Total Quality Management

QI Story: Tools and Techniques

A Guidebook for Teams

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QI Story: Tools and Techniques

First Edition

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I.

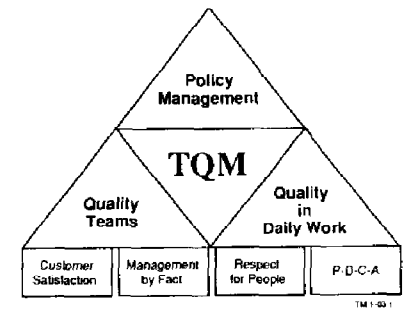
Concepts of Total Quality Management

Total Quality Management

What is Total Quality Management?

Total Quality Management, or TQM, is a way of ensuring customer satisfaction through involvement of all employees in learning how to reliably produce and deliver quality goods and services.

Total Quality Management



The goal of TQM is to improve internal and external customer satisfaction through total quality control. TQM is how we work toward that goal.

The three components that comprise TQM are Quality Teams, Policy Management, and Quality in Daily Work. The four principles of TQM are Customer Satisfaction, Management by Fact, Respect for People, and Plan-Do-Check-Act (P-D-C-A).

This guidebook addresses the Quality Improvement Story and its use by Quality Teams.

Components of TQM

1. ***Quality Teams provide a structured environment for employees to work together to:***
   - improve the quality of products and services.
   - develop and leverage the skills and abilities of employees.
   - promote communication and teamwork.
   - enhance the quality of work life.
2. ***Policy Management targets the achievement of breakthrough by concentrating company efforts and resources on a few priority issues to:***
   - increase performance levels.
   - improve communication within the company and provide direction for departments.
   - attain broad participation in the development and attainment of long-term goals, mid-term goals, and short-term goals.
3. ***Quality in Daily Work (QIDW) requires application of the Plan-Do-Check-Act (P-D-C-A) philosophy to activities necessary to meet the needs and expectations of customers. The goals are to:***
   - maintain gains achieved through improvement projects.
   - achieve consistency in operations as well as results.
   - clarify individual contributions toward achieving customer satisfaction.
   - improve daily operations.

Four Principles of Total Quality Management (TQM)

1. ***Customer Satisfaction*** means satisfying the needs and reasonable expectations of the customer and maintaining an attitude that puts the needs of the customer first. (A telephone call from someone who uses one of my products – my customer – is not an interruption of my work; it ***is*** my work.)
2. ***Management by Fact (often referred to as "speaking with facts")*** means all employees, including managers, manage the work they do by collecting objective data and making decisions based on this information.
3. ***Respect for People*** means that each of us needs to listen to and support the capacity of all other employees for self-motivation and creative thought.
4. ***P-D-C-A (Plan-Do-Check-Act)*** is a work philosophy that emphasizes four phases of activity:
   - Plan what to do
   - Do it
   - Check what you did
   - Act to prevent error or improve the process

Customer Satisfaction

What is customer satisfaction?

Customer satisfaction is the heart of TQM. It means meeting the needs and reasonable expectations of the customer.

External customers are those consumers (end users) whose needs and expectations will be met by your product or service. To satisfy external customers, you must also meet the needs of your *internal* customers, those within your organization who make enhancements or add value to the product or service you provide.

How do we achieve customer satisfaction?

1. We divide up our work process into inputs, activities and outputs.
2. We identify our "next process customers" as those who receive our outputs.
3. We work with our customers to determine what the *valid requirements* are for our process outputs.

4. On the basis of the valid requirements, we develop *quality indicators* through which we can monitor our performance in an on-going way.
5. We take corrective action when necessary to satisfy customer needs.

Customer Satisfaction Philosophy

1. We are in a long-term relationship with our customers.
2. We must help our customers identify and satisfy their needs and wants.
3. We must realize that these needs and wants will change and evolve.
4. We must keep the lines of communication open between suppliers and customers.

Valid Requirements

What are valid requirements?

Valid requirements are standards of quality work agreed upon by customers and suppliers. Valid requirements must:

- be current, realistic, and measurable.
- meet customer needs and reasonable expectations.
- meet corporate responsibilities.

Valid requirements are usually simple statements of how a product should be (including measurement) to meet the customer's needs. (For example, a form legibly filled out and submitted with signature within five days of completion of the job.)

Why are valid requirements useful?

We use valid requirements to satisfy the needs and reasonable expectations of our customers.

How are valid requirements applied?

In the ideal case, we open a clear channel of communication and negotiate the valid requirements with our customers. We start by asking them about their wants and desires; through questioning and consensus, we narrow the focus to those requirements that they ***need*** and can ***reasonably expect.*** Once established, the valid requirements serve as both a goal and a guideline for producing quality products.

When are valid requirements used?

We can use them to guide us in establishing or improving our work processes in general; we also use them in steps 1, 2, and 4 of the QI Story.

Management by Fact

Management by Fact means managing by using data. In this manner, we can make the best possible decisions in delivering quality products and services to our customers.

What is data?

Webster defines data as "facts or figures from which conclusions can be drawn; a basis for reasoning, discussion or calculation." Information collected about a product, service, process, person, or machine is called data. Data (facts), when properly organized and analyzed, provide useful information and serve as the basis of decision making and action.

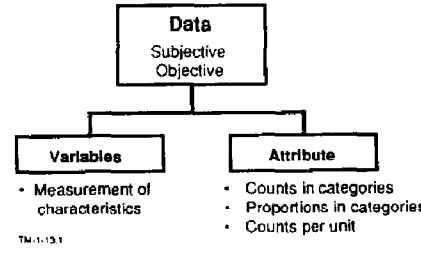
Data can be *subjective* (based on experience, intuition, gut feel, opinion or observation) or *objective* (based on verifiable external events). Data can be represented in either words, pictures (graphs), or numbers. In our search for objective data, numbers become

very important. There are two broad categories of numerical data: *attribute* and *variables*. Understanding the categories and their differences helps us to use each effectively.

- Attribute data describe a particular characteristic being measured. These data depend on counting occurrences that have certain characteristics, and they represent conformity or nonconformity with some quality characteristic. Attribute data are based on counts of the number of times a particular event is observed (for example, classes/categories of products, items, or services; number of defects; proportion of nonconforming items).
- Variables data are continuous data that show degrees of variation when measuring a characteristic of a product, service, or process and computing a numerical value from two or more measurements of data. A quality characteristic, such as diameter, age, weight, or lifetime of a product is actually measured.

When it is important not only to identify and rank items, but also to precisely measure the distribution (the distance or interval between them), we must collect variables data. If attribute data are black or white, then variables data are concerned with measuring the shades of gray. Not only do we identify our data by category, but we measure distance, pounds, feet, rate of disabling accidents, etc.

Graphically, data types look like this:



Why are data collected?

Collect data to:

- quantify the present situation (baseline) as well as future changes to be able to compare the two.
- identify improvement opportunities.
- analyze root causes and select countermeasures.
- track a process and/or a countermeasure.
- explain a problem/opportunity clearly to others.
- "speak with facts."

How are data collected?

Data are collected through the use of standardized forms called Checksheets. The data are collected in sufficient detail so they can be stratified, thus breaking down the total area of concern into smaller related functions or items. Generally, data should be collected at the smallest grouping practical; that data should include *variables* data when available.

When you plan for data collection:

- identify what you want to know.
- select the proper data collection technique.
- plan how the data will be processed and analyzed.
- collect only needed data.
- get the right data for the problem.
- measure things as accurately as possible, given reasonable time and cost constraint.

When are data collected?

Data are collected only after planning and only when needed. In general, steps 2, 3, and 4 of the QI Story require attention to data gathering to verify problems, causes, and countermeasures through facts.

Quality Indicators

What are quality indicators?

Quality indicators are measures of how well we are meeting our customers' needs and reasonable expectations. Put another way, indicators are measurements of the degree and/or frequency of conformance to valid requirements. Above 80 percent conformance, we should focus on non-conformance to aid our improvement efforts.

Examples of quality indicators:

- ◊ Number of forms submitted late
- ◊ Number of billing errors per month
- ◊ Heat rate per unit in a power plant
- ◊ Number of phone calls lost

Why are quality indicators useful?

Quality indicators help us measure the gap between what is and what should be — present performance versus customers' valid requirements. They allow us to meet *measurable* criteria of valid requirements.

How are quality indicators applied?

They are used to establish the current status (a baseline) and to track the number and/or percentage of errors, changes, or improvements.

When are quality indicators used?

They are used in steps 1, 2, and 5 of the QI Story as we identify our theme or problem area and as we measure results.

Targets

What are targets?

A goal is a desired state or standard tracked through an indicator. A target is a milestone toward the accomplishment of that desired goal. Examples of indicators for which targets would be set:

- Number of minutes per outage (goal: reduced/no outages)
- Number of days to process a payment (goal: timely payment)
- Number of meters read per day (goal: fixed number read per day)

Targets are set to give the team milestones to measure the effectiveness of performance and to see if countermeasures are successful in addressing the problem.

When are targets set?

Targets may be set in steps 1 and 2 of the QI Story, after a performance indicator is identified.

How are targets set?

Targets should be set to be challenging, but achievable, during a reasonable period of time. They should be based on logic. An ultimate goal may be needed, but interim targets can be set as milestones towards its accomplishment. In setting targets:

1. First, consider the needs and reasonable expectations of the customer. This may also help to restructure an indicator.
2. Second, consider the performance of similar operations or competitors.
3. Third, your own past performance can be used to set a target. If, at one time, your performance was significantly better, you may want to set that as a target and discover what has changed in the operation to make your performance worse.
4. Fourth, set a target by analyzing processes to determine if waste is present.

Respect for People

Respect for People is one of the most important principles of TQM. It means respecting each person's ability for creative thought and his or her capacity for self motivation. But these words will be meaningless unless each one of us practices this principle through our daily interactions with co-workers.

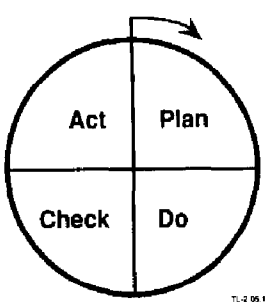
Rules of Conduct

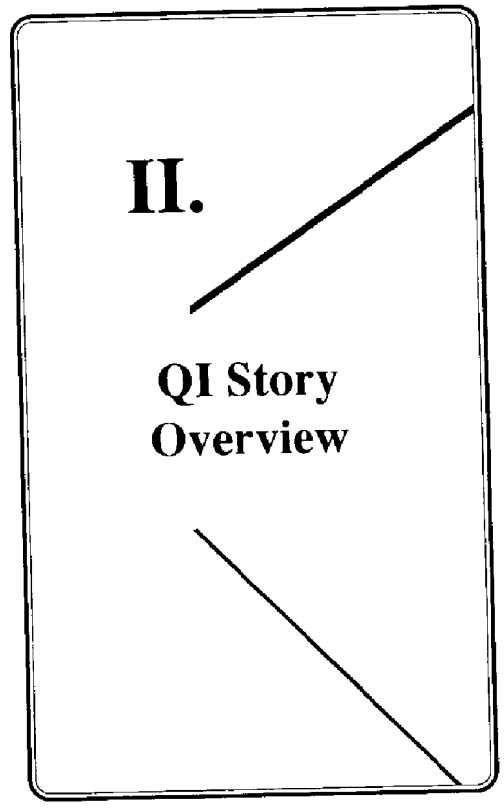
- Respect each person
- Share responsibility
- Criticize only ideas, not people
- Keep an open mind
- Question and participate
- Attend all meetings
- Listen constructively

Plan-Do-Check-Act (P-D-C-A)

What is P-D-C-A?

P-D-C-A stands for "Plan-Do-Check-Act," the concept that underlies the QI Story. This cycle is based upon the simple premise that to achieve continuous improvement you must plan for it, do (implement) it, check and analyze the results, and act for improvement. The cycle (illustrated below) implies an on-going improvement over every current situation.




II.
QI Story
Overview

QI Story

What is the QI Story?

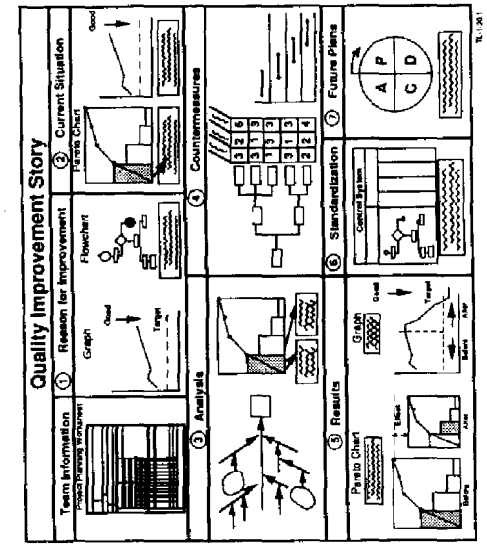
The quality improvement problem-solving process is a systematic, data-based approach to problem solving. The QI Story is a structure to help illustrate the steps to be taken by a team in the improvement process. It provides a standard way of communicating team progress. The vehicle used to document this process is known as a "storyboard," which is essentially a structure allowing a team to display its work in a standardized fashion. (The QI Story is illustrated on page 27.)

Why is the QI Story useful?

- It helps the team organize, collect, and analyze information and monitor how it is doing.
- It helps the team stay on track.
- It encourages the team to obtain and communicate information to non-team members.

How is the QI Story used?

The QI Story serves as a guide at every stage of the team's activity and every step of the improvement process. It guides the team through planning, doing, and checking. When followed step by step, it provides both the team and others with a clear picture of the logical process used for improvement. Each step is described in this booklet.


Quality Improvement Story
Team Information
Reason for Improvement
Current Situation
Analysis
Countermeasures
Results
Standardization
Future Plans
Graph
Flowchart
Pareto Chart
A P
C D

Step One: Reason for Improvement

Objective

Identify a theme (problem area) and the reason for working on it.

Key Activities

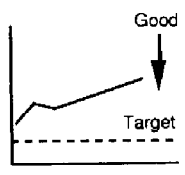
- Research for themes:
  - Review departmental indicators.
  - Survey internal/external customers.
  - Identify what the team already knows (brainstorm).
  - Interview individuals from the work area.
- Consider customer needs to help select the theme.
- Set indicator to track the theme.
- Show how much improvement is needed using data.
- Show impact of the theme.
- Schedule the QI Story activities.
- Describe the procedure used in the problem area.

Helpful Tools/Techniques

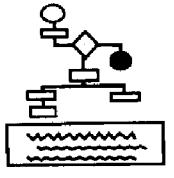
- Graph
- Control Chart
- Process Flowchart
- Control System

Examples:

Graph



Flowchart



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Step Two: Current Situation

Objective

Select a problem and set a target for improvement.

Activities

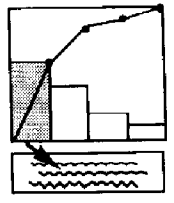
- Collect data on all aspects of the theme.
- Stratify the theme from various viewpoints.
- Select a problem from the stratification of the theme.
- Identify the customer's valid requirements.
- Write a clear problem statement.
- Utilize the data to establish the target.

Helpful Tools/Techniques

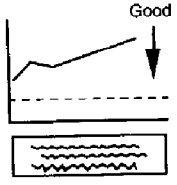
- Checksheet
- Histogram
- Pareto Chart
- Control Chart
- Graph

Examples:

Pareto Chart



Graph



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Step Three: Analysis

Objective

Identify and verify the root causes of the problem.

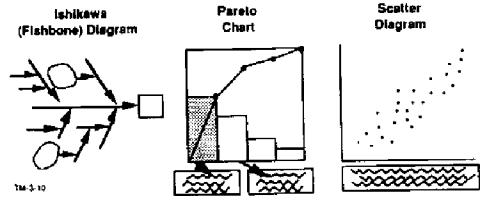
Key Activities

- Perform Cause-and-Effect Analysis on the problem.
- Continue analysis to the level of *actionable* root causes.
- Select the root causes with probable greatest impact.
- Verify the selected root causes with data.

Helpful Tools/Techniques

- Cause-and-Effect Analysis
  - Ishikawa (Fishbone) Diagram
- Checksheet
- Pareto Chart
- Histogram
- Graph
- Scatter Diagram

Examples:



Step Four: Countermeasures

Objective

Plan and implement countermeasures that will correct the root causes of the problem.

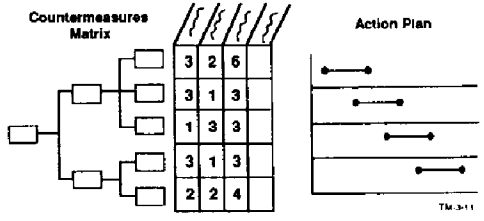
Key Activities

- Develop and evaluate potential countermeasures which:
  - Attack verified root causes.
  - Meet customer's valid requirements.
  - Prove to be cost beneficial.
- Develop an action plan that:
  - Answers who, what, when, where and how.
  - Reflects the barriers and aids needed for success.
- Obtain cooperation and approvals.
- Implement countermeasures.

Helpful Tools/Techniques

- Cost Estimation
- Countermeasures Matrix
- Barriers and Aids
- Action Plan

Examples:



Step 5: Results

Objective

Confirm that the problem and its root causes have been decreased and the target for improvement has been met.

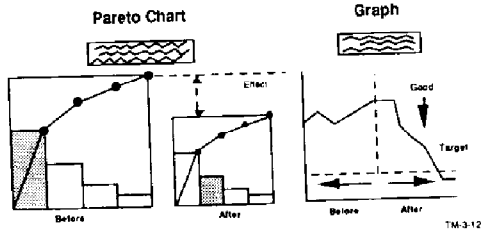
Key Activities

- Confirm the effects of the countermeasures, checking to see if the root causes have been reduced.
- Compare the problem before and after, using the same quality indicator.
- Compare the results to the target.
- Implement additional countermeasures, if results are not satisfactory.

Helpful Tools/Techniques

- Histogram
- Pareto Chart
- Control Chart
- Graph

Examples:



Step Six: Standardization

Objective

Prevent the problem and its root causes from recurring.

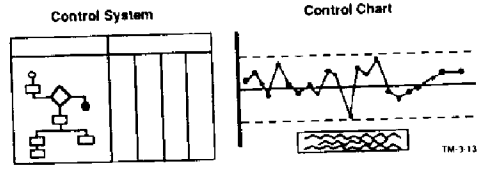
Key Activities

- Assure that countermeasures become part of daily work.
  - Create/revise the work process.
  - Create/revise standards.
- Train employees on the revised process and/or standards and explain the need or purpose.
- Establish periodic checks with assigned responsibilities to monitor countermeasures.
- Consider areas for replication.

Helpful Tools/Techniques

- Control System
- Control Chart
- Graph
- Procedures/Standards
- Process Flowcharts
- Training

Examples:



Step Seven: Future Plans

Objective

Plan what to do about any remaining problems and evaluate the team's effectiveness.

Key Activities

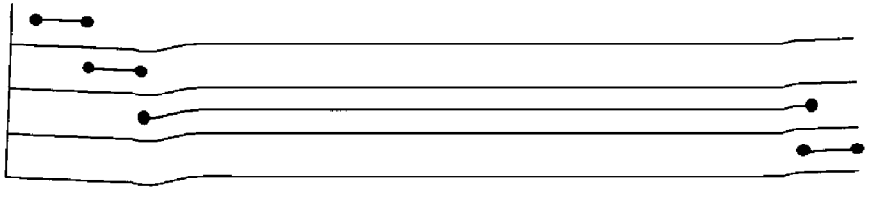
- Analyze and evaluate any remaining problems.
- Plan further actions if necessary.
- Review lessons learned related to problem-solving skills, group dynamics, and team effectiveness.
  - What was done well?
  - What could be improved?
  - What could be done differently?

Helpful Tools/Techniques

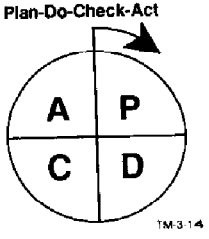
- Action Plan
- P-D-C-A

Examples:

Action Plan



Plan-Do-Check-Act



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QI Story Review Form

Team Name: _____ Theme: _____

QI Story Steps	Objective/Checkpoints	√
1 Reason for Improvement	***To identify a theme (problem area) and the reason for working on it.***	
	1. The criteria for selection was customer oriented.	
	2. The indicator correctly represented the theme.	
	3. The need for improvement was demonstrated using data.	
	4. A schedule for completing the QI Story steps was developed.	
2 Current Situation	***To select a problem and set a target for improvement.***	
	5. The situation was stratified to a component level specific enough to analyze.	
	6. Customer valid requirements were identified.	
	7. Problem statement addressed the gap between the current and targeted values.	
	8. The methodology in establishing goals/target was identified.	
3 Analysis	***To identify and verify the root causes of the problem.***	
	9. Cause & Effect Analysis was performed on the problem.	
	10. Root Causes were taken to an actionable level.	
	11. Root Causes with probable greatest impact were selected.	
	12. Data was used to verify the root causes.	
4 Counter-measures	***To plan and implement countermeasures that will correct the root causes of the problem.***	
	13. Selected countermeasures attacked verified root causes.	
	14. Countermeasures were consistent with meeting customer valid requirements.	
	15. Countermeasures were cost beneficial.	
	16. Action plan answered who, what, when, where, and how.	
	17. Action plans reflected the barriers and aids necessary for successful implementation.	

5 Results	*To confirm that the problem and its root causes have been decreased and the target for improvement has been met.*	
	18. Root causes have been reduced.	
	19. Tracking indicator was the same one used in the reason for improvement.	
	20. Results met or exceeded target (if not, cause was addressed)	
6 Standard-ization	*To prevent the problem and its root causes from recurring.*	
	21. Method to assure countermeasures become part of daily work was developed (include applicable training)	
	22. Periodic checks were put in place with assigned responsibility to monitor the countermeasures.	
	23. Specific areas for replication were considered.	
7 Future Plans	*To plan what is to be done about any remaining problems, and to evaluate the team's effectiveness.*	
	24. Any remaining problems of the theme will be addressed.	
	25. Apply P-D-C-A to lessons learned.	

III.

QI Tools and Techniques

Brainstorming

What is brainstorming?

Brainstorming is a technique used by a group to quickly generate, clarify and evaluate a sizable list of ideas, problems, issues, etc. The phases of brainstorming (generating, clarifying, and evaluating) must be done one at a time. Emphasis is on *quantity* of ideas, not quality. Brainstorming is an excellent technique for tapping the creative thinking of a team.

How is brainstorming done?

Generation phase (first phase):

- The team leader states the topic to be brainstormed in specific, precise terms and makes it visible on a flipchart.
- A recorder is selected to capture ideas on a flipchart.
- The generation phase begins, and each team member takes a turn, continuing the brainstorming until all ideas have been exhausted.

Clarification phase (second phase):

- The team goes over the brainstorming list to make sure everyone understands all of the items and to eliminate duplication.
- Don't discuss ideas; criticism and discussion will take place during the evaluation stage and in multivoting.

Evaluation phase (third phase):

- The team reviews the list to eliminate irrelevancies or issues that are off limits.

Rules of Brainstorming

- Clearly state purpose of the brainstorming.
- Take a turn, in sequence, around the entire group.
- Present one thought at a time.
- Do not criticize or discuss any idea.
- Pass as necessary.
- Build on ideas of others.
- Record ideas where visible for group.

When is brainstorming used?

Brainstorming is used as a data-gathering technique to:

- collect improvement opportunities and/or problem areas (themes).
- identify possible causes when constructing an Ishikawa, or Fishbone Diagram (Cause-and-Effect Analysis).
- suggest possible countermeasures.
- identify barriers or aids.

Multivoting

What is multivoting?

The multivoting technique is a structured series of votes used by a team to help reduce a large number of items to a manageable few (usually three to five).

Why is multivoting useful?

Multivoting helps to accomplish "list reduction" quickly and with a high degree of group agreement. This technique tends to eliminate individuals' close identification with items.

How is multivoting done?

1. First vote -- Each person votes for as many items as desired, but only once per item. The team then agrees on the number of votes that establishes whether an item should remain on the list. A guideline to follow is to circle the items receiving a *relatively higher* number of votes than the

other items. (Example: A team of eight members generates a list of fourteen items after round one. The team decides items receiving six or more votes are circled. In this example, the team circles eight items.)

2. Second vote – Each person gets to vote a number of times equal to *half* the circled items. (Example continued: If eight items receive six or more votes, then each person gets to vote four times during the second vote.)
3. Continue multivoting until the list is reduced to three to five items, which can then be further analyzed. *Never multivote down to only one item!*

When is multivoting used?

Multivoting can be used after a team discusses the various items on a brainstorm list that is too lengthy for everything to be addressed. Multivoting is often used to narrow a list of themes to three to five.

Theme Selection Matrix

What is the Theme Selection Matrix?

The Theme Selection Matrix is a tool that helps the team quickly select a theme on which to begin gathering data. Using its judgment, the team should select a theme which shows a need for improvement. A Theme Selection Matrix appears on the following page.

Why is the Theme Selection Matrix useful?

The matrix allows the team to rank its themes by considering the impact on the customer and the need to improve. Thus, the team is able to focus its energies on improvements which are customer oriented. The matrix also helps the team achieve ownership and clarity in the selection of its theme.

When is the Theme Selection Matrix used?

The matrix is used after the team has reduced its list of themes to three to five items through multivoting. The list is then placed in the matrix and the team works to complete the remaining categories.

Theme Selection Matrix

Themes	Impact on Customer	X	Need to Improve	=	Overall
Themes: The 3 - 5 remaining after the team has *multivoted*. Teams should consider only those themes within their responsibility and control.	**Impact on Customer:** A rating based on the team's present knowledge and judgment of the direct effect this theme has on customer satisfaction. (How severe is each occurrence?) Higher ratings are given to themes which have a more direct effect on customers.		**Need to Improve:** A rating based on the team's present knowledge and judgment of the difference between the present performance and that needed to meet the customer's valid requirements. (How frequently does it occur?) Higher ratings are given to themes with greater need to improve.		**Overall:** The product of *Impact on Customers* X *Need to Improve*. The theme receiving the highest ranking should be investigated, setting an indicator and actually measuring the present level and comparing it to the valid requirements. If there is a difference, then the team should proceed. If not, it should investigate the next theme.

Scale: 1 None 2 Somewhat 3 Moderate 4 Very 5 Extreme

TM-4-08

Checklist

What is a Checklist?

A Checklist is simply a list of the items to be attended to or steps to be taken. In data gathering it is an inventory of the information needed so that you can check your progress in gathering data and be sure the data is complete.

Why is the Checklist useful?

A Checklist provides for a common and organized way of proceeding. It ensures completeness and makes it easier for those involved in gathering data. Checklists can be as simple as the shopping list you prepare before heading to the grocery store or as complicated as the one used by airline pilots as they prepare for takeoff. Your team should strive for simplicity, clarity, objectivity, and completeness when designing a Checklist of items for its own use.

How is a Checklist used?

When making a Checklist, the team should think about the information it needs and the order in which it should be collected. Sometimes a technique like brainstorming will help generate a good list. Careful planning of the Checklist at this stage will eliminate the need to backtrack to fill in what might otherwise be missed.

When is a Checklist used?

A Checklist is used whenever the team wants to assure that things are done in an organized and thorough way. It may also be used to verify conformance to a set of standards or procedures. A sample Checklist appears on the next page.

Conduct A Fuel Check (Cessna 172)

	Checklist	Completed
1.	Check fuel sampler for cleanliness.	____
2.	Plug fuel sampler into fuel sampling valve on **left** wing tank.	____
3.	Draw fuel/water and other contaminants from fuel tank. (It may require more than one sample).	____
4.	Once contaminants are drawn out of fuel tank, check fuel color. (100 octane aviation fuel should be light blue with no presence of water or other contaminants; a good light source such as sunlight or bright flashlight is mandatory.)	____
5.	Repeat steps 2-4 for the **right** wing tank.	____
6.	Open engine cowling access door and pull carburetor fuel drain valve control to open.	____
7.	Drain for 3 to 5 seconds on the ramp.	____
8.	Check for the presence of water in drained fuel. (A good light source such as sunlight or bright flashlight is mandatory.)	____
9.	If water is present, drain carburetor until no water appears.	____
10.	Check fuel level by removing fuel tank cap on top of **right** wing and visually checking fuel level. (A good light source such as sunlight or bright flashlight is mandatory.) **No matches/lighters, please!**	____
11.	Check fuel level by removing fuel tank cap on top of **left** wing and visually checking fuel level (a good light source such as sunlight or bright flashlight is mandatory.) **No matches/lighters, please!**	____

Checksheet

What Is a Checksheet?

A Checksheet is a form qn which data can be recorded in uniform manner. An example of a simple Checksheet is shown on the following page. Other more complex Checksheets include expense account forms, multiple entry ledgers, and payroll check attachments.

Why is a Checksheet useful?

A Checksheet enables us to record a variety of data in a systematic fashion. If the categories are complete, especially if they include the source, this tool can give us a clear and objective picture of the facts.

How is a Checksheet done?

We make a Checksheet by laying out the categories of information and data we wish to gather about the items on the checklist onto a standardized form or grid. We determine the categories by asking such fact-finding questions as:

- What (what happens)?
- Who (who does it, who receives it, who is responsible)?

- Where (what place, what part, what section)?
- When (what time of day, month, how often)?
- How (how does it happen, how much, how long, etc.)?

To obtain categories for the Checksheet, use all the journalistic questions except "why?" Asking "why?" will lead us into a search for causes when we are still trying to determine whether a problem exists and, if so, what it looks like.

The Checksheet should be designed to facilitate the collection of as many different kinds of data as would be useful. The team can brainstorm items and then multivote to refine the list. It is also helpful to gather a little data prior to setting up the Checksheet. You may identify the categories from this smaller sample.

The Checksheet should also clearly indicate who collected the data and where, when, and how it was collected. In a sample, the total population from which the data was gathered should also be indicated.

When is a Checksheet used?

The Checksheet, as shown below, is used whenever the team needs to collect data to help identify and quantify problems and improvement opportunities (themes), especially in steps 1, 2, 3 and 4 of the QI Story. The use of both Checklists and Checksheets will minimize the risk of errors and facilitate the organized collection and analysis of data.

Plant Site

Packaging Line Interruptions, 1990

Source: ______
By: ______
When: ______

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
MAINTENANCE	AM	I	I	I			II	II		III		I		11
	PM				I		卌I	II	卌	I	III	III		21
POWER OUTAGE	AM		I									I		2
	PM						I	I		I				3
RAW MATERIALS	AM	卌	I	卌	III	IIII	卌卌	卌II	卌卌II	卌卌II	IIII	卌	卌卌	78
	PM	II	III	IIII	III	卌I	卌卌卌卌卌卌卌卌I	卌卌卌卌III	卌卌卌卌卌卌卌	卌卌卌卌卌卌卌	卌卌	卌	卌I	173
TL-I-26													TOTAL	288

Stratification

What is stratification?

Stratification is the breaking down of the whole (total area of concern) into smaller, related subgroups. For example: *oranges* into navel, temple and mandarin; *material sources* into vendor, batch, lots; *Divisions* into Eastern, Northeastern, Southern, Southeastern, and Western.

Why is stratification useful?

Stratification of information specifies the data and enables the team to do a more precise analysis of it. It is also a useful tool to verify root cause.

How is stratification done?

1. Review the whole to determine smaller, natural groups made up of relatively similar units.
2. Collect data relative to those smaller groups, rather than the entire area of concern, as a single entity.
3. Analyze data based on those smaller groups.

When is stratification used?

Stratification is used in the QI Story when:

- ◊ Creating a Checklist
- ◊ Designing a Checksheet
- ◊ Selecting a sample
- ◊ Verifying root causes
- ◊ Using the following tools:
  - Histogram
  - Pareto Chart
  - Scatter Diagram
  - Ishikawa (Fishbone) Diagram

Seven QC Tools

A vital part of the QI Story is the utilization of statistical quality control tools.

What are the Seven Basic QC Tools?

The seven basic QC (Quality Control) tools are common analytical methods used to solve problems. They are: Checksheet, Graph, Pareto Chart, Ishikawa (Fishbone) Diagram, Histogram, Scatter Diagram and Control Chart.

Why are the Seven Basic QC Tools useful?

The major use of QC tools is to provide objectivity and clarity in the way we do our work. They help separate opinions from data-based logic, thereby allowing us to "speak with facts."

Eighty percent of all problems can be solved using just three of these seven basic QC tools: Checksheet, Pareto Chart, and Ishikawa (Fishbone) Diagram.

Ninety-five percent of all problems can be solved using the seven basic QC tools.

How are the Seven Basic QC Tools used?

QC tools can be used by everyone. We are "speaking with facts" when we:

- know what the work process involves: its inputs, activities and outputs.
- track the facts about this process and keep records which can be compared to discover how well we are doing and/or where we need to change or improve.
- gradually learn ways of analyzing what the data can tell us (simple statistical analysis techniques).

When are the Seven Basic QC Tools used?

The tools can be used by individuals or teams to examine and improve both work process and outcomes. The use of QC tools is particularly necessary for quality teams since they provide a common means of communication and decision making.

Pareto Chart

What is a Pareto Chart?

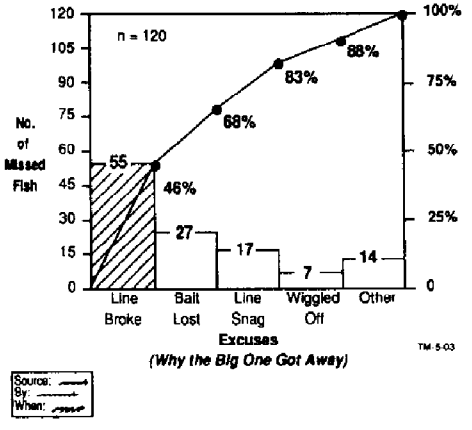
Pareto analysis is a way of organizing data to show what major factor(s) make up the subject being analyzed. It is a search for significance.

A Pareto Chart is a type of chart in which the bars are arranged, in descending order, from the left. The basis for Pareto analysis is the "80-20" rule; 80 percent of the problems result from 20 percent of the causes.

Why is a Pareto Chart useful?

Arranging data on a Pareto Chart helps to highlight "the vital few" in contrast to "the trivial many." Selecting categories, tabulating data, ordering data, and constructing the Pareto Chart can enhance communication among team members and with management. It allows the team to select the component of the problem which will produce the greatest results.

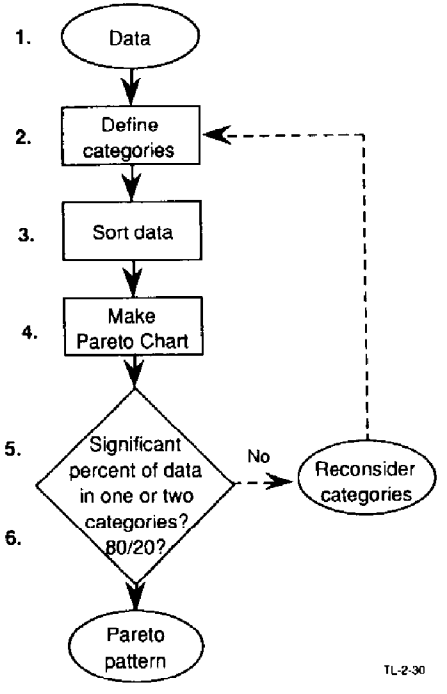
Pareto Chart of Fish Stories
"Why the Big One Got Away"



How is a Pareto Chart done?

1. Identify what data is to be analyzed (such as defects).
2. Select the categories to be used (defects by shift, location, type) and sort the data into the categories; for instance, how many defects related to shift, to location, and to type.
3. If possible, further stratify the data; for instance, "shift" may be broken down into "day," "night," and "graveyard."
4. Make a graph with the bars ordered in decreasing frequency from the left.

   Verify:
   - Bars touching
   - Left axis for actual data
   - Right axis for percent of total
   - Cumulative line from zero
5. Check graph for the Pareto pattern; a "flat" Pareto — categories with similar percentages — indicates the need for different stratification of the data.
6. Avoid mixing dissimilar categories of problems on a Pareto Chart.


1.
Data
2.
Define categories
3.
Sort data
4.
Make Pareto Chart
5.
6.
Significant percent of data in one or two categories? 80/20?
No
Reconsider categories
Pareto pattern
TL-2-30

When is Pareto Analysis used?

Pareto analysis can be used to identify major factors in a subject being analyzed and to help prioritize and select countermeasures. It is a useful way of identifying problems in *Current Situation* step. It can also be useful in the *Analysis* and *Results* steps.

Problem Statement

A good problem statement describes in specific, concrete terms what the data has revealed. It describes the present undesirable situation while avoiding "hidden" solutions.

Criteria for a good problem statement:

- **It states the effect.** It states "what" is wrong, not why it is wrong, and avoids "lack of" statements. These always imply solutions.
- **It focuses on the gap between what is and what should be.** The gap may be a change or deviation from the norm, standard, or the customer's expectation.
- **It is measurable.** It says how often, how much, when.
- **It is specific.** It avoids broad and ambiguous categories like "morale," "productivity," "communication," and "training."

- **It is stated in a positive manner.** Problem statements should not appear as questions. This may tend to imply that the answer to the question is the solution.
- **It focuses on the pain.** The problem statement highlights "how" people are affected and the areas of discomfort, hurt or annoyance.

The Problem Statement Matrix

The Problem Statement Matrix shown on the next page can be used to evaluate problem statements. This matrix should be used after the team has developed its problem statement.

Problem statements do not need to meet all six categories. But, obviously, the more categories each potential problem statement meets, the clearer it is likely to be.

Problem Statement (Who, what, when, where, but not why)	(A) States the effect, not the cause.	(B) Focuses on gap between "what is" and "what should be."	(C) It is measurable.	(D) It is specific. Avoids broad categories.	(E) It is stated in a positive manner. Avoids questions.	(F) It focuses on the pain; how things are affected.

Cause-and-Effect Analysis (Ishikawa or Fishbone Diagram)

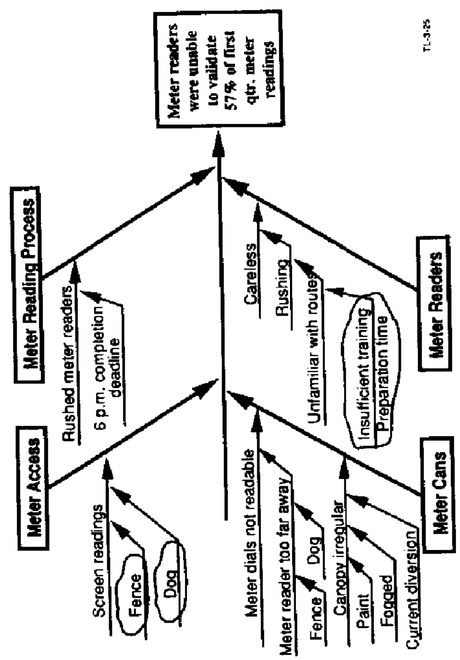
What is the Ishikawa Diagram?

The main purpose of Cause-and-Effect Analysis is to help the team solve its problem by the identification of a root cause(s) so that corrective action can be taken.

Cause-and-Effect Analysis is a picture composed of lines and words designed to represent a meaningful relationship between an effect and its causes. The specific tool that we will focus on is called the Ishikawa or Fishbone Diagram.

Why is the Ishikawa Diagram useful?

This tool helps teams reach a common understanding of problems and exposes gaps in existing knowledge.


Meter readers were unable to validate 57% of first qtr. meter readings
Meter Reading Process
Rushed meter readers
6 p.m. completion deadline
Meter Access
Screen readings
Fence
Dog
Meter Readers
Careless
Rushing
Unfamiliar with routes
Insufficient training
Preparation time
Meter Cans
Meter dials not readable
Meter reader too far away
Fence
Dog
Canopy irregular
Paint
Fogged
Current diversion

How is the Ishikawa Diagram done?

1. Draw the Fishbone Diagram. Start at the right, building the major categories (bones) toward the left.
2. Write the problem statement in the head (box) of the Fishbone. (Only the portion concerning the *effect* of the problem statement is necessary. This was identified in Step 2 through stratification.)
3. Determine the major categories of the Fishbone which relate to the effect. There are four ways to determine these categories:
   a. First, you can review the "generic" categories of:
      People
      Methods
      Machine
      Material
      Environment

Match them, if possible, with major contributors to the problem. For example, a team of delivery drivers is working on a problem that pertains to their functional area:

Generic Categories	Major Contributors
People	Drivers
Methods	Delivery Process
Machine	Truck
Material	Shipments
Environment	Delivery Route

The team used drivers, delivery process, truck shipments, and delivery route as the major bones of its Fishbone.

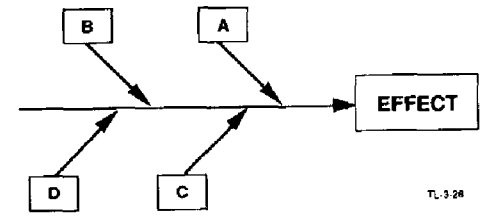
b. Second, if you are working with a process, you can break down the process into its major activities by creating a flowchart. Then assign each activity as a major bone. (Refer to Fishbone on page 81.)

c. Third, the team can brainstorm possible causes of the problem. When brainstorming, it is often helpful to review in detail at least one instance of the problem you will analyze. Be sure you understand how it occurred and what the situation was when it occurred.

   After the list is generated, segment the ideas into major categories. Name the categories and use as major bones.

d. Fourth, a Pareto Chart can be used to break down the effect into component parts, if the necessary data is available. These parts can then be used as major bones.

4. Prioritize the major categories in descending order, beginning with the category that has the highest likelihood of producing a potential root cause. For example:

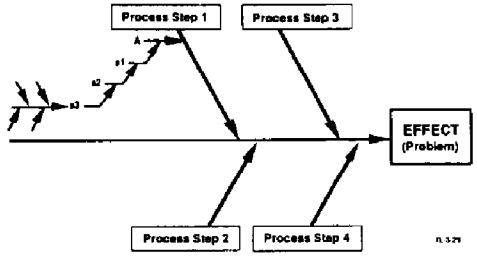


In the Fishbone with four major categories or bones (shown above), the prioritization order would be A, C, B, D. Therefore, A is the major bone aligned most closely to the head of the fish, followed by C, B, and D.

This prioritization is especially useful later when the Fishbone is reviewed. If a reviewer can trace the logic flow in the construction of the Fishbone, then he or she can follow the team's thinking and offer better diagnostic advice to the team.

5. Once the Fishbone is set up with major categories, begin with the major category the team has identified as most likely to produce the actionable root cause (the category aligned most closely to the head of the fish) and begin to ask "why?"
   - Why does this occur?
   - Why does this condition exist?

   Be sure to walk through the logic of your diagram in both directions, as shown below (This a1 is caused by this a2, which is caused by this a3. Then, in reverse, a3 caused a2, which caused a1.) Often illogic will not surface until the second direction is tried. This completes one logic chain.



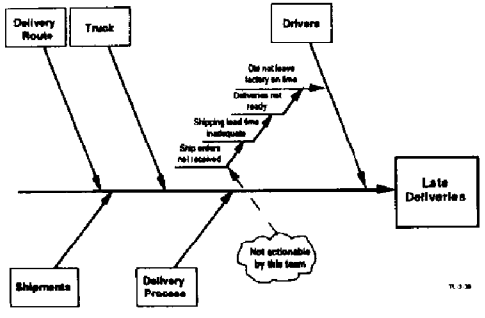
Now revisit each sub-bone for additional causes; specifically, move back to a2 and ask again, "Why does a2 occur?" Next, ask again "Why does a1 occur?" and continue this process of asking "why?" back to the major bone (Process Step 1).

6. Complete the entire Fishbone before moving to Step 7.
7. Identify the likely, actionable root cause(s) and circle (or cloud) the last element in the chain.
8. *Verify*, with data, the most likely root cause. Teams should collect data to verify that these are indeed the root causes of the "effect."

   If a potential cause seems to have many complicated subcauses, break into a separate diagram.

Here is an example of a Fishbone constructed by a QI team:

Fishbone — Late Deliveries



In the above example, begin the questioning: *"Why do drivers cause late deliveries?"* Proceed on this logic chain until it is no longer actionable or logical. After the chain is exhausted, retrace the logic from cause to effect. If the logic pattern is valid from both *effect to cause* and *cause to effect*, leave it on the Fishbone. If it is not logical, rework or remove it.

After completing one logic chain, move up to the next level and ask "why?" again. In the previous example, the team had to stop at *"Ship orders not received"* because it was out of their control.

The next area for consideration should be — Is there another cause for "shipping lead time inadequate" about which the team could ask "why?" If there is, continue asking "why?" If there is not, go up to the next level. Continue to work the Fishbone in this process until all major categories are questioned.

After completing the Fishbone, the team assesses which areas might be worth further examination as potential root cause(s). Once these areas (usually two or three) are identified, data is collected to verify that the area(s) investigated are, in fact, the root cause(s) of the "effect."

Countermeasures (Solutions)

Sometimes those who have been involved in quality improvement talk as though the solution "falls out automatically" at the end of the process. On occasion only one solution is possible (build or not to build, buy or not to buy), but this is rare.

Ordinarily, as much care should be taken in choosing a solution, or countermeasure, as at any other stage of the process. The team should work from its database; should research options; should be as creative as the issue will allow; and certainly should be diligent in the pursuit of not just an adequate answer, but the "right" answer.

Some possible solutions, or countermeasures, will be obvious, but *brainstorming, interviewing, and management suggestion* are also good sources of possible solutions. Once the most likely have been chosen, they be should investigated. What will they involve, how many people, manhours, money, time, etc.?

A principal tool at this point is the *Countermeasures Matrix*. After the team has selected the appropriate countermeasures, it will develop an *Action Plan* to implement these countermeasures. The term "countermeasure" is appropriate, because at this point, we are not sure that the action to be taken is really a solution. Only after the results are obtained and tracked over time, can we be sure of a "solution."

What is the Countermeasures Matrix?

It is a matrix of factors to help the team show the relationship between effect, root causes, and countermeasures. It also helps the team to evaluate which countermeasures should be implemented.

Why Is the Countermeasures Matrix useful?

We use it to assure that the countermeasures address the significant root causes.

The Countermeasures Matrix guides the team in identifying alternative countermeasures and determining the effectiveness and feasibility* of its countermeasures. Other prioritization matrices may be used to evaluate countermeasures, but the example on the next page is one which can be used easily by most teams.

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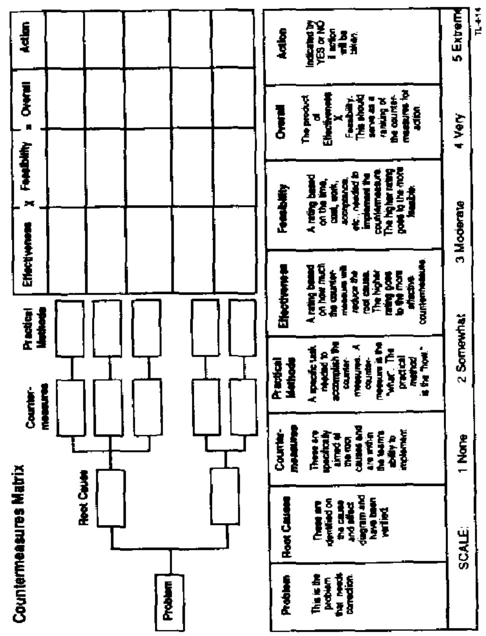
* Effectiveness and feasibility may be broken down into several components if the team feels the need. Feasibility may be broken down into cost and time.


Countermeasures Matrix
Problem
Root Cause
Counter-measures
Practical Methods
Effectiveness X Feasibility = Overall
Action
Problem
This is the problem that needs correction.
Root Causes
These are identified on the cause and effect diagram and have been verified.
Counter-measures
These are specifically aimed at the root causes and are within the team's ability to implement.
Practical Methods
A specific task needed to accomplish the counter-measure. A counter-measure is the "what". The practical method is the "how".
Effectiveness
A rating based on how much the counter-measure will reduce the root cause. The higher rating goes to the more effective countermeasure.
Feasibility
A rating based on the time, cost, work, acceptance, etc. needed to implement the countermeasure. The higher rating goes to the more feasible.
Overall
The product of Effectiveness X Feasibility. This should serve as a ranking of the counter-measures for action.
Action
Indicated by YES or NO if action will be taken.
SCALE: 1 None 2 Somewhat 3 Moderate 4 Very 5 Extreme
TL-4-14

QI Story

How is the

1. After veri
   the first t
   filled in.
2. Next, the
   counterm
   the root c
3. In the "pr
   task(s) is
   counterm
4. The tean
   measure
   feasibilit
   counterm
   and mor
5. The ratir
   counterm
   tion acc

6. To determine how many of the counter-measures should be implemented, the team will need to consider its resources and its target for improvement. Sufficient countermeasures need to be implemented to achieve the target.
7. The team will indicate if the counter-measure will be implemented by writing either "yes" or "no" in the action column.

When is the Countermeasures Matrix used?

The Countermeasures Matrix is used after the team has identified those countermeasures which address the significant root cause(s).

Cost/Benefit Analysis

What is Cost/Benefit Analysis?

Cost/Benefit Analysis, or Cost Estimation, is a technique for determining the dollar impact of problems and countermeasures. There are two approaches to estimating costs: the "bottom-up approach" and the "top-down approach." It is not necessary to have precise and detailed accounting data to get a general idea of the financial impact of a problem or issue; you need to make some assumptions and verify them as you gather data.

Why is Cost/Benefit Analysis useful?

It is useful as a tool for determining the dollar impact of problems and countermeasures.

How is Cost/Benefit Analysis done?

Bottom-up approach — Start with smaller units and build the estimate toward an overall amount.

1. Estimate how many times the problem occurs per unit of time. (Example: 12 uniforms/week)
2. Estimate cost per occurrence. (Example: $3/cleaning)
3. Estimate total time involved. (Example: 52 weeks)
4. Calculate total/annual cost by multiplying above factors. (Example: 12 x $3 x 52 = $1872)

Top-down approach — Start with overall cost of some budget item or other known variable and an estimate of the percentage of that total which represents the problem and calculate unit cost.

1. Estimate the percent of some expenditure on the problem area (percent of total labor devoted to problem, percent of total "down-time" attributed to the problem).
2. Multiply the percentage by the budgeted annual cost to get the estimated amount spent on the problem in one year. (Example: 10% x $185,000/year budgeted = $18,500/year.)
3. Divide by unit of time. (Example: $18,500/ year ÷ 52 weeks/year = approx. $355/ week.)

When is Cost/Benefit Analysis used?

Since it may aid in prioritizing and selecting countermeasures, data gathered using Cost/ Benefit Analysis can be used to construct a Pareto Chart. It is used as the raw data in many decision-making processes.

Barriers and Aids Analysis

What is Barriers and Aids Analysis?

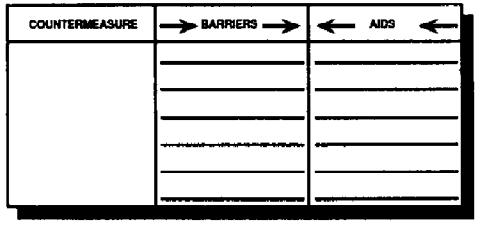
Barriers and aids is a technique for pinpointing and analyzing elements which resist change (barriers) or push for change (aids). This technique helps a team to meet its objectives by planning to overcome barriers and to make the maximum use of available aids.

Consider the following categories when doing Barriers and Aids Analysis:

- People
- Environment
- Hardware or equipment
- Dollars

Why is Barriers and Aids Analysis useful?

Barriers and aids helps teams to carefully analyze a situation when they are planning for change. Once barriers and aids are identified, the team can make plans to use the available aids and/or to overcome the barriers which can prevent implementation of a solution.


COUNTERMEASURE
BARRIERS
AIDS

How Is Barriers and Aids Analysis done?

1. Identify the countermeasure, task, change or concern.
2. Identify (through brainstorming) and list possible barriers.
3. Identify and list likely aids.
4. Rank all listed items as high, medium, or low.
5. Match aids which balance or overcome barriers.
6. List matching Bs & As on a chart.
7. List non-matching Bs & As and brainstorm any offsetting factors.

   (It is not necessary to come up with an aid for every barrier.)
8. Identify items needing team action using your rankings (high, medium, low).
9. Develop an Action Plan.

When is Barriers and Aids Analysis used?

When a team has identified the most appropriate countermeasures, it can use Barriers and Aids Analysis to assist in planning the trial implementation. The Barriers and Aids Analysis should be a part of the team's Action Plan.

Action Plan

What is an Action Plan?

The team's Action Plan is a technique that catalogues all the things that must be done to ensure a smooth and objective trial of the solution or improvement. Although the Action Plan may have different formats, it should answer:

- Who
- What
- When
- Where
- How

The Action Plan should also consider the barriers and aids necessary for success. An example of an Action Plan form is shown on page 100.

Why is an Action Plan useful?

A plan allows us to explain our ideas to management and peers and to ensure an organized, objective implementation of the selected countermeasures.

How is an Action Plan done?

1. Analyze the proposed improvement or solution and then break it down into steps.
2. Consider the hardware and numbers of people involved at each step.
3. Brainstorm, if necessary, for other items of possible significance.
4. Add to the list until the team feels the list is complete.

When is an Action Plan used?

We develop an Action Plan as part of step 4, Countermeasures. The plan will be one of the items that helps the team obtain cooperation and approvals and effectively implement its countermeasures.

Action Plan Date: _____

Task/Project	Assigned to	Due Date	Status/Remarks

GB-6-130

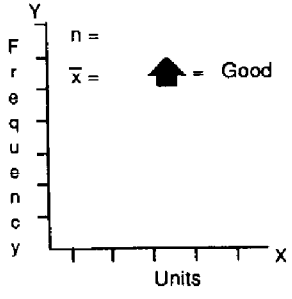
Graphs: Pie, Line, Bar

What are Graphs?

Graphs are visual displays of quantitative data. They lay out, describe, or summarize a set of numbers or statistics. Graphs can be constructed in many different forms; some of the major ones are shown in detail in the following pages. In general, good graphs have these elements in common, as shown on the chart form (page 102).

- A title describes what is portrayed in the graph.
- The vertical, or Y, axis represents *frequency* — how many times something has happened, percentage of something, number of dollars, etc.
- The horizontal, or X, axis represents distribution or division of the data — how often something happens (days, weeks, months), how many times things happened within a particular measure (how many data points between 7.34 and 7.45), etc. Both the X and Y axes should be clearly labeled.

Chart Form



Collected

By:	
On:	
At:	
Formula:	

TL-2-15

- The scale used in a graph can be adjusted to show the situation, expanded to emphasize variables, compressed to show control. All graphs should have an indication of the total number of data points represented, as indicated by n = ___.
- If appropriate, the average of the data points in a sample is indicated by $\bar{x}$ = ___.
- If there is a "good" direction, it should be indicated with an arrow.
- Every graph should indicate:
  - *when* the data was gathered.
  - *where* it was gathered.
  - by *whom* it was gathered.
  - whether it is raw data, a percentage, averages.
  - *how* the data was calculated (a formula)

Why are graphs useful?

Because they visually display complex data, graphs aid us in understanding and interpreting data and in speaking with facts.

When are graphs used?

The following matrix shows some of the types of graphs used throughout the QI Process and when they are most often used.

Graph	Most Often Used in QI Story Step				
	Reason for Improvement	Current Situation	Analysis	Countermeasures	Results, Standardize, Future Plans
Line, Bar, Pie Graphs	x	x			x
Pareto Chart		x	x		x
Cause and Effect Analysis (Ishikawa or Fishbone Diagram)			x		
Histogram	x	x	x		
Scatter Diagram	x		x		
Control Chart	x	x			x

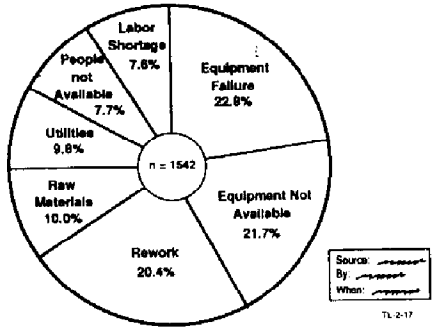
TM-7-05

Pie Chart

What is a pie chart?

A pie chart is a graphic representation which compares relative magnitudes or frequencies.

Production Delays by Type



Why is a pie chart used?

It is used to show the percentage (proportion) an item contributes to the total.

How is a pie chart constructed?

1. Divide a circle (pie) into a number of wedges, so that each wedge represents a proportion of the total number of items.
2. Calculate the proportion of the item by dividing the item by the total. For example, the proportion for equipment failure shown on page 140 is:

$$\frac{315}{1542} = 0.228$$

3. Convert the proportions into wedges by multiplying the proportions by 360 degrees.

   Example: .228 X 360 = 82 degrees

4. Starting with the largest wedge, at the vertical position and going in the clockwise direction, measure off the wedge sizes with a protractor.

Line Graph

What is a line graph?

This graph is another way to visually display data for comparison. Specific data points are entered by number and then connected by a line.

Why is a line graph useful?

A line graph sketches an outline of a data pattern. It is easy to construct. Analysis of the shape of a line graph provides information on which areas need future investigation.

How is a line graph done?

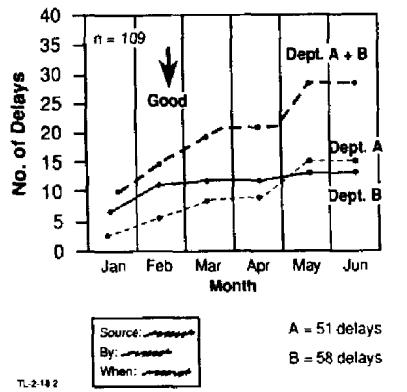
1. The center of each class interval is labeled on the horizontal axis.
2. A *trend line* displays some variable over a period of time. Here, the display is not of frequencies of occurrence, but of variable values (vertical axis) over time (horizontal axis).

When using line graphs in your QI Story, follow these rules:

a. If using several lines, the solid black line is of greatest emphasis. *Dotted lines are used for projections only.*

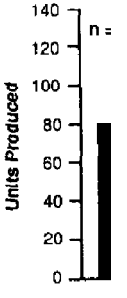
b. If the line graph tracks data over time, ensure that the most recent data is shown.

c. If the degree of conformance is above 80 percent, then track the degree of non-conformance.


40
35
30
25
20
15
10
5
0
No. of Delays
n = 109
Good
Dept. A + B
Dept. A
Dept. B
Jan
Feb
Mar
Apr
May
Jun
Month
Source:
By:
When:
A = 51 delays
B = 58 delays

What Is a I

A bar chart
compares
rectangles
heights pro
represente



Why is a bar chart used?

A bar chart presents a visual representation of data, thus making it easier to compare.

How is a bar chart done?

On the horizontal (X) axis, show the items or things being compared through vertical bars of uniform width. On the vertical (Y) axis, show the quantities (frequencies of events in different locations, costs of different types of breakdowns, etc.) through the height of the bars. For a horizontal bar chart, reverse the labeling of the axes.

Comparison of the Advantages of the Pie, Line, and Bar Chart

Pie Chart	Line Graph	Bar Chart
This chart is useful for more than one level of stratification: all on one graph, equivalent to several bar charts. This chart shows relative proportion of each category to the total.	Lines make trends and data variations over time easy to track. Line graphs are an excellent tool for highlighting change and can be used to track more than one set of data at a time.	Bars make it easier to recognize small differences in quantities or frequencies and to compare one category with another.

TM-7-10.1

Histogram

What is a histogram?

A histogram, also called a frequency distribution, is a visual representation of the spread or distribution of data (for example, the height, in inches, of 36 employees). Information in a histogram is represented by a series of rectangles or "bars" of equal width or class sizes. The heights of these "bars" indicate the relative number of data points in each class.

The number of occurrences (frequency) is plotted on the vertical axis, and the data groups, or classes, are plotted on the horizontal axis. To evaluate a histogram, we need to know the central tendency as well as the dispersion of the data.

Measures of central tendency

- Mean (average) – The sum of all the measured, or counted, data divided by the total number of data points; for example, all the data points added together equal 2,482 divided by 36 = 68.9 inches.
- Mode – The value repeated most often in the raw data. In this example it is 70 inches. If the data is presented as grouped frequency like a histogram, we talk about *modal class* instead of the mode. Modal class is the class interval with the highest frequency. In this example, the modal class is 68.5 - 71.5.
- Median – The middle of all the measured or counted data points (if an even number of data points, the median will be a fraction); for example, in our data of 36 measurements, the median value is the average of the middle values (69 + 70 = 139 divided by 2 = 69.5 inches).

Measures of dispersion

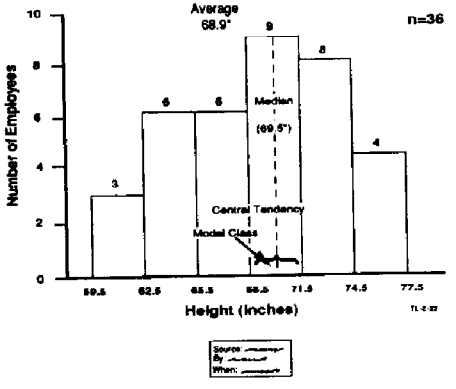
- Range – The maximum value minus the minimum value.
- Standard deviation (SD) – A measurement that shows how widely spread (dispersed) any set of data is from the mean (average) of the entire data distribution. The standard deviation takes into account all the data points. It is far less sensitive to the addition of another data point than is the range, so it is a more reliable measure of variability.

Heights of Employees for Histogram

Employee	Height (Inches)	Employee	Height (Inches)	Employee	Height (Inches)
FV	64	GH	69	DG	68
BH	63	JH	71	MS	72
IW	66	BK	73	KH	75
BB	73	CZ	62	TG	76
CT	60	BS	70	CS	69
MM	67	GL	65	JS	70
GB	68	SS	72	LO	72
MF	70	DF	63	JO	70
JR	65	RK	73	JF	76
DR	61	BD	74	BH	73
MS	66	KM	70	KP	65
MC	76	CR	66	JB	69

TL-2.21

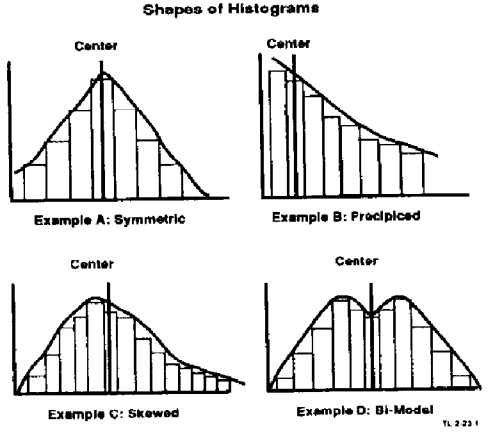
Histogram


Average
68.9"
n=36
Median
(69.5")
Central Tendency
Model Class
Number of Employees
Height (inches)
59.5
62.5
65.5
68.5
71.5
74.5
77.5
3
6
6
9
8
4
0
2
4
6
8
10

Why is a histogram useful?

It is not always easy to review a page of measured data and be able to recognize patterns or analyze what the data is trying to tell us. A histogram can provide information on the degree of variation of the data and indicate the distribution pattern. Drawing a curve around the heights of the bars of a histogram gives the general shape.

Dispersion of the data can produce a wide variety of histogram shapes depending on the process or subject on which you have collected data. Some of the more common shapes are shown on the following page.


Shapes of Histograms
Center
Example A: Symmetric
Center
Example B: Precipiced
Center
Example C: Skewed
Center
Example D: Bi-Model

- **Symmetric (Example A)**
  Most values fall toward the center of the distribution (central tendency) with the variation balanced on both sides of the center. An example of such a histogram will be discussed under normal distributions.
- **Precipiced (Example B)**
  Most of the values appear on the extreme left as shown in Example B. This type of distribution could occur where there is a natural barrier or in cases where the data has been sorted (products which do not meet a particular specification limit removed from the data set; or the failure rate of components).
- **Skewed (Example C)**
  A skewed type has a long tail on one side. There is more variation on one side than on the other, indicating a shift of some variable during the process.
- **Bi-Modal (Example D)**
  In a bi-modal (or twin-peaked) type, two peaks (two modes) appear. This usually occurs when two different data groups are mixed (a population of very short people is added to a population of extremely tall people). In effect, we have two histograms pushed together.

How is a histogram done?

To construct a graph, draw horizontal and vertical axes. The horizontal (X–axis) shows class intervals; the vertical (Y–axis) shows frequencies. Draw a bar to represent the frequency of data in each class. The bars should be touching.

STEP	EQUATION	EXAMPLE
Start with an unorganized set of at least 30 data points.		64, 63, 66, 73, 60, 67, 68, 70, 65, 61, 66, 76, 69, 71, 73, 62, 70, 65, 72, 63, 73, 74, 70, 66, 68, 72, 75, 76, 69, 70, 72, 70, 76, 73, 65, 69
Arrange the numbers in ascending or descending order.		60, 61, 62, 63, 63, 64, 65, 65, 65, 66, 66, 66, 67, 68, 68, 69, 69, 69, 70, 70, 70, 70, 70, 71, 72, 72, 72, 73, 73, 73, 73, 74, 75, 76, 76, 76
Each number is a data point. Count the number of data points.	N	N = 36
The range (R) of the set is the smallest (minimum) data point subtracted from the largest (maximum) data point.	R = MAX-MIN	N = 76-60 = 16

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Continued on next page

STEP	EQUATION	EXAMPLE
The class (K) is used to calculate the number of bars. Class equals the square root of N. Rule of thumb 6-12.	$K = \sqrt{N}$	$K = \sqrt{36}$ $K = 6$
The class width (H) is used to calculate the width of the bars. It is calculated by dividing the range by the class.	H = R/K	H = 16/6 H = 2.6 (Round-up H) = 3
To begin constructing the histogram, establish the starting point for the first class. This is calculated by subtracting from the minimum data point the measurement unit divided by 2.	Measurement Unit (M) M = 1 Min - M/2	60 - 1/2 = 59.5
Now that the first class limit is established, construct a frequency table with three columns.		Class Limits (Column 1) / Tally (Column 2) / Freq. (Column 3)
For Column 1, add to your starting point the class width (H).	59.5 + H	59.5 + 3 Class Width is 59.5 - 62.5 62.5 - 65.5, etc.
For Column 2, go back to your original set of data points. Tally those that fall within each class limit. Add each item in Column 2 and enter the total frequency in Column 3.		Class Limits (Column 1) / Tally (Column 2) / Freq (Column 3) 59.5 - 62.5 | 3 62.5 - 65.5 | 5 65.5 - 68.5 | 6 68.5 - 71.5 | 9 71.5 - 74.5 | 8 74.5 - 77.5 | 4

TM 7-16

When is a histogram used?

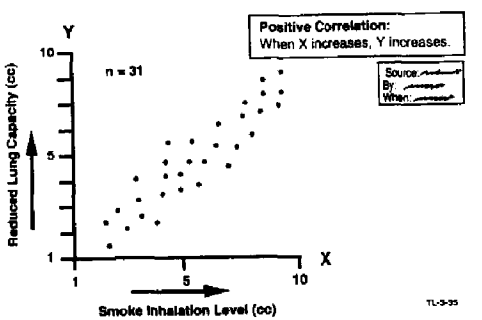
A Histogram is especially useful in the *Current Situation* step of the QI Story when we want an accurate picture of the dispersion or spread of the data.

Scatter Diagram

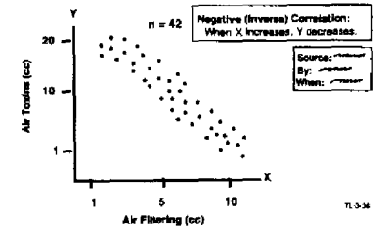
What is a scatter diagram?

A scatter diagram is a visual tool for showing the relationship between two variables (for example, speed and gas consumption, or hours worked and production output).

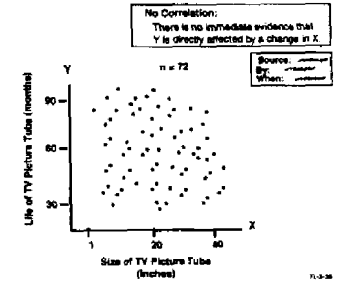
Example 1



Example 2



Example 3



Why is a scatter diagram useful?

It shows clearly if there is a relationship, or correlation, between the two variables:

- Positive correlation – as X increases, so does Y.
- Negative correlation – as X increases, Y decreases.
- No correlation – one quantity has no particular relation to the other.

How is a scatter diagram done?

1. Collect at least 30 sets of paired data (X, Y).
2. Find the lowest and highest values for X and Y. Determine the scales of the axes so that they are more or less equal in length, but try to have no more than 10 gradations. (Rule of thumb: between 3 and 10 gradations.)

3. Arrange the axes so that the suspected driving factor (independent variable) is on the X axis and the one influenced by it (dependent variable) is on the Y axis. In example 1, showing the relationship between inhaled smoke and reduced lung capacity, "Smoke Inhalation Level" goes on the X axis and "Reduced Lung Capacity" on the Y axis, since inhaling smoke causes the *effect* of reducing lung capacity.

   In example 2, the incidence of air toxins is decreased as the amount of air filtering increases. Air filtering causes a reduction in the amount of toxins, so it goes on the X axis.

   Example 3 illustrates how the size of a TV picture tube (X axis) may cause change in the life of a TV picture tube (Y axis). The diagram shows no correlation.

4. Plot the data on the chart, point by point; be sure to make the chart complete with the title, date, place, etc.
5. A correlation analysis of the data can be made. The correlation measure or coefficient is called "r"; "r" can have values from -1.0 to + 1.0. The closer "r" is to +1.0, the stronger the positive correlation.

When is the scatter diagram used?

The scatter diagram is probably most useful in the *Analysis* step for further examination of the elements isolated in Cause-and-Effect Analysis; for example, it may verify a cause identified by the Ishikawa (Fishbone) Diagram. Care needs to be taken in plotting a scatter diagram to assure that a valid relationship exists.

Process Flowcharts

What is a process flowchart?

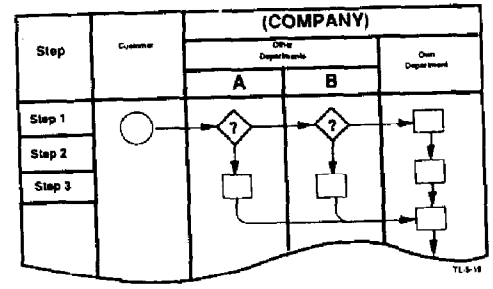
Flowcharts are graphic representations of a process, which show us clearly just how the process flows. They show a systematic sequence of steps for completing a job and what groups are involved.

Why are flowcharts useful?

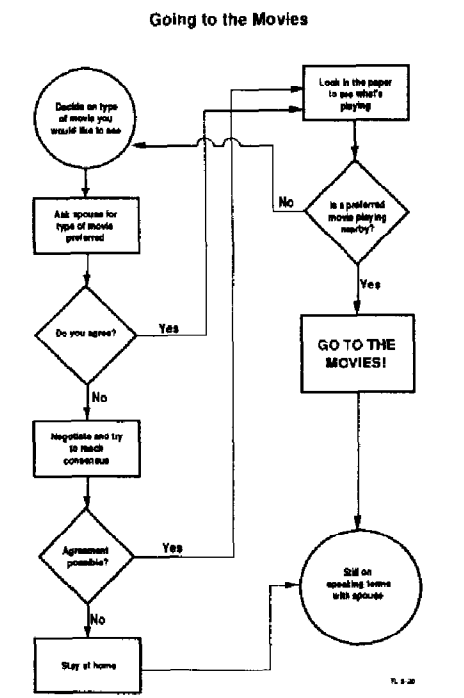
- To document or describe an existing process
- To develop modifications to an existing process, or to investigate where problems might occur
- To design an entirely new process
- To identify how, when or where to measure an existing process to see if it complies with valid requirements

What are the Types of Flowcharts?

A "macro" level flowchart:

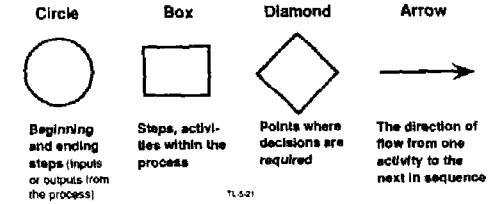


A "micro" level flowchart:



How is a flowchart constructed?

Think of a process flowchart as a map of steps for completing a job. Specific symbols are used to indicate certain activities.



Dotted symbols may be used to indicate secondary process flow. (Example: copy of processed form returned to originator).

The first row is used to separate the process into areas of responsibility.

The first column is used to designate general steps and their durations.

Steps should be organized so that each step falls under the correct area of responsibility.

When is a flowchart used?

Most *Current Situation* and *Standardization* steps require process flowcharts; however, flowcharts can also be used in *Reason for Improvement, Analysis,* and *Countermeasures.*

Control Charts

What are control charts?

Control charts are line graphs specifically used to track the trend or performance of a process over time. This is accomplished by observing how the variability within the process causes the trend line to fluctuate within a pair of statistically calculated limits. Control charts illustrate process variability.

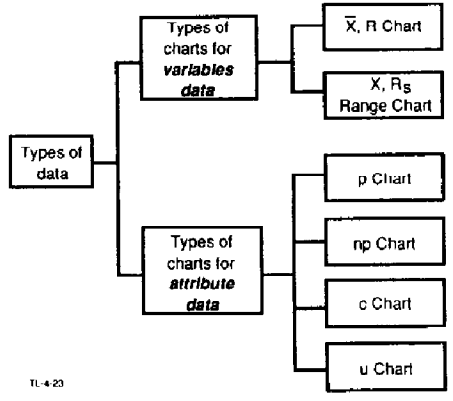
All natural processes are subject to variation. Even identical twins are often slightly different in height, weight, and looks. But how much variation is acceptable and what kinds of variation are controllable and, therefore, improvable?

When the fluctuations within the process occur in a non-random pattern or go outside a control limit, the process is statistically out of control. If action is not taken, the process stability is uncertain. *This indicates opportunities for improvement.*

Control limits are statistically derived from samples of a stable process. They are not to

be confused with specification limits, which are determined by the customer's valid requirements.

Control Charts can be classified into two main application groups, depending on the type of data generated from the process. Below is a chart summarizing the types of control charts that will be discussed on the following pages.



Variables Control Charts

◊ **$\bar{x}$ (X-bar), R Chart:** This is a two-part control chart used to monitor processes with variables data. The number of items observed at each instance (or subgroup size) must be at least 2 or at most 10.

Example: Average time it takes to drive to work each day. Consider a work week of 5 days as a subgroup.

The $\bar{x}$ chart tracks how the process average varies from one point to another. In the example, this will be how the average drive time varies from week to week. The R (or Range) chart tracks the variation that occurs within each subgroup (the time difference between each trip to work).

◊ **X, Rs Chart:** This chart is used to monitor processes with variables data. It is similar to the $\bar{x}$, R chart, but the number of items observed at each instance is equal to 1. In other words, the X, Rs chart tracks how each process data point varies from another.

Example: The total overtime hours reported per month for a department.

Attribute Control Charts

◊ **p Chart:** This is a one-part control chart used to chart the progress which generates attribute data. It is applicable to problems which deal with the *fraction* that do not conform to specifications.

Example: Percentage of jobs reworked per month.

◊ **np Chart:** This is a special type of p chart where the *number* of nonconformances is tracked from a fixed sample size at each observation point.

Example: Number of rejects found in a lot inspection with equal sample size at each inspection.

◊ **c Chart:** This chart tracks the number of nonconformities.

Example: Number of injuries reported in a department per month. (Assume *same* number of employees every month.)

◊ **u Chart:** This chart tracks the number of nonconformities per unit, where the number of units varies. If the number of injuries per employee per month is tracked, but the number of employees *changes* each month, the u chart should be used.

Why are control charts useful?

Control charts are helpful tools to monitor the performance of an ongoing process in determining answers to the following questions:

1. Is the process in statistical control?
2. Does action need to be taken to keep the process in control?
3. Does action need to be taken to bring the process back into control?
4. Does an opportunity for process or system improvement exist?
5. Have countermeasures improved the process?

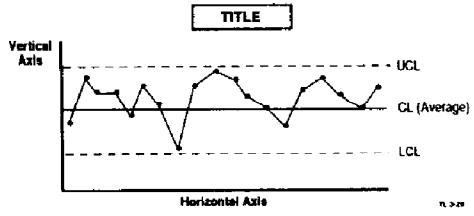
What do control charts look like?

In general, control charts are line graphs in which the process is shown as a trend line drawn on a chart along with these three lines:

1. A mean, or central line (CL), represents the average value of the process.

2. An upper control limit (UCL) drawn at a calculated distance above the central line represents the maximum variation that could be expected if only normal/common causes of variation are present.
3. A lower control limit (LCL) drawn at a calculated distance below the central line represents the minimum variation which could be expected if only normal/common causes of variation are present.

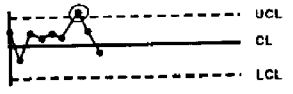
Below is an example of what a control chart may look like:



The horizontal axis tracks time or sequential order, and the vertical axis tracks the factor being studied. The average of the process is indicated and control limits are added above and below the average.

How Do We Interpret Control Charts ?

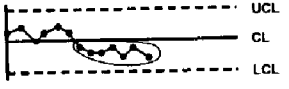
1.



Point outside of the limit:

Control limits are calculated to measure the natural variability of a process. Any point on or outside the limit is considered abnormal and requires investigation.

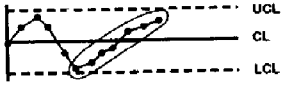
2.



Run:

A "run" is points occurring continually on one side of the center line. A "run" of seven points is considered abnormal. Also considered abnormal: 10 out of 11, 12 of 14 , or 16 of 20 points on one side of the center line.

3.



Trending:

Seven points in a continuous upward or downward direction.

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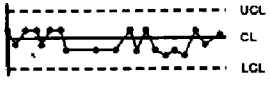
Continued

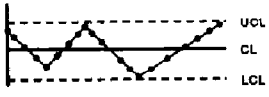
4.



Approaching the center line (hugging):

When most points lie within the center line and 1.5 *sigma (σ), it is not a controlled state and usually means the mixing of data from different populations. This makes the control limits too wide and stratification of data is usually necessary.

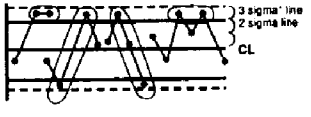
5.



Cycling (periodicity):

Any repeated up and down trend is abnormal and requires investigation.

6.

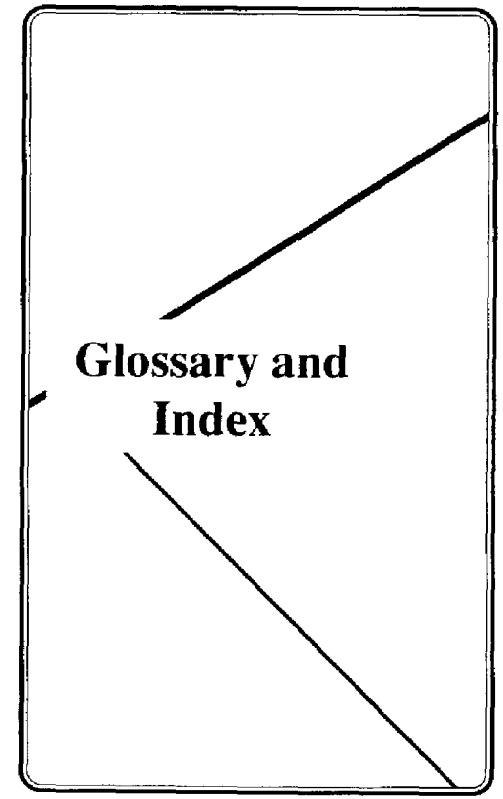


Approaching control limits:

2 of 3 points lying outside the 2 sigma* (σ) line is considered abnormal.

*Sigma (σ) is also commonly referred to as Standard Deviation

GB-8-174


Glossary and
Index

Action Plan

A technique which catalogues everything that must be done to ensure a smooth and objective trial of a solution or improvement.

Bar Chart

A graphic representation which compares items in bars of uniform width heights proportionate to the quantity being represented.

Barriers and Aids Analysis

Identifying elements resisting change (barriers) and elements pushing for change (aids). (Barriers and Aids Analysis is sometimes referred to as "Force Field Analysis.")

Brainstorming

A technique designed to encourage creative thinking; used to generate ideas quickly.

Checklist

A list of items or steps.

Checksheet

One of the seven basic QC tools. A form on which data is collected systematically and recorded in a uniform manner.

Control Chart

One of the seven basic QC tools, the Control Chart is a special type of line graph specifically used to track the trend or performance of a process over time.

Cost Estimation

Technique used to determine the dollar impact of problems and countermeasures.

Countermeasures Matrix

A matrix of factors to help show the relationship between effect, root causes and countermeasures. It also helps the team to evaluate which countermeasures should be implemented.

Data

Any facts the team gathers; can be in the form of numbers, words or pictures.

Fishbone

A diagram used to relate cause and effect to help determine possible root causes; sometimes called *Ishikawa* diagram.

Graph

One of the seven basic QC tools. Graphs (pie, line, bar) are visual displays of quantitative data which help us speak with facts.

Histogram

A visual display of the information presented in a frequency distribution. A series of rectangles or bars proportionate in height to frequency of a particular class. Rectangles are of equal width.

Ishikawa (Fishbone) Diagram

One of the seven basic QC tools. A way to visually isolate an effect and to diagram possible related causes; can be used to identify the potential root causes of problems. (This tool was developed by Dr. Kaoru Ishikawa.)

Multivoting
Method of voting to help reduce a large number of items to a manageable few.

P-D-C-A
Plan-Do-Check-Act Cycle of continuous improvement.

Pareto Chart
Type of bar chart which indicates what major factors affect the subject being analyzed.

Problem
An undesired condition; a deviation from valid requirements.

Problem-solving Process
A systematic approach to problem-solving which uses seven specific steps.

Problem Statement
Describes in specific terms what is wrong or an undesirable situation.

QC
Quality control; the use of statistical tools to analyze data.

Quality in Daily Work

The application of Plan-Do-Check-Act (P-D-C-A) philosophy to activities necessary to meet the needs and reasonable expectations of customers.

QI

Quality Improvement.

QI Story

A storyboard structure to help illustrate the steps to be taken by a team in the problem-solving process. It provides a standard way of communicating team progress.

Quality

Satisfying the needs of the customer through conformance to valid requirements.

Quality Indicator

Measurement of the degree and/or frequency of conformance to valid requirements.

Root Cause

The major stimulus behind the undesired condition.

Scatter Diagram

A visual technique for investigating the possibility of a causal relationship between two variables.

Stratification

The breaking down of data into smaller related sub-groupings.

TQM

Total Quality Management, a more comprehensive term than Quality Improvement. TQM is a way of ensuring customer satisfaction through the involvement of all employees in reliably producing and delivering a quality product.

Theme Selection Matrix

A matrix which helps the team to select a theme on which to begin gathering data. It allows the team to rank its themes considering the impact on the customer and the need to improve.

Tracking

A process to observe or monitor the steps or phases of an action plan to determine if desired results are obtained.

Valid Requirements

Specifications or standards which define the customer's expectations of a product or service.

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