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Section 1

MANE 6313

Subsection 1

Week 1, Module D

Some Typical Applications

1. Improved process yields
2. Reduced variability and closer conformance to nominal or target requirements
3. Reduced development time
4. Reduced overall costs

Engineering Design Activities

1. Evaluation and comparison of basic design configurations
2. Evaluation of material alternatives
3. Selection of design parameters so that the product will work under a wide variety of field conditions (robust design)
4. Determination of key product design parameters that impact product performance

Basic Principles

- **Replication**. Repetition of basic experiment. Two important properties.
  - Allows an estimate of the experimental error to be obtained
  - Replication permits a more precise estimate of $\bar{x}$ $V(\bar{x}) = \frac{\sigma^2}{n}$
- **Randomization**. The allocation of the experimental material and the order of the experiments. Statistical methods require that the errors are independent. Randomization usually makes this assumption valid.
- **Blocking**. A technique used to improve the precision of an experiment. A block is a portion of the experimental material that should be more homogeneous than the entire set of material.

Guidelines for Designing Experiments

1. Recognition of and statement of the problem
2. Choice of factors, levels and ranges
3. Selection of the response variable
4. Choice of the experimental design
5. Performing the experiment
6. Statistical analysis of the data
7. Conclusions and recommendations

History of DOE

DOE can be divided into four eras

1. Agricultural era
   Pioneered by Fisher in the 1920's and 1930's (3 principles)
2. Industrial era
   Development of RSM methods by Box and Wilson (1951).
3. Western industries and Taguchi
   increasing interest in quality improvement and impact of Taguchi (late 1970's - early 90's)
4. Modern era
   renewed general interest in statistics, use in many new fields, focus on industrial problems

From another point of view

Table 1.2

Checklist for Designed Experiments*

A. *Obtain a clear statement of the problem.*
   1. Identify the new and important problem area.
   2. Outline the specific problem within current limitations.
   3. Define the exact scope of the experiment.
   4. Determine the relationship of the problem to the entire research or development program.

B. *Collect available background information.*
   1. Investigate all available sources of information.
   2. Tabulate data pertinent to planning the experiment.

C. *Design the experiment.*
   1. Hold a conference of all parties concerned and brainstorm.
      a. State the propositions to be proved.
      b. Agree on the magnitude of differences considered worthwhile.
      c. Outline the possible alternative outcomes.
      d. Choose the factors to be studied.
      e. Determine the practical range of these factors and the specific levels to be used.
      f. Choose the end measurements to be made.
      g. Consider the effect of sampling variability and precision of measurement methods.
      h. Consider possible interrelationships (interactions) of the factors.
      i. Determine limitations of time, cost, materials, human resources, instrumentation, and other facilities and the impact of extraneous conditions such as weather.
      j. Consider human relations and their effects on the experiment.
   2. Design the experiment in preliminary form.
      a. Prepare a systematic and inclusive schedule.
      b. Provide for stepwise performance or adaptation of the schedule if necessary.
      c. Eliminate the effect of variables not under study by controlling, balancing, or randomizing them.
      d. Minimize the number of experimental runs required.
      e. Choose the method of statistical analysis.
      f. Arrange for orderly accumulation of data.

From another point of view, continued

Table 1.2

Checklist for Designed Experiments* *(Continued)*

D. *Plan and carry out the experimental work.*
1. Develop methods, materials, and equipment.
2. Apply the methods or techniques.
3. Attend to and check details; modify methods if necessary.
4. Record any modifications of experimental procedures.
5. Take precautions in collecting data.
6. Record the progress of the experiment.

E. *Analyze the data.*
1. Reduce the recorded data to numerical form if necessary.
2. Apply proper statistical techniques.

F. *Interpret the results.*
1. Consider all the observed data.
2. Confine conclusions to strict deductions from the evidence at hand.
3. Test questions suggested by the data by conducting independent experiments.
4. Make conclusions about the technical meaning of results as well as their significance.
5. Point out implications of the findings for application and further work.
6. Account for any limitations imposed by the methods used.
7. State results in terms of verifiable probabilities.

G. *Prepare the report.*
1. Describe work clearly. Give background, pertinence of the problems, and meaning of results.
2. Use tables and graphs to present data in a usable form.
3. Supply sufficient information to permit the reader to verify results and draw conclusions.
4. Limit conclusions to an objective summary of evidence so that the work recommends itself for prompt consideration and decisive action.

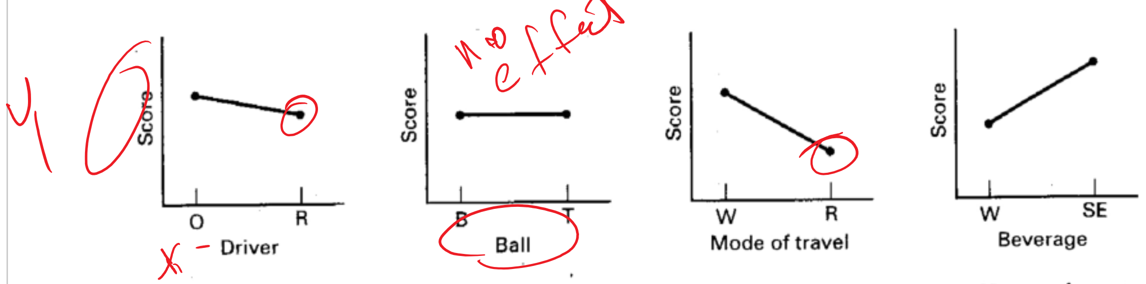
Using Statistical Techniques in Experimentation

- Use your nonstatistical knowledge of the problem
- Keep the design and analysis as simple as possible
- Recognize the difference between practical and statistical difference
- Experiments are usually iterative

↳ Don't spend entire budget on 1st experiment

Case Study

The wrong approach - one factor at a time



■ FIGURE 1.2 Results of the one-factor-at-a-time strategy for the golf experiment

4 Factors

Figure 3: image

Driver → set other 3 factors

Huge Assumption: all factors are independent of each other (additive)

Case Study, continued

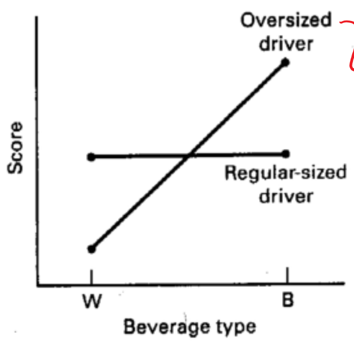
No interaction: Parallel lines

Interactions are an important concept

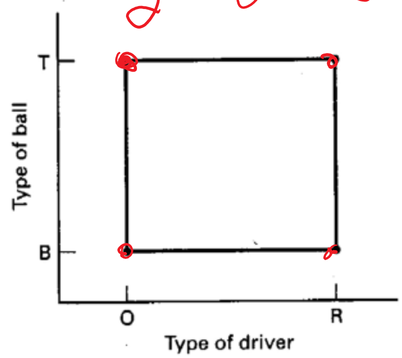
Two-factors

Driver

2^2 design



■ FIGURE 1.3 Interaction between type of driver and type of beverage for the golf experiment

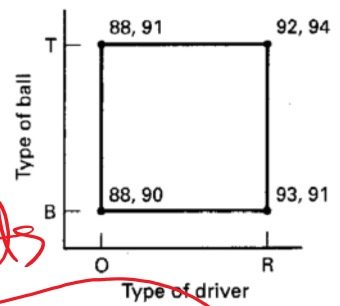


■ FIGURE 1.4 A two-factor factorial experiment involving type of driver and type of ball

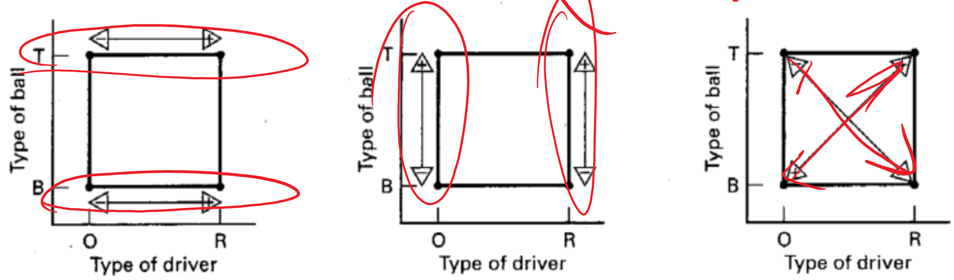
Figure 4: image

Recognize interaction requires factorial experiment with either multiple replicates or multiple center-points

Case Study, continued



(*a*) Scores from the golf experiment



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

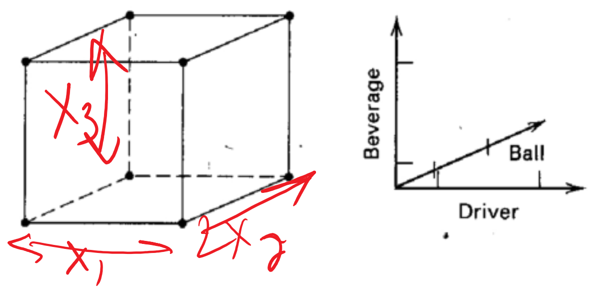
(*c*) Comparison of scores leading to the ball effect

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

Case Study, continued

two-level experiments

Cube

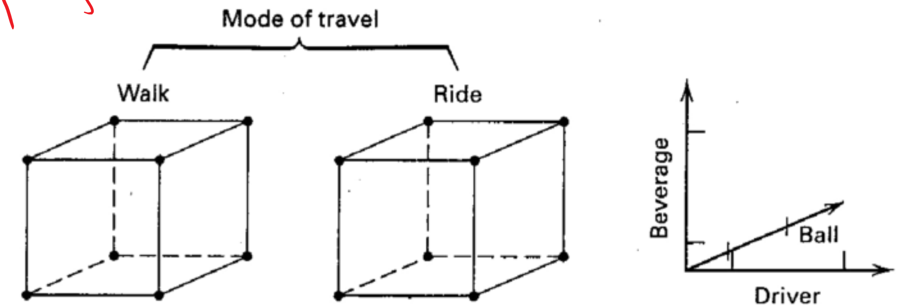


■ **FIGURE 1.6** A three-factor factorial experiment involving type of driver, type of ball, and type of beverage

Figure 6: image

Case Study, continued

4 factors 2^4



■ **FIGURE 1.7 A four-factor factorial experiment involving type of driver, type of ball, type of beverage, and mode of travel**

Figure 7: image