Design and Analysis of Experiments Chapter 1

- **Introduction** of DOX
- An abbreviated **history** of DOX
- Some basic **principles** and terminology
- The **strategy** of experimentation
- **Guidelines** for planning, conducting and analyzing experiments

Introduction to DOX

- An **experiment** is a test or a series of tests

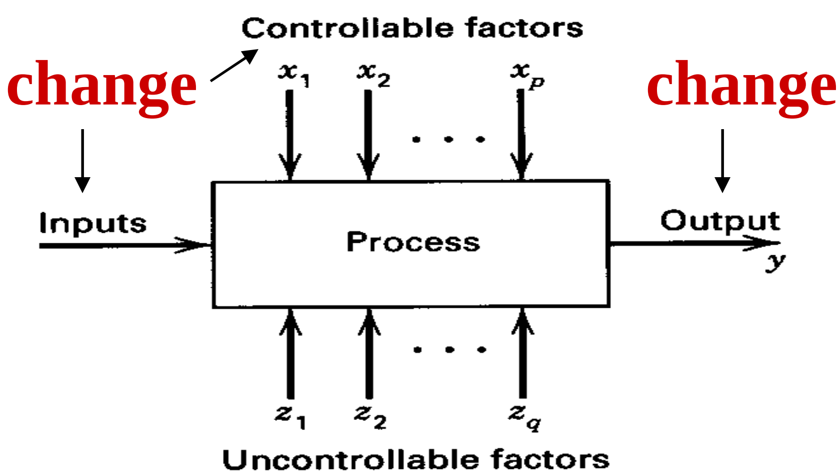


Figure 1-1 General model of a process or system.

- The objectives of the experiment
  1. Which variables are most influential on the response y

  2. Where to set the influential x's so that y is almost always near the desired nominal value

  3. Where to set the influential x's so that variability in y is small

  4. Where to set the influential x's so that the effects of the uncontrollable variables $Z_1, Z_2, \ldots, Z_q$ are minimized

Four Eras in the History of DOX

- The **agricultural** origins, 1918 – 1940s
  - R. A. Fisher & his co-workers
  - Profound impact on agricultural science
  - Factorial designs, ANOVA
- The **first industrial** era, 1951 – late 1970s
  - Box & Wilson, response surfaces
  - Applications in the chemical & process industries
- The **second industrial** era, late 1970s – 1990
  - Quality improvement initiatives in many companies
  - Taguchi and robust parameter design, process robustness
- The **modern** era, beginning circa 1990

The Basic Principles of DOX

Motivated Example:

A metallurgical engineer wants to know which one of the two hardening processes, oil quenching and saltwater quenching, produces the maximum hardness for a particular alloy. The engineer subjects a number of alloy specimens to each quenching medium and measures the hardness of the specimens after quenching. He then compares the average hardness of the specimens treated in each quenching solution.

What questions may come to your mind?

- **Randomization** How should the specimens be assigned to the quenching solution, and in what order should the data be collected?
  - the independence of the observations
  - what happens if all the specimens subjected to the oil quench are thicker than those subject to the saltwater?
- **Replication** How many specimens should be tested in each quenching solution?
  - Sample size (improving precision of effect estimation, estimation of error or background noise)
  - Replication versus repeat measurements?
- **Blocking** Are there any other factors that might affect hardness that should be controlled in this experiment?
  - Dealing with nuisance factors

Strategy of Experimentation

- **“Best-guess” experiments**
  - Used a lot
  - More successful than you might suspect, but there are disadvantages…
- **One-factor-at-a-time (OFAT) experiments**
  - Sometimes associated with the “scientific” or “engineering” method
  - Devastated by interaction, also very inefficient
- **Statistically designed experiments**
  - Based on Fisher’s factorial concept

Factorial Designs

- In a factorial experiment, **all possible combinations** of factor levels are tested
- The golf experiment:
  - Type of driver
  - Type of ball
  - Walking vs. riding
  - Type of beverage
  - Time of round
  - Weather
  - Type of golf spike
  - Etc, etc, etc…

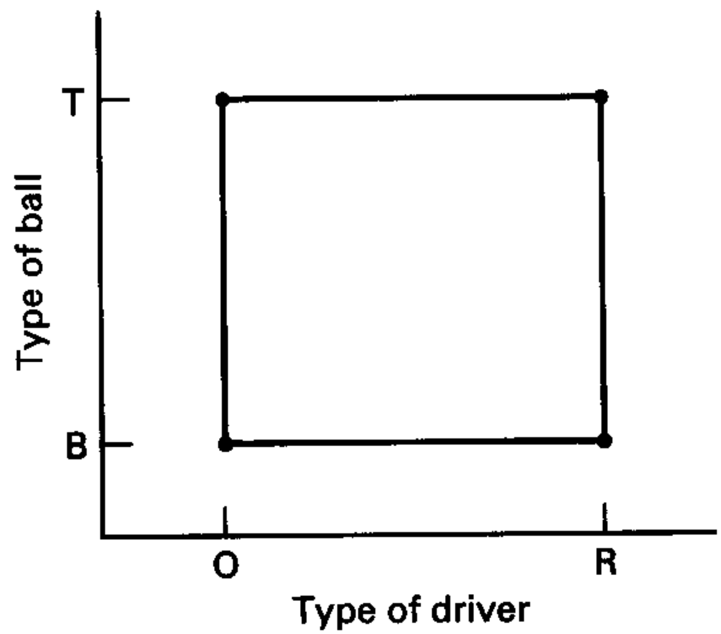
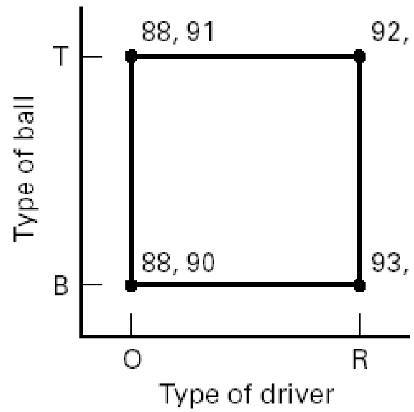
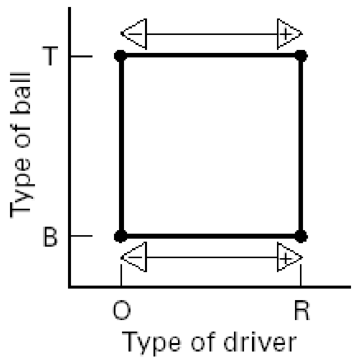


Figure 1-4 A two-factor factorial experiment involving type of driver and type of ball.

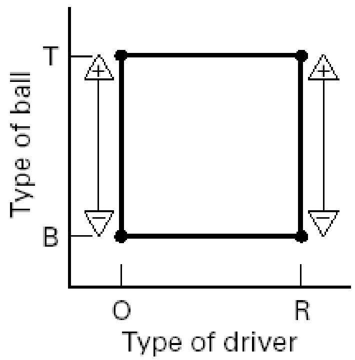
Factorial Design



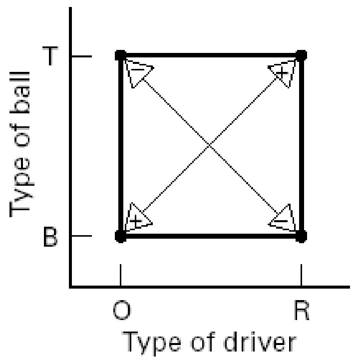
(*a*) Scores from the golf experiment



(*b*) Comparison of scores leading to the driver effect



(*c*) Comparison of scores leading to the ball effect



(*d*) Comparison of scores leading to the ball-driver interaction effect

Figure 1-5 Scores from the golf experiment in Figure 1-4 and calculation of the factor effects.

Factorial Designs with Several Factors

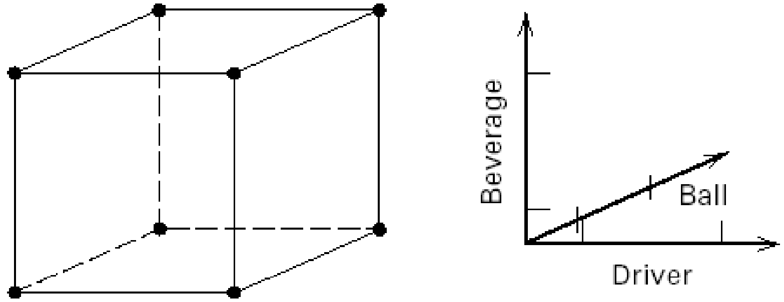


Figure 1-6 A three-factor factorial experiment involving type of driver, type of ball, and type of beverage.

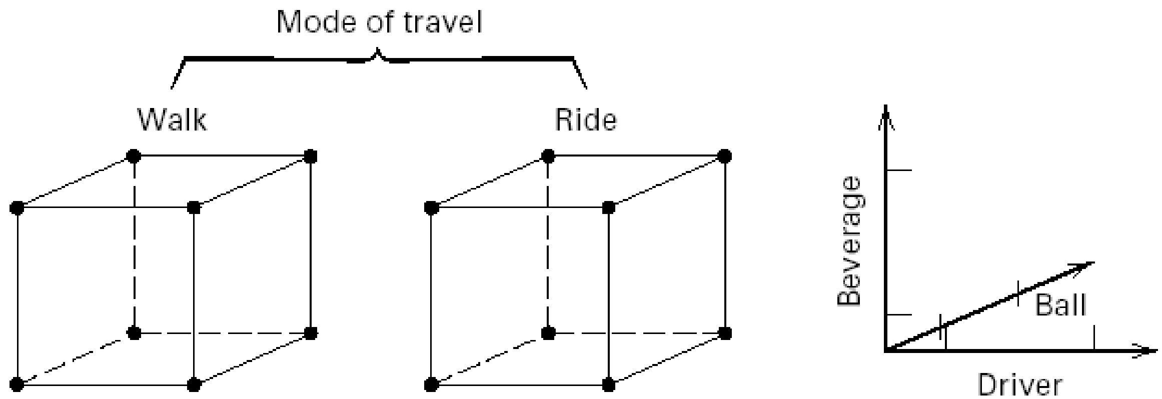


Figure 1-7 A four-factor factorial experiment involving type of driver, type of ball, type of beverage, and mode of travel.

Planning, Conducting & Analyzing an Experiment

1. Recognition of & statement of problem
2. Choice of factors, levels, and ranges
3. Selection of the response variable(s)
4. Choice of design
5. Conducting the experiment
6. Statistical analysis
7. Drawing conclusions, recommendations

Keep in Mind!

1. Use your nonstatistical knowledge of the problem
2. Keep the design and analysis as simple as possible
3. Recognize the difference between practical and statistical significance
4. Experiments are usually iterative