Basic Tools for Quality Improvement

Improving quality of products and services is key to maintaining competitive edge in today's business environment. Companies of all sizes, whether involved in delivery of service or manufacturing products of any kind, should practice one of the many available modern quality improvement methodologies like Six Sigma, TQM and ISO-9000. While formal implementation of any of these approaches may create strain on your resource and time, some form of quality awareness training is an effective way to change the mindset. For example, employees at all level in the organization, regardless of their roles and responsibilities, can easily learn a few basic quality improvement tools and immediately apply it in quality improvement activities within the organization.

This brief session is designed for participants with minimum education to learn a few proven quality improvement philosophies and learn how to apply common quality improvement techniques including the seven basic tools.

Upon completion, the attendees are able to:

- Adopt and share some common quality values
- Follow a structured approach for projects
- Be more customer focused
- Identify customer requirements and define objectives
- Commit to working as team and consensus decision
- Use fishbone diagrams, Pareto & Control charts to identify causes
- Use check sheets to gather data for analysis
- Use GANTT chart to manage put your plan into action
- Be aware of advance techniques and know where they are applicable.
Who Should Attend

- All individuals whose work affects internal or ultimate products and services of the organization
- Quality improvement specialists
- Practicing production and process professionals
- Customer service representatives
- Service and delivery professionals and managers at all levels

Prerequisites:
There are no specific prerequisites for this course

Course Content

- Course Objective and Introduction
- Quality Operating Philosophies
  - Basic Approach
  - Advanced Methodologies
- Value of Team and Consensus Decisions
- Basic Quality Improvement Tools
  - 1. Flow Chart
  - 2. Check Sheet
  - 3. Histograms
  - 4. Pareto Charts
  - 5. Cause and Effect Diagrams
  - 6. Scatter Diagrams
  - 7. Control Charts
- Project Schedule Management
  - Gantt Chart
- Advanced Techniques (TRIZ, QFD, DOE/Taguchi, FMEA, SPC, Process Capabilities, etc)
- Implementation Strategies
- Appendix
**Principal Instructor (Course Developers)**

**Ranjit Roy, Ph.D., P.E., PMP**

- Mechanical engineer
- Independent consultant since 1987
- Specializes in product and process design improvement technique
- Published books and developed technical software
- Adjunct professor (Oakland University, Rochester, MI since 1976)
- Fellow of American Society for Quality (ASQ)
- Provisionally certified Lead Auditor (ISO/QS-9000)

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**Team Building Exercise**

Playing cards: 4 x 10 cards into 5 stacks of equal total number.
Quality Operating Philosophies

“Quality operating principles and values are important for any business organization to do well and stay in business.”

Origin of Quality Thinking

In colonial times Andrew Bradford had the contract for the public printing in Pennsylvania. One day the governor made an important address and Bradford printed it in his usual, careless manner.

Another young printer realized this was the opportunity he'd been waiting for. He printed the speech in elegant form, then mailed a copy with his compliments to the governor and each member of the assembly. The next year Ben Franklin—the young printer who showed concern for his customers—received the contract for all Pennsylvania's public printing.

Make products or deliver service:
- Better (Delivery, Performance, Looks, Service life, Shelf life, etc.)
- Faster (Productivity, Down time, etc.)
- Inexpensive (Reduced waste and loss, maintenance cost, etc)
- Consistent

What is QUALITY as applied to your work?
Quality & Cost Improvement Pioneers

Elliot Whitney (1765 - 1825) was an American inventor and manufacturer who is credited with creating the first cotton gin in 1793. This cotton gin was a mechanical device which removed the seeds from cotton, a process which was until that time extremely labor-intensive. Whitney’s greatest contribution to American industry was the development and implementation of the American System of manufacturing and the assembly line, which he was the first to use when producing muskets for the US Government. Whitney's concepts were later exploited by Henry Ford and others in manufacturing.

In 1798, Whitney received a US Army contract to make 10,000 muskets. At that time muskets were produced by hand, one by one, by skilled craftsmen. Whitney realized that production would be faster if identical, interchangeable parts were used. Whitney decided that this machine was too important for his company to patent, so he made it available to industry to patent, so he made it available to industry so that others could profit from his discoveries.

Frederick Winslow Taylor (1856-1915) devised a system he called scientific management, a form of industrial engineering that established the organization of work as in Ford’s assembly line.

Frank and Lillian Gilbreth (1868 - 1924): One of the great husband-and-wife teams of science and engineering. Frank and Lillian Gilbreth early in the 1900s collaborated on the development of motion study as an engineering and management technique. Frank Gilbreth was much concerned until his death in 1924, with the relationship between human beings and human effort.

Taiichi Ohno was born in Manchuria, China in 1912 and graduated from Nagoya Institute of Technology. He joined Toyota in 1932 and for about twenty years worked his way up in the firm. In the 1940’s and early 1950’s, Ohno was the assembly manager for Toyota and developed many improvements that eventually became the Toyota Production System (Known as Lean Manufacturing).
Many Disciplines and Tools for Quality

Standards:
- ISO 9001:2000
- SAE AS9100
- TQM
- Lean
- SPC
- FMEA

Many Religions - One GOD

Modern practices of quality disciplines:
- Military Standards
- Zero Defects – Phil Crosby (70's)
- TQM - 1980’s
- ISO 9000 - 1980’s later part
- QOS, Q1, etc. (1990 by Ford)
- QS-9000 – Early 1990’s (Automotive)
- AS9110 – 2000+ (Aerospace)
- Six Sigma – Late 1990’s
- Lean Six Sigma – Now
- Design for Six Sigma (DFSS) - now

Like all religions, there are some common principles that all quality philosophies follow:
- Find out what customers want
- Make and deliver it
- Continually improve what you deliver
- Use data to determine course of action
- Describe and document what you do and follow it.
**Why focus on quality activities?**

**Motivation:**
- Stay in business and do well.

**Details:**
- Keep customer happy
- Help employees become more effective (Team work, share common values and goals, follow common approach, etc)
- Make products or deliver services with least resources
- Reduce waste & loss (Loss- internal as well as at customer’s hand)
- Minimize rejects, rework, and warranty cost

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**Quality Operating System**

- One such quality operating principle was followed by Ford Motor Company in early 1990’s.
- It is a very simple set of steps that businesses of all kinds can benefit from.
- Let’s quickly review the steps in this method.
Thoughts for the day . .

One morning, having moved into a new neighborhood, the family noticed that the school bus didn’t show up for their little boy. The dad volunteered saying, “I will drive you, if you show me the way”. On their way the young student directed dad to turn right, then a left, and a few more lefts and rights. Seeing that the school was within a few blocks from home, dad asked, “Why did you make me drive so long to get to the school this close to home”. The boy replied, “But dad, that’s how the school bus goes everyday”.
- Mort Crim, WWJ 950 Radio, Detroit, MI, 10/30/01

“When you always do what you always did, you will always get what you always got”

Quality Basis - Business Values

- How do we treat our customers
- How do we take care of our employees
- How do we deal with our suppliers

What are our values? What beliefs do we hold?
Quality Roles and Responsibilities

How do you deal with your suppliers?

Clearly describe your needs.

......

How do you satisfy your customers?

Find out and deliver what they want.

......

Constant Employee Awareness

How to make all employees aware and involved in the quality improvement effort?

How to communicate information to all?
Identify Customer Expectations

Who are customers and what are their expectations?

CUSTOMER
- Internal customer
- External customer

EXPECTATIONS
- Specific needs
- Process & measurable to satisfy them

STRATEGY
- Satisfy expectations

Means of Gathering Customer Expectation Data

- Customer comments
- Satisfaction survey
- Field performance data
- Phone calls
- Direct contact & visit
- Focus group
- Benchmarking data
- Market research
- Etc.

Facts about Customer Behavior

Research has shown that:
1. Dissatisfied customers (business or individual) tend not to complain.
2. Complaints often do not directly identify the source or causes of the problem.
3. Complainers tend to be the heaviest users of the product.
Notes on Customer Expectations

Type of Expectations: Customer may have expressed or implied expectations. The implied expectations are those that are unwritten, very basic, otherwise difficult to clearly communicate, e.g., customers of a calculator expects batteries it, customers of an automobile expects all wheel on it, etc.

Determination Methods: Market research, warranty, face-to-face meeting, site inspection, written agreement, work orders, warranty records, focus group, satisfaction survey, verbal feedback, phone calls, competitive benchmarking, third party review, news media reports, etc.

Do you expect customers to change their expectations? Customers have the right and rationale to change their expectations. Generally it will change over time because of the enhancements to products and services by the competitors. The improvements are generally brought about by technological innovations and production methods. You must, therefore, periodically update your knowledge of customer expectations. You can use the same method used before or different ones if necessary to identify the changing expectations.

Class Exercise: Miller Muffler

Customer Expectations:
1. Assume that you (or group) are an employee of the Miller Muffler (select any one position from the following):
   - Mechanic
   - Shop Manager
   - Accounting
   - Maintenance
   - Purchasing
   - Other administrative/staff management personnel

2. Based on your role in Miller Muffler, discuss and determine who your internal and external customers are (list).

3. Brainstorm to identify methods you could employ to specifically learn what the customers specifically expects from your products and services.
**Group Activity 2: Customer Expectations (15 minutes):**

1. Assume that you (or group) are an employee of the Miller Muffler (select any one position from the following):
   - Mechanic
   - Shop Manager
   - Accounting
   - Maintenance
   - Purchasing
   - Sales and Marketing
   - Other administrative/staff management personnel

2. Based on your role in Miller Muffler, discuss and determine who your internal and external customers are.
   - Internal customers (list 2 – 4)
   - External customers (list one or more)

3. Brainstorm to identify methods you could employ to learn what the customers specifically expect from your products and services.
   - Method 1.
   - Method 2.
   - Method 3.

4. Based on your customers ASSUME (for this exercise) and establish one or more expectations of customers that you would want to satisfy.
   - Customer expectation 1.
   - Customer expectation 2.

5. Present and explain the customer expectations to the class.

**Select Key Internal Processes and Events**
What are Internal Key Processes & Events

- Identify processes that are very basic to operations.
- The processes should have a direct bearing on customers’ expectations.
- Key processes are those that have significant consequence if not done right.
- When key processes and events are too many, order them from most influential to the list.

How do you solve problems?
Do you follow a structured approach?

1. Describe Problem
2. Contain Problem
3. Identify Root Causes
4. Find Solutions
5. Implement Permanent Solution
6. Establish Controls
7. Establish Controls
8. Recognize Team

Etc.

Examples of Key Processes and Events

**Manufacturing Processes:** Material procurement, Machining, Plating, Painting, Assembly, etc.

**Staff Processes:** Hiring Personnel, Training, Accounts receivable, Attendance, etc.

- The key processes and events should have direct relation to customer expectation.
  **Example:** If customers expect the knife to be sharper, how the handle of the knife is made is not related to expectation, but the method of sharpening the knife or how its material is selected could be the key processes.

- **QOS** is not limited to manufacturing or production operations only. It can be applied to all aspects of your business.

- When there are too many processes and events, address the more important ones first.
Class Exercise: Miller Muffler

Customer Expectations:
1. Assuming you (or group) are the same employee of the Miller Muffler, brainstorm and list all the processes and events within your job responsibilities.
2. Select and prioritize those processes that have direct influence on the customer expectations you identified before.

Group Activity 2: Key Processes and Events (15 minutes):

1. Assuming you (or group) are the same employee of the Miller Muffler, brainstorm and list all the processes and events within your job responsibilities. (Class: Point of how the job gets done, list activities, draw work flow or process diagram, arrange activities in their normal sequence, etc.)

2. Select and prioritize those processes that have direct influence on the customer expectations you identified before.
   - Process with most influence on the customer expectation
   - Process or activity with second most influence, etc.

3. Present and explain the key processes you selected to the class.

Identify Measurables for Key Processes
Process and Measurable Examples

<table>
<thead>
<tr>
<th>Internal Key processes</th>
<th>Potential Measurables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping – Products packaged, recorded in database, shipping documents prepared, shipped.</td>
<td>- Number of packages shipped</td>
</tr>
</tbody>
</table>
| Accounts Payable – Invoice received & verified, secure approval, issue checks, and mail payments. | - Number of days elapsed between receipt of invoice and payment  
  - Number of invoices paid per week |
| Training – Develop program, register attendees, deliver training. | - Number of employees completing training.  
  - Number of applications resulted after training |
| R&D – Pursue research on new ideas, demonstrate production feasibility, make prototype, etc. | - % of projects made to production.  
  - Number of publications in professional journals |
| Product Development – Parts designed or sourced out. | - % of parts sourced to production supplier  
  - % of part design readied as planned |

Type of Measurable

There are two common types of measurables:

Process (Production Focus)
- Manufacturing
- Engineering
- Training
- Test & Validation

Result (Customer Focus)
- Surveys
- Audits
Characteristics of Measurables

What are some characteristics of measurables?
10. Obvious (of obvious importance to business)
11. Actionable (it helps define course of action)
12. Accessible (easily obtained)
13. Understandable (easily understood and simple)
14. Agreed upon (all understood and agreed. Assures team focus.)
15. Predictive (relates well to performance and can be used to predict expected results)

How are goals set?
Each measurable must have a goal. Set it by benchmarking, industry standard, customer requirements, etc.
Goals to be: aggressive, yet attainable, agreed upon, clearly beneficial to the business and flexible.

Class Exercise: Miller Muffler

Measurables for Key Internal Processes:

1. Chose one of your key internal processes. Write a brief (3 – 5 sentences) description of the process including the goal or outcome of this activity.

2. Brainstorm and list some measurables that could be used to indicate how well that process is being accomplished.
**Group Activity 4: Measurables for Key Internal Processes (20 minutes):**

1. Choose one of your key internal processes you identified in the last exercise and write a brief (3 – 5 sentences) description of the process including the goal or outcome of this activity.
   - What is the process all about?
   - What is input to this process and what is output

2. Brainstorm and list some measurables (must be in quantitative terms) that could be used to indicate how well that process is being accomplished.
   - How do you measure the outcome of the PROCESSES?
   - How can you compare how well you are doing the process?

3. Present and explain the measurables you selected to the class.

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**Track Trends of Measurables**

Purpose – Track progress of measurable against goals.

Method – Generally presented in Trend Chart or Pareto Chart. Trends, good or bad, are examined.

Source of Data – Use existing data when possible.
Charts and Diagrams

- Trend Chart – shows how well measurables do with respect to goals.
- SPC chart - helps you identify special causes for the problem and gives you a handle on the natural variability in the system. If special causes are found, you will need to eliminate them in order to continue to meet customer expectations.
- Pareto Diagram – identifies the ‘trivial’ many from the ‘vital’ few. It helps you pick those that have significant impact.

Focus – Proactive than reactive

[Diagram showing a grid with axes for Problem Solving, Prevention, Vision Futuring, and Detection. The grid is divided into areas labeled Proactive & Optimizing, Find & Fix.]
**QOS Focus** *(Diagram on Previous Slide)*

Y-axis  
**Prevention** - # of failure/problems prevented  
**Detection** - # of problems after it occurred

X-axis  
**Problem Solving** - # of problems actually solved  
**Vision Futuring** - # of anticipated future problems and preventive actions taken

4. Ideally, the Optimization line should be 45 degrees inclined  
5. Desirable, we should always be in the first quadrant

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**The Kano Model**

The Kano model is a theory of product development developed in the 80s by Professor Noriaki Kano which classifies customer preferences into various categories.

The Kano model of customer satisfaction (Kano, 1984) can determine which requirements of a product or service bring more than proportional satisfaction to customers. Also, it determines which requirements don’t bring satisfaction when present, but bring dissatisfaction when they are not met.
Group Activity 5: Trends of Measurables (15 minutes):

1. Suppose that you have collected data (ASSUME a set of appropriate data) on the measurables you identified in the last phase, what quality tools would you use to track the measurables?
   - Identify tools you will use (Normal distribution, Pareto chart, Bar graph, Trend Plot, Pie chart, etc.)
   - Show a sample plot for each type of measurables data.

2. Present and explain the kind of observations you will make from such data analyses.
Group Exercise: Quality Operating System

Consider your own activity (select one of your own activities) and discuss among your group member to answer the questions.

Be prepared to present your answers to the class when asked.

1. What is the name of your activity? (Describe activity in 2 or 3 sentences)
2. What methods would you use to let everyone know about your quality effort?
3. Who are your CUSTOMERS?
4. What is the most important customer expectation?
5. What are some of the KEY PROCESSES (name at least 2) that relates to customer expectations.
6. How would you measure and track the key process performances (find out how well you are doing)?

Team and Consensus Decision

“A
Work as Teams

Benefits:
- Generally more effective
- Gain early buy-in
- Reduces conflict among coworkers
- Easy implementation when done well
- Increases ownership and accountability
- Expedites project completion

Risks:
- May exclude expertise available
- Reduced opportunities for creative ideas
- Success may depend on role of team leader

Group Consensus Decision

Characteristics:

Democratic process
  - Allow time for discussion
  - Experts bear the burden to convince others
  - In the end, one person one vote

Approach: Work as team and decide things by CONSENSUS.

WHO ARE TEAM MEMBERS?

Two situations are common:
1. Majority rules for YES/NO decision.
2. Set priorities and create PARETO diagram based on subjective preferences.
   - 12 people team to decide which 10 among 30 things are important (each to vote 0-30 for each item)
   - Faced with many problems and limited resources, which ones to address first, and in what order?

Goal: Bring some objectivity in subjective world.

Facilitator: Be fair and objective.
### Group Exercise: Consensus Building

Assume that you are part of the steering committee reporting to the president of a small company. The president asked your team to prioritize and recommend THREE of the projects shown.

1. Order the projects in terms of importance by group consensus
2. Select the top three for this year's budget

<table>
<thead>
<tr>
<th>To do list for this year's budget.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects</td>
</tr>
<tr>
<td>A: Expand research group</td>
</tr>
<tr>
<td>B: Renovate reception area</td>
</tr>
<tr>
<td>C: Build a new training room</td>
</tr>
<tr>
<td>D: Upgrade cafeteria</td>
</tr>
<tr>
<td>E: Expand exercise area</td>
</tr>
<tr>
<td>F: Resurface parking lot</td>
</tr>
<tr>
<td>G: Purchase company cars</td>
</tr>
<tr>
<td>H: Install new air-conditioning system</td>
</tr>
</tbody>
</table>

### A Sample Group Activity (Solution)

<table>
<thead>
<tr>
<th>Projects</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Expand research group</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: Renovate reception area</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: Build a new training room</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D: Upgrade cafeteria</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: Expand exercise area</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F: Resurface parking lot</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G: Purchase company cars</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H: Install new air-conditioning system</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each team member assigns 0–10.
Seven Basic Quality Tools

These fundamental quality control (QC) tools were first emphasized by Kaoru Ishikawa, professor of engineering at Tokyo University and the father of quality circles in Japan. They were identified for the average person to analyze and interpret data. These tools have been used worldwide by companies, managers of all levels and employees.

Basic Tools and Their Utilities

<table>
<thead>
<tr>
<th>Tools</th>
<th>Use and Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flow Chart</td>
<td>Understand process and depict situation in graphical form.</td>
</tr>
<tr>
<td>2. Check Sheet</td>
<td>Find facts by collecting and recording data.</td>
</tr>
<tr>
<td>3. Histograms</td>
<td>Identify problems and their relative importance.</td>
</tr>
<tr>
<td>4. Pareto Charts</td>
<td>Separate “Significant few” from Trivial many” causes.</td>
</tr>
<tr>
<td>5. Cause and Effect Diagrams</td>
<td>Generate and capture ideas.</td>
</tr>
<tr>
<td>6. Scatter Diagrams</td>
<td>Study trend and predict behavior.</td>
</tr>
<tr>
<td>7. Control Charts</td>
<td>Study performance learn about common and special causes of variation.</td>
</tr>
</tbody>
</table>

Advanced Quality Improvement Technique:
FMEA, SPC, DOE (Taguchi Method, Robust Design), QFD, TRIZ, etc.
1. Flowchart

“A flowchart (also spelled flow-chart and flow chart) is a schematic representation of an algorithm or a process.” - Wikipedia

The process flowchart was first introduced by Frank Gilbreth in 1921. He used it show as a graphical and structured method for documenting process activities.

Flow Charts:
Understanding and Communicating How a Process Works

Also known as Process Maps and Process Flow Diagrams

Flow charts are useful tools for communicating how processes work, and for clearly documenting how a particular job is done. It is an effective way to clarify understanding of the process, and helps thinking about where the process can be improved.

It can be used to:
- Define and analyze processes
- Build a step-by-step picture of the process for analysis, discussion, or communication
- Define, standardize or find areas for improvement in a process

Most flow charts are made up of three symbols:
- Elongated circles, which signify the start or end of a process;
- Rectangles, which show instructions or actions; and
- Diamonds, which show decisions that must be made

Within each symbol, write down what the symbol represents. This could be the start or finish of the process, the action to be taken, or the decision to be made.

Symbols are connected one to the other by arrows, showing the flow of the process.
Example: Prescription Medicine

In typical run to the drug store, the activities include:

- Drop off prescription
- Shop around while the prescription is being filled (or do other things)
- Check to see if prescription is filled
- Pick up medicine if it is ready

This can be shown in a flowchart as shown at right.

Example: Chicken Grilling process

Start Grill
Bring chicken out of refrigerator
Marinate Chicken
Check grill temperature
No
Yes
Flip chicken side 2
Check if side I done
Cook side 1
Place meat on grill
No
Yes
Cook side 2
Check grill temperature
Remove chicken & serve
End
Clutch Plate Rust Inhibition Process

The Clutch plate is one of the many precision components used in the automotive transmission assembly. The part is about 12 inches in diameter and is made from 1/8-inch thick mild steel.

Figure: Clutch Plate Fabrication Process

Stamping / Hobbing - Clutch plate made from 1/16 inch thick rolled steel
Deburring - Clutch plates are tumbled in a large container to remove sharp edges
Rust Inhibitor - Parts are submerged in a chemical bath
Cleaned and dried parts are boxed for shipping.

Group Exercise: Flowchart

Do it as a group
1. Select an activity/process
2. Identify tasks (3 – 5 tasks and 1 or 2 decision points)
3. Draw FLOWCHART
4. Review and refine chart

Present your process to the class and show your FLOWCHART.
2. Check Sheet

"The check sheet is a simple document that is used for collecting data in real-time and at the location where the data is generated." – Wikipedia

The check sheet is made of a blank piece of paper and is used to record quantitative or qualitative information quickly. Often it is also called a tally sheet when the data collected is quantitative. Often it forms the Histogram in front of the person collecting the data so they can see how it builds up.

The Check Sheet is one of the first seven quality tools.

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Check Sheet

**Purpose & Intended Application:**
Collect data using pencil and paper such that it is easily understood without much analysis. Check sheets vary in type, style and complexity from a simple tally sheet to multiple entry ledger.

Typical applications are:
- Check defective items in production
- Observe production process distribution
- Check for location defects in a part/assembly
- Identify cause of a common failure
- Record customer preferences

**Approach:**
1. Think of purpose
2. Creatively construct your check sheet

**Construction Notes:**
Proper construction is important for usefulness of the check sheet. When properly designed, certain objectives and trends may be visually observed with further analysis.

1. Define the purpose of the data collection.
2. Identify the source of the data (machine, facility, shift, location, etc.)
3. Record name of person collecting data
4. Define all categories of data to be collected.
5. Determine the time period for data collection
6. Design a check sheet by listing categories to be counted.
7. Test the check sheet by recording sample data to find out ease of use and reliability of results. Modify if needed.
Deciding on Data to be Collected

To determine categories and capture all necessary information in your check sheet, try to answer the following questions about the events.

- What is observed to have happened?
- Who is affected and who might have caused it?
- Where and when does it occur?
- How long and how does it happen
- To what extent does it affect or how much is required to make it happen
- Etc.

Involving people who are familiar with the process and or make use of the data. It is a good idea to develop a consensus on what data to be collected.

How to Lie with Statistics by Darrell Huff

It is worth remembering:

“Statistics do not lie, people do.”

Example:

As part of her Weight Watchers program, Cass Carethers wishes to keep record of her evening exercises over a period of 12 weeks. What kind of check sheet should she use?

<table>
<thead>
<tr>
<th>Week &amp; Days</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mon</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tue</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wed</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fri</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example: (Group Exercise)

In a roll of dice, there is 1/6 probability that a particular number will appear. Statistically speaking, if the die is rolled a large number of times, each face/number has equal probability of occurrence which will displaying a **uniform distribution**. Create a check sheet to record such data.

![Graph showing uniform distribution of die faces](image)

Repeat the process by plotting the average of group. Watch what happens to the distribution (Central Limit Theorem – average is normally distributed even if the individual sample data is not.)

---

Example: Hospital Meal Delivery

Local large hospital was interested in finding out the causes and timing of missed-delivery or return of meals. To collect data they prepared a check sheet that record data over a week for delivery of lunch (L) and dinner (D). (Among a large number of categories, a set of important ones were selected)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Mon</th>
<th>Tues</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>L</td>
<td>D</td>
<td>L</td>
<td>D</td>
<td>L</td>
<td>D</td>
<td>L</td>
<td>D</td>
</tr>
<tr>
<td>Wrong order</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6+</td>
</tr>
<tr>
<td>Patient in treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Patient Asleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Changed Order</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Wrong Room #</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Diet Changed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Cold Food</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cart Unavailable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7</td>
<td></td>
<td>16</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example: Automobile Axle Alignment

Production supervisor of an automobile assembly plant wanted to find out which among many adjustments that are done to correct the axle alignment (Toe & camber) we predominant. The proposed the following check sheet to record the data from 60 units selected that failed to pass first time.

<table>
<thead>
<tr>
<th>Categories</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamping pressure</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Servo speed</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-torque bolt</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Back-off angle</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration level float</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolt/washer edge</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Toe Pre-condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheel rotation time</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Toe adjustment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Production Check Sheet

Product name: Power Window

Usage:                  Data:                  Location:
Part: Data Collector: Section: Specification: 12 +/- 2
Lot:                  Specification: 12 +/- 2
Other areas of Applications

- **Customer support** group of popular consumer products (Computer, phone system, TV, appliances, etc) use CHECK SHEET to document the frequency of customer call throughout the day. This data allows them to allocate support personnel properly.

- **Large grocery retailers** can use CHECK SHEET to determine demands of certain products during the week and schedule stocking requirements.

- **Emergency room of busy hospital** can keep track of patients and type of problems using CHECK SHEET. This data then can be utilized to schedule care giving physicians and nurses appropriately.

---

**Group Exercise: Check Sheet**

**Do it as a group**

1. Select an activity/process for which you wish to collect data
2. Identify performance and its measure
3. Design **Check Sheet**
4. Review and refine chart

**Present your data collection scheme to the class.**
3. Histogram

The histogram is a summary graph which shows the count of total number of data points that fall in various ranges.

The word histogram is derived from Greek: histos 'anything set upright' (as the masts of a ship); gramma 'drawing, record, writing'.

4. Histogram

Histogram is a special bar graph of number of parts (frequency of occurrence) in y-axis and the value of the quality characteristic along the x-axis in the increasing order.

- Generally y-axis is not shown
- Number of parts (data) along the y-axis
- Value of the data is along x-axis

The heights of 310 students whose height range between 4.8 feet and 6.4 feet can be plotted in terms of a histogram as shown below.

![Histogram](image)
5a. Histogram Construction

While construction of histogram is not that difficult, it is too time consuming for this class. Besides, it is what histogram helped scientists learn about population from which the data came from is more important than the histogram itself.

Histogram from representative sample data tells about how the population (totality of all that the sample is made up of) behavior is expected to be.

Notice how the tip of the bars in the histogram look like. For most naturally occurring characteristics, the profile looks like a mountain (bell shaped) with a single peak and symmetrical valley.

5b. Population Distribution

- When the class interval (0.2 inches in this case) is reduced and the number of data is increased a smooth frequency distribution results. The shape of this distribution is an indication of the population distribution (where and how the data lies).
5c. Shapes of Distribution

The distribution can be of many shapes

(a) General type (normal distribution)

(b) Skewed type

5d. Shapes of Distribution (+)

- There are many more kinds of distributions are present than those shown here.

(b) Twin-peak type

(b) Isolated-peak type
Group Exercise: Histogram

Do it as a group

1. Select an activity/process
2. Identify performance or type of occurrence
3. Design Horizontal & Vertical scale
4. Review and refine chart

Present your process to the class and show your Histogram.

4. Pareto Chart

“A Pareto chart is a special type of bar chart where the values being plotted are arranged in descending order.” – Wikipedia

The Pareto Chart is named after Vilfredo Pareto of Italy who used it for study of population & wealth distribution. The chart was popularized by Joseph M. Juran and Kaoru Ishikawa which they often used to represent most common sources of defects, the highest occurring type of defect, or the most frequent reasons for customer complaints, etc. Their use gives rise to the 80 – 20 Rule which implied that 80 percent of the problems stem from 20 percent of the causes.
3. Pareto Analysis

- Pareto analysis is most frequently used data analysis. It is a simple technique that can produce valuable information in quantitative terms. It is done by creating bar graphs of collected data.

  In 1897, Italian scientist V. Pareto presented his findings that the distribution of income is uneven. Similar observation also was reported by M. C. Lorenz in the U.S. in 1907. Based on the arrangement of the income distribution bars, these scholars pointed out that by far the largest share of wealth is held by a very small number of people. In the field of quality control, in early part of the 20th century, Dr. J. M. Juran used the Pareto principles to isolate the quality problems into vital few and trivial many.

3a. Making Pareto Diagrams

Step 1. Decide the kind of problem you want to investigate.


Determine what data will be necessary and how to classify them.

Example: Type of failure, miles driven, etc.

Specify method of data collection and the period of collection.

Example: All vehicles in Metro-Detroit area with VIN number XYZ.

Step 2. Design a data Tally Sheet listing items and room for totals

Step 3. Fill out the Tally Sheet and calculate totals.

Step 4. Prepare a Pareto diagram with (a) individual total, (b) cumulative totals, percentage of overall totals (for individual cumulative percentages).
### 3b. Pareto Diagram (Contd.)

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Tally</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Crack</td>
<td>XXXX XXXX</td>
<td>10</td>
</tr>
<tr>
<td>B: Scratch</td>
<td>XXXX XXXX XXXX ..........X</td>
<td>42</td>
</tr>
<tr>
<td>C: Stain</td>
<td>XXXXX</td>
<td>6</td>
</tr>
<tr>
<td>D: Strain</td>
<td>XXXX XXXX XXXX XXXX ....X</td>
<td>104</td>
</tr>
<tr>
<td>E: Gap</td>
<td>XXXX</td>
<td>4</td>
</tr>
<tr>
<td>F: Pinhole</td>
<td>XXXX XXXX XXXX XXXX</td>
<td>20</td>
</tr>
<tr>
<td>G: Others</td>
<td>XXXX XXXX XXXX</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>200</strong></td>
</tr>
</tbody>
</table>

**Step 5.** Arrange all items in order of quantity (highest to lowest), and fill out the data sheet.

*Note: The group “Other” is composed of many small contributors each of which is smaller than the smallest item listed individually.*

### 3c. Pareto Diagram (Contd.)

<table>
<thead>
<tr>
<th>Type of Defect</th>
<th>Number of Defects</th>
<th>Cumulative Total</th>
<th>% of Overall Total</th>
<th>Cumulative Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>D: Strain</td>
<td>104</td>
<td>104</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>B: Scratch</td>
<td>42</td>
<td>146</td>
<td>21</td>
<td>73</td>
</tr>
<tr>
<td>F: Pinhole</td>
<td>20</td>
<td>166</td>
<td>10</td>
<td>83</td>
</tr>
<tr>
<td>A: Crack</td>
<td>10</td>
<td>176</td>
<td>5</td>
<td>88</td>
</tr>
<tr>
<td>C: Stain</td>
<td>6</td>
<td>182</td>
<td>3</td>
<td>91</td>
</tr>
<tr>
<td>E: Gap</td>
<td>4</td>
<td>186</td>
<td>2</td>
<td>93</td>
</tr>
<tr>
<td>G: Others</td>
<td>14</td>
<td>200</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>200</td>
<td><strong>100</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 6.** Draw bar graph and line graph with two vertical axes and a horizontal axis as shown in the next slide.

- construct bar diagram
- draw the cumulative curve
Group Activities & Practice Session
2.5A Practice & Learn: The sales figures for a retail store are as shown below.

(1) Order the months in the list below with higher selling month first, the least selling month last. Complete the last two columns of the table and plot the Pareto Chart with cumulative sales/performances.

(2) Determine the three months with higher performances.

(3) Identify the months that make up 85% of the total sales.

<table>
<thead>
<tr>
<th>Month</th>
<th>$Sales (in $)</th>
<th>%</th>
<th>Cum %</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>160</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>290</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hint: Before calculating % and cumulative %, rearrange the months in the descending order of $Sales. Use TEMPLATE at page A.77 for plotting graph.
Group Exercise: Pareto Chart

Work on an additional project:
1. Select an performance data
2. Show how data will be collected
3. Design plotting scheme
4. Review and refine chart

Present your process to the class and show your Pareto Chart.

5. Cause-And-Effect Diagram (Ishikawa Diagram)

“It is simply a diagram that shows the causes of a certain event.” - Wikipedia

The Ishikawa diagram or fishbone diagram or cause-and-effect diagram is the brainchild of Kaoru Ishikawa, who pioneered quality management processes in the Kawasaki shipyards in 1960. The diagram generally can reveal key relationship among various variables and possible causes identified may provide additional insight into process performance.
4 S’s - Service  (From SmartDraw Software)

6 M’s – Manufacturing
8 P’s – Administration

Ideas for Brainstorming - Summary

8 P’s for Administration
1. Process
2. People
3. Promotion
4. Price
5. Product
6. Procedures
7. Policies
8. Place/Plant

6 M’s for Manufacturing
1. Man
2. Machine
3. Method
4. Mother Nature
5. Materials
6. Measurements

4 S’s for Service
1. Skill
2. System
3. Suppliers
4. Surroundings
Example: High Heating Cost (List of factors/causes)

Materials
- Natural Gas
- Propane
- Oil/Hot water

Method
- Duct Cleanliness
- Vents Open & Close
- Space Heaters
- Insulation
- Window Glass

Measurement
- Meter Reading Error
- Leaky Gas Tube
- Thermostat Control

Machine
- Furnace
- Filters
- Humidifiers

Man
- Temperature Setting
- Fireplace
- Late Night Stay
- Lack of Warm Clothes
- Excessive door open/close

Mother Nature
- Too many cold days
- Windy nights
- Storm and Rain

Example: High Heating Cost

- Temperature Settings
- Late Night Stay
- Lack of Warm Clothes
- Too many Cold Days
- Windy nights
- Storm and Rain
Group Exercise: Ishikawa Diagram

Brainstorm and Create Your Own Fish-Bone Diagram

Define Problem:
(One sentence)

List Major Categories:

List Factors under each Category:

DRAW DIAGRAM

Show and share your project to the class.

---

6. Scatter Diagram
(Trend Chart)

In a scatter graph or scatter diagram, the data is displayed as a collection of points, each having the value of one variable determining the position on the horizontal axis and the value of the other variable determining the position on the vertical axis. It can be used to relate the dependent or independent variables under study.

An equation for the correlation between the variables can be determined by established best-fit procedures. For a linear correlation, the best-fit procedure is known as linear-regression.
6. Time-History (X vs. Y) Plot

- There are times when you benefit from plots that compare one factor with another (X and Y). Such plots produce a direct relation between the two variables.
- A common X vs. Y plot is a time history plot where one factor is studied over time.

6a. X vs. Y Plots

- Sweetness, Y vs. Amount of Sugar in Coffee, X
- Number Contracting Cold & Flu, Y vs. Age of Patients, X
6b. Dependent Plots

- In addition to the X vs. Y plot, commonly two other plots can be derived. One is plot of cumulative value, and the other is of rate information.
- Cumulative:
  - Sales volume Vs. Time can produce Total Sales Volume Vs. Time.
- Rate:
  - Distance Vs. Time information can produce Velocity Vs. Time, and Acceleration Vs. Time.
  - Similar plots among two characteristics, Velocity Vs. Distance can now be also plotted from the same data set.

7. Scatter Diagram

- Scatter diagram is plot of two variables, a quality characteristic and factor affecting it, to study their relationship.
- Scatter diagram is made when there are many data points over the range of the factor.
- The purpose is to observe some trend between the two.

Note: Outliers are generally excluded from correlation analysis after the causes are investigated.
7a. Making Scatter Diagram

Step 1. Collect \((x, y)\) in the range desired. Use at least 30 pairs of data.

Step 2. Find maximum and minimum values of \(x\) and \(y\), and determine the scales. Keep the number of unit graduations in each axis within 4 to 10. Use the vertical axis for quality characteristic and the horizontal for the factor.

Step 3. Plot data on the paper with grid lines. Mark points with duplicate values for reference.

Step: label graph with (a) Title, (b) Time interval, (c) Number of pairs of data, (d) Title and units of axes, (e) Name of the person who prepared diagram, etc.

7b. Looks of Correlations

If the factors bear a relation/trend, a correlation is considered to exist.

- Positive Correlation
- Negative Correlation
- May be Positive Correlation
- No Correlation
7c. Correlation Coefficient (r)

-1.0 \leq r \leq 1
- \text{Abs}(r) = 1 \text{ represent straight line}
- \text{If } r > 1 \text{ there has been calculation error.}

\[ r = \frac{S(xy)}{\sqrt{S(xx).S(yy)}} \]

\[ S(xx) = \text{Sum} \left[ x_i - x_{avg} \right]^2 \]
\[ S(yy) = \text{Sum} \left[ y_i - y_{avg} \right]^2 \]
\[ S(xy) = \text{Sum} \left[ (x_i - x_{avg}) \cdot (y_i - y_{avg}) \right] \]

Sum implies additions of all such terms for \( i = 1 \) to \( n \).
\( n = \text{number of pairs of } (x,y) \text{ data} \)

8. Regression Analysis

How do you express the correlation between two factors in mathematical form?
How do you quantify the trends?

Regression analysis allows a way to express the scatter diagram in terms of mathematical equations. Subsequently, the equation can be used to predict one factor when the other is known.

\[ y = mx + c \]
8a. Straight-line Equations

Generalized equation for straight line: \( Y = mx + c \)

Where:
- \( C \) = intercept distance of the line on y-axis
- \( m \) = slope \((y/x)\) which the line makes with the positive x-axis

\[
\begin{align*}
  y &= (3/4)x + 3 \\
  \text{Or} \\
  y &= (3/4)x + 3 \\
  y &= ( - 2/4)x - 4 \\
  \text{Or} \\
  y &= -(1/2)x - 4
\end{align*}
\]

8b. Line Through Origin

When the line goes through the origin \( c = 0 \),

Line: \( y = mx \), \( m \) = unknown slope

Example: If takes 20 minutes to inject 3 cc of drug under gravity feed, how long would take to inject 30 cc of the same.

\[ y = (20/3)x \]

Answer: \( Y = \) Time, \( x = \) Drug, \( y = (20/3)x \)

When \( x = 30 \), then \( y = (20/3) \times 30 = 200 \) minutes.
8c. Best-Fit Line

Regression analysis can define the line that best represent the data that has a relationship. In other words, it can find m and C for the equation of the line that is least distant away from all data points.

\[
Y = mx + c
\]

8d. Regression Lines

- The regression lines can be straight or curved
- **Straight lines are most useful** for the purposes of predictions (extrapolation or interpolation)

How to define straight line:

*Eyeball a line through the middle of the data after eliminating outliers. Describe equation*

\[
y = mx + c
\]

by finding slope (m) and intercept (c) from the scaled graph.
8e. Regression Mathematics

Example: Relationship between Air Pressure and tank thickness (Ref. H. Kume, page 83)

<table>
<thead>
<tr>
<th>Air Pressure (kg/cm sq.)</th>
<th>8.0</th>
<th>8.5</th>
<th>9.0</th>
<th>9.5</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickness (mm)</td>
<td>4.62</td>
<td>4.12</td>
<td>3.21</td>
<td>2.86</td>
<td>1.83</td>
</tr>
<tr>
<td>n = 20</td>
<td>4.50</td>
<td>3.88</td>
<td>3.05</td>
<td>2.53</td>
<td>2.02</td>
</tr>
<tr>
<td></td>
<td>4.43</td>
<td>4.01</td>
<td>3.16</td>
<td>2.71</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>4.81</td>
<td>3.67</td>
<td>3.30</td>
<td>2.62</td>
<td>1.95</td>
</tr>
</tbody>
</table>

8f. Regression Calculations

\[ m = \frac{S(\text{xy})}{S(\text{x}x)} \quad \text{and} \quad c = \bar{y} - m \bar{x} \]

Where

\[ x_{\bar{}} = \frac{(8.0 + 8.5 + \ldots + 10.0) \times 4}{20} = 9.0 \]

\[ y_{\bar{}} = \frac{(4.62 + 4.50 + \ldots + 1.95) \times 20}{20} = 3.276 \]

\[ S(\text{x}x) = [\text{Sum}(x)^2] - [\text{Sum}(x)]^2/n \]

\[ = 1630 - 180^2/20 = 10 \]

\[ S(\text{xy}) = [\text{Sum}(x,y)] - [\text{Sum}(x) \times \text{Sum}(y)]/n \]

\[ = 576.88 - 180 \times 16.552/20 = -12.8 \]

Which give, \[ m = -12.8/10 = -1.28 \]

and \[ c = 3.276 - (-1.28) \times 9.0 = 14.80 \]

The line intercept y-axis at 14.8 mm when \( x = 0 \) (origin, left of y-line)
Approximate Method – Equation of a Line

Equation:
Y = mX + C
Where m = Slope of the line
C = Intercept

Both slope and intercept can be found graphically by extending the line till they intersect both axes.

m = - (intercept on Y)/(intercept on X)
or m = - (3/6) = 0.50
C = - 3 (intercept on the y-axis)
Y = 0.50X - 3

Question you can answer:
Q1. What will be the revenue from customer support in 17 months? (Ans: $5.5M)
Q2. When would the revenue from customer support reach $10M? (Ans: 26 Months)

Group Activities & Practice Session
Potholes Filled by Road Construction Crews

Teams of construction workers fill potholes in variable amount as shown. The regression line represents the average number of holes filled by a team.

Question you can answer:
Q1. If the team receives $25/hole, what would be their earning at end of 6 months.
Q2. If the crews were to work year around, how many potholes could each team fill within a budget of $750,000 for each team?

Group Exercise: Scatter Diagram

Do it as a group
Present your process to the class and show your Diagram.
7. Control Chart

The control chart, also known as the 'Shewhart chart' or 'process-behavior chart' is a method to determine whether a process is in a state of statistical control or not. When the process is not in control, the chart can reveal the source of variation to be eliminated to bring the process back into control.

The control chart was invented by Walter A. Shewhart while working for Bell Labs in the 1920s. It represents a diagram which contain all of the essential principles and considerations for process quality control.

10. Control Charts

These charts are used for statistical quality control of production process. Regular production performances are monitored and compared against collected performance data of the same process.

- Control charts using data sample (usually 20 x 5 data sets) are prepared prior to monitoring performance. Performance data (average of sample of 5) is then plotted in the control charts.
- Some standard rules are followed to judge whether the process is in control or out of control.
10a. Sources of Variations

- Most variations of characteristics (length, weight, volume, time, voltage, etc.) are normal (due to chance causes), that is due to natural causes and should be expected. But, some variations are due to some unusual (not normal, due to assignable causes) causes and should be corrected.
- The main purpose of the control charting is to identify the variations that are not normal.

10b. Example Control Chart

Yearly rainfall in a region is as shown below. Prepare the control chart for plotting future rainfall data.

Rainfall in inches: 22, 19, 13, 15, 19, 14, 20, 18, 23, and 17
Calculation gives \( \bar{x} = 18 \), \( s = 3.3 \)
\( UCL = \bar{x} + 3s = 18 + 9.9 \)
\( LCL = \bar{x} - 3s = 18 - 9.9 \)

Note: There are many types of distributions and all data do not conform to normal distribution. However, normal distribution applies to most control charting because of the finding known as Central Limit Theorem. It says that even though the data may not fit normal distribution, the sample means do for larger sample sizes.
Group Activities & Practice Session

Quantitative & Statistical Data Analysis

Group Practice Activities:
Control Chart

2.5B Practice & Learn: In Michigan’s winter months, normal production data for a particular brand of Salsa for Garden Fresh Gourmet Company is as shown below:

<table>
<thead>
<tr>
<th>Volume (Boxes)</th>
<th>Determine:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1235</td>
<td>1. Average production volume</td>
</tr>
<tr>
<td>2. 1220</td>
<td>2. Standard Deviation (σ) for the production volume</td>
</tr>
<tr>
<td>3. 1470</td>
<td>3. Plot a control chart showing average and +/- 1σ, +/- 2σ, +/- 3σ</td>
</tr>
<tr>
<td>4. 1390</td>
<td>4. A routine check in recent time winter month showed the following data: 1230, 1450, 1650, 1445, 1290, 1020, 1360 &amp; 1480. What is your conclusion about the nature of production variation?</td>
</tr>
<tr>
<td>5. 1490</td>
<td></td>
</tr>
<tr>
<td>6. 1530</td>
<td></td>
</tr>
<tr>
<td>7. 1510</td>
<td></td>
</tr>
<tr>
<td>8. 1310</td>
<td></td>
</tr>
<tr>
<td>9. 1420</td>
<td></td>
</tr>
<tr>
<td>10. 1290</td>
<td></td>
</tr>
<tr>
<td>11. 1335</td>
<td></td>
</tr>
<tr>
<td>12. 1355</td>
<td></td>
</tr>
<tr>
<td>13. 1220</td>
<td></td>
</tr>
<tr>
<td>14. 1370</td>
<td></td>
</tr>
<tr>
<td>15. 1540</td>
<td></td>
</tr>
</tbody>
</table>

Assume that the Standard Deviation = 104. Use TEMPATE in next slide.
Group Practice Activities:
Control Chart  (SOLUTION)

Special cause – an unusual event affecting change in result
Random causes – normal process variations

Tolerance – results are acceptable when falling within the tolerance range
Control limits – the process is in control if the results fall within the control limits

Key indicators for a process not “in control” are.

1. A point is beyond the upper or lower control limits
2. Six consecutive points are in an upward trend
3. Eight consecutive points are above the centerline.
Exercise I: Present Data in Graphical Form

<table>
<thead>
<tr>
<th>Hour of Day</th>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thurs</th>
<th>Fri</th>
<th>Sat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-12 am</td>
<td>470</td>
<td>380</td>
<td>445</td>
<td>527</td>
<td>419</td>
<td>1,467</td>
<td>1,132</td>
<td>5,150</td>
</tr>
<tr>
<td>12-3 pm</td>
<td>684</td>
<td>308</td>
<td>246</td>
<td>273</td>
<td>407</td>
<td>744</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td>3-6 pm</td>
<td>526</td>
<td>572</td>
<td>578</td>
<td>584</td>
<td>624</td>
<td>519</td>
<td></td>
<td>3,540</td>
</tr>
<tr>
<td>6-9 pm</td>
<td>402</td>
<td>576</td>
<td>565</td>
<td>599</td>
<td>839</td>
<td>580</td>
<td>419</td>
<td>7,060</td>
</tr>
<tr>
<td>Noon-3</td>
<td>721</td>
<td>741</td>
<td>677</td>
<td>743</td>
<td>719</td>
<td>833</td>
<td>876</td>
<td>7,400</td>
</tr>
<tr>
<td>9-12 am</td>
<td>470</td>
<td>676</td>
<td>715</td>
<td>757</td>
<td>818</td>
<td>1,177</td>
<td>1,190</td>
<td>6,240</td>
</tr>
<tr>
<td>12-3 pm</td>
<td>684</td>
<td>769</td>
<td>639</td>
<td>718</td>
<td>1,297</td>
<td>1,132</td>
<td>5,830</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6,000</td>
<td>4,020</td>
<td>3,020</td>
<td>4,020</td>
<td>1,000</td>
<td>1,000</td>
<td>7,000</td>
<td>40,400</td>
</tr>
</tbody>
</table>

Task: It is possible to prepare and present a large number of graphs from the above data. Prepare and present at least one graph of your choice.

References:

Sources of Example Graphs
- Financial reports and magazines
- USA Today news paper
- Wall street Journal

Texts:
Useful Properties of Normal Distribution

Normal Distribution
Among several distribution equations, most widely used is the Normal Distribution which was discovered by Gauss, Laplace and De Moivre, independently. But it is generally identified as Gaussian distribution or the Gaussian error law.

\[ f(x) = \frac{1}{\sigma \sqrt{2 \pi}} e^{-\frac{(x - \mu)^2}{2 \sigma^2}} \]

where \( x \) is the random variable, \( f(x) \) probability of \( x \), \( \mu \) = average (Mean) of population, \( \sigma \) = standard deviation of population.
Quality Standards

**AS9100** is the aerospace industry harmonized standard for quality systems for quality assurance in design, development, production, installation and servicing. The purpose and objectives of AS9100 is to:

- provide increased consistency in the expectations of the industry,
- reduce verification requirements, methods and audits,
- improve quality and safety, and
- decrease costs and waste.

**ISO 9000 Series** (ISO 9001, 9002, etc) provides general quality assurance guidelines as well as quality system models that can be used by any type or size of company anywhere in the world.

**QS-9000** requirements were developed by the Chrysler/Ford/General Motors Supplier Quality Requirements Task Force.

**ISO 14000** is the internationally recognized standard for Environmental Management Systems (EMS).

**TL 9000** requirements were developed by the QuEST forum (The Quality Excellence for Suppliers of Telecommunications Leadership), comprised of leaders in the telecommunications field.

**ISO 13485** is the international standard for quality management systems for medical devices.

**ISO/TS 16949** used the ISO 9001 Standard as the basis for their development and included the requirements from these Standards with specific 'adders' for the automotive supply chain. The 2002 revision of TS builds off the ISO9001:2000 document.

Terms and Definitions

**Active part** – is one currently being supplied to the customer for original equipment or service application.

**ANOVA** – Stands for Analysis of Variance. It is statistical calculations that determines relative influences of individual factors when they all affect the outcome.

**Assessment** – is an evaluation process including a document review, an onsite audit and analysis and report.

**Corrective action** – is an action taken to eliminate the cause of an existing nonconformity or other undesirable situation that prevents recurrence.

**Design Review** – is a formal, documented, and systematic review of a design. The purpose is to evaluate the design to see that it meets requirements, satisfies performance objectives, and identify problems and solutions.

**Documentation** – is the systematic, orderly, and understandable written descriptions of those policies and procedures that affect the product and service quality.

**Inspection** – represents the activities like measuring, examining, testing, and gauging one or more characteristics of a product or service, and comparing these with specified requirements to determine conformity.

**Management Review** – is the continual review of the quality system by management to make sure that the quality system remains suitable and effective.

**Nonconformity** – is a process which does not conform to a quality system requirements.

**OEM** – stands for Original Equipment Manufacturer.

**Procedures** – represents documented processes that are used when work affects more than one function or activity of an organization.

**Process capability** – is the total range of inherent variation in a stable process.

**Process capability indices** – indicate whether a process is capable of meeting established customer requirements or specifications.

**Quality** – is the totality of features and characteristics of an entity (product or service) that bear on its ability to satisfy stated or implied needs (ISO 8402, Clause 2.1).

**Quality Assurance** – is all the planned and systematic activities implemented within the quality system and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality.
**Terms and Definitions**

- **Quality Audit** – is a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives (ISO).

- **Quality management** – represents all activities of the overall management functions that determine the quality policy, objectives, and responsibilities, and implement them by means such as quality planning, quality control, quality assurance, and quality improvement within the quality system (ISO).

- **Quality manual** – is a document stating the quality policy and describing the quality system of an organization.

- **Quality plan** – is a document that defines the specific quality practices, resources, and sequence of activities relevant to a particular product, project, or contract.

- **Quality planning** – consists of the activities that establish the objectives and requirements for quality and for the application of quality system requirements.

- **Quality policy** – is the overall intentions and direction of an organization with regard to quality, as formally expressed by top management.

- **Quality records** – are the documented evidence that the supplier’s processes were executed according to the quality system documentation and records results.

- **Quality system** – is the organization structure, procedures, processes, and resources needed to implement quality management.

- **Statistical process control** – is the application of statistical technique to the control of processes.

- **Traceability** – is the ability to trace the history, application, or location of an entity, by means of recorded identification.

- **Validation** – indicates conformation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled (ISO).

**Development and Implementation of the American System of Manufacturing and the Assembly Line**

**Eli Whitney** (December 8, 1765 - January 8, 1825) was an American inventor and manufacturer who is credited with creating the first cotton gin in 1793. The cotton gin was a mechanical device which removed the seeds from cotton, a process which was until that time extremely labor-intensive.

- However, the gin was a minor accomplishment compared to his invention of interchangeable parts. Whitney developed this about 1798 when he took a contract from the U.S. Army for the manufacture of 10,000 muskets at the unbelievably low price of $13.40 each.

- In 1798, Whitney received a U.S. Army contract to make 10,000 muskets. At that time muskets were produced by hand, one by one, by skilled craftsmen. Whitney realized that production would be faster if identical, interchangeable parts were used. He built a factory, designed a musket, made a pattern for each part, and invented machines that could be used by unskilled workers to produce the parts in quantity. Whitney’s system was the first example of mass production in the United States.

- For the next 100 years (1800 – 1890) manufacturers primarily concerned themselves with individual technologies dealing with system of engineering, drawings development, perfecting modern machine tools and development of large scale processes such as the Bessemer process for making steel which held the center of attention.

- Production specialists were oblivious of many issues of concern as products moved from one discrete process to the next through the logistics system and within factories: very few people cared about:
  - What happened between processes?
  - How multiple processes were arranged within the factory?
  - How the chain of processes functioned as a system?
  - How each worker went about a task?

These issues were only addressed in the late 1890’s with the work of early Industrial Engineers.
The Principle of Scientific Management

Frederick W. Taylor was a mechanical engineer whose writings on efficiency and scientific management were widely read. He began to look at individual workers and work methods. The result was Time Study and standardized work. Taylor was a controversial figure. He called his ideas:

- Scientific Management
- The concept of applying science to management was sound but Taylor simply ignored the behavioral sciences.

President Roosevelt, in his address to the Governors at the White House, prophetically remarked that "The conservation of our national resources is only preliminary to the larger question of national efficiency."

Taylor’s method of doing away with slow working and "soldiering" in all its forms and so arranging the relations between employer and employee, that each workman will work to his very best advantage and at his best speed, accompanied by the intimate cooperation with the management and the help (which the workman should receive) from the management, would result on the average in nearly doubling the output of each man and each machine.

Frank Bunker Gilbreth was born on July 7, 1868 in Fairfield, Maine. He was a bricklayer, a building contractor, and a management engineer. He added Motion Studies and invented Process Charting. Process Charting depicted all work elements including non-value added elements that are normally present between "official" elements.

Lillian Evelyn Moller was born on May 24, 1878 in Oakland, California. She graduated from the University of California with a B.A. and M.A. and went on to earn a Ph.D. from Brown University. She brought psychology into the mix by studying the motivations of workers and how attitudes affected the outcome of a process.

Leaders of Lean Manufacturing

Henry Ford and his associate Charles E. Sorensen introduced the first comprehensive manufacturing strategy in 1912. They took all the elements of a manufacturing system—people, machines, cooling, and products—and arranged them in a continuous system for manufacturing the Model T automobile. Ford’s success quickly made him one of the world’s richest men. Ford is considered by many to be the first practitioner of Just In Time and Lean Manufacturing.

- Ford’s success inspired many others to copy his methods.
- Ford is considered by many to be the first practitioner of Just In Time and Lean Manufacturing.
- Product proliferation, annual model changes, multiple colors, and options put a lot of strain on Ford system as it did not fit well in the factories.

Taiichi Ohno - In the 1940's and early 1950's, Ohno was the assembly manager for Toyota and developed many improvements that eventually became the Toyota Production System.

- The 1950's, he collaborated with Shingo Shingo to refine their earlier efforts into an integrated Manufacturing Strategy.
- In the early 1980's, Ohno retired from Toyota and was president of Toyota Gosei, a Toyota subsidiary and supplier.
- Taiicho Ohno died in Toyota City in 1990.

Dr. Shigeo Shingo - After graduation from Yanagisawa Technical College in 1930 he went to work for the Taipei Railway Company. In 1943 shingo was transferred to the Amano Manufacturing Plant in Yokohama.As Manufacturing Section Chief, he raised productivity 100%.

- In 1955, Dr. Shingo began another long association with Taiichi Ohno of Toyota.
- In 1959, Dr. Shingo left JMA to start his own consulting company developed his concepts of "Mistake-Proofing."
Taguchi Method for Design Optimization

- Dr. Genichi Taguchi has done much research with Design Of Experiments (DOE) technique and has developed a complete philosophy for "Quality Engineering". Some of his ideas are:
  - **Loss Function** - A quality of a product is measured in terms of loss (expressed in money) to society during its entire life. The relation between this loss and the performance characteristics is expressed by the loss function.
  - **Off Line Quality Control** - Quality must be built into products and processes.
  - **Robust Design** - Performance is influenced by different types of noise (variation within tolerance, external conditions, influence of neighboring systems, ...). The influence of these noises needs to be minimized. To minimize the influence of these noises, we need to develop products and processes that are insensitive to such influences. The robustness of a system is measured by its ability to function optimally when exposed to the influence of the noise conditions.
  - **Standardized Experiment Designs** - Fundamental part of the Taguchi methods is to determine a combination of parameter settings that enhances robustness (parameter design). A set of special orthogonal arrays proposed by Dr. Taguchi helps accomplish experiment design easily by practitioners with or without background in statistical science.

Ishikawa diagram

- An **Ishikawa diagram** is a diagram that shows the causes of a certain event in graphical form. This diagram is also known as a fishbone diagram or cause and effect diagram. It was first used by Dr. Kaoru Ishikawa in the 1960s. It is one of the **SEVEN basic tools of Quality management**:
  1. Histogram
  2. Pareto Chart
  3. Check Sheet
  4. Control Chart
  5. Scatter Diagram
  6. Flowchart
  7. Ishikawa Diagram

The cause and effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output). It does not have a statistical basis, but are excellent aids for problem solving and trouble-shooting. The causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events. Cause-and-effect diagrams can reveal important relationships among various variables and possible causes provide additional insight into process behavior. This can help us to search the root causes, identify areas where there may be problems, and compare the relative importance of different causes.
**Kaizen Event – What does it mean?**

*kaizen* is often synonymous with “Kaizen Event” or “kaizen Blitz” (Better Japanese word is “Kaikaku”)

Such events rapidly implement workcells, improve setups or streamline processes. However, a better Japanese word for this activity is *kaikaku*

The Japanese definition of Kaizen is “Continuous Improvement” – slow, incremental but constant. It is an important tool in Lean manufacturing practiced by Taiichi Ohno and Shigeo Shingo at Toyota.

**Large scale improvement** - is quantum jumps in productivity, quality and effectiveness. However, it is difficult to implement because it affects many areas, people and processes. The design must be near perfect because failure courts disaster. *The risks and difficulties work against large-scale improvements.*

**Small-scale improvement** - is easier and faster. The risks are low because they generally have limited effect. However, the accumulated effect is often greater than a single large improvement.

The Kaizen Blitz is a localized, smaller scale improvement. An *event* usually includes training followed by analysis, design, and re-arrangement of a product line or area. The results are immediate, dramatic and satisfying. (Such Kaizen Events over 50 years, has helped make Toyota the lowest cost and highest quality automobile company in the world.)

Message: *Go for many small improvements rather than a few quantum improvements.*

Source: [http://www.strategicsinc.com/kaizen.htm](http://www.strategicsinc.com/kaizen.htm)

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**Group Activities & Practice Session**

- Explore data plotting needs & practices
- What ideas you need to communicate
- Think of graphics that will help

(STORY BOARD)
Figure 2.19 Sample Pareto Chart - SOLUTION

Group Practice Activities - Pareto Chart

2.5A Practice & Learn: SOLUTION

(1) SOLUTION BELOW
(2) Determine the three months with higher performances.
(3) Identify the month that makes up 85% of the total sales.

<table>
<thead>
<tr>
<th>Month</th>
<th>$Sales (000)</th>
<th>%</th>
<th>Cum. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>290</td>
<td>22.05</td>
<td>22.05</td>
</tr>
<tr>
<td>November</td>
<td>160</td>
<td>12.16</td>
<td>34.21</td>
</tr>
<tr>
<td>January</td>
<td>120</td>
<td>9.12</td>
<td>43.33</td>
</tr>
<tr>
<td>October</td>
<td>118</td>
<td>8.97</td>
<td>52.30</td>
</tr>
<tr>
<td>February</td>
<td>105</td>
<td>7.98</td>
<td>60.28</td>
</tr>
<tr>
<td>March</td>
<td>90</td>
<td>6.84</td>
<td>67.12</td>
</tr>
<tr>
<td>April</td>
<td>85</td>
<td>6.46</td>
<td>73.58</td>
</tr>
<tr>
<td>September</td>
<td>82</td>
<td>6.24</td>
<td>79.80</td>
</tr>
<tr>
<td>July</td>
<td>70</td>
<td>5.32</td>
<td>85.14</td>
</tr>
<tr>
<td>August</td>
<td>70</td>
<td>5.32</td>
<td>90.46</td>
</tr>
<tr>
<td>June</td>
<td>65</td>
<td>4.94</td>
<td>95.40</td>
</tr>
<tr>
<td>May</td>
<td>60</td>
<td>4.56</td>
<td>99.96</td>
</tr>
<tr>
<td>Total</td>
<td>1315</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 2.19 Sample Pareto Chart - SOLUTION

Group Practice Activities:
Control Chart (SOLUTION)

A routine check in recent time winter month showed the following data: 1230, 1450, 1650, 1445, 1290, 1020, 1360 & 1480. What is your conclusion about the nature of production variation?

Avg. = 1385, Std. Dev. = 104.3
1489.3, 1593.6, 1697.9
1385
1280.7, 1176.40, 1072.1

The process is operating with normal variation.

Slide 134
Group Practice Activities:
Control Chart  
(2.5B SOLUTION)

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Group Exercise

Consider your own activity and see how the data analysis technique can be helpful

Are there any data that your activity currently generates?
If not, do you expect any data can be generated?
Which form of presentation of data is currently done or may be valuable?
What type of questions does your data answers?

What do you anticipate your management could value and ask?
What kind of data and presentation could respond to such questions?