


DATA COLLECTION & ANALYSIS FOR MANAGERS

Prepared and presented for the
ASQ Toronto Section
by
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Objectives :


- At the conclusion of this session, you should
 - understand the ISO 9001 requirements to collect and analyse data,
 - have identified sources and ways to analyze and use data from the Quality System (QS) and other Management Systems (MS), and
 - have identified opportunities to integrate the QS and MS

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Reason:

Whether motivated by the requirements of a standard or by the needs of business, effective management is based primarily on facts; notwithstanding recent enthusiasm for “right brain” management.

(And the class lawsuits after corporate failures also tend to be fact-based.)



Main resources:

- We will make reference to both ISO 9001 and ISO/TR10017
 - ISO 9001:2000 “Quality management systems - Requirements”
 - “BEST” source “ISO 9000 Essentials” (PLUS 9001 3rd ed) CSA
 - ISO/TR 10017:1999 “Guidance on statistical techniques for ISO 9001:1994”, under revision to harmonize with ISO 9001:2000

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ISO 9001- Requires

- Determine, collect, analyze data
 - QMS performance
 - Process & product conformity
 - Continual improvement
 - Monitoring & measurement
 - “Records”
- Apply to
 - Customer satisfaction
 - Product conformity
 - Process & product characteristics and trends
 - Preventive action
 - Supplier control and development

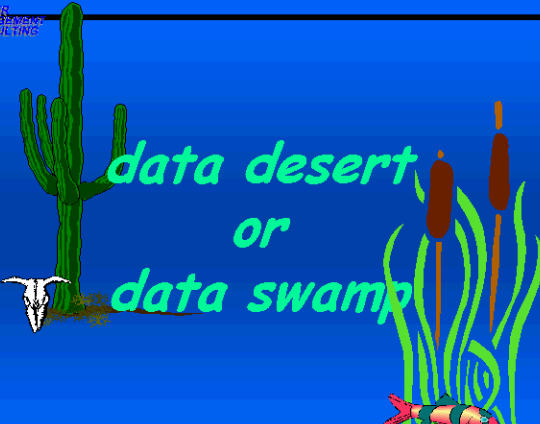
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ISO 9001:2000 obligates you to examine the performance of your own quality system by collecting and analysing observations and acting on them to eliminate and prevent problems. A bit like the cod liver oil of your grandparents day, these unpleasant chores yield great benefits to those who don't choke on them.

Curiously, most organizations take a different attitude to financial performance. They monitor, analyse and act on every twitch in earnings, stock value or sales volume.

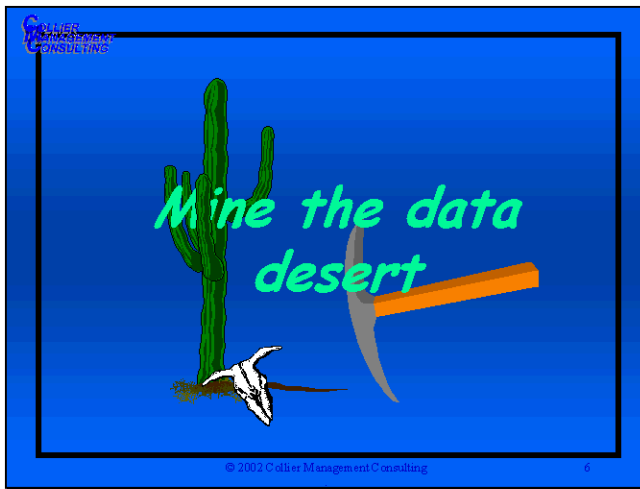


data desert or data swamp

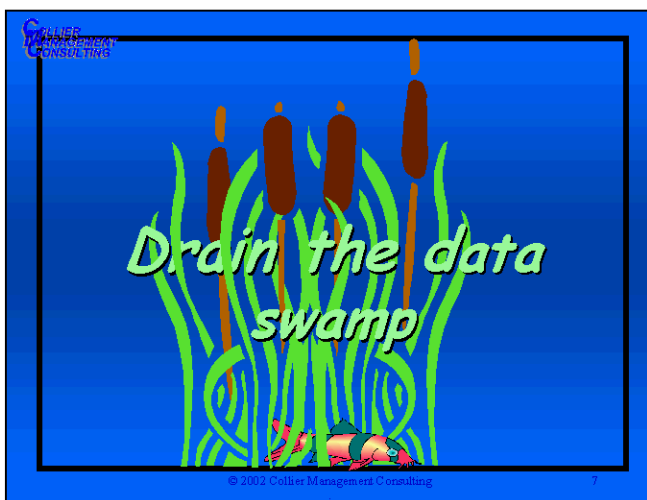


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Question: Do you have too much or too little information in your organization?

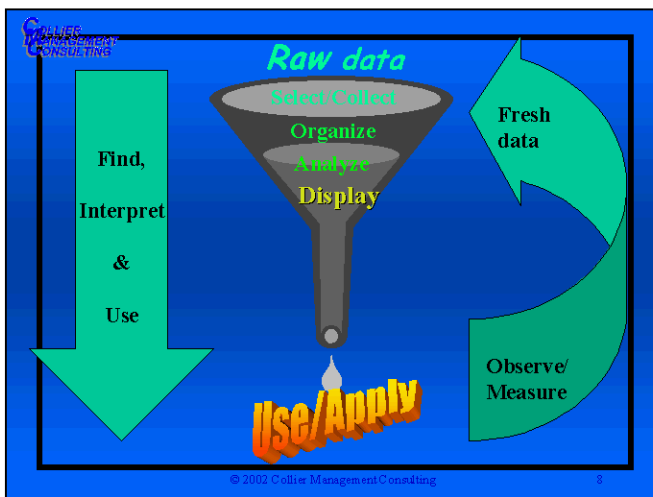


If you don't have info (or don't know that you have it) then you need to go prospecting. It is available, and you ignore it at your peril.



More commonly, management is awash in information. The in-basket deluge is the biggest time management challenge facing most managers and supervisors. Many handle it by deferring everything they can't quickly comprehend and dealing only the things they think they understand.

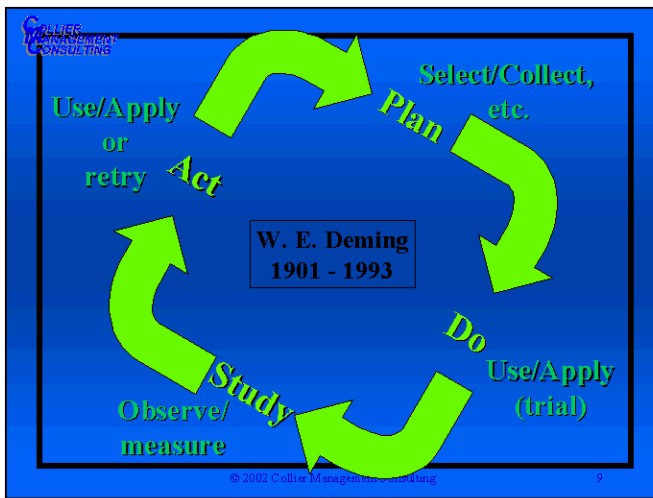
Does this explain the lack of progress and change in many companies?



Data collection and analysis is a closed loop process. It starts with discovery and collection of an incomprehensible and often disorganized mass of facts. It proceeds through filtering, organization and analysis until we create a picture that is intelligible both to ourselves and to others who need to know.

This becomes the basis for creative thinking: speculated causes, possible improvements and outright innovations.

By trying out new ideas and measuring the results we create fresh data and repeat the process.

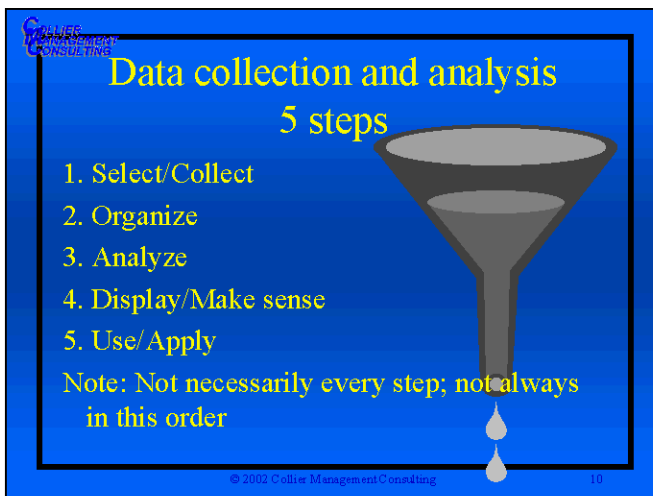


While not exactly parallel, the process described is related to W. Edwards Deming’s famous PDCA cycle for systematic improvement.

Deming actually called this the Shewhart Cycle, crediting the concept to Walter A. Shewhart in his 1931 book, “Economic Control of Quality of Manufactured Product”. (Yes, the world has been glacially slow to catch on!)

The message Deming intended to convey with this mnemonic was to continually explore the prospects for change and improvement:

- Plan a change or a test aimed at improvement. Design an experiment or pilot run.
- Do the experiment. Carry out the change, preferably on a pilot scale or limited time.
- Study the results of the experiment and draw conclusions as the worth of the change.
- Act by a) adopting the change or b) abandoning it or c) running another experiment to search for a better way.



Introducing a programmed approach to MBD.

These five steps are like the instructions or requirements for a computer programmer. They are not explicit enough to be executed as written, but they tell you (the organizational programmer) to create processes and systems, suited to your own needs, that will:

- identify and collect the data you need to understand and improve operations,
- organize it so that is manageable and intelligible,
- analyze it to reveal patterns and relationships and to draw conclusions,
- display the patterns and relationships so that others can understand the conclusions, and
- apply the conclusions by making improvements to your processes.

1. Select/Collect

- "Quality" sources
 - The QS is designed to gather information and apply it to control and improve quality
- "un-Quality" sources
 - The MS is designed to gather information and apply it to control and improve the business

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Management systems ("quality" or other) exist to control the behaviour of the organization.

Control by definition requires knowledge of the intended goal, measurement of the actual output, comparison of the two and correction or redirection to reduce the difference.

The first step is to select the desired information and to collect it without distortion or bias.

1. Select/Collect

"Quality" sources

- Quality system
 - Records kept
 - Results of all tests, measurements and inspections
 - Audit results
 - Nonconformances, complaints, failures
 - Management review input
- Review input (5.6.2)
 - Audit results
 - Customer feedback,
 - Process/product Q
 - PA/CA status
 - Past review actions
 - Changes
 - Improvements

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This list is a precis of what data and information you would be required retain under ISO 9001:2000. You are invited to add to it and make it more explicit to your organization.

1. Select/Collect

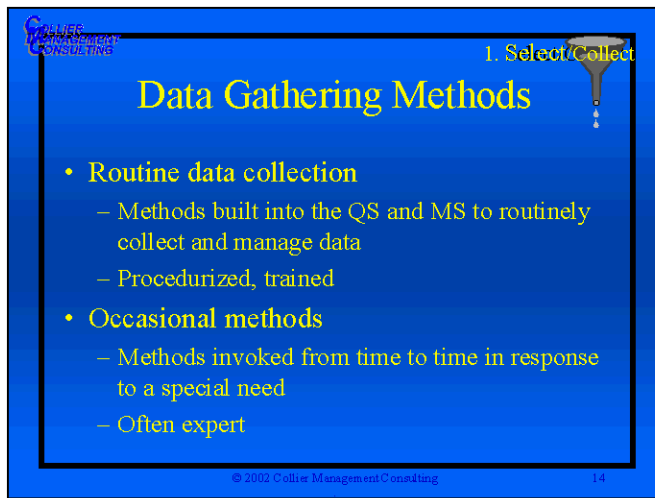
"un-Quality" sources

- Sales & marketing
- MRP/ERP systems
- Production control system
- Accounting system
- IT system
- Others?

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"Un-Quality" does not mean low quality. Chances are, your organization already has impressive data acquisition systems, many of them automated to the point that they are nearly invisible.

Therein lies the commonest failing of companies preparing a formal quality management system. Unaware of what they already have, they regress several decades and create dozens or hundreds of forms to be completed, entered, filed and (often) forgotten.



1. Select/Collect

Data Gathering Methods

- **Routine data collection**
 - Methods built into the QS and MS to routinely collect and manage data
 - Procedurized, trained
- **Occasional methods**
 - Methods invoked from time to time in response to a special need
 - Often expert

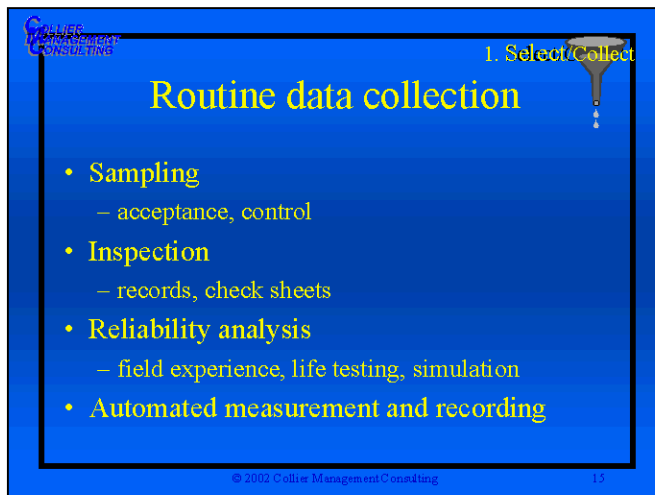
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Some data are needed regularly (hourly, daily, weekly, ...) so there is justification to design and implement a regular collection and entry system. Paper forms and computer screens should be self explanatory and easy to use. Automation is inviting: electronic gauges interface directly with a PC; bar code readers count, catalogue and route; process control sensors can send data to a PLC and a record file.

Data needed only for a particular occasion may require the invention of a collection system for the purpose.

Problems:

- Routine - People forget why
- Occasional - People forget how

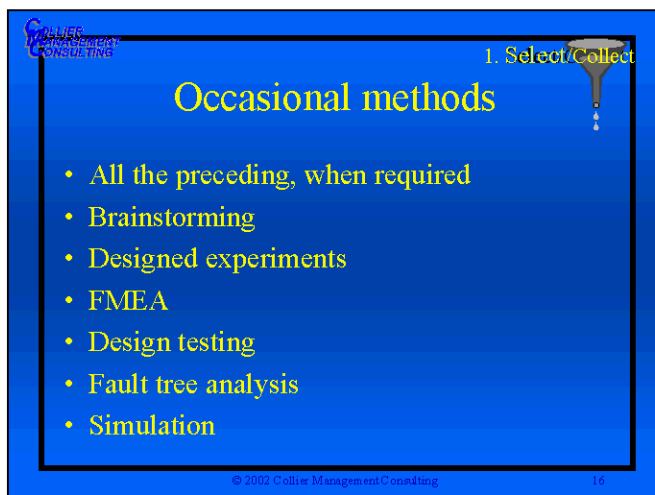


1. Select/Collect

Routine data collection

- **Sampling**
 - acceptance, control
- **Inspection**
 - records, check sheets
- **Reliability analysis**
 - field experience, life testing, simulation
- **Automated measurement and recording**

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1. Select/Collect

Occasional methods

- All the preceding, when required
- Brainstorming
- Designed experiments
- FMEA
- Design testing
- Fault tree analysis
- Simulation

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2. Organize

- Tabulation
 - spreadsheet, database
- Histogram
- Statistical distribution
 - pictures that fit
- Run chart
- SPC chart
- Scatter diagram
- Cause & effect diagram
- Affinity diagram

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The most valuable single thing you can do with data is to draw a picture.

3. Analyze

- There must be enough data to analyze
- “One observation is worse than none at all.”
 - no estimate of variation
 - no history, no predictive power
 - actions almost certainly counterproductive

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Your newly designed single cavity mould has just produced its first trial part.

Spec = 3.50 ± 0.05

Measurement = 3.52

Action = ?

ISO TR 10017 Recommends:

- Where data are useful to meet ISO 9001 requirements
- How to analyse the data using well known techniques

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Will return to this standard later.

Here's a partial index:

1 Scope

2 Terms and definitions

3 Identification of potential needs for statistical techniques

4 Descriptions of statistical techniques identified (12 useful techniques briefly described.)

and some handy tables in the Appendix.

3. Analyze

Index of statistical techniques listed in ISO TR 10017

- Descriptive statistics
- Design of experiments
- Hypothesis testing
- Measurement analysis
- Process capability analysis
- Regression
- Reliability analysis
- Sampling
- Simulation
- SPC charts
- Statistical tolerancing
- Time series analysis

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3. Analyze

Compare data

- To other data
 - Descriptive statistics
 - Hypothesis testing (Confidence & significance)
 - Time series analysis
 - SPC charts
 - Design of experiments (DE, DOE)
 - Reliability analysis
- To standards or predictions
 - Measurement analysis
 - Process capability analysis
 - SPC charts
 - Design of experiments
 - Hypothesis testing
 - Reliability analysis

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Compare current data to historical data to learn whether things have improved or worsened.
 Compare to standards to learn whether you meet a requirement.
 Compare to predictions to test your understanding of the process.

3. Analyze

Find patterns

- Regression
- Time series analysis
- SPC charts
- Reliability analysis

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Patterns in data, especially over time, provide warnings, predictions and insight into causes.

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4. Display/Make sense

4. Display/Make sense

- For yourself
 - Very few can comprehend a page of numbers at a glance (Rain Man genius)
- For an audience
 - You need to convey your understanding to others who have not been through the process of analysis and interpretation
 - Clarify with pictures
 - Confuse with tables

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Examine any list or table of 50 or more numbers. (Accountants and inspectors are good sources).

Did you search for the highest and lowest? The one in the middle?

Did you look to see whether the last was greater than the first? Whether they generally increased or decreased?

If you immediately know the largest, smallest, average, etc. you may identify with the Dustin Hoffman in Rainman. (Search “Savant Syndrome” on the web.)

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50 numbers

0.77	0.95	0.59	0.10	0.32
0.85	0.76	0.45	0.47	0.58
0.40	1.00	0.55	0.01	0.47
0.81	0.55	0.78	0.85	0.77
0.98	0.58	0.15	0.74	0.69
0.82	0.72	0.13	0.84	0.14
0.44	0.37	0.51	0.30	0.34
0.95	0.66	0.79	0.94	0.33
0.86	0.05	0.28	0.19	0.79
0.85	0.73	0.82	0.97	0.20


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4. Display/Make sense

Pictures

- Pareto analysis
- Run charts
- Flow charts
- Graphs



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4. Display/Make sense

Numbers

- Tables
 - OK for small amounts of data
- Descriptive statistics
 - Powerful summary but may mislead
- Misleading data
 - Correlation is not cause-effect
 - Deceptive suggestions
 - “Lies, damned lies, statistics” - Disraeli

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Some numbers you can calculate instantly (e.g. using the Formulas and Data Analysis menus in Excel)

average (mean), median, mode, maximum, minimum, range, standard deviation, variance, correlation coefficient, ...

Note that some graphical methods taught until quite recently were used mainly because computation was so difficult but they still provide useful pictures to summarize results.

5. Use/Apply

- Collecting and analyzing is expensive; the ROI lies in action to correct and improve the business.
- To test the usefulness of a report, stop sending it.
- The following slides list some techniques and systems for wringing value from data analysis

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Unused data is a sad waste. If you don't learn from experience, you are destined to have many painful experiences.

5. Use/Apply

Numeric

- Statistical tolerancing
- DE (DOE)
- Reliability engineering
- PDSA

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Statistical tolerancing drives you towards a rational combination of requirements and methods; requirements set high enough for the customer, methods that are sufficient and economical .

DE gathers most information with greatest economy and certainty.

Reliability deals with performance over time.

PDSA is a discipline for managing many numerical methods for improvement.

5. Use/Apply

Non-numeric

- Total Quality Management
 - old but durable philosophy
- Project management
 - objective, plan, resources, reporting
- PDSA again
 - cyclic improvement
- Problem solving
 - connecting problem definition to solution
- Group Techniques
 - brainstorming, .
- QFD
 - linking systems and actions to customer wants and organization goals

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These are beyond the scope of this lecture.

References abound in the literature.

ISO TR 10017

A quick overview of techniques from ISO TR 10017

- Descriptive statistics
- Design of experiments
- Hypothesis testing
- Measurement analysis
- Process capability analysis
- Regression
- Reliability analysis
- Sampling
- Simulation
- SPC charts
- Statistical tolerancing
- Time series analysis

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ISO TR 10017

Descriptive statistics

- Summarize complex data or relationships
- Graphical methods
- Central tendency (mean, mode, median)
- Spread or dispersion (range, standard deviation, variance)
- Shape of distribution (skewness, kurtosis)
- Usually the first step in analysis

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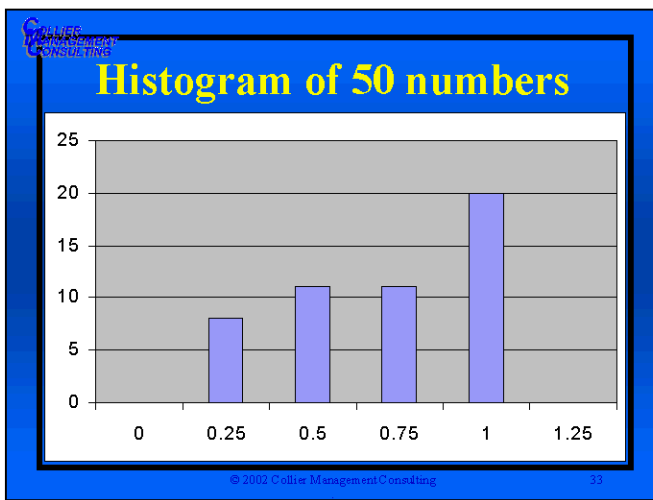
“Descriptive statistics” includes single numbers or pictures that summarize and characterize some aspect of a set of data; e.g., mean, median, mode = location; range, variance, standard deviation = spread.

They may also approximate the “parameters” of an underlying distribution that describes the process that generated the data. The Normal distribution or “bell curve” is the most familiar, but not the only one.

50 numbers

0.77	0.95	0.59	0.10	0.32
0.85	0.76	0.45	0.47	0.58
0.40	1.00	0.55	0.01	0.47
0.81	0.55	0.78	0.85	0.77
0.98	0.58	0.15	0.74	0.69
0.82	0.72	0.13	0.84	0.14
0.44	0.37	0.51	0.30	0.34
0.95	0.66	0.79	0.94	0.33
0.86	0.05	0.28	0.19	0.79
0.85	0.73	0.82	0.97	0.20

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Descriptive statistics for 50 numbers

Mean	0.583259743
Standard Error	0.040188806
Median	0.623871339
Mode	#N/A
Standard Deviation	0.284177775
Sample Variance	0.080757008
Kurtosis	-1.023171367
Skewness	-0.408229218
Range	0.989175759
Minimum	0.007396724
Maximum	0.996572482
Sum	29.16298716
Count	50
Largest(5)	0.945692266
Smallest(5)	0.136251805

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Design of experiments

- Investigate by planned changes and statistical assessment of results
- Discover or verify source, magnitude and relationship of influences on complex system
- Maximize or optimize product, process, design or conditions
- Minimize amount of experimentation

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DOE or DE consists of imposing planned changes on a system under investigation and statistically assessing the effects to draw conclusions with a known level of confidence.

The “design” is the plan under which the experiments are performed. It is determined by the objectives of the study and the conditions under which the experiments are done.

DOE may invoke several of the techniques for data analysis.

In industry, the greatest benefit often lies in minimizing the number of experiments, and therefore the cost and nuisance of disruption to the system.

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ANOVA - after the experiment

Group	Count	Sum	Average	St. Dev.	St. Dev. (adj.)
RND Fixed	60	16298718	0.583259743	0.500000000	0.500000000
R+L	60	41298718	1.808259743	0.500000000	0.500000000
R+C	60	53241891	1.510848378	0.600000000	0.600000000
R+P	60	33298718	0.926859743	0.120000000	0.120000000
R+all	60	1539524189	3.079848378	1.140000000	1.140000000

Source of Variation	SS	df	MS	F	P-value	F _{crit}
Between Groups	188.2195211	4	46.55488028	95.98216699	5.37604E-49	2.408491184
Within Groups	118.8587755	245	0.485137659			
Total	305.0782967	249				

Annotations:
 - The "F" statistic is the ratio of two "variances".
 - The value at which we lose faith.
 - Probability that this value of F could arise by pure chance.
 - S S / df
 - A measure of variation

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Hypothesis testing

- Decide with known risk whether data compatible with hypothesis
 - Are differences due to cause or chance?
 - Does population parameter meet a standard?
 - Are there differences among populations?
 - Is a distribution normal?
 - Is sample data random?
- Invoked in other statistical techniques

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Statistics cannot “prove” anything about a system, but it can establish the level of skepticism to bring to a theory or recommendation. Hypothesis testing helps answer such questions as, “If I repeat the experiment or test some more product, how likely is it that the result will be significantly different?”, or “Should I trust this number to be accurate within ±0.01 units? ±0.005 units?”

ISO TR 10017

Measurement (system) analysis

- Evaluate measurement system uncertainty
- Quantify variation from various sources
- Compare measurement system variation to process variation or allowable variation
- Decide whether measurement system is suitable for intended purpose
- Select appropriate measurement instruments and systems

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To measure something the measurer needs an instrument, a method and a requirement. The commonest requirements are the ability to distinguish between acceptable and unacceptable products with known error and the ability to distinguish process variation from the inherent variation of the measurement system. The measurer may be human, machine or even animal. The instrument may be a physical device, a psychological test or a complex system in its own right.

Measurement system analysis helps decide whether a proposed system consisting of measurer/instrument/method is able to meet the requirement.

ISO TR 10017

Process capability analysis

- Determine and assess inherent variability and distribution of a process
- Estimate ability to produce conforming output
- “spread” of process when in statistical control (six standard deviations)
- Process capability indices, " Cp ", " Cpk ", proportion nonconforming, .

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To make something, or to deliver a service, the producer needs equipment and materials, a process and a requirement. (Remember measurement systems?)

The process needs to produce outputs (products, services) that consistently meet the requirements; best done by knowing and controlling the variability of the process.

Process capability analysis helps decide whether a proposed system consisting of producer/equipment/materials/process is able to meet the requirement.

ISO TR 10017

Regression analysis

- Statistically relate “response variable” behaviour to “explanatory variables”
 - “Fit” observations to mathematical relationship with minimum unexplained error
 - Explain how much each factor contributes to variation
- Predict behavior of response variable with variation of the explanatory variables

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Caution: You can “fit” any curve to any data (provided you don’t insist on a very good fit). And you can find a curve that will provide as good a fit as you wish to any data set.

Regression analysis is most meaningful if the explanatory variables really do have a logical/physical connection to the effect you are studying.

(Note: Regression has nothing to do with finding your inner child.)

2-click Regression

SUMMARY OUTPUT		R+L	"CL" = 95%			
Regression Statistics						
Multiple R	0.921015246					
R Square	0.848269084					
Adjusted R Square	0.845109023					
Standard Error	0.209019221					
Observations	50					
ANOVA						
	df	SS	MS	F	Significance F	
Regression	19	4.208577	0.221504	19.42086914	2.74907E-21	
Residual	46	1.072445774	0.02331404	0.072370903		
Total	65	5.281022774				
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.705897311	0.077245705	9.152440198	4.23825E-12	0.551074603	0.862200119
Slope	0.043197164	0.002836357	16.28137572	2.74907E-21	0.327888407	0.840487982

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- ISO TR 10017
- ### Reliability analysis
- Assess, predict, and assure performance over time
 - Statistical methods to deal with estimation, sampling, statistical modeling (time-to-failure or time-between-failures)
 - Engineering techniques (FMEA, fault tree analysis) deal with physical nature and causes of failure
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The “bathtub” curve shows the common life cycle failure pattern of many systems, including animals from which we derive some of the common language of reliability: infant mortality, the tendency for the weak or defective items in a new batch to fail early; wearout, the same tendency at end of (useful) life for things to fail.

Reliability analysis invokes other techniques, such as failure mode and effect analysis and fault tree analysis, which focus on the nature and causes of failure and methods for reducing or preventing failures.

Reliability engineers should have a voice in setting warranty terms and reserves. The economics may be surprising.

- ISO TR 10017
- ### Sampling
- Sample size, type to support test or estimate
 - Representative sample to study population
 - Acceptance sampling to accept or reject a “lot”
 - Survey sampling to estimate parameters
 - Errors reduced by increasing sample size
 - Cannot be eliminated
 - Sample size for desired level of confidence and precision may be impracticably large
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First question: How many items do you need to examine to feel confident about the rest?

The most sobering conclusion is that any company that relies on acceptance sampling with “modest” or “affordable” sample sizes, is probably running the risk of a massive recall, unless the expectation in their market is so low that no one cares.

Second question: If you were a diabetic, how many contaminated syringes would you accept in a lot?

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Simulation

- Mathematical system representation may include random functions
- Behavior under variable conditions studied with random inputs (Monte Carlo methods)
- Results analyzed statistically
- Often used if no satisfactory theory known or model is impossible or difficult to solve

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Simulation of complex systems is often the only economical way to proceed, especially when failure is not an option.

Examples: Traffic management system for urban rail control, all space projects, airport baggage management, ... ; you probably remember cases where the system failed anyway.

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SPC charts

- Plot periodic sample data with control limits
 - control limits depict inherent process variability
 - distinguish random from assignable variation
- Variable or attribute data
- Process control, Process capability and Measurement system analysis, Cause and effect analysis, Continuous improvement

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Truly ancient history: 1931, Walter A. Shewhart and still misapplied and misunderstood.

1. A process in statistical control has a stable, predictable average and variation.
2. A capable process is one that is in control and producing consistently within the allowable specifications.
3. Repetitive, small samples can be used to monitor the behaviour of the average and variation.
4. When the average or variation does not behave as predicted, the process is probably no longer in statistical control.
5. When the process is not in control it cannot be capable.

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Statistical tolerancing

- Distribution of component dimensions determines overall tolerance for product
 - Statistical tolerance less than arithmetical
 - Permits wider tolerances for component to meet final product specification
 - Permits simpler, more economical production methods
- Process and product design iterations optimize tolerances and production methods

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A wall is to be 3000 mm ± 6 mm high.

Bricks are specified to be 100 ± 6 mm thick (4 ± .25").

If all the bricks in a shipment were 106 mm the wall would be 3180 mm.

If the brick spec were tightened to ±0.2 mm, the wall would be in spec using arithmetic tolerancing.

If bricks are produced with a controlled process, Cp = 2, the wall would be in spec most of the time. (simulate or calculate)

Simulation and Tolerancing

Brick wall simulation and Statistical Tolerancing

100 mm (4") brick with 50 mm (2") tolerance	30 bricks	Wall	995.3998 mm	
1 metre wall with 50 mm tolerance		Off spec	-2004.6 mm	
Minimum tolerance of 30 bricks	0.2 mm			

brick no.	length (m)	brick #	total (m)	process capability	0 bricks	995.40 mm
nominal	100	3000	30	Total	250.9037	250.9037
USL	94	30	2928	AVO	5.018073	5.018073
USL	106	30	3180	SO	0.868601	0.868601
				EPG	5.211604	5.211604
				CP	2.302564	2.302564

99.11	99.15	99.94	100.55	100.26
101.59	100.71	99.43	100.39	100.10
98.56	101.66	98.85	100.10	98.81
99.50	99.53	100.44	100.89	99.59
100.17	98.59	100.24	101.01	99.96
97.95	100.11	100.70	98.36	100.46
99.64	101.44	98.19	99.31	100.59
99.30	101.18	99.45	101.06	100.62
99.55	99.51	100.10	99.64	101.26
99.43	100.37	100.46	100.60	101.60

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- ### Time series (trend) analysis
- ISO TR 10017
- Graphical & analytical study of behaviour of sequential data
 - Trends, "lag" patterns (correlation with preceding observations), cyclical, seasonal, "outliers"
 - Predicting future behaviour
 - Detecting turning points in a trend
 - Projecting future values
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Time series analysis can vary from looking at graphs to Fourier analysis that breaks out all the cyclic components in a varying time line.

In many practical situations, simplicity and common sense work very well - look for coincidences with shifts, seasons, weekends, daylight saving time, maintenance cycles, tool wear, accounting cycles, inventory changes, ...

See also regression analysis.

