Statistics and Science, Business and Industry

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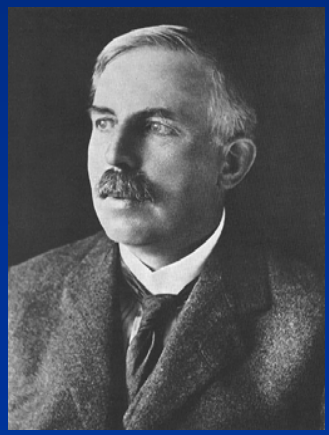
- At the beginning of the 20th century, science, and most of business and industry was based on determinism
- Physical (economic) laws = reality = ability to predict future events
- All we needed was a complete set of the appropriate formulas and sufficient measurements

- Big successes in the 19th century supported this viewpoint
  - Newton's methods were used to predict the existence of Neptune (1840s)
  - Enhanced belief in determinism
- Science (business, industry) dealt with things that were constant
- We just needed enough data to describe these events precisely
- Statistics had a relatively minimal role (some exceptions in agriculture and genetics)

- “If your experiment needs statistics, you ought to have done a better experiment.”

Ernst Rutherford (1871 – 1037),
Nobel Prize in Physics, 1908



- “God doesn’t play dice.”

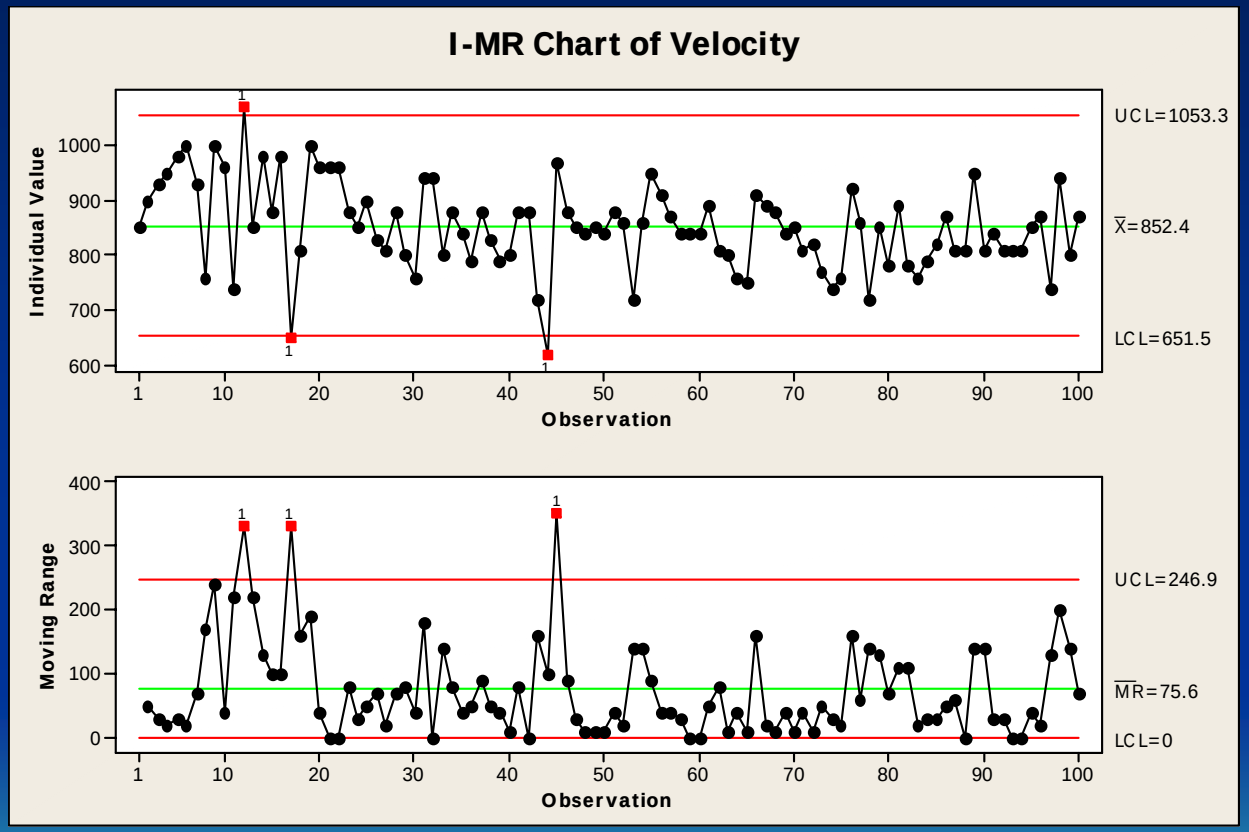
Albert Einstein (1979 – 1955),
Nobel Prize in physics, 1921

Albert A. Michelson (1852 – 1931)

- One of the first scientists to discover that more data doesn't resolve ambiguities
- Michelson graduated from the United States Naval Academy
- Academic appointments at USNA, Case School of Applied Science, University of Chicago, and Mount Wilson Observatory
- Nobel Prize in physics, 1907

- Michelson is perhaps most famous for his invention of the interferometer
- Used in experiments (with E. W. Morley) to measure the velocity of light
- Michelson and Morley took lots of measurements – remember the contemporary thinking was that with more data, we can describe things precisely

Data from the Michelson and Morley Experiment Velocity = observed velocity – 299,000 k/s

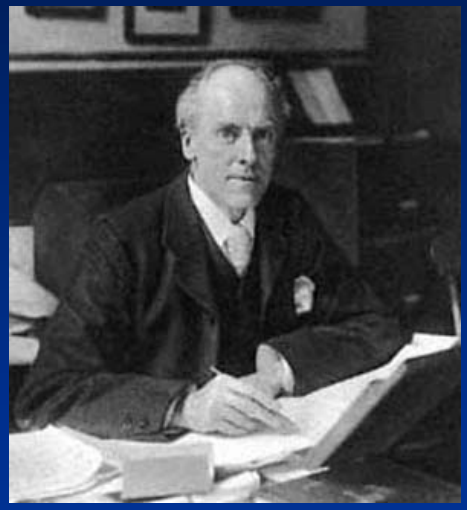


Variability

- By the early 20th century, science was advancing in measurement capability; more measurements and greater precision in those measurements were theoretically possible
- But the more “precise” the measurements, the more “error” was observed
- Variability in the response was being recognized as an “evil” that must somehow be overcome (or at least reckoned with!)
- Courses on statistical mechanics began to appear in physics, engineering curricula
- Frederick Taylor, “Scientific management”
- Frank Gilbreath and the science of work measurement

Karl Pearson (1857 – 1936)

- One of the first to change traditional thinking
- It was the probability distribution of things that was real
- The distribution is described by parameters that can only be estimated from data
  - Methods of estimation were not the best
  - Pearson's distributions did not cover all situations

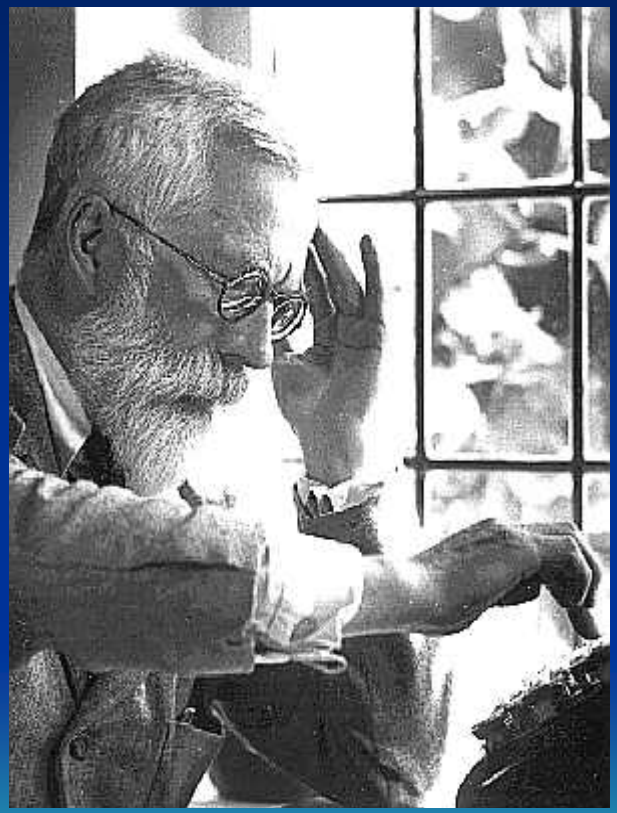


The First Two Industrial Statisticians?

- William Sealy Gosset (1876 – 1937)
  - Guinness, 1899 (although not hired as a statistician)
  - Provided a scientific tool used by nearly everyone
  - Fabulous collaborator and mentor
- A. K. Erlang (1878 – 1929)
  - Copenhagen Telephone Company, 1908
  - Trunking tables, loss formula
  - Still the basis of modern switching system design

Ronald Aylmer Fisher (1890 – 1962)

- Design of experiments
- Important contributions to estimation, hypothesis testing, mathematical foundations of statistics
- Agricultural science, genetics, biological and medical sciences



Four Eras in the History of DOX

- The **agricultural** origins, 1918 – 1940s
  - R. A. Fisher & his co-workers
  - Papers on “Studies in Crop Variation, I – VI”, 1921 – 1929 produced ANOVA, ANCOVA
  - Factorial designs came into use
  - Profound impact on agricultural science

Four Eras in the History of DOX

- The **first industrial** era, 1951 – late 1970s
  - Differences between industrial and agricultural experiments
  - Box & Wilson; sequential experimentation, response surfaces
  - Applications in the chemical & process industries

Four Eras in the History of DOX

- The **second industrial** era, late 1970s – 1990
  - Global competitiveness
  - Quality improvement initiatives in many companies
  - Taguchi and robust parameter design, process robustness
  - SEMATECH and the process characterization plan
  - DOX spreads to organizations with no history of using it

Four Eras in the History of DOX

- The **modern** era, beginning circa 1990
  - Widespread availability of good software
  - Better statistics education of engineers and scientists in universities
  - Six sigma
    - DMAIC, DFSS
    - Recognizes, exploits the potential impact of DOX
  - Applications of DOX spreads to many new areas
    - Transactional systems, services
    - Computer models

Three Others Who Changed the Industrial World

- Walter A. Shewhart (1891 – 1967)
  - Studied physics at U of Illinois, UC Berkeley
  - Brief academic career, then in 1918 joined Western Electric & Bell Labs
  - Reliability of telephone gear an issue

Walter A. Shewhart

- Sources of variability
  - Chance (or common) causes
  - Assignable (or special) causes
- The Shewhart control chart
- The Shewhart Cycle
  - Plan
  - Do
  - Check
  - Act

Three Others Who Changed the Industrial World

- W. Edwards Deming (1900 – 1993)
  - Trained in electrical engineering and physics (Wyoming, Colorado, Yale)
  - Met Shewhart at Western Electric
  - Long career in government statistics, USDA, Bureau of the Census
  - Fundamental contributions to sampling theory
  - Sent to Japan after WW II to work on the census
  - Long career as a management consultant, lecturer

W. Edwards Deming

- Advocate of Shewhart's theories, methods
- Instrumental in getting Shewhart's methods adopted in improving efficiency of wartime production
- Consultant to management
- The 14 points, the deadly diseases
- Much of Deming's philosophy was about organizational change, and the barriers

Three Others Who Changed the Industrial World

- Joseph M. Juran (1904 -)
  - Born in Romania
  - Worked at Western Electric, influenced by Walter Shewhart
  - By 1937, he was the head of Industrial Engineering at Western Electric
  - Administrator for the Lend-Lease program during WW II

Joseph M. Juran

- After WW II he became Chair of the Department of Administrative Engineering at NYU
- Built an extensive consultancy, the Juran Institute
- Emphasizes a strategic, planning-based approach to quality improvement
  - The Juran Trilogy (planning, improvement, control)
  - Breakthrough, project approach

Other Milestones

- L.H.C. Tippett, E.J. Gumbel, statistics of extremes
- P.C. Mahalanobis, T.W. Anderson, multivariate analysis
- Wilcoxon, Mann & Whitney, nonparametric statistics
- The Weibull distribution, Nancy Mann, reliability engineering
- Harold Dodge and Harry Romig, sampling
- I.J. Good, codebreaking, empirical Bayes, hierarchal Bayes models
- Yvonne Bishop, the national halothane study, log-linear models
- David Cox, 25 years as editor of *Biometrika*, contributions to biostatistics
- *Technometrics* founded, 1959
- *Journal of Quality Technology* founded, 1969
- Box, Cox and transformations
- Tukey, FFTs, exploratory data analysis
- Tukey and others, the Princeton robustness study
- Janet Norwood, the US CPI
- GLMs, GEEs
- Etc, etc, etc…

A New Environment

- Statisticians are needed more than ever
  - Microarray experiments – lots of data points, many parameters
  - Particle physics
  - Biotchnology
  - Quantum effect microelectronic devices
  - Massive data sets in astronomy, biology, medicine, business and commerce

Six Sigma Plays a Role in This

- Three “generations” so far
  - Generation I: focus on defect reduction, Motorola, 1987-1883
  - Generation : focus on cost reduction, GE/Allied Signal-Honeywell, 1994-1999
  - Generation III; focus on value creation; Dupont, 2000-present
- What’s next?

Look at History

- SQC, DOX – origins in the 1920s, 1950s
- Operations Research/Industrial Engineering – “the science of better” (1940s)
- Value engineering, zero defects, 1950s
- FDA, EPA in the 1970s
- TQM in the 1980s
- Business process Reengineering, late 1980s
- Six sigma, 1987

- Commercial applications
  - Banking and finance
  - Public sector
  - Services including health care
- DFSS
  - Only so much improvement can be wrung out of an existing system
  - New product & process design
- Link business, suppliers, customers together – logistics and supply chain
- Statistics will play a huge role in this

Framework of an Overall System: Six Sigma/DMAIC/Lean/DFSS

Design for Six Sigma

- Requirements allocation
- Capability assessment
- Robust Design
- Predictable Product Quality

Lean

- Flow Analysis/Mapping
- Waste Elimination
- Cycle Time
- WIP Reduction
- Operations and Design

Operational Six Sigma

- Predictability
- Feasibility
- Efficiency
- Capability
- Accuracy

Advantages of an Integrated Approach

- Broad-based
- End-to-end approach
- Reaches all parts of the organization
- Management involvement/commitment
- High business impact
- Does not necessarily focus on just the “visible numbers”
- A “systemic” approach, consistent with Deming’s philosophy

Project-Based Implementation

- Project-based approach speeds up improvement
- Good projects:
  - Should be clearly connected to business goals, and reflect both strategic objectives and the priorities of the current operating plan.
  - Are recognized to be of major importance to the business, both in terms of its quality and financial impact.
  - The scope should not be too big; completion within six months is a desirable objective.
  - Should have quantitative measures of success that can be evaluated both before/after the project is completed.
  - Should have management support

Project Selection

- You have a four-sigma process (6210 ppm)
- Objective = six sigma performance (3.4 ppm)
- Suppose that we have a 25% annual improvement rate
- To achieve the goal will take *x* years, where

$$3.4 = 6210(1-0.25)^{x}$$

- *x* = 34 years!

Project Selection

- A goal of 50% annual improvement reduces *x* to about 11 years
- At the 75% annual improvement rate, *x* is about 5 years
- Projects
  - Strategic
  - Formal selection process
  - Management and execution
  - Implementation/holding gains/replication

Deming's System of Profound Knowledge

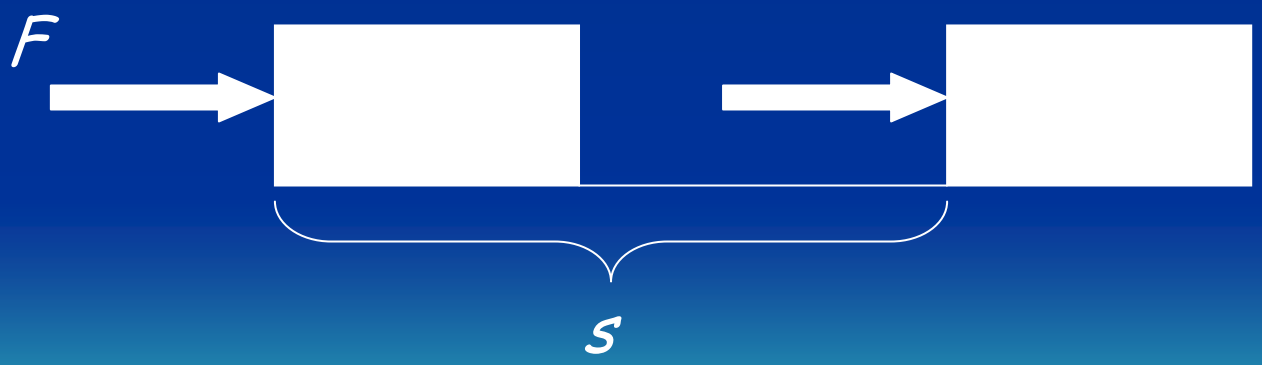
- Appreciation of a System – the system involves operations, design, and transactional components
- Knowledge about Variation = reduces variation throughout the system
- Theory of Knowledge = identifies key cause and effect relationships that permit system-wide optimization
- Theory of Psychology - management, teams-workforce involvement, focus on business impact, leadership development

“The long-term impact of statistics on science, business and industry depends not so much on getting a lot of highly trained statisticians into industry as it does in creating a *statistically minded* generation of physicists, chemists, engineers and managers who will develop and direct the productive processes of tomorrow”

Increasing the Power of Statistics

A force *F* acting through a distance *s* performs work:

$$W = Fs$$



Increasing the Power of Statistics

Power is a measure of how fast work is done:

$$P = \frac{Fs}{t} = \frac{W}{t}$$

Increasing the Power of Statistics

$$P = \frac{Fs}{t}$$

More force = more power

More distance = more power

Shorter time = more power

How well can we apply force to our opportunities?

How much leverage (distance) can we generate?

How quickly can we apply it?

Thank You