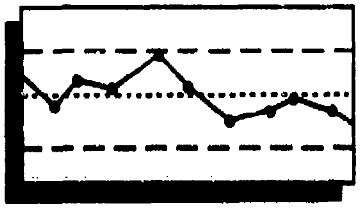
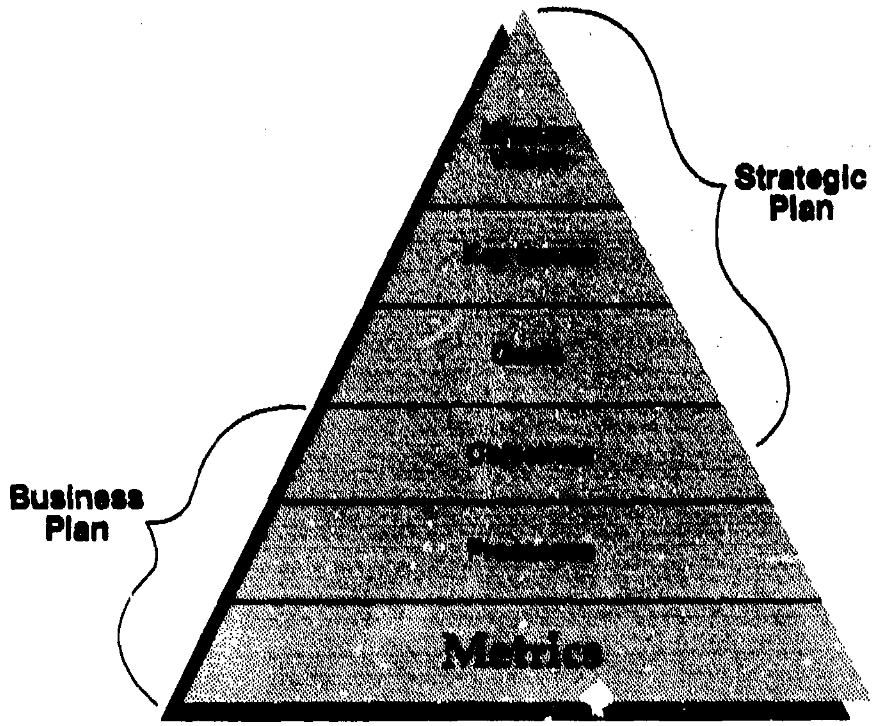
The Metrics Handbook





August 1991
1st Edition

Metrics Handbook
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THE METRICS HANDBOOK

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Chapter 1: Introduction

a. Handbook Purpose:

This handbook is designed to help you develop and use good metrics. It is intended to provide you with sufficient information to begin developing metrics for your own objectives, processes, and tasks, and to steer you toward appropriate actions based on the data you collect. It should be viewed as a road map to assist you in arriving at meaningful metrics and to assist in continuous process improvement. This handbook is the result of a team effort by people from the product divisions, test centers, and other command organizations who have struggled to develop their own metrics.

b. Handbook Layout:

Chapter One answers your most basic questions about metrics. Chapter Two provides the characteristics of good metrics and discusses what metrics are NOT meant to be. Chapter Three provides a methodology for developing metrics and introduces the concept of the metric package. Chapter Four explains performance and introduces some of the tools used in analyzing processes and developing metrics. Chapter Five presents some guidelines and ideas for metrics presentation. Chapter Six addresses implementation--what to do with metrics once you have them. The handbook closes with three appendices. Appendix A is a brief orientation to the eight basic tools introduced in Chapter Four. Appendix B is a glossary of terms helpful in understanding metrics. Appendix C is a resource of references that will provide you with more help.

A second volume of this handbook is planned for later publication. This will contain the Command Standard Metrics and Big Picture Metrics. It will be maintained and published out of the command headquarters.

c. Metrics - Measurement You Can Use:

Metrics are nothing more than meaningful measures. For a measure to be meaningful, however, it must present data that allow us to take action. It must be customer oriented and support the meeting of our organizational goals and objectives. Metrics foster process understanding and motivate action to continually improve the way we do business. This is distinguished from measurement, in that, measurement does not necessarily result in process improvement. Good metrics always will.

d. Metrics and Command Strategic Planning:

Metrics also play an integral role in linking organizational processes to the achievement of the Command Corporate Plan. They are the diagnostics which show progress in meeting corporate goals and objectives. As shown in Fig 1-

1, corporate planning begins with a statement of the Command Mission and its Vision of the future. A strategic analysis of major internal and external influences identifies key issues which must be addressed to achieve that long-term Vision. The analysis and key issues define where current capabilities and future organizational requirements are not aligned. The Strategic Plan culminates in the identification of goals which specifically address those issues.

Goals and their subordinate near-term objectives chart the appropriate course of action. Those objectives, in many cases, include the improvement of processes and tasks which involve command organizations and personnel. You should be able to align selected metrics to organizational objectives and identify which processes are targeted for improvement through their application. Organizational objectives, and processes, and metrics which are developed to support them make up the organizations' business plan.

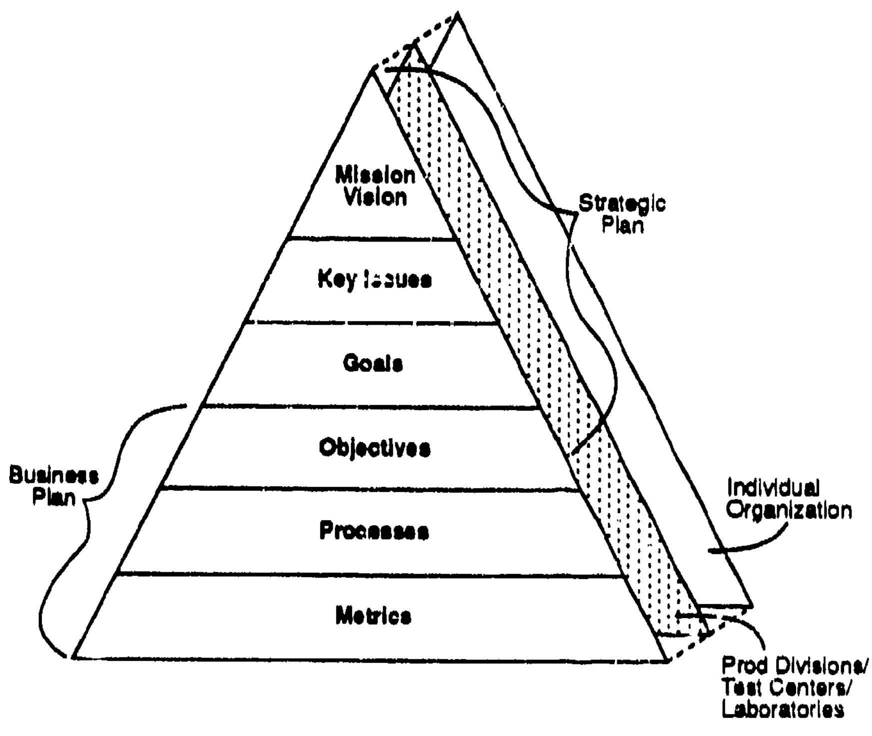


Figure 1-1: Corporate Planning Framework

Good metrics will gauge progress in reaching the processes' desired outcomes. This will lead to accomplishment of organizational objectives. This will consequently result in achieving the Command Goals and Vision.

e. Why Metrics?:

Metrics facilitate quality improvement. Metrics help us understand our processes and their capabilities so we can continually improve them. As Belasco points out "what gets measured gets empowered and produced."[1] Good metrics will help us "face reality, communicate it, and deal with it."[2]

f. Who Needs Metrics?:

Metrics can apply to any individual or any organization responsible for a task, activity, system, or process. They can be developed and integrated into any organization's long-range planning process at any level. Metrics can be applied to any ongoing or recurring task, activity, system, or process. One time tasks and projects are still measurable, but the benefits of measuring may not be worth the effort.

[1] James A. Belasco, Teaching the Elephant to Dance, New York, NY: Crown, 1990, p 158

[2] Perry L. Johnson, Keeping Score, New York, NY: Harper & Row Publishers, 1989, p.111.

Chapter 2: Fundamentals

a. What Metrics Are:

As our Commander has stated, metrics are measures of how we are doing[3]. That implies several things. First and foremost, since we are a service organization, our metrics must be founded in a customer orientation. Second, a metric must communicate the health of a process. Third, the metric must distinguish "health" from sickness. To know what health means, we must know where we are now and where we want to go. Fourth, a time dimension is necessary for true metrics.

For purposes of this handbook, a metric will be defined as a measurement made over time, which communicates vital information about the quality of a process, activity, or resource.

Measurement is a means to an end: continuous improvement of the way we do business.

b. Attributes of a Good Metric:

The following are the basic characteristics of a good metric:[4]

1. It is accepted as meaningful to the customer.
2. It tells how well organizational goals and objectives are being met through processes and tasks.
3. It is simple, understandable, logical and repeatable.
4. It shows a trend.
5. It is unambiguously defined.
6. Its data is economical to collect.
7. It is timely.

BUT MOST IMPORTANTLY:

8. It drives the "appropriate action."

[3] Ronald W. Yates, AFSC/CC, Letter to HQ AFSC DCS, ACS, and SSOs, 20 Aug 90

[4] Primarily derived from a handout from the 26 Sep 90 AFSC Commander's Staff Meeting

c. What Metrics are Not:

Metrics are not:

1. Charts. Charts may graphically display the results of a metric. But the chart itself is not the metric.

2. Schedules. Some forms of schedule can lead to good metrics, but usually schedules do not provide information that by itself will lead to process improvement.

3. Goals, Objectives, Strategies, Plans, Missions, or Guiding Principles. Most of these can be measured, but as we stated before, the metric is not by itself the end. It is a means to an end – to achieving objectives and goals through process improvement.

4. Counts of activity. Counts of activity can result in metrics, but just because you have statistics does not mean that you have a measure that will drive appropriate action.

5. Snapshots or one-time status measures as displayed in pie charts, stoplight charts, etc. These convey little trend information. Comparison of status over time can be a metric, but it tends to be very top level and does not provide much understanding of the process.

d. Metrics and Process Variation:

All processes exhibit some variation. Continuous improvement of any process means pursuing uniformity of output, that is, reduction of variation. If you do not know the variation of a process and you change the process, you risk having no effect or making the process worse. You will be "tampering" with the process rather than systematically making improvements. The discussion of normal and abnormal variation and the use of histograms and control charts described in the Appendix A provide useful information for interpreting metrics.

Chapter 3: Development Process

a. General:

The previous chapters of this Handbook were oriented toward providing you with the theoretical framework of metrics. This chapter deals with the nuts and bolts of developing metrics. It describes the concept of a physical "Metric Package," and provides a step-by-step process for developing metrics.

As mentioned previously, metrics are measurements you can use. They are a subset of the variety of measurements we can make. Some measurements of data have the potential to become metrics, but not all.

Ultimately, two criteria must be satisfied for a measurement to be an effective metric. As mentioned before, a metric must present us with data we can use. It should show a status over time. Only trend data has the potential to be evaluated to the degree needed in order to establish actions to be taken. It should further present us with information which allows us to take some initial action. Second, a metric must directly support corporate goals or objectives because it is built from the strategic and business plans. All efforts to evaluate your current situation and steps taken to improve your processes will be in vain unless the end result is the advancement of the organization toward successfully meeting corporate goals. Both of these attributes are further elaborated on in Chapter Five. The importance of each will become apparent once you've begun to make changes and are well into the implementation phase.

b. The "Metric Package":

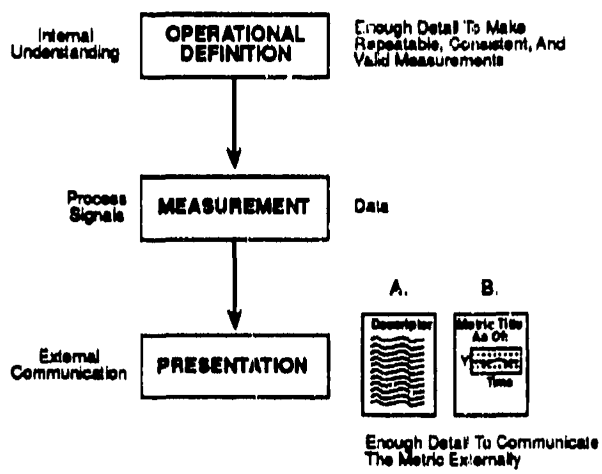


Figure 3-1: The Metric Package

A metric consists of the following three basic elements: the operational definition, the actual measurement and recording of data, and the metric presentation. Together these elements are called the metric package. This is illustrated in Figure 3-1. The operational definition is the precise explanation of the process being measured. The measurement and data collection is the translation of data from the process into understandable and useful information. The metric presentation is the metric's communication link to the process customer and process manager.

The first element of the metric package is the operational definition. According to some "there is nothing more important for the transaction of business than the use of operational definitions."[3] The operational definition is the who, what, when, where, and how of the metric. It is customer oriented and accepted. It must be detailed enough to allow valid, repeatable, and consistent measurement to be made over time and is the key to internal communication for process understanding which is a vital step if we hope to have improvement. The amount of detail required will vary from metric to metric, but at a minimum, it should consist of the following elements:

- An unambiguous description of the metric
- The population that the metric will include
- The frequency of measurement
- The source of the data
- Any equations required in doing the measurement
- Precise definition of key terms
- A description of the graphic presentation that will eventually be used to display the data
- The customer of the metric
- The accountable process owner
- The desired outcome expressed in terms of a positive or negative trend (not a numerical goal)
- The link between the process being measured, your organization's strategic plan, and the command goals.

The second element is the actual measurement of the process. This is the step of collecting and recording the data. This step is the heart of the metric concept and serves as the translation of data from the process being measured to meaningful information that will be the basis of your process improvement activities.

The third element of the metric package, the metric presentation, has two parts. The first part is the metric descriptor and the second part is the graphic presentation of the data. The descriptor and presentation are actually planned when developing the operational definition, before most of the data is collected. The amount of detail required in the descriptor will vary with the purpose of the presentation. At a minimum, it will include a clear definition of the metric, the source of the data, the population that the metric will include, the owner of the process the metric measures, and identification of the command goal that this process is linked to. It should contain enough information to clearly communicate the information contained in the second part of the presentation. The second part of the metric presentation, the chart, is often mistakenly referred to as the metric. Together the descriptor and the chart should provide enough information to clearly communicate the metric. These are further discussed in Chapter Five.

[3]W. Edwards Demming, Out of the Crisis, Cambridge, MA: MIT CAES, 1986, p. 276.

c. The Steps to Metric Development:

This section provides the steps for formulating the metric package and measuring associated process improvement. Keep in mind that these steps may require tailoring before they can be applied to your particular situation. These steps are pictured with an example in Figure 3-2.

STEP I. IDENTIFY YOUR PURPOSE

It is important to first align your purpose with your organization's mission, vision, goals, and objectives. These should be inextricably linked to meeting customer needs and serve as a foundation for accomplishing and sustaining continuous, measurable improvement.

STEP II. DEVELOP YOUR OPERATIONAL DEFINITION STARTING WITH YOUR CUSTOMER

Define the who, what, when, why and how of this metric in sufficient detail to permit consistent, repeatable and valid measurement to take place. The operational definition starts with an understanding of your customers' expectations. You then "operationalize" the expectation(s) by defining characteristic(s) of the product, service, or process which are internally measurable and which, if improved, would better satisfy your customers' expectations. This is actually an iterative process involving Steps II-VII. This is the first element of your metric package.

STEP III. IDENTIFY AND EXAMINE EXISTING MEASUREMENT SYSTEMS

Once the link to objectives and goals has been established, it is essential to determine if existing metrics or other measurement systems exist that satisfy your requirements. Don't "reinvent the wheel." Use existing process measurements when they exist.

STEP IV. GENERATE NEW METRICS IF EXISTING METRICS ARE INADEQUATE

Most measurements used in the past were not process oriented. They were results indicators related to final outputs, products or services for external customers. With metrics, the focus is on how processes are performing in making these final outputs. We are interested in those upstream process measures which drive the final outcome and are the key to making process improvements. The assumption is: if process performance is monitored and improved, the quality of the products and services will improve.

STEP V. RATE YOUR METRIC AGAINST THE "EIGHT ATTRIBUTES OF A GOOD METRIC"

Refer to the attributes listed in Chapter Two. If you feel your metric sufficiently satisfies these criteria for a good metric, go on to Step VI. If not, return to Step II and correct the deficiencies.

STEP VI. SELECT APPROPRIATE MEASUREMENT TOOLS

Select the proper tool for analyzing and displaying your data. The "Eight Basic Tools" identified in Figure 4-1 are those most commonly used. Other statistical and non-statistical tools may be more appropriate for your application. Use whatever you feel is best. The tools will be discussed further in Chapter Four and Appendix C.

STEP VII. BASELINE YOUR PROCESS

Start acquiring metric data. This serves as a baseline for determining the capability of your process. Ask if the data, is accumulated over time and adequately measures the important characteristics of your process. If the answer is uncertain, examine other possibilities. And if you change your metric, remember to coordinate it with your customer again.

STEP VIII. COLLECT AND ANALYZE METRICS DATA OVER TIME

Continue aggregating metric data over time. Examine trends. Special and/or common cause effects on the data should be investigated and assigned. Compare the data to interim performance levels. This is the second element of your metric package.

STEP IX. FINALIZE THE METRIC PRESENTATION

Based on the results of the previous steps, you are finally ready to present the metric externally. The descriptor will provide enough information to communicate the appropriate details of the metric to your customer. The appropriate level of detail should be determined by discussion with the customer. This information should be an abbreviation of the key elements of the operational definition. The graphic presentation clearly and concisely communicates how you are performing. This is the third element of your metric package.

STEP X. INITIATE PROCESS IMPROVEMENT ACTIVITIES

Initiate process improvement activities in conjunction with the key process owners. Chapter Six provides more guidance in this area. Once improvements have been implemented, the process above may start over or it may pick up again at almost any step. Remember, continuous improvement requires continuous effort. THIS STEP IN THE DEVELOPMENT PROCESS IS THE MOST CRITICAL FOR YOUR IMPROVEMENT EFFORTS TO BECOME A REALITY. Remember that metrics are just a means to an end! That end is continuous process improvement.

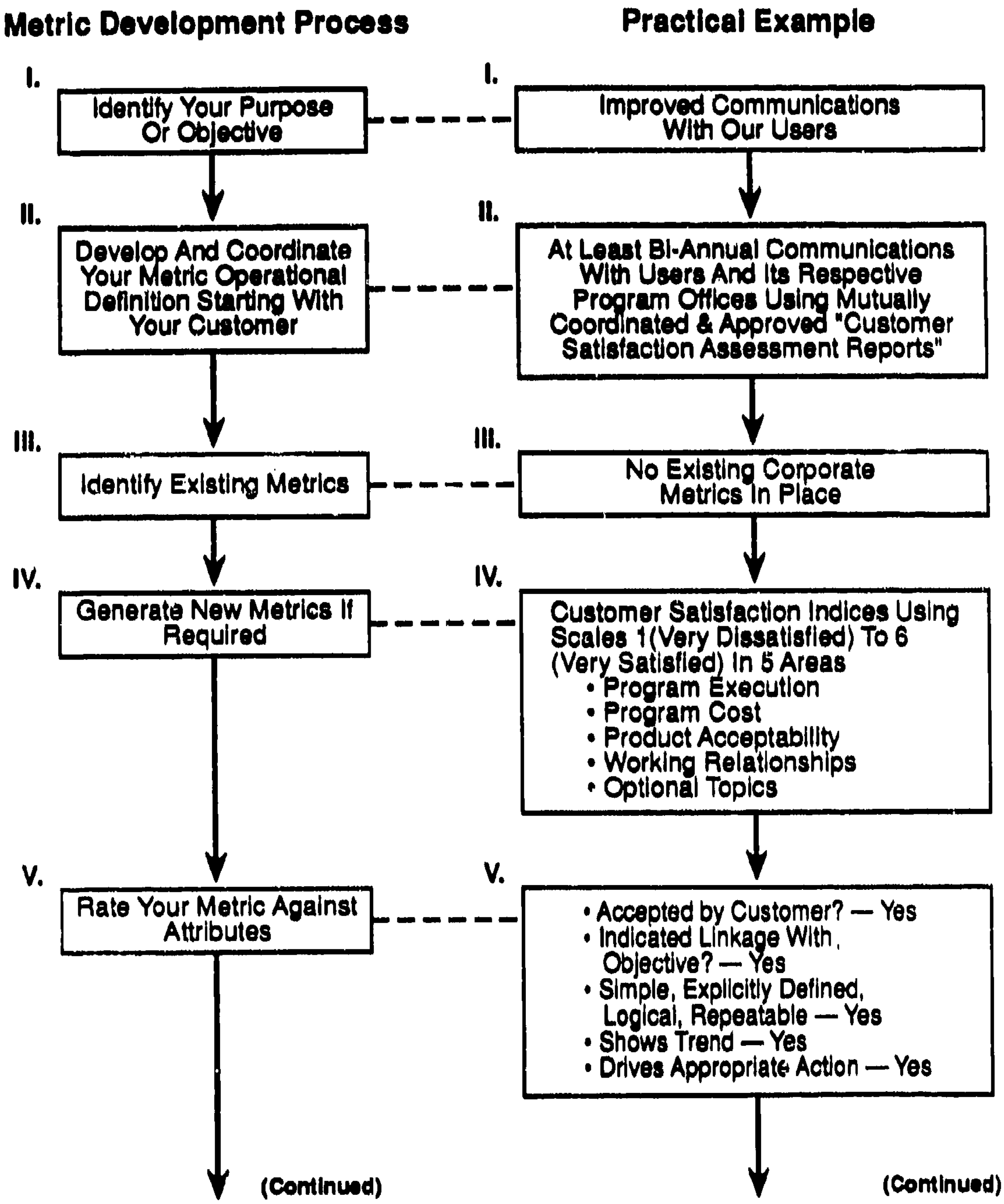


Figure 3-2: Metric Development Process

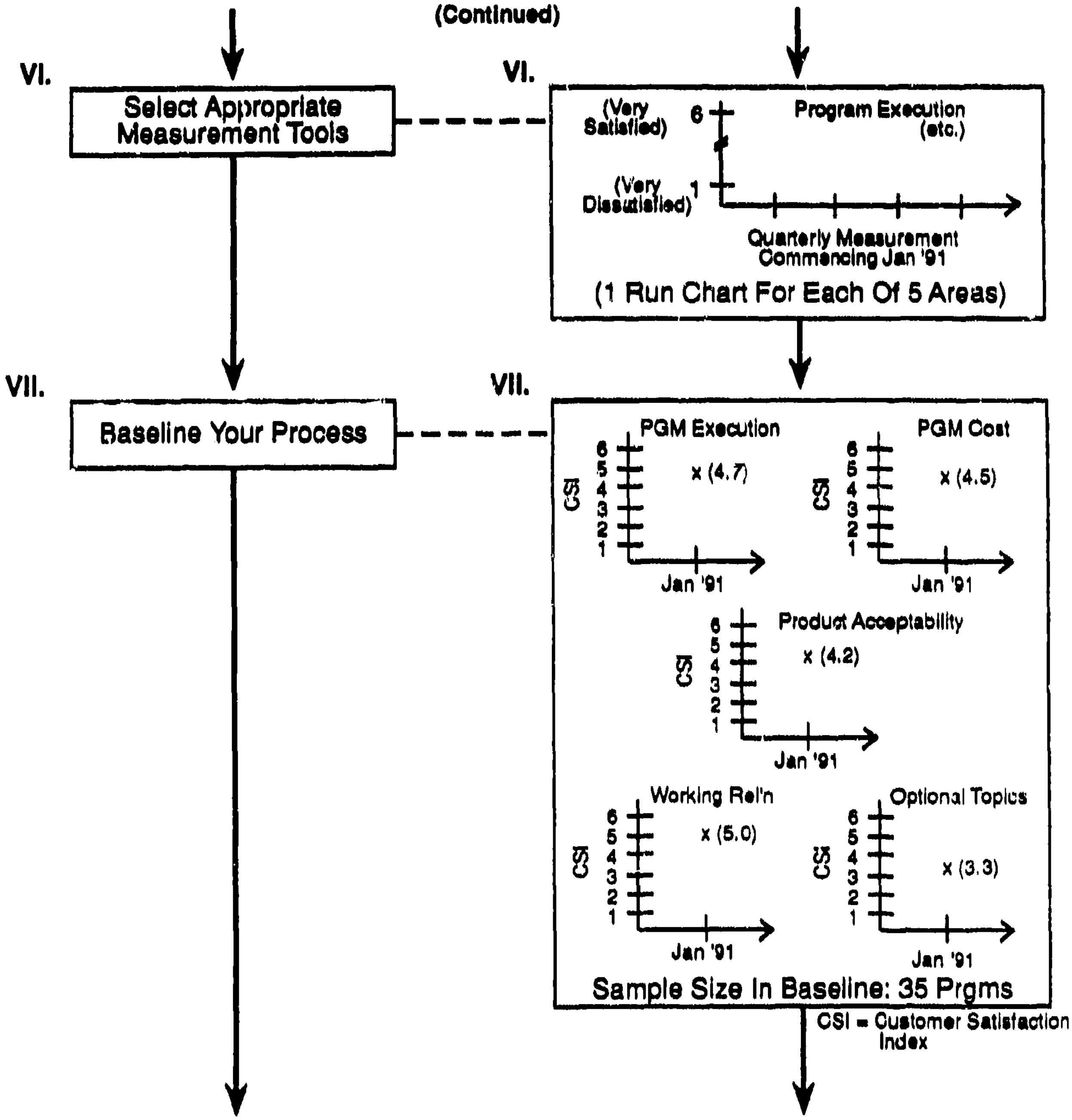


Figure 3-2: Metric Development Process

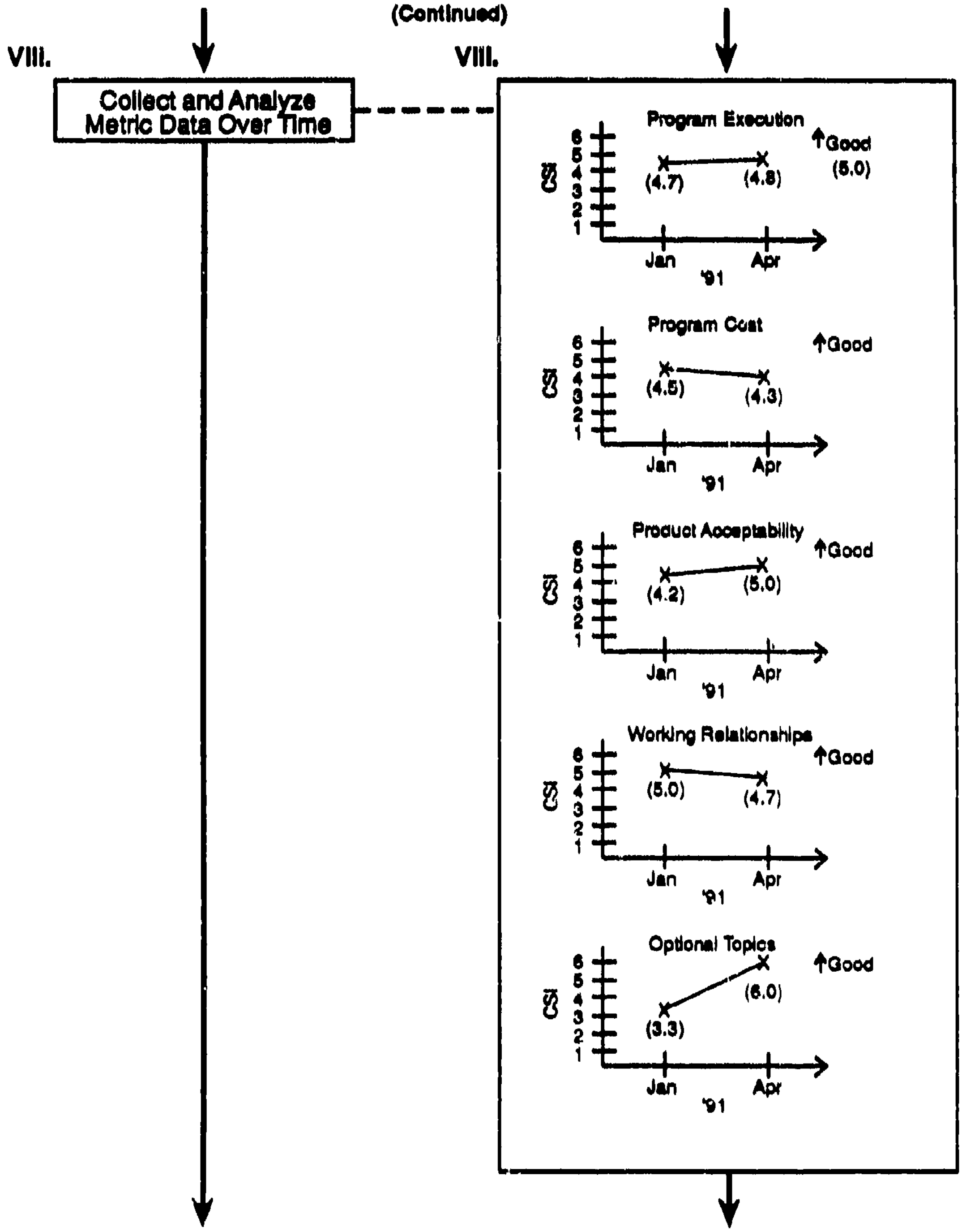


Figure 3-2: Metric Development Process

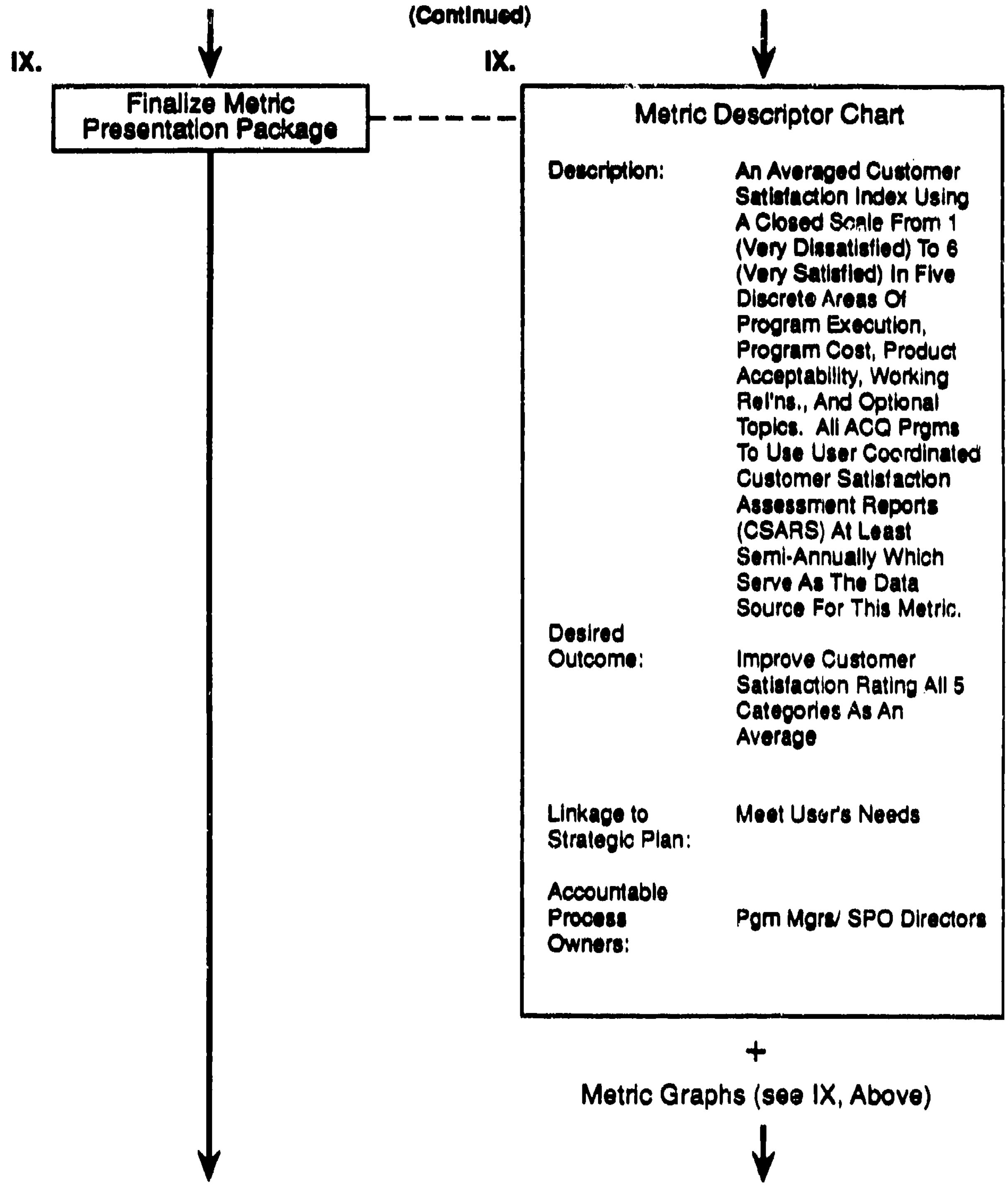


Figure 3-2 Metric Development Process

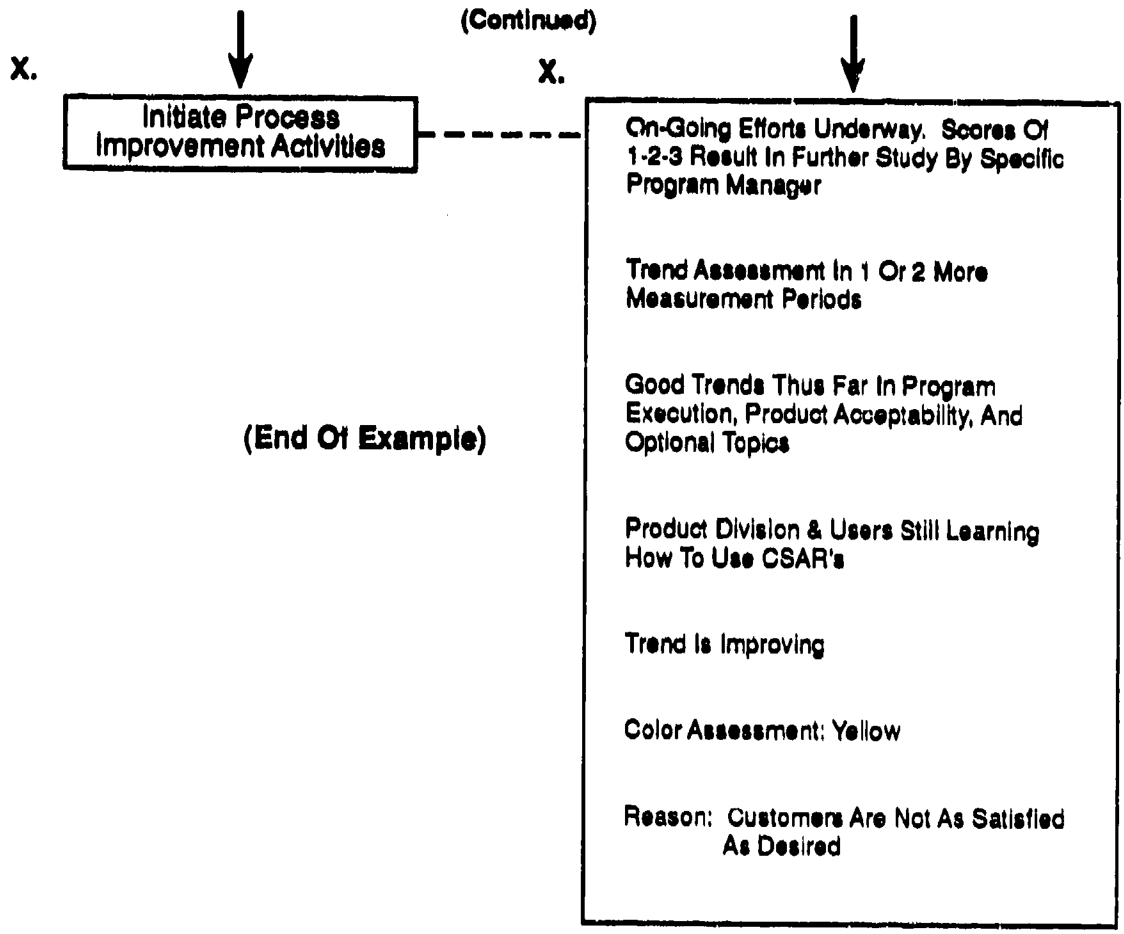


Figure 3-2: Metric Development Process

Chapter 4: Introduction to TQM Tools

a. Process Performance:

This chapter introduces process performance and several common statistical tools that will be useful in developing metrics.

Process performance means how and how well a process works. Since what the customer wants defines your standard of quality, you will analyze the process in terms of its capability to meet customer needs and expectations. The tools in Appendix A will help you interpret the data you collect. These tools are a bit like x-rays used by doctors. They provide pictures which enable you to understand how your process is currently performing.

Depicting and understanding process variation using metrics is key to systematically improving processes. Why study variation? It is the cause of most unsatisfactory performance in the government and industry today. Variation adds unnecessary problems to any job. Some of the consequences often associated with variation in process performance are:

- Unpredictable performance
- Additional reviews and inspections to weed out undesirable results
- Avoidable rework and/or scrap
- Schedule delays
- Lower productivity
- Lower reliability
- Higher costs
- Customer dissatisfaction (which, by definition, means poor quality)

There are two types of variation: abnormal variation and normal variation.

Abnormal variation results from "special causes," that is, something unusual has happened to the process. For example, errors have increased because a manager assigned a new and untrained employee to a critical process. Special causes can usually be eliminated by people close to the process and without changing the process.

Normal variation is the routine fluctuation of process performance due to the interaction of the process components: manpower, machines, work methods, materials and the work environment. Over time, process indicator data may go up or down, but you can predict with a reasonable degree of certainty what the range of variation will be. Normal variation occurs because of "common causes." These may be the level of training of all employees in a process, the reliability of equipment and methods normally used, or simply minor random events.

Special causes account for only about 15 percent of the variation in a process, and common causes for 85 percent. Process performance metrics help managers focus their attention on both special and common causes of variation. Fires (special causes) still get put out, but now continuous improvement (reducing the effects of common causes of process variation) gets emphasized.

Process variation is often disguised. Therefore, you need to look at your data and your metrics on the performance of your process from several perspectives to allow the process to "tell" you about its variation. The questions you want the process to answer are:

- What is the total variation in the process? Histograms will help here.
- What is the long-term predictability of the process? Run charts and control charts will provide the answer.
- What is the short-term stability of the process? Control charts (of range values) will reveal this.
- Is the variation normal or abnormal? Histograms and control charts can help distinguish between these two types of variation.

b. Tools:

The same statistical tools which support effective process control can be useful in developing good metrics. You must decide which statistical approaches are appropriate for your applications.

The tools most commonly mentioned in TQM literature are control charts, run charts, flow charts, cause and effect (or fishbone) diagrams, histograms, Pareto diagrams, scatter diagrams, and check sheets[6].

[6] Memory Jogger, Walton, Booz Allen, Scherkenbach, Kiemele, et al.

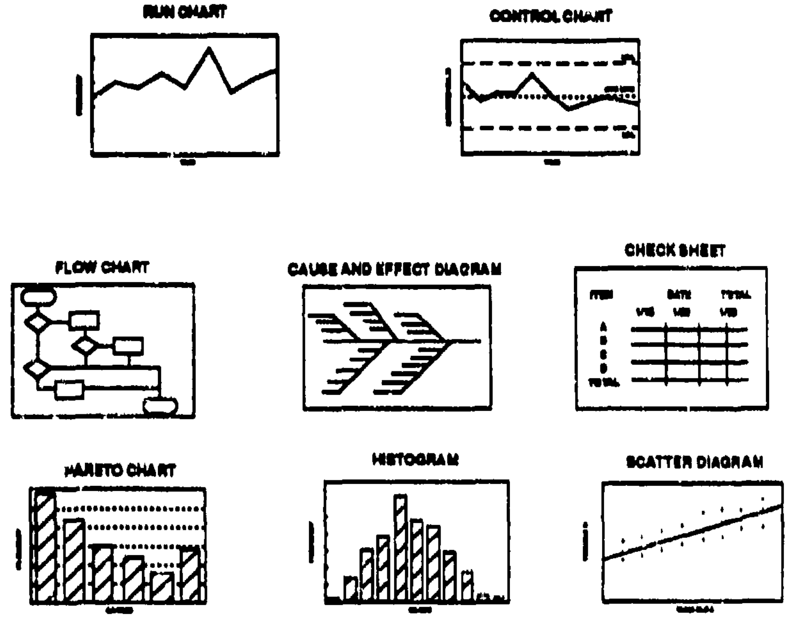


Figure 4-1: Eight Useful Tools

Above (Figure 4-1) is an illustration of these eight tools. Of these eight, run charts and control charts most readily lend themselves to the display of good metrics. This is because they best show process performance information over time. There are many more tools, available to the interested user. Table 4-1 is presented to help you determine which of this small selection of tools may best apply to your situation. The remaining six tools are oriented toward problem solving. Those who understand the process are in the best position to determine which statistical techniques to apply. It is suggested that those using a tool understand it before they use it. Many courses and books are available as indicated in Appendix C. A good place to get assistance is your organization's TQM office.

Tool	Proper Use	Attributes	When Appropriate For Metric Display	Comments
Run Chart	To Display Trends. Problem Identification And Analysis.	Measures Process. Shows Time Dimension. Does Not Indicate Control. (May Be Too Early In Measurement To Apply Control Limits) Shows Trends. Simple.	When Statistical $\overline{X}$, UCL, LCL Have Not Been Determined.	Do Not Dwell On Variations, Process Control Has Not Been Established. Time Is Always On The Horizontal Axis.
Control Chart	To Analyze Process Variability.	Measures Process Shows Time Dimension. Indicates Process In Or Out Of Control. Shows Variability Within A Process.	When Properly Derived, Generally Control Limits Require 20-25 Samples To Be Statistically Valid.	Do Not Confuse CLs With Spec Limits. CL Are Stat. Determined, Spec Limits Are Based On Desires Or Needs Control. Control Implies Product Is Consistent. Not Necessarily Acceptable.
Flow Chart	To Analyze/ Breakdown A Process Into Steps, Identify Problems. Compare Actual To Ideal Process.	Clear Visual Display Of Process Using Easy To Understand Terms And Symbols.	Not Appropriate As Metric Display, Can Assist In Identifying Potential Metrics.	
Cause & Effect Chart (Fishbone)	Problem Identification.	Shows Relationship Between Possible Causes And Effects.	Not Appropriate As Metric Display. Can Assist In Identification Of Metrics.	Focus On Identifying The Root Causes Of The Problems, Not Just The Symptoms.

Table 4-1: Overview of TQM Tools

Tool	Proper Use	Attributes	When Appropriate For Metric Display	Comments
Check Sheet	Data Collection And Classification.	Easy To Understand, Good For Counting And Stratifying.	Appropriate For Many Metrics As Data Collection Tool But Not As Graphical Display.	Sample Should Be Unbiased; Population Should Be Homogeneous.
Pareto Chart	Separation Of Vital Few From Trivial Many. Lead-In For Problem Solving, Root Cause Identification, Measure Change, Impact Stratification.	Form Of Bar Graph Clearly Displays Relative Importance Of Problem Or Conditions. Leads To Next Step For PDSA Cycle.	When Identifying A Problem To Be Worked. Should Lead To Time Based Displays In Later Periods.	Exercise Caution In Drawing Conclusions From Straight "Counts." Data Often Requires Idiot Check.
Histogram	To Display Data Distribution. Problem Analysis And Identification.	Data Distribuition. Shows Variations. Shows Abnormalities In Data.	Use Metric Input For Specific Period Of Time.	Histograms Usually Show A Snapshot Of Process Performance For A Specified Time Period.
Scatter Diagram	Test For Relationships. Problem Analysis.	Shows Relationships Between Two Variables.	Not Appropriate As Metric Display, Can Assist In Identifying Potential Metrics.	Do Not Confuse This With A Run Chart; Relationship Does Not Imply Cause And Effect.

Table 4-1: Overview of TQM Tools

Chapter 5: Presentation

This chapter provides guidance for effectively communicating process performance using metrics.

There are two basic elements which make up the Metric Presentation Package. First, a metric descriptor should be provided which defines your metric, and provides other essential information about the metric. The "descriptor" is displayed in Figure 5-1 below.

It is strongly recommended that you formulate the operational definition as specifically as possible prior to formulating your metric descriptor. Spending as much time as is warranted on both will pay rich dividends down stream in terms of reduced confusion and accuracy.

Metric Title

Description:

Briefly define your metric along with the population to be measured and the source of your data. These and other items of information on your metric should be contained in your metric operational definition

Desired Outcome:

Define the outcome in terms of improved processes. Do not use numerical goals.

Linkage to Strategic Plan:

Identify one or more of your organization's objectives or goals that are addressed by tracking this metric. This linkage to your organization's business plan is essential; metrics for metrics' sake are unwarranted.

Process Owner:

Identify the principal individual or organization who can initiate and sustain process improvement.

Figure 5-1: Metric Descriptor

The second element of a Metric Presentation Package is a graphic illustration of how the metric tracks over time. The illustration should be simple to interpret and will generally be either a run chart or a control chart. Both were introduced in Chapter Four and are explained in more detail in Appendix A.

In addition to the guidance presented in Appendix A, a few other helpful hints are appropriate. Insure your graph is titled, and both axes are labeled as well. Time is usually represented in the horizontal or x-axis, and your metric, as summarized in the descriptor chart, is labeled on the vertical, or y-axis. Use a common marker for each data string such as an x or o. It may be appropriate to use an upward or downward arrow to indicate your preference for raising or lowering the metric overall in time. For control charts, plot the center line and upper and lower control limits. *Your upper and lower control limits are statistically calculated based on your process capability.* They are never defined from customer specifications or needs! And in most cases, both your metric descriptor and graphics should be printed horizontally to make them easier to read.

Figures 5-2 and 5-3 provide an example of a complete Metric Presentation Package. Figure 5-2 is the descriptor, Figure 5-3 is its accompanying graphic.

Progam Office Overhead: Metric Description

Reduce Overhead

Description:	Average Percent Overhead Expressed As A Function Of Total Program Cost. All Programs Are Counted Within The Division That Currently Use 3600, 3400, Or 3080 Funds. The Data Will Be Obtained From Each Program's Current FINPLAN. Elements Of Overhead Include FFRDC/TEMS/SETA, TDY, Overtime, Supplies, Equipment, Training, And Assessments.
Desired Outcome:	A Divisional Trend Which Indicates A Net Average Reduction Of Overhead Over Time
Linkage to Strategic Plan:	Meet User's Needs Through Reduced Costs
Process Owner:	Program Director

Figure 5-2: Sample Metric Descriptor

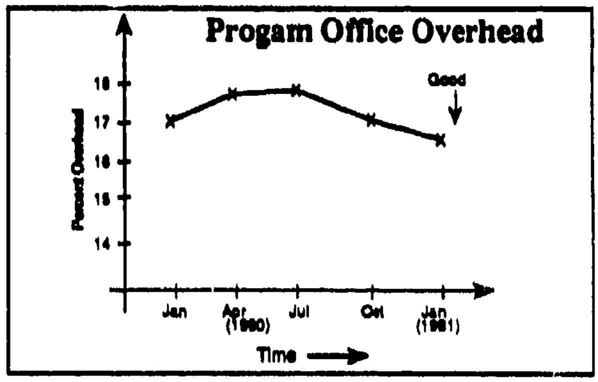


Figure 5-3: Sample Metric Graphic

Finally, a comment on "Stop Light" charts is appropriate. Management may wish to assign a color rating or color-code for each measurement period. An example of a color assessment scheme is provided in Figure 5-5. The assignment of a specific color may be predicated on the trend of your metric over time. An illustration of how a Stop Light chart could be integrated into a metric graph is illustrated below in Figure 5-4:

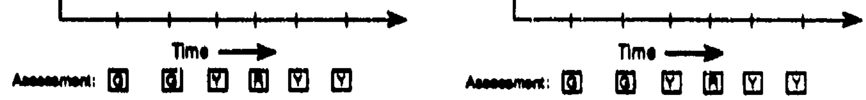


Figure 5-4: Sample Stoplight Assessment

Establish your assessment criteria early-on, and stick with it over time. Avoid changing your rules at mid-stream. One possible set of assessment criteria could be as simple as:

Green	Process in control and capable
Yellow	Process in control, not capable
Red	Process out of control

Figure 5-5: Sample Stoplight Criteria

The point to remember is to establish your targets and threshold after careful consideration of your customer's needs or specifications AND an understanding of what your process is capable of accomplishing. Your targets or thresholds, if numerically defined, should not be arbitrarily established. If a color code is also required, establish your color-coding criteria with customer agreement, and maintain consistency in this criteria over time.

Chapter 6: Implementing Metrics for Process Improvement

a. Introduction:

This chapter deals with the task of using data and metrics to systematically target and implement process improvements, and to then monitor and evaluate the effect of these improvements. Now that you have gathered data and presented it in a format you are comfortable with, you are ready to take the next, and most important, step in the metrics process. This is the step of actually using the data to effect change within your organization.

To an extent, implementation began informally when your leadership agreed with customer and subordinate on what would be measured. Tacit approval was then given for eventually making changes based on the metrics data.

The ability to implement change based on accumulated measured data is the distinguishing factor between taking a measurement and having a metric. Only after exercising the "appropriate action" step of implementation have you successfully developed true metrics and taken full advantage of them.

b. Evaluation:

As mentioned earlier, every metric package should include a desired outcome. A fundamental step in implementation is an evaluation of where you stand - with respect to meeting your customer's needs, with respect to corporate goals, and with respect to any appropriate benchmark or competition. As a minimum, this evaluation should result in a clear understanding of how your processes are achieving customer satisfaction.

A formal approach to the evaluation may take place using Control Charts. In this case, Upper Control Limits (UCLs) and Lower Control Limits (LCLs) are used to evaluate whether or not a process is in control. The formal approach need not be used, however. A simpler evaluation may adequately lead to the "appropriate action." The point is that an evaluation need not be overly complicated.

An important tool in making your evaluation will be your customer's perspectives and feedback. As a Total Quality organization, the value of customer satisfaction is paramount, and cannot be over-emphasized. It is vital to consider the customer's input in any assessment of performance and process changes.

Your evaluation may also be based on an assessment of your position relative to that of others, often your competition. Such an assessment can be extremely beneficial, but only if a positive attitude toward benchmarking exists in the organization. In the past, the tendency of military organizations to perceive comparisons with a "report-card mentality" was exercised. But a competitive evaluation may foster improvement by demonstrating that a particular process can be further improved, and suggesting possible approaches to make improvements.

c. Basis for Action:

The need to improve is fundamentally important to any organization. This is true regardless of your motivation and whether you are ahead of or behind your desired outcome. Without improvement, there is stagnancy at best. The inevitable result is failure.

There are many sources from which to draw upon in determining an effective action to improve a process. Five valuable sources are the process itself, your customer, your people, your competition, and your competition's customers. A more general source is anyone reputed to be the best at what they do or to have established the "best practices" in so doing.

If your metrics are effective, you'll never have to ask "Now What?" or "So What?" after an evaluation of your data. Good metrics should enable your process to provide at least an initial indication of where to focus your energies toward uncovering the "appropriate action" to be taken.

As mentioned earlier, benchmarking can be extremely beneficial to an organization. It allows you to draw upon others' successes to improve your processes. Benchmarking involves studying other similar organizations that perform above expected norms and applying their ideas to your processes. Don't limit yourself to studying your competition!. Good ideas can be transplanted from anywhere. Benchmarking is taking advantage of others' experience to avoid pitfalls encountered earlier somewhere else. More importantly, it allows you to benefit from others' "best practices" so your organization will excel.

d. Communicating Your Intentions:

Setting the stage for change within your organization can be as important as actually making the changes. Before taking any action, you must clearly explain to your people what you are changing, why you are changing it, and when it will happen.

Communication serves two purposes. First, it educates your people. Continuous improvements or, in a few cases, new processes take some getting used to. The time lag from initial introduction, down the learning curve, to final integration and acceptance can be minimized by education. Second, and more importantly, communication shows your people that you value them as integral to the success of any changed processes and policies. Explaining your actions will maximize your chances for success at implementing change. The degree to which you explain your actions up front will serve to achieve consensus earlier than otherwise possible.

e. Take Action:

TAKE ACTION! This may not be easy. A continuous improvement philosophy requires the support and commitment of customers, suppliers, and process owners and members. Customer dissatisfaction and process problems must now be seen as valuable feedback and not as causes for punishment. In many cases, reward systems will require changes to support customer and process oriented behavior.

Be careful not to over-react - Deming calls this "management tampering." It inevitably leads to an erratic trend and an increase in process variation. In follow-up evaluations of the implemented change, consider whether you have addressed a symptom and not the root cause of the problem.

f. Repeat the Process:

Even now you're not done! Continuous improvement means eternal vigilance. You'll need to continually monitor your processes to determine the success of process changes. The steps you've just taken are shown in the flow-chart at Figure 6-1. Use them as a guide for continually taking action based on what your metrics tell you.

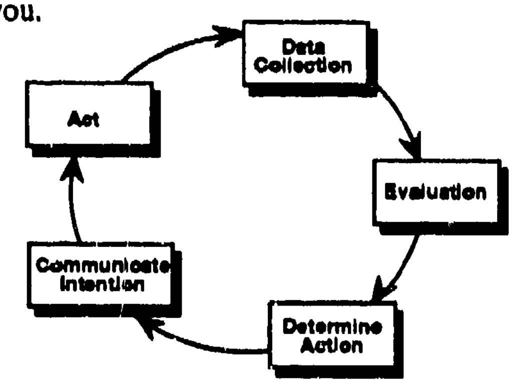


Figure 6-1 Metric Implementation

Remember that leadership must constantly seek feedback from both internal and external sources. The process of quality improvement is never ending. You must continue to measure, and continue to act on what your metrics tell you, and continue to update your metrics to facilitate even further improvement.

Appendix A: Eight Measurement Tools

Run Chart

What it is:

A run chart is a graph of process measurement over time. It can be used to:

- Begin to understand the basic characteristics, including variation, of a process.
- Document variation while a process is ongoing.
- Plot historical data to get a better understanding of what has happened in the past.
- Track short term processes where each resulting product or service is measured.

How to use it:

- Construct the Chart. Label the vertical axis with the key measurement of the process being measured. Label the horizontal axis with units of time.
- Plot the Data. Collect 7-10 data points and plot them on the chart. Average all the points and plot a centerline.
- Interpret the Chart. Interpret the chart using your best judgement. Two common tests can be made to detect significant process changes:
  - A run of seven consecutive points on one side of the average;
  - Seven or more consecutive points steadily increasing or decreasing.[1]
- Recompute the centerline when you have reason to believe something has changed in the process. If you do recompute the centerline, annotate the change on the chart.

Points to Remember:

- For ease of interpretation, approximately the same time interval should occur between measurements.
- Not every variation in the data is significant. Since the factors that make up a process vary over time, any measurment coming from the process can reasonably be expected to vary. Investigating every variation as though it is critical can be frustrating and wasteful.

[1] Mark J. Kiemele and Stephen R. Schmidt. Basic Statistics: Tools for Continuous Improvement. Colorado Springs, CO: Air Academy Press, 1990, p. 2-18.

• You should keep in mind that it is appropriate to start a run chart with a limited amount of data or a limited number of time periods. You should, however, consider findings from this intial data as preliminary.

Run Chart Example 1:

AEDC collected statistics on data deliverables over the past four years to determine if a trend was forming.

Fiscal Year	% Of Data Delivered On Time
1987	48%
1988	49%
1989	73%
1990	77%
Partial Year 1991	94%

Simple Average 68%

Table A-1: AEDC Data Deliverables

This is displayed on a run chart (Fig A-1). It should be noted that the 1991 data is not for a full year and should be considered preliminary. It appears that there is an improvement trend in this process, but since there are only five data points in this plot, the results may be deceptive. More data should be collected, or the data collected should be attributed to shorter time periods.

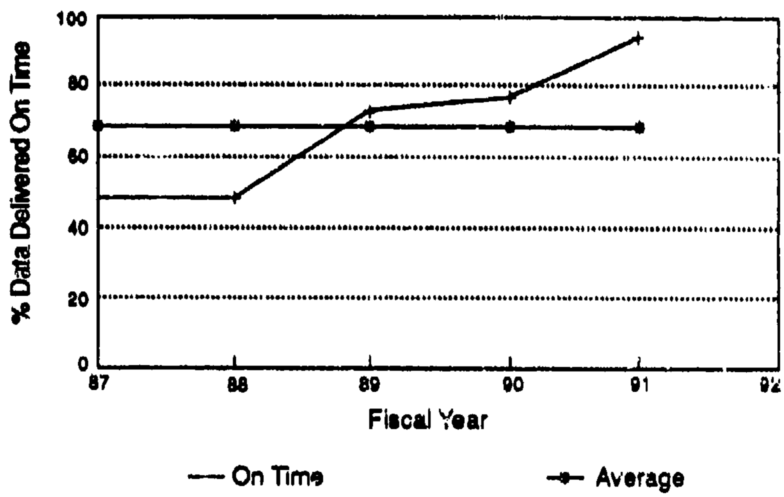


Figure A-1: Data Deliverables Run Chart

Run Chart Example 2:

HSD collected data over a 20 month period. Samples were taken every other month. The following data resulted.

Month Sampled	Median Technical Report Processing Time (In Days)
Jul	250
Sep	260
Nov	258
Jan	224
Mar	341
May	290
Jul	196
Sep	158
Nov	165
Jan	173
Mar	144

Simple Average 224 Days Of Median Days

Table A-2: HSD Technical Report Processing Time

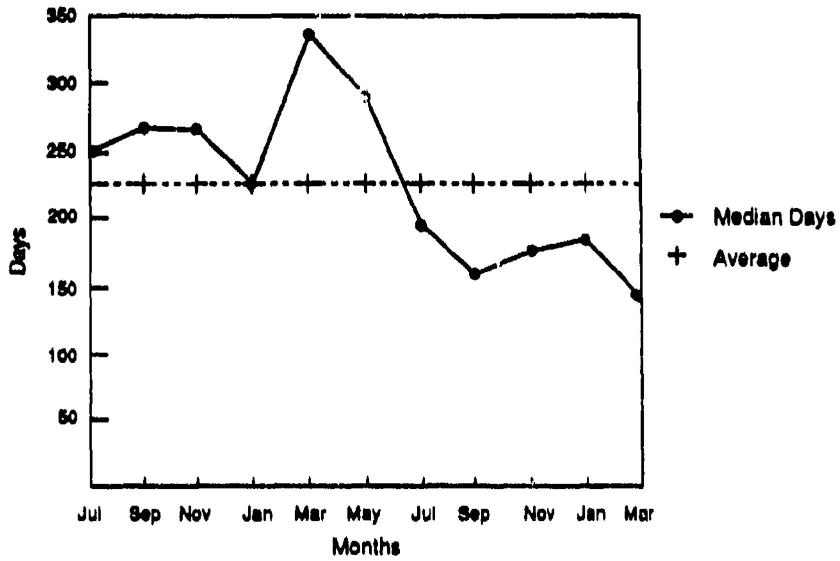


Figure A-2: Technical Report Processing Time Run Chart

The run chart shows what appears to be a favorable trend. This apparent trend should be analyzed before basing any decisions on this information.

Control Chart

What It Is:

A control chart is a tool for analyzing and monitoring the variability of a process over time. A process is said to be in a state of "statistical control" when the variation present in the process is consistently random and within predictable limits. When a process is in this state, process measurements vary randomly within the statistical control limits.

Control limits and tolerance limits are not the same. While control limits are based on the process being used, tolerances are specified by drawings, specifications, standards, etc.

A control chart can help a group or individual:

- Understand and recognize variability and how to control it.
- Identify the presence of "special causes" of variation or changes in performance of a process, i.e., a shift in the process average, change in the variance, cyclic behavior, etc.
- Stop trying to "fix" a process that is varying consistently over time and objectively determine the root causes of problems.

Caution:

Control charts should *not* be the *first* tool used to analyze data. Unless you have clearly identified the process in question and have data to support investigating the process you want to "control," your improvement efforts will not be fully successful.

How to use it:

- The type of data to be collected will dictate the type of control chart to be used. In general, variables data require some form of measurement, e.g., length, temperature, etc. and the recording of those measurements. Attributes data require a good/bad or go/no-go decision and counting, e.g., types of defects, percent late, etc. Since attributes data doesn't require detailed measurements, it is easier and less costly to obtain. Use the Figure A-3 to determine the type of control chart needed.
- Once the type of data to be collected is determined, follow the appropriate chart construction techniques on Pages A-9 – A-14.

- Eliminate the special or assignable causes of variation. The existence of these causes is indicated by one or more of the following seven signals:

  - One or more points outside the control limits.
  - Seven or more points on one side of the centerline.
  - Six points in a row steadily increasing or decreasing.
  - Fourteen points alternating up and down.
  - Two out of three points in a row in the outer third of the control region.
  - Fifteen points in a row within the center third of the control region.
  - Eight points on both sides of the center line with none in the center third of the control region.

  NOTE: The probability that any of these seven events will occur at random is very small, which is why they're a signal that something has changed in your process.

- When you have eliminated all special causes, work on reducing the remaining variability in your process. This is usually achieved through fundamental changes to the process, and these changes require management assistance. To achieve continuous process improvement, it's essential to reduce variability.

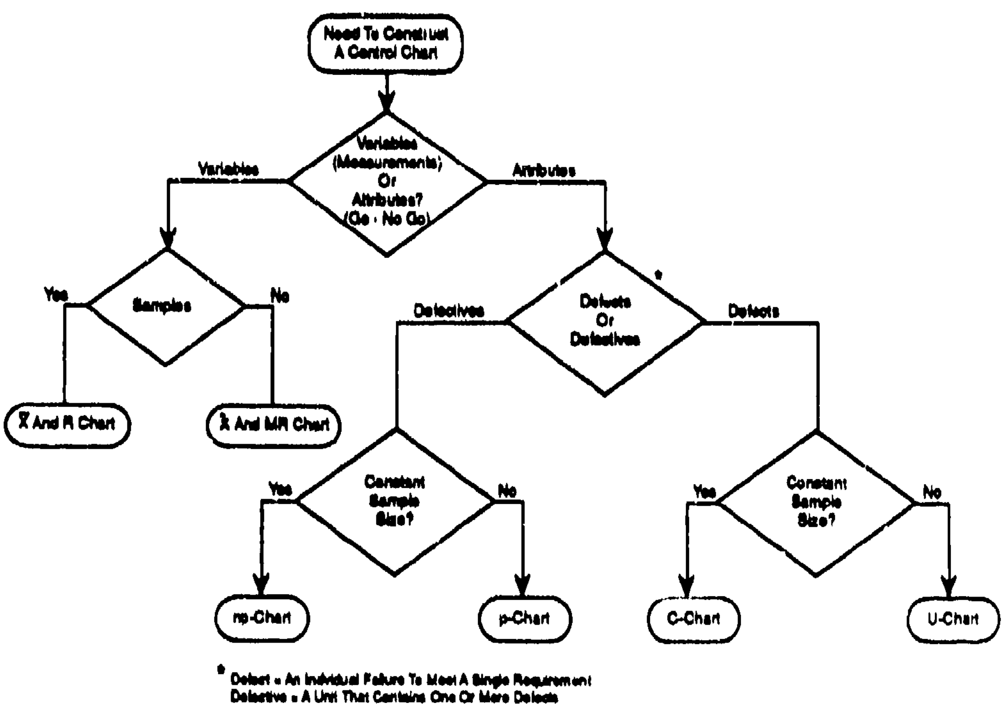


Figure A-3: Control Chart Selection Process

Construction Steps:

General:

1. Determine the type of data that is to be collected. Consult Figure A-3 to determine the appropriate type of control chart to employ.
2. Collect the data.
3. Mark the vertical (y) axis with the name of the variable measured and its unit of measurement.
4. Mark the horizontal (x) axis with units of time.
5. Label the chart with descriptive title(s) which describe the measurement and its time frame.
6. Determine sub-groups, calculate upper and lower control limits, and mean as appropriate.
7. Divide and label the horizontal and vertical axes into even increments which easily allow all the data to be plotted.
8. Plot the data points and the control limits.

Chart Construction Techniques:

$\bar{X}$ and R Control Chart:

1. You will analyze the ranges (R) chart first, then the sample averages ($\bar{X}$).
2. Compute R for each subgroup, $R = X_{max} - X_{min}$.
3. Scale the lower portion of the chart and plot the points.
4. Compute $\bar{R} = (R_1 + R_2 + \cdots + R_3)/k =$ _____
5. Select A_2, D_3 and D_4 from the table below based on your subgroup size.

Subgroup Size	A_2	D_3	D_4	Subgroup Size	A_2	D_3	D_4
2	1.880	0	3.267	6	0.483	0	2.004
3	1.023	0	2.574	7	0.419	0.076	1.924
4	0.729	0	2.282	8	0.373	0.136	1.864
5	0.577	0	2.114	9	0.337	0.184	1.816
				10	0.308	0.223	1.777

Table A-3: Control Chart Constants

6. Compute $UCL_R = D_4 \times \bar{R} =$ _____ x _____ = _____
7. Compute $LCL_R = D_3 \times \bar{R} =$ _____ x _____ = _____
8. Draw the control lines and check for any points out-of-control. Recompute the control limits, if necessary.
9. Compute $\bar{X}$ for each subgroup.
10. Scale the upper portion of the chart and plot the points.
11. Compute $\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2 + \cdots + \bar{X}_k)/k =$ _____
12. Compute $UCL_{\bar{X}} = \bar{\bar{X}} + (A_2 \times \bar{R}) =$ _____ + (_____ x _____) = _____
13. Compute $LCL_{\bar{X}} = \bar{\bar{X}} - (A_2 \times \bar{R}) =$ _____ - (_____ x _____) = _____
14. Draw the control lines and check for any points out of control. Recompute the control lines on both charts, if necessary.

X and MR Control Chart:

1. You will analyze the moving range (MR) chart first, then the individuals (X).

2. Compute MR for each subgroup. MR is the absolute value of the difference between consecutive range values. $MR = R_n - R_{n-1}$ where n and n-1 are consecutive observations. Remember there is no MR associated with the first X value.

3. Scale the lower portion of the chart and plot the MR points. Remember to start at the second position along the time axis.

4. Compute $\overline{MR} = (MR_1 + MR_2 + \cdots + MR_{k-1})/(k-1) =$ _____

5. Compute $UCL_{MR} = 3.268 \times \overline{MR} = 3.268 \times$ _____ = _____

   Note: $LCL_{MR} = 0$

6. Draw the control lines and check for any points out-of-control. If a point is out-of-control investigate the associated X value. If the X value is removed as abnormal, remember that one MR will be removed and another will change. Recompute the control limits, if necessary.

7. Scale the upper portion of the chart and plot the X points.

8. Compute $\overline{X} = (X_1 + X_2 + \cdots + X_k)/k =$ _____

9. Compute $UCL_X = \overline{X} + (3 \times (\overline{MR}/ 1.128))$

   = _____ + (3 x (_____/ 1.128)) = _____

10. Compute $LCL_X = \overline{X} + (3 \times (\overline{MR}/ 1.128))$

    = _____ + (3 x (_____/ 1.128)) = _____

11. Draw the control lines and check for any points out-of-control. Recompute the control lines on both charts, if necessary.

Attributes Control Charts:

- Determine which chart to use. The information in Table A-5 helps clarify the options in the Figure A-3.

  Defect: An individual failure to meet a single requirement.

  Defective: A unit containing one or more defects.

	Varying Sample Size	Constant Sample Size
Defectives	$\bar{p}$- Chart Used to chart the function or percent defective	n$\bar{p}$- Chart Used to chart the number of defects in a subgroup
Defects	U- Chart Used to chart the number of defects per unit.	C- Chart Used to chart the number of defects in a subgroup

Table A-4: Attributes Control Chart Selection Grid

- Collect 10-20 subgroups of data. Each subgroup consists of multiple data points that are arranged in a rational manner, day, lot, office, etc. The size of each subgroup is represented by "n."

- Use the general construction steps from page A-9 with the following formulas:

p-Chart:

n= size of subgroup

$p = \frac{\text{number of defectives in a subgroup}}{n}$ = fraction or percent defective

$\bar{p} = \frac{\text{total defective}}{\text{total inspected}}$ = centerline = average fraction defective

$UCL = \bar{p} + 3 * \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ = upper control limit (varies by subgroup)

$LCL = \bar{p} + 3 * \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ = lowercontrol limit (varies by subgroup)

Note: You can use an average subgroup size to obtain a single set of control limits if:

- The largest subgroup size is less than twice the average subgroup size.
- The smallest subgroup size is more than half the average subgroup size.

Plot p for each subgroup.

np Chart:

$\bar{p}$, n= same as for p-chart, except n must be constant.

$n\bar{p}$= centerline = average number of defectives

$UCL = n\bar{p} + 3 * \sqrt{n\bar{p}(1-\bar{p})}$

$LCL = n\bar{p} - 3 * \sqrt{n\bar{p}(1-\bar{p})}$

u Chart:

$$u = \frac{\text{number of defects per subgroup}}{\text{number of units per subgroup}} = \frac{c}{n}$$

$$\bar{u} = \frac{\text{total number of defects for all subgroups}}{\text{total inspected}} = \text{centerline}$$

$$UCL = \bar{u} + 3 * \sqrt{\frac{\bar{u}}{n}}$$

$$LCL = \bar{u} - 3 * \sqrt{\frac{\bar{u}}{n}}$$

Plot u for each subgroup

C Chart:

C= number of defects per subgroup

$$\bar{C} = \frac{\text{total defects}}{\text{total number of suggroups}} = \text{centerline}$$

$$UCL = \bar{C} + 3 * \sqrt{\bar{C}}$$

$$LCL = \bar{C} - 3 * \sqrt{\bar{C}}$$

Plot C for each subgroup

Control Chart - Example 1:

$\overline{X}$ and R Chart

$\overline{\overline{X}} = 4.37$

$\overline{R} = 0.34$

$n = 5$

$A_2 = 0.577$

$D_3 = 0$

$D_4 = 2.114$

Week	Mon.	Tues	Wed.	Thurs.	Fri	X	R
1	4.50	4 60	4.50	4.40	4.40	4.48	0.2
2	4.60	4.50	4.40	4.30	4.10	4.38	0.5
3	4.60	4.10	4.40	4.40	4.10	4.32	0.5
4	4.40	4.30	4.40	4.20	4.30	4.32	0.2
5	4.30	4.30	4.40	4.20	4.30	4.30	0.2
6	4.60	4.60	4.20	4.50	4.40	4.46	0.4
7	4.10	4.30	4.60	4.50	4.20	4.34	0.5
8	4.50	4.50	4.40	4.60	4.40	4.48	0.2
9	4.40	4.20	4.60	4.60	4.20	4.40	0.4
10	4.20	4.20	4.20	4.50	4.20	4.26	0.3

Table A-5: $\overline{X}$-R Chart Data

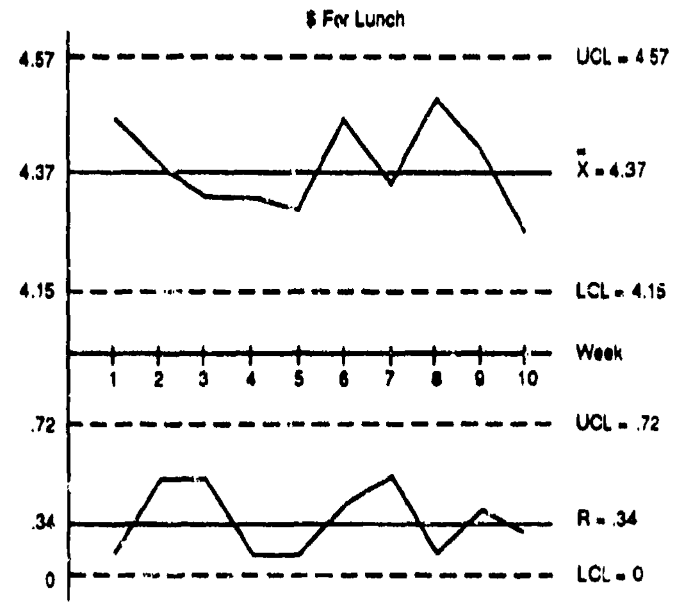


Figure A-4: $\overline{X}$ and R Control Chart $ For Lunch

Control Chart - Example 2:

$n\bar{p}$ Chart

Week	Number Of ECPs Boarded
1	9
2	7
3	4
4	2
5	4
6	5
7	2
8	3
9	5
10	5

$n = 50$

$\bar{p} = \frac{46}{500} = 0.092$

$n\bar{p} = 4.6$

UCL = 10.73

LCL = 0.0

Table A-6: ECPs Boarded Per Week ($n\bar{p}$-Chart)

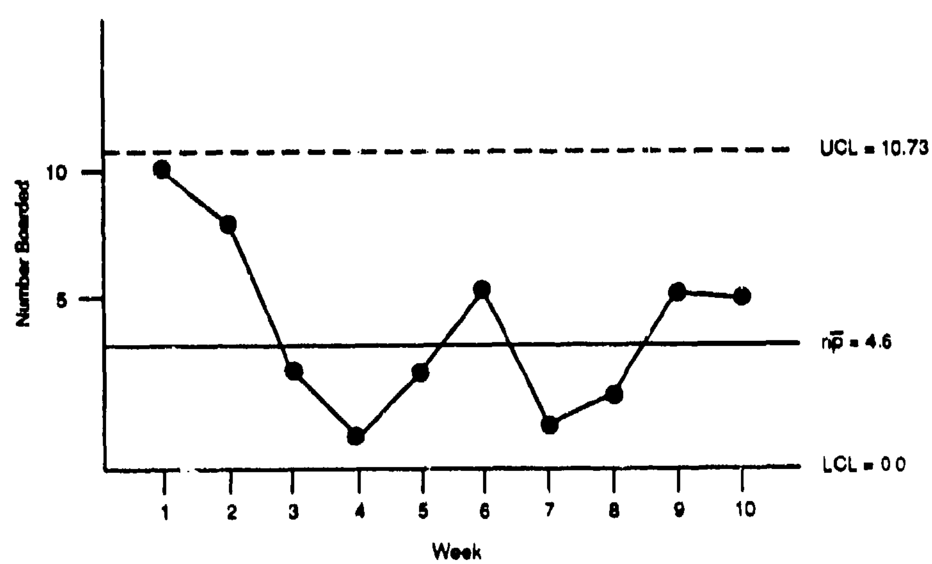


Figure A-5: ECPs Boarded Per Week ($n\bar{p}$-Chart)

Control Chart Example 3:

The following is an example from SSD in which several types of control charts were used to analyze a Service Report process.

Control Charts

Sample Month	X	R	p
1	143	244	0.71
2	139	348	0.71
3	116	337	0.54
4	84	9	0.54
5	88	155	0.52
6	60	133	0.54
7	90	154	0.60
8	210	294	0.51
9	125	241	0.74
10	51	29	0.47
11	56	64	0.62
12	65	56	0.39
13	143	351	0.43
14	—	—	0.65
15	—	—	0.70
Central Line	105	186	0.58
UCL	212	393	0.76
LCL	0	0	0.40

Table A-7: Service Reports Control Chart Data

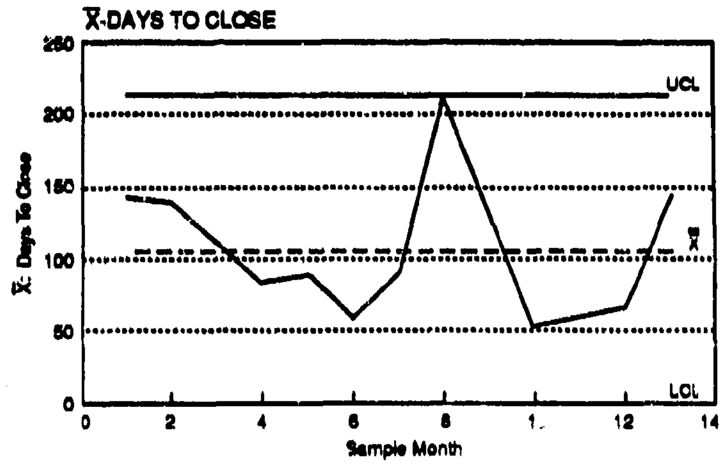


Figure A-6: Service Reports Time To Close-$\bar{X}$ Chart

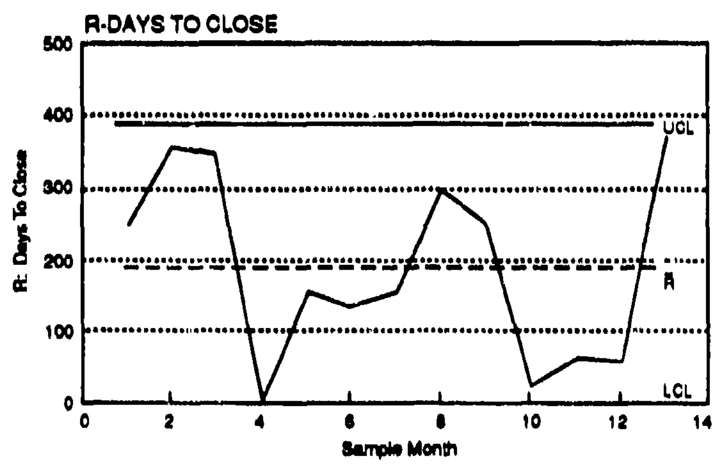


Figure A-7: Time To Close-p Chart

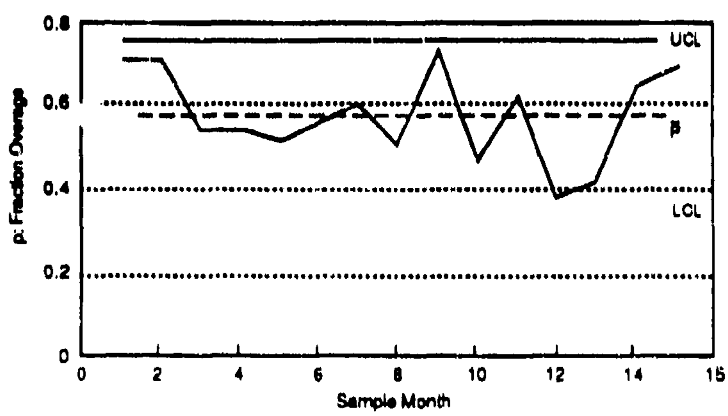


Figure A-8: SR Fraction Of Open Reports Overage p-Chart

Flow Chart

What It Is:

A flow chart is a graphic representation of all the major steps of a process. It can be used to help:

- Understand a complete process.
- Identify the critical stages of a process.
- Locate problem areas.
- Show relationships between different steps in a process.

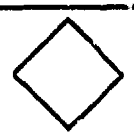
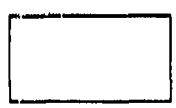
This Symbol...	Represents...	Some Examples Are...
	Start/Stop	Recieve Direction From Boss Submit Final Report Wake Up Go To Sleep
	Decision Point	Approve/Disapprove Accept/Reject Yes/No Pass/Fail
	Activity	Fill Out Travel Voucher Walk Down To CBPO Brush Teeth Get Dressed

Table A-8: Flow Chart Symbols

How to use it:

- Define the start point and finish point for the process to be examined.
- Describe the current process, charting the whole process from beginning to end. You can use the symbols shown in the figure to improve the clarity of your flow chart, but don't get hung up on symbols.
- Chart the ideal process and try to identify the easiest and most efficient way to go from the "start block" to the "finish block." While this step isn't absolutely necessary, it does make it easier to do the next step...
- Search for improvement opportunities. Identify all the areas that hinder your process or add little or no value. If you did the previous, optional step, examine all areas that differ from your ideal process and question why they exist.

- Build a new flow chart that corrects the problems you identified in the previous step.

Helpful Hint:

Consider putting the steps of your process on index cards or stick-back note paper. This lets you rearrange the diagram without erasing and redrawing. Making it easy to reconfigure the diagram encourages contributions.

Flow chart example:

The following flow chart was built to show the administrative process for an Air Force Form 9.

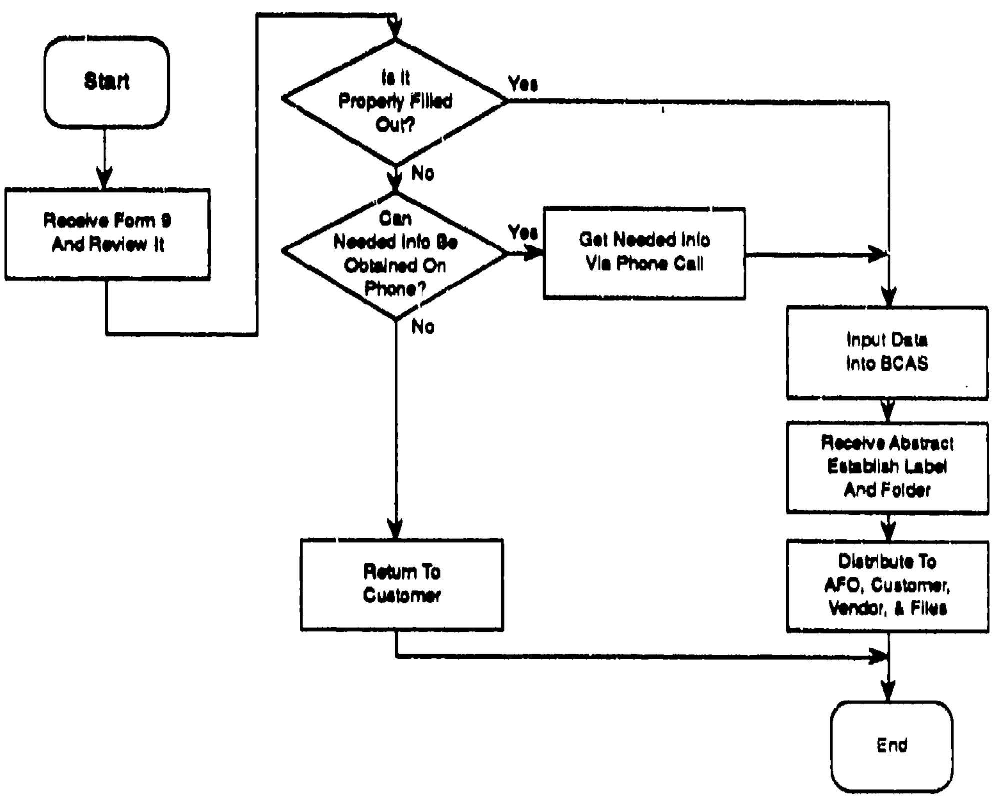


Figure A-9: Flow Chart For AF Form 9 Process

Cause & Effect Diagram

What It Is:

A cause and effect diagram graphically illustrates the relationship between a given outcome and all the factors that influence this outcome. It is sometimes called an Ishikawa Diagram or a Fishbone Diagram. Cause and effect diagrams provide a structured approach to determining the root causes of a problem, an objective, or some other effect. They can be used to:

- Determine the factors that cause a positive or negative outcome or effect.
- Focus on a specific issue without resorting to complaints and irrelevant discussion.
- Identify areas where there is a lack of data.

How to use It:

- Specify the effect to be analyzed. The effect can be positive, e.g. objectives,or negative, e.g. problems. Place it in a box on the right side of the diagram.
- List the major categories of the factors that influence the effects being studied. The "4 Ms" (methods, manpower, material, machinery) or the "4Ps"(policies, procedures, people, plant) are commonly used as a starting point.
- Use an idea-generating technique to identify the factors and subfactors within each major category. An easy way to begin is to use the major categories as a catalyst. For example, "What policies are causing...?"
- Look for factors that appear repeatedly or are a root cause to the effect and list them.
- Prioritize your list of causes using a decision-making tool. Keep in mind that the location of a cause in your diagram is *not* an indicator of its importance. A subfactor may be the root cause to all of your problems.

Helpful Hint:

Consider using an objective instead of a problem as the effect to be discussed. A problem oriented focus may produce "finger pointing," while focusing on desired outcomes foster pride and ownership over productive areas. The resulting positive atmosphere will enhance the group's creativity.

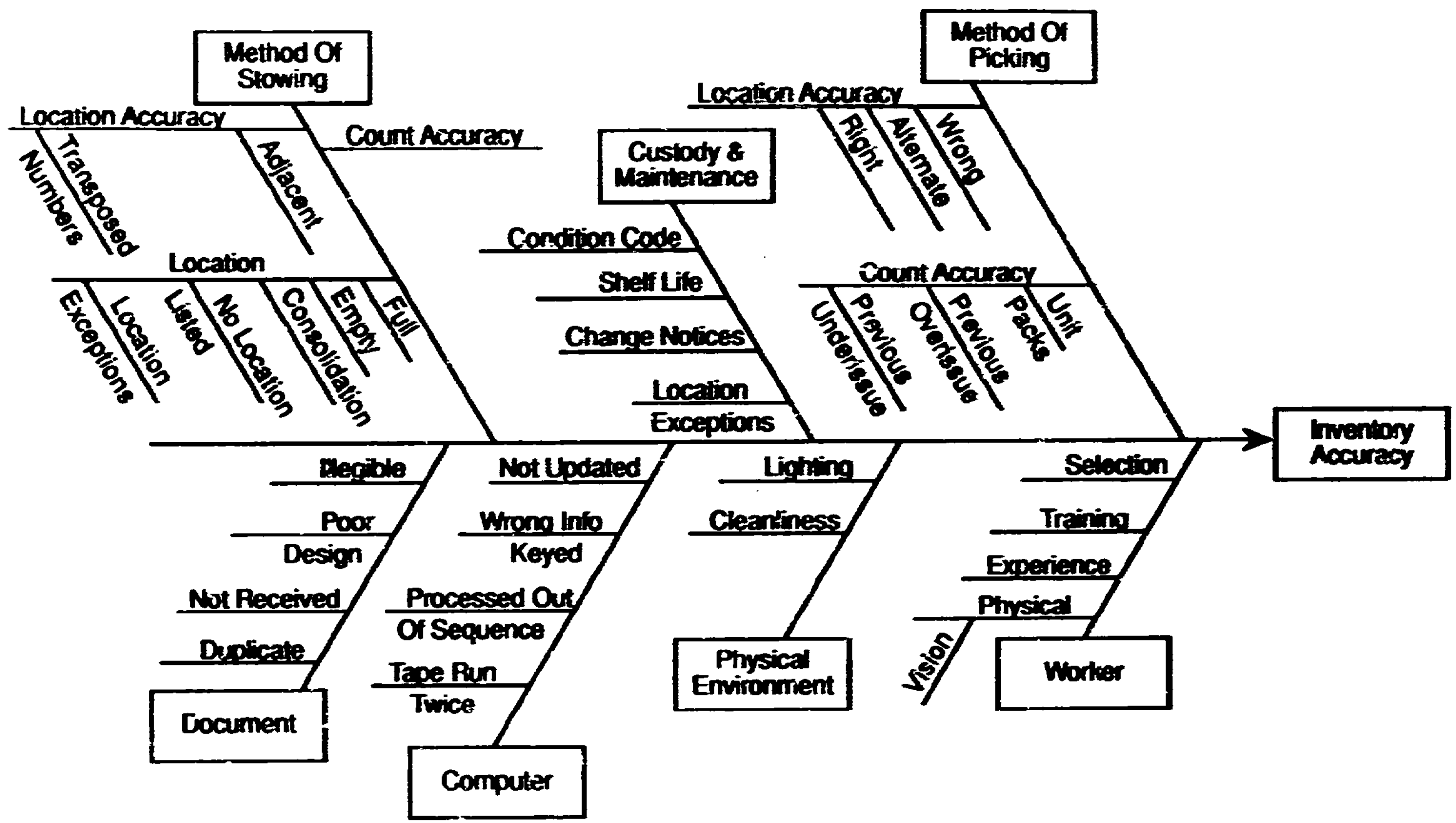


Figure A-10: Error Free Documents Cause and Effect Diagram

Check Sheet

What It Is:

A check sheet is a simple form which can be used to collect data in an organized manner and easily convert it into readily useful information. With a check sheet, you can:

- Collect data with minimal effort.
- Convert raw data into useful information.
- Translate opinions of what is happening into what is actually happening. In other words, "I think the problem is..." becomes "The data says the problem is..."

How to use It:

- Clearly identify what is being observed. The events being observed should be clearly labeled. Everyone has to be looking for the same thing.
- Keep the data collection process as easy as possible. Collecting data should not become a job in and of itself. Simple check marks are easiest.
- Group the collected data in a way that makes the data valuable and reliable. Similar problems must be in similar groups.
- Try to create a format that will give you the most information with the least amount of effort.

Check Sheet Example:

Table A-9 presents data collected on Unfunded Requirement (UR) processing times in FY91. The check sheet shown in Table A-10 was built to better understand this data.

Days To Processes URs

OBS	Days	OBS	Days	OBS	Days
1	28	8	19	11	9
2	18	7	15	12	12
3	58	8	119	13	117
4	9	9	97	14	114
5	79	10	78	15	8

Table A-9: UR Processing Time Data

Class (Days)	Observations	Total
0 - 9	|||	3
10 - 19	||||	4
20 - 29	|	1
30 - 39		0
40 - 49		0
50 - 59	|	1
60 - 69		0
70 - 79	||	2
80 - 89		0
90 - 99	|	1
100 - 109		0
110 - 119	|||	3
Total		15

Table A-10: UR Processing Time Check Sheet

Pareto Chart

What It Is:

A Pareto chart is a bar chart used to separate the "vital few" from the "trivial many." These charts are based on the Pareto Principle which states that 10-20 percent of the problems have 80-90 percent of the impact. These 10-20 percent of the problems are the "vital few" and the remaining problems are the "trivial many." Pareto charts help groups and individuals:

- Separate the few major problems from the many possible problems so that improvement efforts can be properly focused.
- Categorize and prioritize problems and/or data.
- Determine which problems that are most important using data and not intuition or perception.

How to use It:

- Use idea-generation techniques to list all the possible problems in a particular process.
- Use existing reports or collect new data on the process. Be sure these units are consistent throughout your data.
- Label the units of measure on the left vertical axis and the categories of problems on the horizontal axis.
- Order the categories according to their frequency, how many, not their classification, what kind. Use a descending order from left to right.
- Check that the labels are clear and identify the measurement units used.

Points to Remember:

- The measurement units used can significantly impact your Pareto chart. For example, 100 cosmetic-type defects may account for only a fraction of the total cost, while 2 material-type defects may account for a large percentage of the cost. You must determine if cost or number of defects is most important.
- It is essential to use the same units of measure, and clearly mark these units on the chart, ($,#, %,...).

Nested Pareto Charts:

Broad causes can be broken down into more specific areas to facilitate improvement efforts. These specific areas are "nested" within the broad causes, hence the term "Nested Pareto Charts. Figure A-14 illustrates the concept of nested Pareto charts.

Stratification Analysis:

The same data can be plotted against different potential causes to determine the significant problem. This concept is very useful when your original Pareto chart doesn't clearly identify one or two significant problem areas. Use your imagination and be creative when you define your problem categories. Figures A-12, and A-13 show an example of stratification analysis.

Pareto Chart - Example 1:

An investigation of Laser Photography reliability was undertaken at AEDC because the existing 84% reliability did not meet customer requirements.

A sample of recent test shots showed 36 failures. These occurred in three categories: trigger failures, shot failures, and system failures. 23 of the 36 were trigger failures, 7 were shot failures, the remaining 6 were classified as system failures. A simple Pareto Chart (Figure A-11) clarifies the area to investigate further. These failures were further investigated in Figures A-12 and A-13. These are examples of stratification.

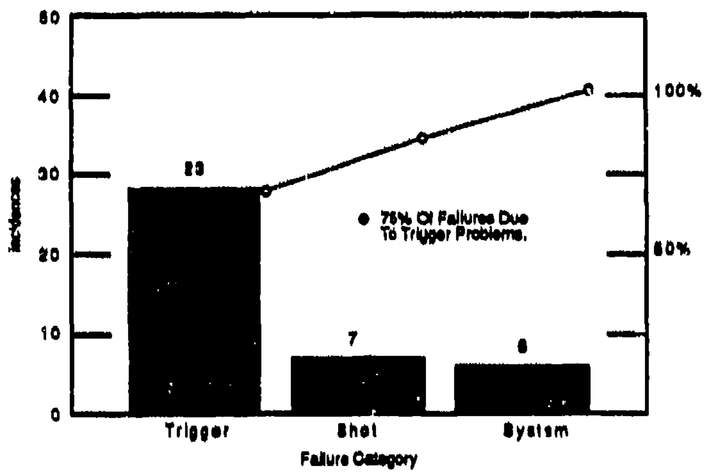


Figure A-11: Laser Photography Failures

This data identified trigger stations 24 and 8 as the main culprits of trigger failures. This led to a closer look at these stations. Marginal components at these stations were replaced and the trigger sensitivities were optimized. The data collection effort is continuing to determine if the problems located and addressed will result in improved performance.

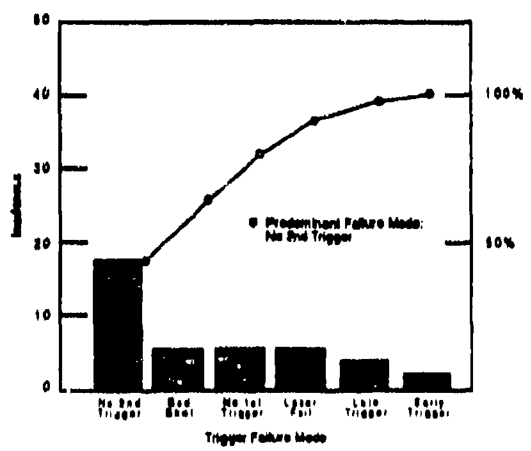


Figure A-12: Trigger Failures

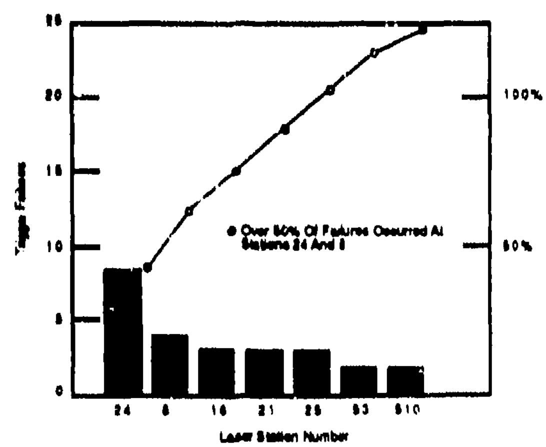


Figure A-13: Laser Station Identification

Pareto Chart Example 2:

Nested Pareto Charts

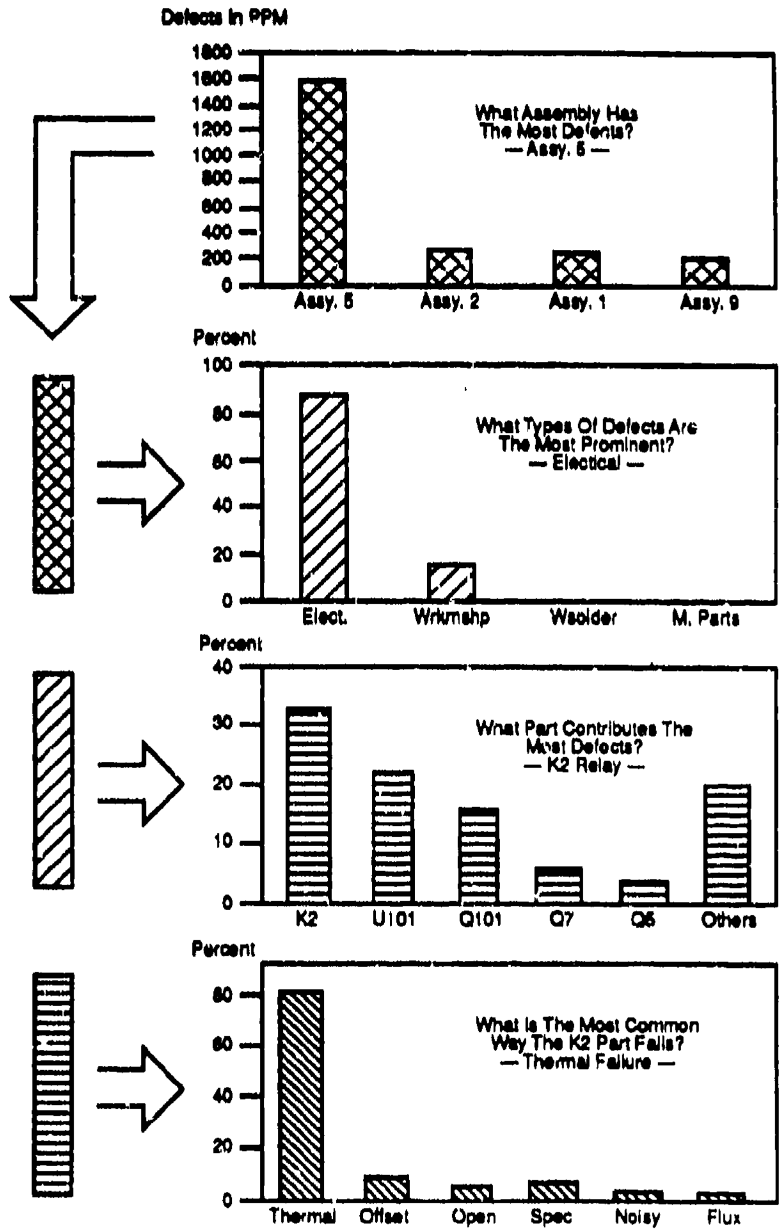


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Figure A-14: Defects Analysis

Histogram

What It Is:

A histogram is a bar graph used to depict the variability of a data set in the form of a frequency distribution. A histogram can help a group or individual:

- Display the variability in a data measurement.
- Quickly and easily assess the shape of the underlying distribution of a process.

How to use It:

- Collect as many measurable data points, i.e., time, length, speed..., as possible.
- Count the total number of points you have collected.
- Subtract the smallest value in the dataset from the largest. This value is the range of your dataset.
- Divide the range into a certain number of intervals, or bars, on the graph. Use the following guidelines to determine the appropriate number of intervals to use.

Number of Data Points	Number of Intervals
Under 50	5-7
50-99	6-10
100-249	7-12
Over 249	10-20

- Divide the range by the number of intervals. Round your answers up to a convenient value. For example, if the range of the data is 17 and you have decided to use 9 intervals, then your interval width is 1.88. This can be rounded to 1.9 or 2.0. It is helpful to have intervals defined to one more decimal place than the data collected.
- Determine the starting point of each interval. Start with the smallest data point as the starting point of the first interval. Now add the interval width that you determined in the previous step. The sum is the starting point for the next interval. For example, if your smallest data point is 10, the next is 12 and so on. Label these intervals along the horizontal axis.

- Count the number of data points that fall within each interval and plot this frequency on the histogram. Keep in mind that each datapoint can appear in only one interval. For example, if your first interval begins with 10.0 and the second with 12.0, then all data points that are equal to or greater than 10.0 and still less than 12.0 are counted in the first interval.

Points to Remember:

- Each data point appears on one and only one interval.
- The number of intervals can influence the pattern your data will take.
- Don't expect the histogram to be a perfect picture; variations will occur. Ask yourself if the picture is reasonable and logically correct.

Histogram - Example:

Table A-11 is a check sheet that was built from data collected on unfunded requirements processed by HQ AFSC in FY 90. This check sheet was used to build Figure A-15, a histogram that was used to display the distribution of UR processing times.

Processing Time (In Days)	Number Of Observations	Total	Range Mid-Point
0 - 19	卌 卌 卌 卌 ||	22	10
20 - 39	卌 卌 卌 卌 卌	25	30
40 - 59	卌 卌 卌 ||||	19	50
60 - 79	卌 卌 ||	12	70
80 - 99	卌 ||||	9	90
100 - 119	||||	4	110
120 - 139	|||	3	130
140 - 159	|||	3	150
160 - 179		0	170
180 - 199	||||	4	190
200 - 360	卌 ||	7	240 *
		108	

* Computed From Data Not Shown Here

Table A-11: UR Processing Time Check Sheet

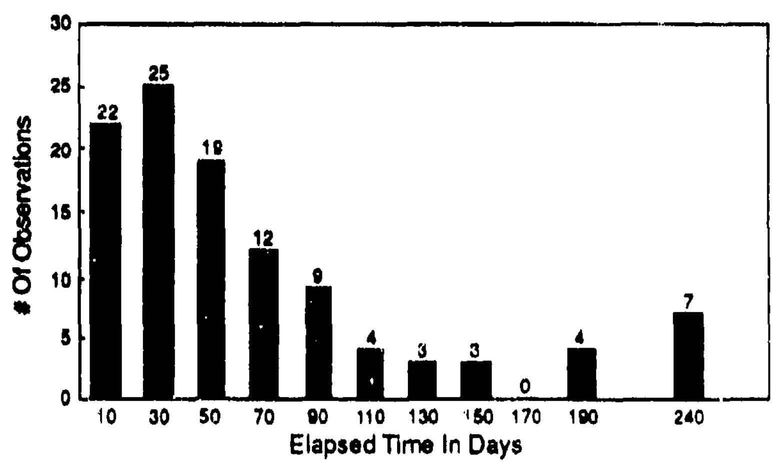

Figure A-15: UR Processing Time Histogram

Scatter Diagram

What it is:

A scatter diagram is a graph used to reveal the possible relationship between two variables. It can help a group or individual:

- Identify possible causes of problems.
- Recognize the correlation between one important variable and another.

How to use it:

- Collect the data in pairs. For each data point obtained for the first variable, a data point must be available for the second variable which represents the same time, location, or occasion. The larger the number of data points collected, the more reliable the conclusions drawn from the scatter diagram.
- Mark the horizontal axis with the name and units of measure of the variable suspected as being the causal or independent variable.
- Mark the vertical axis with the name and units of measure of the variable suspected as being the effect or dependent variable.
- Label the chart with descriptive titles and the appropriate time frame. Divide and label both axes into increments which allow all data to be plotted.

- Plot the data. As you plot each point circle repeated points. Look for patterns in the data, Figure A-16 will help you interpret patterns in the plot.

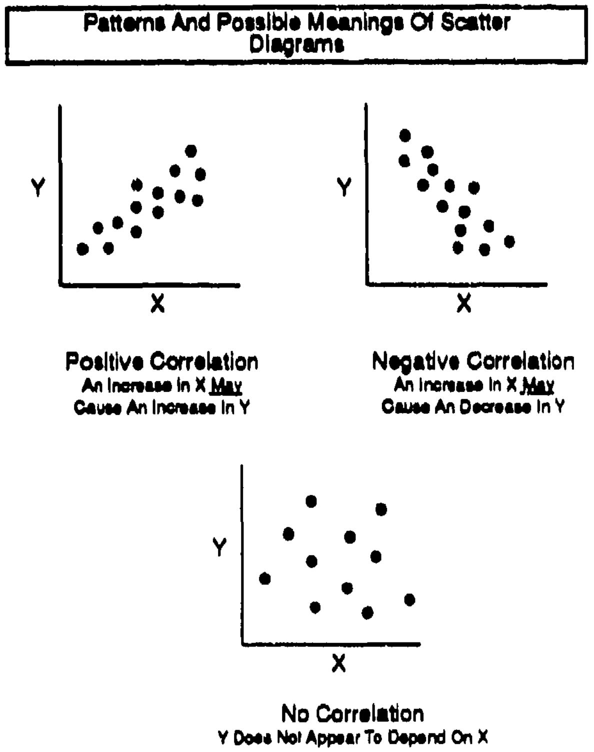

Figure A-16: Scatter Diagrams

Points to Remember:

- This technique only shows that a relationship exists, not that one variable causes the other. In general, it is wise to not base conclusions about cause-and-effect relationships solely on the basis of a scatter diagram.

- As with all statistical tools, it is better to have more data than not enough. Scatter diagrams based on small sample sizes can be misleading.

Scatter Diagram Example:

This example shows actual data from a manpower study. The measurement was taken to determine if a relationship for predicted workload could be established.

Work Center: Base Supply Funds Management

Workload Factor (WLF): An Item Record Loaded

WLF Definition: The Average Monthly Number Of Item Records For Base Supply For Which Supply Inventory Section Performs Inventory

Location	Manhours (Y)	Avg. Workload* (X)
Aviano	258.08	41.65
Bentwaters	323.81	65.64
Hahn	301.45	73.74
Lackland	279.56	16.86
Lowry	350.80	42.76
Williams	222.75	40.04
Wright-Patterson	529.35	130.37
Dover	292.08	55.16
Little Rock	355.09	90.56
Hickam	515.46	95.52
Kadena	496.79	127.79
Carswell	265.24	72.50
Fairchild	405.44	72.43
Malmstrom	299.52	64.90
Pease	357.16	54.21
Whiteman	247.47	29.17
Edwards	438.11	101.75
Mt. Home	439.24	54.56
Myrtle Beach	340.76	40.23

* In Thousands

Table A-12: Workload Factor Study Data

When the measurement data in Table A-13 was plotted on Figure A-18 a strong positive correlation between manhours required and item records loaded was identified. This information was then regressed, and the results became the basis for manning levels at base supply shops.

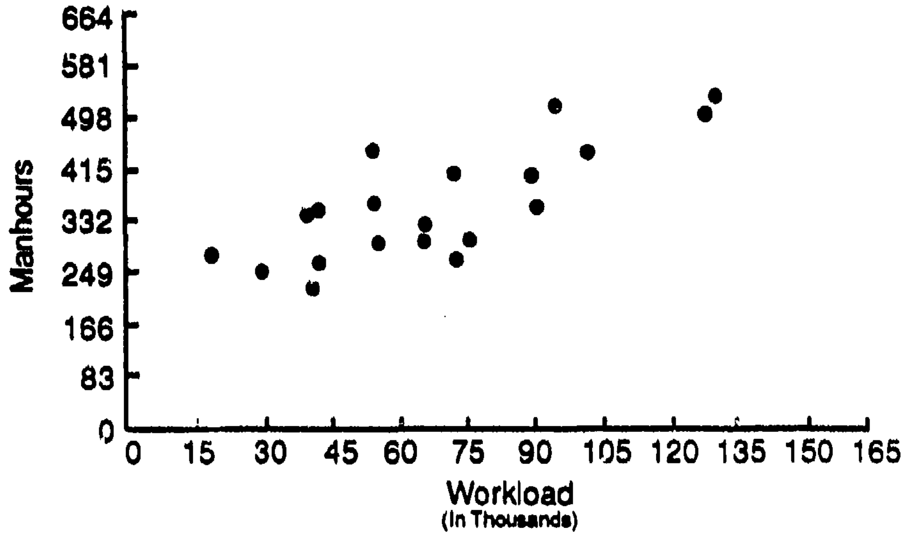

Figure A-17: WorkLoad Factor Study Scatter Diagram

Appendix B: Glossary

Activity • Segments of processes that, when coordinated, add up to a particular process.

Benchmarking • A reference point established by the "lead" organization within an "Industry" that can be used as a comparison point for other organizations in the same "Industry."

Best practices • Closely related to benchmarks, these are the state-of-the-art process execution practices.

Big Picture Metric (BPM) • A top level measure of the health of the command and/or its critical processes. It should have a direct link to the Command's Goals. A BPM will usually be supported by one or more command standard metrics. There will be a select few BPMs, designated by the Command Leadership.

Cause • A proven reason for the existence of a defect.

Cause and effect diagrams • A diagram that graphically illustrates the relationship between a given outcome and all the factors that influence this outcome. Also called Ishikawa or Fishbone Diagram.

Check Sheet • A simple form used to collect data in an organized manner

Command Standard Metric (CSM) • A metric for which a common approach for measuring, reporting and presenting has been agreed to by the Field Commanders.

Command standard presentation format • A standard for graphically presenting data. A command standard for chart format. A format should not be confused with the metric itself.

Common cause • A source of variation that is always present; part of the random variation inherent in the process itself.

Control charts • A tool used to analyze process variability over time. They measure the process in a time dimension and show movement toward or away from an average. Control charts have statistically calculated upper and lower control limits.

Control limits (Upper & Lower) • Statistically derived limits that represent upper and lower bounds for processes that are considered "in control."

Customer • An organization or individual to whom you provide a product or service.

Detection • A reactive quality assurance strategy that attempts to identify unacceptable output after it has been produced and separate it from the good output. Also known as inspection.

Fishbone diagram • See "Cause and Effect Diagram."

Flow chart • A graphic, structured representation of all the major steps in a process.

"4Ms" • Major categories often used to build a Cause and Effect Diagram. Manpower, Machines, Methods, Materials.

"4Ps" • Major categories often used to build a Cause and Effect Diagram. People, Procedures, Policies, Plant.

Goal • A statement describing a desired future condition or change without being specific about how much and when.

Histogram • A bar chart used to depict the average and variability of a data set.

Ishikawa diagram • See "Cause and Effect Diagram"

Metric • A measurement, taken over a period of time, that communicates vital information about a process or activity . A metric should drive appropriate leadership/management action. Physically, a metric package consists of three parts: (1) An operational definition, (2) Measurement over time, (3) A presentation package.

Metric classes • General division for types of metrics within the command. These classes are broadly related to command mission areas. There are presently 5 classes identified: Program Management, Test and Evaluation (T&E), Science and Technology (S&T), Base Operating Support (BOS), and Functional. These classes may change.

Metric package • Three elements that physically make up a metric. (1) An operational definition, (2) Measurement and data recording, and (3) Metric presentation package.

Metric presentation package • A two-part package needed to communicate a metric. This package consists of a description of the metric and a graphical illustration. The graphical illustration can be of many types but usually should be a run chart or control chart.

Mission • A single overriding goal statement for an organization. It should encompass all of an organization's significant activities.

Objective • A more specific statement describing a desired future condition or change than a goal. It includes measurable end results to be accomplished within specific time limits.

Operational Definition • A detailed, unambiguous definition that provides enough information to allow consistent, repeatable and valid measurement.

Pareto Chart • A type of bar chart used to separate the "vital few" from the "trivial many." Based on the Pareto Principal which states that 10-20 percent of the problems have 80-90 percent of the impact.

PDSA • (Plan, Do, Study, Act) cycle- A four step variation of the scientific method for managing process improvement. PDSA can be described as applied research where the emphasis is on getting things to work well without being overly concerned with the theoretical foundation. It encourages practical problem solving by people who are knowledgeable about a process (also known as Shewhart cycle).

Prevention • A proactive quality assurance strategy that improves quality by directing analysis and action towards correcting the production process.

Process • Any specific combination of machines, tools, methods, materials, and/or people employed to attain specific characteristics in a product or service. A change in any of the constituents results in a new process.

Process capability • The measured, built-in reproducibility of the product turned out by the process. Such a determination is made using statistical methods, not wishful thinking. The statistically determined pattern or distribution can only then be compared to specification limits to decide if a process can consistently deliver the product within those parameters.

Product • Output of a process. This may be goods or services.

Run Charts • A graph of a process measurement over time.

Quality • All features and characteristics of a product or service that bear on its ability to satisfy stated or implied customer needs.

Range • The difference between the smallest value and the largest value in a data set.

Service • Work performed for someone else.

Scatter diagram • A type of graph used to reveal the possible relationship between two variables.

Special cause • A source of variation that is not always part of the process, but arises because of specific circumstances; also called an assignable cause.

Stable process • A process in statistical control.

Statistical control • The condition describing a process when the variation present in that process is consistently random and predictable over time.

Statistical process control • The application of statistical techniques for measuring and analyzing the variation in processes.

Subgroup • One or more data points rationally grouped. Subgroups are used in control charts.

System • An interdependent group of items, people, or processes with a common purpose.

Task • Specific activity necessary in the function of an organization.

TQM • Total Quality Management. A leadership philosophy, organizational structure, and working environment that fosters and nourishes a personal accountability and responsibility for quality and a quest for continuous improvement in products, services, and processes.

Trend • A measurement over time extending in a general direction.

User • An external organization that uses the final product or service.

Variation • The difference among individual outputs of the same process.

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METRICS HANDBOOK

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