction generally includes other elements of service besides food).
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- **Models**
- Problem solving with analytics
Models in Business Analytics

- **Model** - an abstraction or representation of a real system, idea, or object.
  - Often a *simplification* of the real thing.
  - Captures the **most important features**.
  - Can be a written or verbal description, a visual representation, a mathematical formula, or a spreadsheet.
Example 1.4: Three Forms of a Model

The sales of a new product, such as a first-generation iPad or 3D television, often follow a common pattern.

1. **Verbal description**: The rate of sales starts small as early adopters begin to evaluate a new product and then begins to grow at an increasing rate over time as positive customer feedback spreads. Eventually, the market begins to become saturated and the rate of sales begins to decrease.
2. **Visual model**: A sketch of sales as an S-shaped curve over time
3. Mathematical model:

\[ S = ae^{bct} \]

where

- \( S \) is sales,
- \( t \) is time,
- \( e \) is the base of natural logarithms, and
- \( a, b \) and \( c \) are constants that need to be estimated.
Influence Diagrams

- Visual representation of a descriptive model that shows how the elements of the model influence, or relate to, others.
- An influence diagram is a useful approach for conceptualizing the structure of a model and can assist in building a mathematical or spreadsheet model.

![Basic Influence Diagram]

- Total Cost
  - Fixed Cost
  - Variable Cost

![Expanded Influence Diagram]

- Total Cost
  - Fixed Cost
  - Variable Cost
    - Unit Variable Cost
    - Quantity Produced
Example 1.6: Building a Mathematical Model

- total cost = fixed cost + variable cost \quad (1.1)
- variable cost = unit variable cost \times \text{quantity produced} \quad (1.2)
- total cost = fixed cost + variable cost
  \quad = \text{fixed cost} + \text{unit variable cost} \times \text{quantity produced} \quad (1.3)

Mathematical model:

- \( TC = \text{Total Cost} \)
- \( F = \text{Fixed cost} \)
- \( V = \text{Variable unit cost} \)
- \( Q = \text{Quantity produced} \)

\[
TC = F + VQ \quad (1.4)
\]
A logical or mathematical representation of a problem or business situation that can be used to understand, analyze, or facilitate making a decision.

- **Inputs:**
  - *Uncontrollable variables*, which are quantities that can change but cannot be directly controlled by the decision maker.
  - *Decision variables*, which are controllable and can be selected at the discretion of the decision maker.
Example 1.7 A Break-Even Decision Model

\[ TC(\text{manufacturing}) = $50,000 + $125 \times Q \]
\[ TC(\text{outsourcing}) = $175 \times Q \]

Breakeven Point:
Q where \( TC(\text{manufacturing}) = TC(\text{outsourcing}) \)

\[ $50,000 + $125 \times Q = $175 \times Q \]
\[ $50,000 = 50 \times Q \]
\[ Q = 1,000 \]

- General Formula
  \[ F + VQ = CQ \]
  \[ Q = \frac{F}{C - V} \quad (1.5) \]

**Decision**: Only do this if you expect to sell more than 1,000 units!
In the grocery industry, managers typically need to know how best to use pricing, coupons and advertising strategies to influence sales.

Grocers often study the relationship of sales volume to these strategies by conducting controlled experiments to identify the relationship between them and sales volumes. That is, they implement different combinations of pricing, coupons, and advertising, observe the sales that result, and use analytics to develop a predictive model of sales as a function of these decision strategies.
Model: \[ \text{Sales} = 500 - 0.05(\text{price}) + 30(\text{coupons}) + 0.08(\text{advertising}) + 0.25(\text{price})(\text{advertising}) \]

If the price is $6.99, no coupons are offered, and no advertising is done (the experiment corresponding to week 1), the model estimates sales as

\[ \text{Sales} = 500 - 0.05 \times 6.99 + 30 \times 0 + 0.08 \times 0 + 0.25 \times 6.99 \times 0 = 500 \text{ units} \]

How do we find this model?

In this case: linear regression
Assumptions are made to
- To **simplify** a model and make it more tractable; that is, able to be easily analyzed or solved.
- To **add prior knowledge** about the relationship between variables.

The task of the modeler is to select or build an appropriate model that best represents the behavior of the real situation.

Example: economic theory tells us that demand for a product is negatively related to its price. Thus, as prices increase, demand falls, and vice versa.
Example 1.9: A Linear Demand Prediction Model

As price increases, demand falls.

Issues: Demand can become negative + empirical data has a poor fit.
Example 1.10 A Nonlinear Demand Prediction Model

Assumes price elasticity is constant (constant ratio of % change in demand to % change in price)
Uncertainty and Risk

- **Uncertainty** is imperfect knowledge (of what will happen in the future).
- **Risk** is the potential of (gaining or) losing something of value. It is the consequence of actions taken under uncertainty.

Often measured using standard deviation of variables. (=Deviation risk measure)

“To try to eliminate risk in business enterprise is futile. Risk is inherent in the commitment of present resources to future expectations. Indeed, economic progress can be defined as the ability to take greater risks. The attempt to eliminate risks, even the attempt to minimize them, can only make them irrational and unbearable. It can only result in the greatest risk of all: rigidity.”

– Peter Drucker
Prescriptive Decision Models

- **Prescriptive decision models** help decision makers identify the best solution.

- **Optimization** - finding values of decision variables that minimize (or maximize) something such as cost (or profit).
  - **Objective function** - the equation that minimizes (or maximizes) the quantity of interest.
  - **Constraints** - limitations or restrictions.
  - **Optimal solution** - values of the decision variables at the minimum (or maximum) point.
Example 1.11: A Prescriptive Pricing Model

- A firm wishes to determine the best pricing for one of its products in order to maximize profit.

- Analysts determined the following model:
  \[ \text{Sales} = -2.9485(\text{price}) + 3240.9 \]
  \[ \text{Total revenue} = (\text{price})(\text{sales}) \]
  \[ \text{Cost} = 10(\text{Sales}) + 5000 \]

- Identify the price that maximizes profit, subject to any constraints that might exist.

\[
\begin{align*}
\text{max. Profit} \\
\text{s.t. Sales} & \geq 0 \\
\text{Sales} & \text{ is integer}
\end{align*}
\]
Types of Prescriptive Models

- **Deterministic model** – all model input information is known with certainty.

- **Stochastic model** – some model input information is uncertain.
  - For instance, suppose that customer demand is an important element of some model. We can make the assumption that the demand is known with certainty; say, 5,000 units per month (deterministic). On the other hand, suppose we have evidence to indicate that demand is uncertain, with an average value of 5,000 units per month, but which typically varies between 3,200 and 6,800 units (distribution, confidence, etc. -> stochastic).
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Problem Solving With Analytics

1. Recognize a problem
2. Define the problem
3. Structure the problem
4. Analyze the problem
5. Interpret results and make a decision
6. Implement the solution

Focus of the remainder of this course
Problems exist when there is a gap between what is happening and what we think should be happening.

- For example, costs are too high compared with competitors.
Define the Problem

- Clearly defining the problem is not a trivial task.

- Complexity increases when the following occur:
  - large number of courses of action
  - the problem belongs to a group and not an individual
  - competing objectives
  - external groups are affected
  - problem owner and problem solver are not the same person
  - time limitations exist

- What is part of the problem? What not?
Structure the Problem

- Stating goals and objectives
- Characterizing the possible decisions
- Identifying any constraints or restrictions
Analyse the Problem

- Analytics plays a major role.

- Analysis involves some sort of experimentation or solution process, such as evaluating different scenarios, analyzing risks associated with various decision alternatives, finding a solution that meets certain goals, or determining an optimal solution.
Interpret Results and Make a Decision

- What do the results found by the model mean for the application?

- Models cannot capture every detail of the real problem. Managers must understand the limitations of models and their underlying assumptions and often incorporate judgment into making a decision.
Implement the Solution

- Translate the results of the model back to the real world.

- Requires providing adequate resources, motivating employees, eliminating resistance to change, modifying organizational policies, and developing trust.
How to do an analytics project?  
CRISP-DM Reference Model

- **Cross Industry Standard Process for Data Mining**
- De facto standard for conducting data mining and knowledge discovery projects.
- Defines tasks and outputs.
- Now developed by IBM as the Analytics Solutions Unified Method for Data Mining/Predictive Analytics (ASUM-DM).
- SAS has SEMMA and most consulting companies use their own process.