Seven Basic Quality Tools
Objectives

- Introduce some basic quality analysis and control tools for gaining insight from metrics
  - Seven “Basic” Quality Tools
  - Plus a few “additional” tools

- These are tools to ...
  - Analyze quality metrics data to gain insight on attainment of quality goals and opportunities for quality improvement
  - Focus quality assessment and improvement activities on high-value results
The Seven Basic Tools

- Checklists (Checksheets)
- Pareto Diagrams
- Histograms
- Run Charts
- Scatter Diagrams (Scatter Plots)
- Control Charts
- Cause-and-Effect (Fishbone) Diagrams
What Are These Tools?

- Simple techniques to:
  - Track quality performance and trends
  - Identify the existence of quality problems
  - Analyze and gain insights into the causes and sources of quality problems
  - Figure out which problems to address
  - Help eliminate quality problems
    - Defect prevention, not just detection and correction
- Basic knowledge for anyone interested in quality, engineering problem solving, and systems design
- Probably already familiar with most of these
Kaoru Ishikawa promoted the notion of seven basic tools that could be used to address quality
  - Designed for manufacturing environments, but applicable to engineering & management, too

There are other very useful tools:
  - Templates, workflow automation
  - Pie charts and other graphical representations
  - Relationship diagrams, tree diagrams, etc. (“Seven new quality tools”)
  - System dynamics diagrams and influence diagrams

We learn a basic subset here, others left to “lifelong learning”
  - Corporate training often introduces/uses quality tools & techniques
  - See the American Society for Quality (http://www.asq.org/)
What to Learn About Each Tool

- What is the tool?
- How is it used?
- For what purposes is it useful?
- What value does it add?
- What are its limitations?
- How can it be used effectively?
Histogram

- A bar graph showing frequency counts
- X axis often a nominal or ordinal scale; Y axis is how often that X value occurred in measurements or observations
- Use/value: Easy to see relative magnitudes / frequencies
  - Sometimes low frequency items are of interest
    - For example, dissatisfied customers: histogram may “minimize” these high-impact but infrequent occurrences
  - Can use different color or other ways to highlight importance
- Sometimes multiple bars for each item (e.g. last year / this year), to show trends and changes
- Pie chart representation useful if these are parts of a whole
  - Not very good if there are several low-frequency items of interest
- Sometimes cumulative frequency line added to show “total at or below this level” – useful if X axis is ordinal scale
Histogram Example: A Pizza Shop

From http://www.freequality.org
Example: Distribution of Component Size

Component Size (KLOC)

Frequency

- < 1
- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- > 10
Run Charts

- Plot of some measurement/metric vs. (usually) time
  - Use this when X axis is interval or ratio scale, such as project time, component size, team size, etc.
- Often used to show trends over time
  - Easier to spot overall upward or downward trend, or cyclical variations and other patterns
- Visually separate random from significant variation
  - Major spikes or valleys are triggers for explanation, investigation, or action
- Value: Identification of problems, trends, unexpected good results (may learn a lot from these)
Run Chart Example for Pizza Shop

From http://www.freequality.org

Getting Warmer
Cause-And-Effect (Fishbone) Diagram

- Diagram showing hierarchical structure of causes that contribute to a problem or outcome:
  - Problem of interest forms the backbone
  - Spines are causes that contribute to the problem
  - Spines may have bones that represent its contributory factors and so on
- Used in brainstorming to diagram and identify various possible factors contributing to a problem, and to identify causal sequences (A causes B causes C) and root causes
  - Very simple but extraordinarily useful tool
- Initially both minor factors (that occur rarely or contribute very little) and major causes may all get listed
Example Fishbone Diagram

- Example: High Inventory Shrinkage at local Drug Store

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Shrinkage

- Expensive merchandise out in the open
- Anti-theft tags poorly designed
- No security/surveillance

employees

- attitude
- new trainee

shoplifters

- training
- benefits
- practices
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From http://www.freequality.org
Design Inspection
Example from Tian Textbook

FIGURE 5.16
Cause-and-Effect Diagram of Design Inspection
Pareto Diagram

- Histogram arranged by decreasing frequency
- Used to identify causes that contribute most to the problem
- After fishbone analysis, may do data gathering to figure out the frequency with which each cause contributes to the problem
  - In software, review reports are good data sources
- Plot histogram, identify the major causes
- Based on Juran’s Pareto Principle – the 80/20 rule
  - “80% of the effects come from 20% of the causes”
  - Indicates general principle that some causes likely to be a lot more significant than others
- Highest cost-benefit from addressing the most significant problems
  - Less significant problems may barely be worth addressing
Pizza Shop Example

From http://www.freequality.org
Four Basic Defect Prevention Tools

- Checklists
- Templates
- Processes
- Workflow automation
Checklists

- Once we identify the causes of problems, how do we eliminate them?
  - Checklists are simple and incredibly effective at preventing & eliminating defects on repetitive tasks
    - To Do lists, “did you ...” on bill payment envelopes, etc.
- Capture knowledge about common problems and how to avoid them
- Can be used in review processes to identify problems
- Lightweight: low additional effort to use (not zero!)
- Checklists that become too long lose value (use Pareto analysis!)
Flowcharts (Process Diagrams)

- Flowcharts show sequencing of activities and decisions
  - Depiction of processes for doing things
- Streamline the flow of activities
- Capture knowledge about how to perform activities effectively
- Eliminate problems due to missed activities and badly sequenced activities
- Can be used to analyze and implement improvement ideas:
  - Good processes can save work and avoid problems
    - Less than zero cost for improving quality
    - Should always be the goal of process design
Flowchart Example for Pizza Shop

From http://www.freequality.org

Window (start)

Take Customer Order

Money?

Get Pizza

Put More in Oven

2 Pies Available?

Time to Close?

Lock Up

Take to Customer

yes

no

yes

no

no

no
Templates (A Type of “Checklist”)  

- Templates are another near zero-cost defect elimination mechanism  
  - Pre-created document structure  
  - Often pre-populated with “boilerplate” stuff: standard explanations, disclaimers etc.  
  - Avoids problems due to missing information, incompleteness  
  - Avoids problems in activity for which the document is the output  
  - Need to fill in form, so get the data/do the activity!  

- Problems with templates:  
  - Not all sections are always applicable; may sometimes want different structure  
  - Can constrain people from doing what they need to  
  - Can lead to “automaton” mode where people just fill in form without thinking if that’s the most appropriate thing to do  

- Make templates as guidelines, not “set in stone” forms
Are you using the document outline of your project as a checklist?
Workflow Automation

- Creation of computerized tools that streamline activities, such as automated check-in and build, automated testing
  - Implements process, templates
  - Eliminates many kinds of defects
  - Saves effort
- Flexibility is often a major problem
  - If the needs are different from what the tool supports, can’t do it at all (or significant work-arounds)
  - Designing flexible tools which automate workflow is a major technical challenge
Scatter Diagram

- Used to determine whether there is really a relationship between two variables
  - Fishbone cause-effect diagramming identifies possible causes
  - Doing a scatter plot can show whether the proposed cause and its effect are correlated
    - Visual plot can show degree of correlation, non-linear correlations
      - Often annotate fishbone diagram to show whether a possible cause-effect has been shown to be statistically correlated
        - Linear correlations if most points are along a straight line
        - Poor (linear) correlation if points scattered all over
  - Remember: correlation does not imply a causal relationship!
Scatter Diagrams
Measuring Relationships Between Variables

Positive Correlation
An increase in y may depend upon an increase in x.

Negative Correlation
An decrease in y may depend upon an increase in x.

No Correlation
There is no demonstrated connection between x and y.

Positive Correlation?
If X is increased, y may also increase.

Negative Correlation?
If X is increased, y may decrease.

Non-Linear Correlations?
Example Scatter Plot from Tian Text

FIGURE 5.9
Scatter Diagram of Program Complexity and Defect Level
Example Scatter Plot from Tian Text

0.69 Correlation Coefficient

95% Confidence Interval

Linear Regression Line

FIGURE 5.10
Correlation of Defect Rates of Reused Components Between Two Platforms
Example Scatter Plot from Tian Text

- Classify the scatter plot according to medians of component defect rate
  - Apply different analysis and improvement strategies to different quadrants

Components with high defects in both systems

FIGURE 5.11
Grouping of Reused Components Based on Defect Rate Relationship
Control Charts

- Plot of a metric with control limits defined
  - Upper control limit: If value of metric exceeds this, take action
  - Lower control limit: If value goes below this, take action
  - Warning levels: If value outside this, check if all is well
- Control limits may be derived statistically or less formally (based on “reasonable” values or other impacts)
  - Formal statistical process control has formulas for deriving limits: often 3 sigma deviation from desired outcome
- Useful to flag “outlier” values, such as components with very high defect rates, projects that have parameters outside “normal levels” etc.
- Formal statistical process control not used much in software
Control Charts -- Pizza Example

Upper Limit
17 inches

Lower Limit
15 Inches

16 inches = $\bar{X}$

Small Pie

From http://www.freequality.org
Conclusion

- The quality tools provide a suite of methods for quality analysis and control:
  - Histograms, run charts, control charts can identify problems
  - Fishbone is used to brainstorm possible causes
  - Scatter plots can be used to analyze whether relationships exist
  - Pareto analysis identifies which causes are most worth addressing
  - Checklists, templates, process definition and workflow automation can prevent problems