Six Sigma & Software Process Improvement

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Six Sigma Starts with Business Results

- **Six Sigma uses a metrics driven approach to continuous improvement**
  - **Starts with quantitative business goals providing direct value to the customer**
  - **Data analysis is used to identify specific processes with the greatest leverage on these goals**
  - **Critical inputs affecting process performance are identified**
  - **Goals are related to changes in process outputs**
  - **Improvements are implemented on a pilot basis**
  - **If measurements indicate goals have been achieved, improvements are institutionalized**
  - **Process performance is controlled to the new levels by controlling critical inputs**

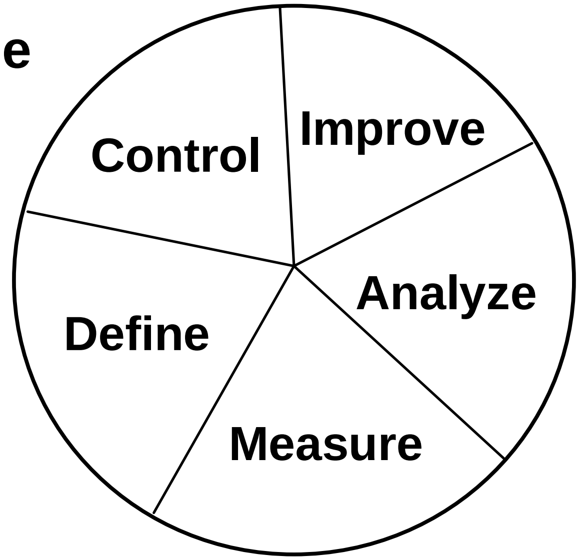
What are you going to tell your new boss when she asks you to quantify the return on your SPI activities?

"Six Sigma"

- In the narrowest sense, Six Sigma is used as a measurement of product quality
  - A Six Sigma quality level means that products have less than 3.4 defects per million opportunities, i.e. the product is 99.9997% error-free
- By extension, a process capable of producing products at Six Sigma quality levels is referred to as a Six Sigma Process
  - typical software processes operate at between 2.3 and 3.0 sigma
  - the best software processes operate at 4 - 5 sigma although they exhibit all the characteristics of a typical 6 sigma process
- In the broadest sense, Six Sigma is the application of a specific continuous improvement methodology called DMAIC (Define Measure Analyze Improve Control) used
  - in conjunction with a more or less standard toolkit of statistical analysis methods,
  - with the object of producing & managing Six Sigma processes

DMAIC

The Six Sigma Continuous Improvement Cycle

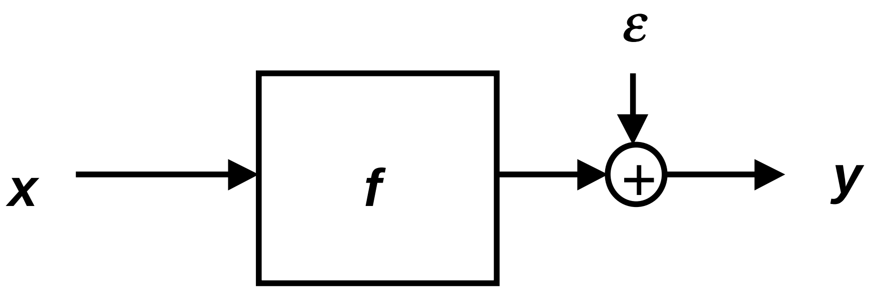


DMAIC MODEL

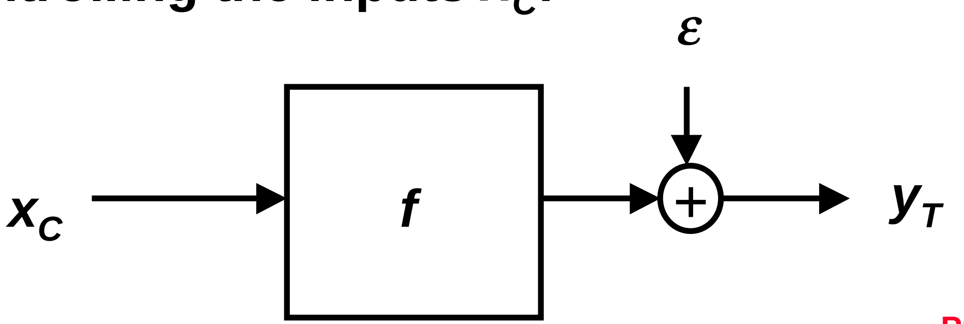
- **Define the process**
- **Measure the process**
- **Analyze the process to identify causal variables**
- **Improve the process**
  - Modify the process
  - Measure the modified process
  - Verify the improvement
  - Define control mechanism
- **Control the process to new performance levels**
  - Monitor performance metrics & take designated action when required
  - Perform continuous verification of the stability & capability of the process

A Control System Viewpoint

- **Process outputs, *y*, are a function, *f*, of a set of controllable input variables, x, and process noise ε:**
  - **$y = f(x) + \varepsilon$**
  - **The *y*'s are not directly controllable, but they can be controlled by controlling the *x*'s.**
  - **Statistical measurements are necessary to avoid re-acting to the noise ε**

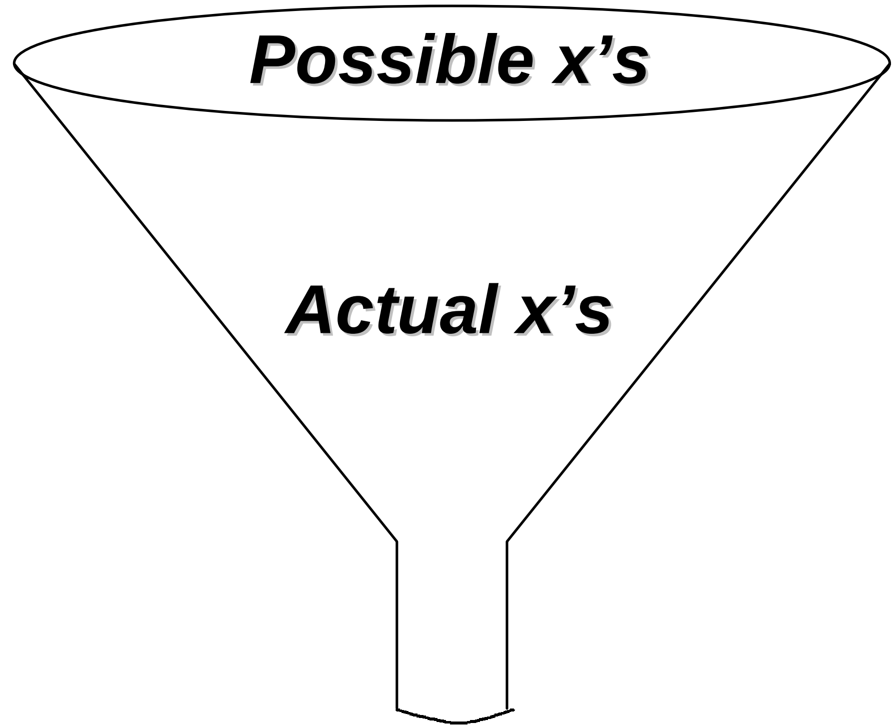


- **Six Sigma techniques are used to develop a process model, identify the control variables x_C, and drive performance to targeted values y_T, by actively controlling the inputs x_C:**



Using the Six Sigma Toolkit

Define & Measure	• Process Maps • Descriptive Statistics • Statistical Process Control (SPC) • Measurement System Evaluation (MSE)
Analyze	• Failure Mode Effects Analysis (FMEA) • Root Cause Corrective Action (RCCA) • Statistical Process Control (SPC) • Regression Analysis • Analysis of Variance (ANOVA) • Design Of Experiments (DOE)
Improve & Control	• Statistical Process Control (SPC)



Key x's

$$y = f(x)$$

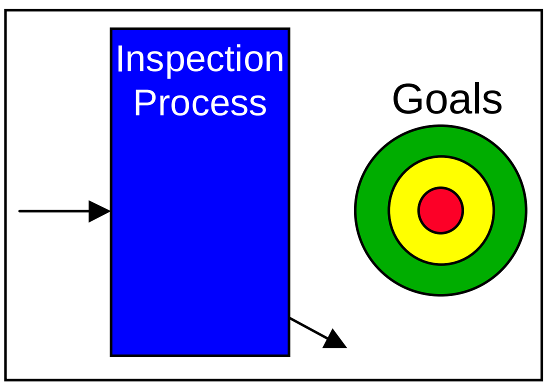
Six Sigma Toolkit is a more or less standard set of statistical tool for data analysis and modeling

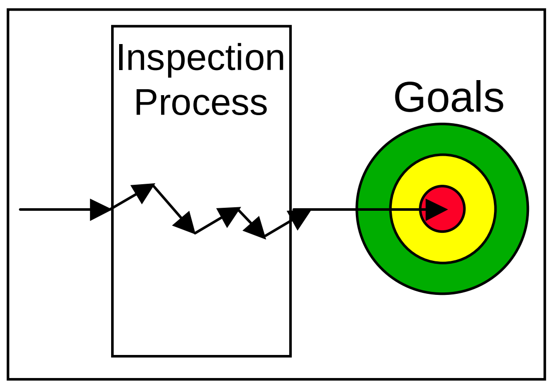
Driving CMM Based SPI With Six Sigma

- Six Sigma can drive CMM based SPI bottoms-up
- Direct coupling to business results & measurable improvements
  - allows easy quantification SPI ROI
  - moves organization away from level oriented goals – levels become a by-product of SPI, not the primary goal
  - sustains executive sponsorship
- More likely to result in measurable benefits than level goal driven process improvement
  - Objective measurements are required to successfully manage a process - a process that is not managed is unlikely to perform well
  - Apply DMAIC to one or two processes at a time as part of an SPI action plan
  - Use process metrics to access success in achieving business goals thereby quantifying process effectiveness
  - Track and report SPI ROI

Measurements, Goals, & Management

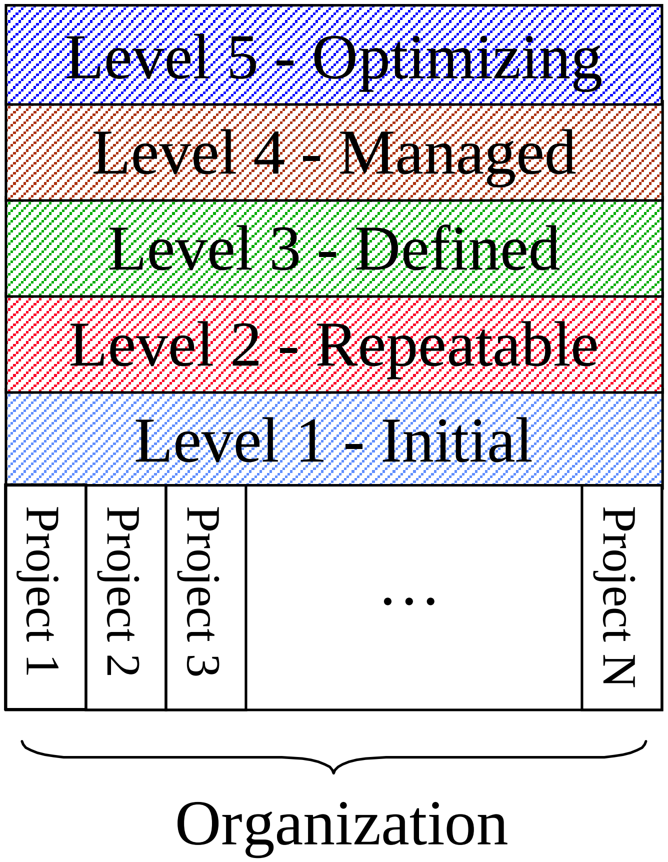
- Measurements
  - At the start, we don't know what we don't know about a process
  - If we can't measure a process, we cannot manage it much less systematically improve it.
  - If we do not actively manage a process, it's performance is a matter of chance
- Goals should be stated in terms of measurable quantities if we hope to achieve them
- Example: an inspection process that is not *actively managed* will probably be less effective in achieving its goals. It might even be counterproductive





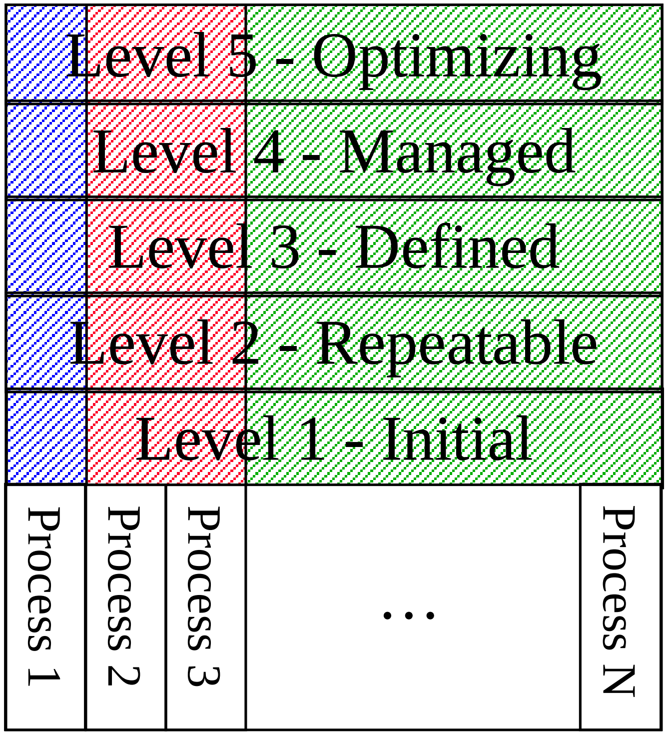
Measurements are the key to managing the process & achieving the goals

Staged Improvement Model



- **Processes at the lower levels provide the foundation for processes at the higher levels**
- **Success at the lower levels prepares the organization to accept the changes required at the higher levels**
- **Most of the organization's projects move forward more or less in parallel one level at a time**
- **The main drawback is organizational inertia – it can literally take years to move a level**

Process Deployment Model



- **Six Sigma is used to deploy processes with managed and optimizing characteristics at each individual CMM level**
- **Selection is guided by business value and CMM level**
- **Measurable successes are used to pull through the next round of process improvements**
- **Number of processes operating with managed and optimizing characteristics grows as organization moves from level 1 to level 3**
- **Organization moves from level 3 to level 5 very quickly**

Some Common Misconceptions

- Many organizations put off getting involved with six sigma until they are CMM level 3
  - A Six Sigma software process is basically a level 5 process so they wait until they are ready to move to level 4
  - Don't realize that Six Sigma as a continuous improvement methodology is applicable to any process element at any CMM level
  - Miss opportunity to make their CMM effort more likely to succeed and to achieve measurable business results
- Some organizations attempt to provide the same Six Sigma training to everyone resulting in sending software engineers to training courses appropriate for manufacturing
- Other organizations have heard about good experiences with Six Sigma in operations or services, but know that software development is not like manufacturing. So they assume that Six Sigma is not applicable because "software is different"

Software <u>is</u> different!

- **Process variation can never be eliminated or even reduced below a moderate level**
  - **No two modules are alike so process performance always includes an intrinsic degree of variability**
  - **There are very large differences in skills & experience from one developer to another that cause dramatic differences in process performance**
- **Specifications are not based around tolerances**
  - **Systems don't fail because they are assembled from many loosely toleranced components**
  - **A single well-placed defect in a low level component can be catastrophic**
  - **Concept of quadratic loss function has less applicability because the true goal is no "serious" defects**
- **Early defect removal is just as important as defect prevention**
  - **Certain classes of defects can be prevented**
  - **The application of Six Sigma to software development emphasizes defect containment & early removal as well as prevention**

But software is measurable & controllable!

- **Software development processes can be fully characterized by just three simple measurements**
  - **Time: the time required to perform a task**
  - **Size: the size of the work product produced**
  - **Defects: the number & type of defects, removal time, point of injection & point of removal**
- **Statistical analysis techniques can be applied to software measurements provided:**
  - **Data is complete, consistent, and accurate**
  - **Data from individuals with widely varying skill levels is not mixed**
- **Metrics need to be put into a statistical context before being used to make decisions**
- **Software process performance can be managed using statistical process control**

Six Sigma is applicable and has the potential for dramatic performance improvements

Process Performance Models

- In order to understand the relationship between cost and quality, we can begin by modeling the economics of the software development process
- Starts with quantitative business goals providing direct value to the customer
  - Frequently they are on-time delivery, cost, cycle time, and product quality
- In order to understand where and how to improve, one needs to understand how the development process x's drive these process y's
  - Costs are driven by productivity, product quality, and time on task
  - Cycle time is driven by cost and time on task
  - Predictability is driven by product quality

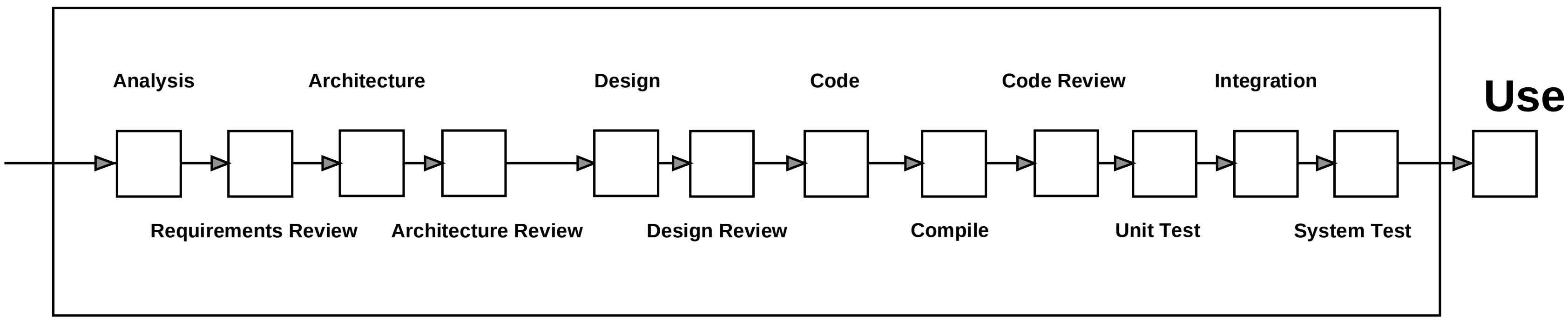
Software Development's Hidden Factory

The "Hidden Factory"

Defects are not recorded prior to system test

Yield = $n_{system}/(n_{system} + n_{escapes})$

Six Sigma View



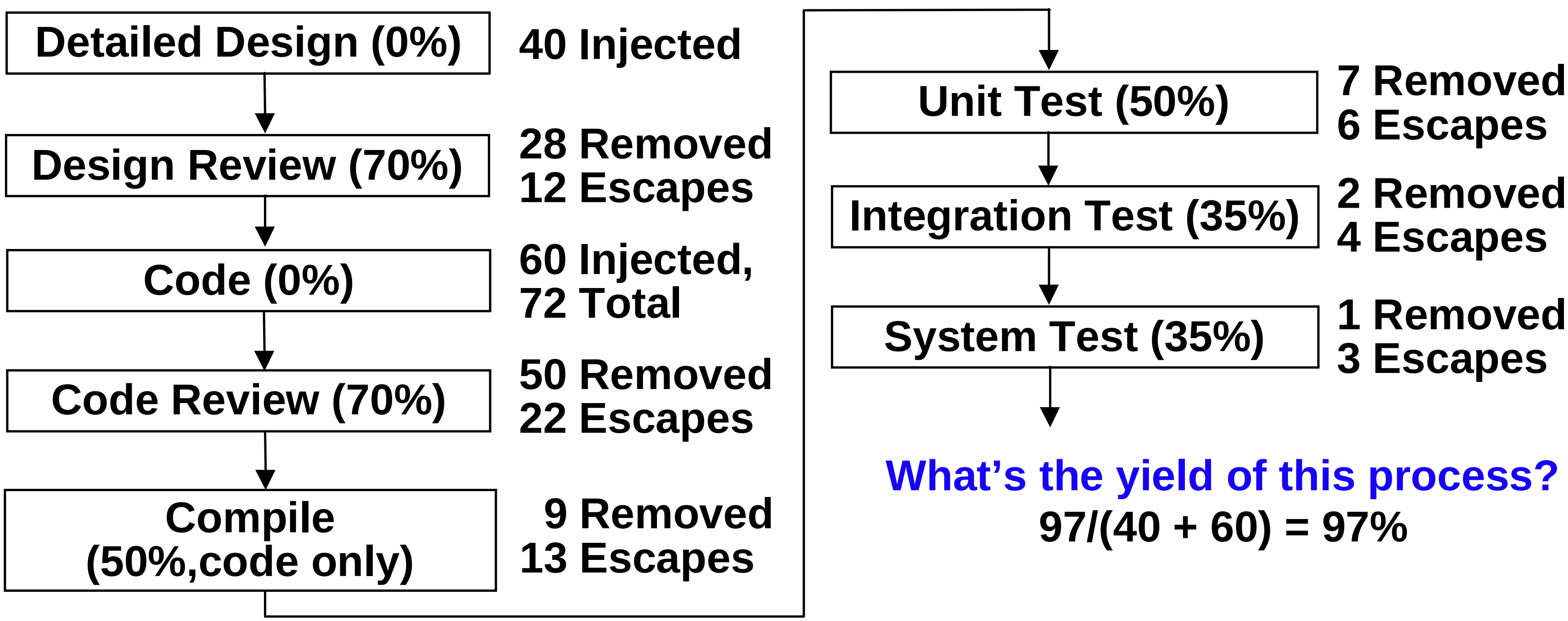
The <u>true</u> yield for the development process must include all defects injected during the development process

Yield = $n_{developmen}t/(n_{development} + n_{escapes})$

- **Usually, the later a defect is removed, the higher its removal costs**

Working with Yields

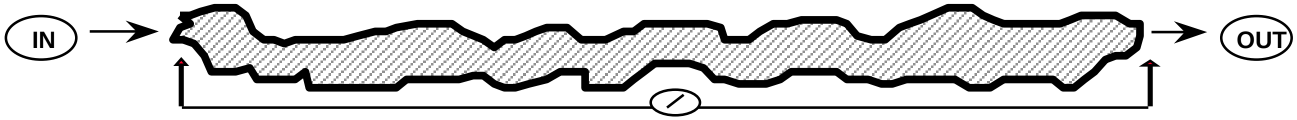
- **Historical injection numbers and yields can be used to estimate the number of defects that will be removed during each phase**
  - typical inspection yields are 50% - 80%
  - typical testing yields are less than 50%
  - typical injection rates are 100/KLOC



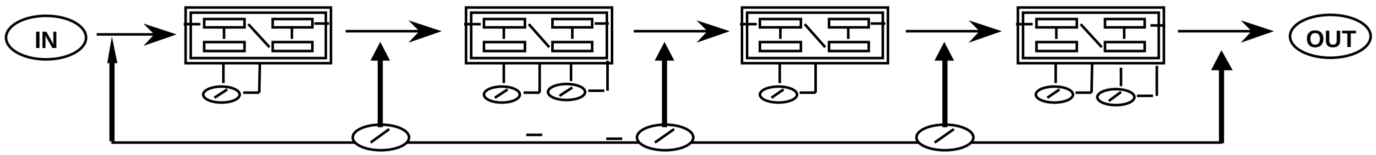
What's the yield of this process?

97/(40 + 60) = 97%

Process Modeling & Design



Are the business goals achievable?



Code & Test

Phase	Remaining	Injected	Present	Yield	Removed	Cost/Defect	Activity Cost	Failure Cost
Design	0.0	40	40.0	0%	0.0	5	0	0
Design Review	40.0		40.0	0%	0.0	5		0
Design Inspection	40.0		40.0	0%	0.0	10		0
Code	40.0	60	100.0	0%	0.0	1	2000	0
Code Review	100.0		100.0	0%	0.0	3		0
Compile	100.0		100.0	50%	50.0	1		50
Code Inspection	50.0		50.0	0%	0.0	5		0
Unit Test	50.0		50.0	50%	25.0	12	180	300
Integration	25.0		25.0	35%	8.8	300	180	2625
System Test	16.3		16.3	35%	5.7	600	180	3413
Customer Test	10.6		10.6	35%	3.7	1200	180	4436
Total (minutes)							**2720**	**10824**

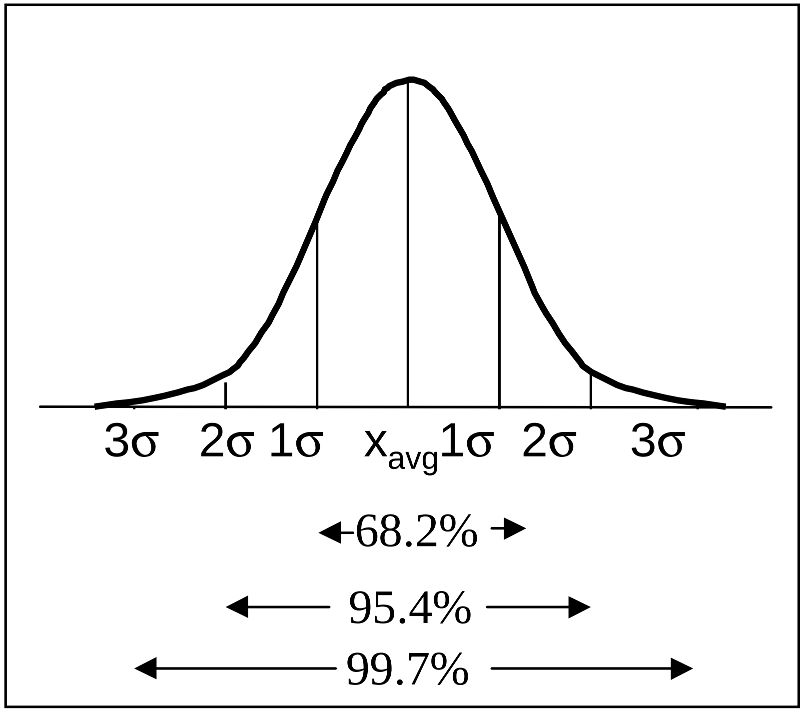
Grand Total (hrs) **226**

Variation

- Most data tends to follow the normal distribution or bell curve.
- The standard deviation (σ) measures variation present in the data

$$\sigma = \sqrt{\frac{1}{n-1}\sum (x - x_{avg})^2}$$

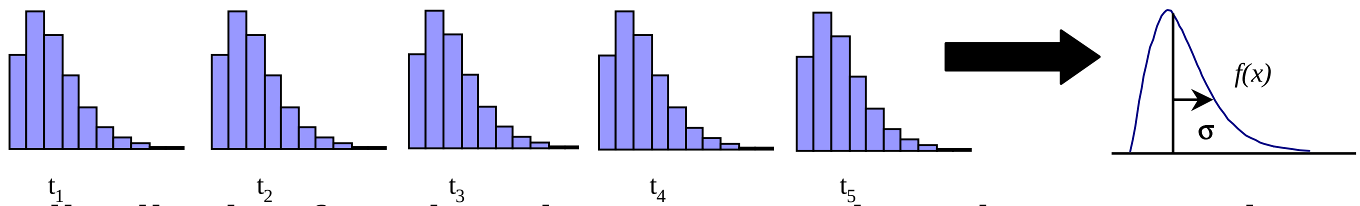
- For data that follows a normal distribution
  - 99.99999975% of the data is within ± 6σ



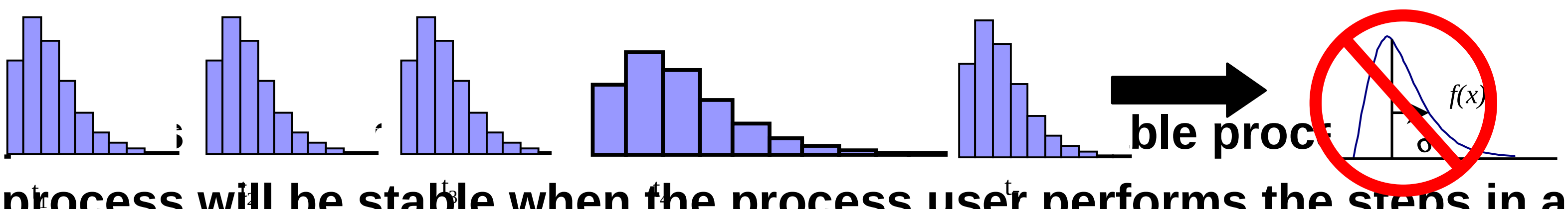
- ±3σ is natural limit of random data variation produced by a process
- The empirical rule allows us to treat non-normal data as if it were normal for the purposes of statistical process control
  - 60%-75% of the data is within 1σ of the mean
  - 90%-98% of the data is within 2σ of the mean
  - 99%-100% of the data is within 3σ of mean

Process Stability & Statistical Control

- A process exhibits statistical control when a sequence of measurements x_1, x_2, x_3,…x_n,… has a consistent & predictable amount of variation
- It is possible to model this pattern of variation with a stationary probability density function f(x) & we can make statistically valid predictions about process performance



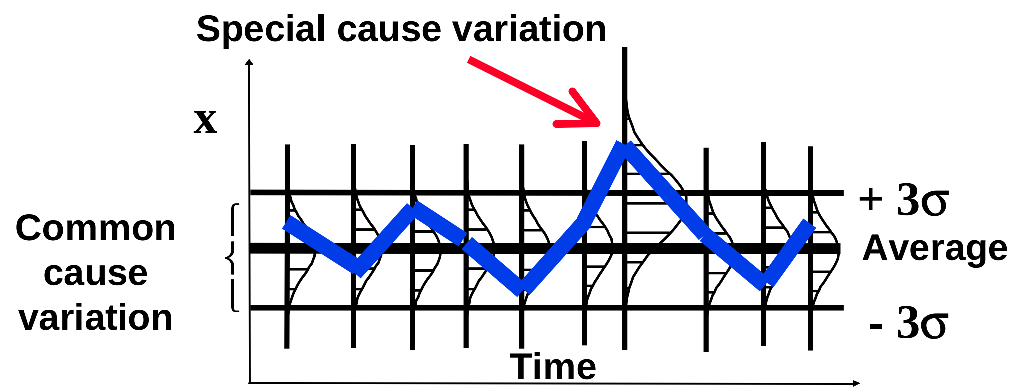
- If the distribution function changes over time, the process is not in statistical control & we can't make statistically valid predictions



- A … ble proc…
- A process will be stable when the process user performs the steps in a consistent repeatable way

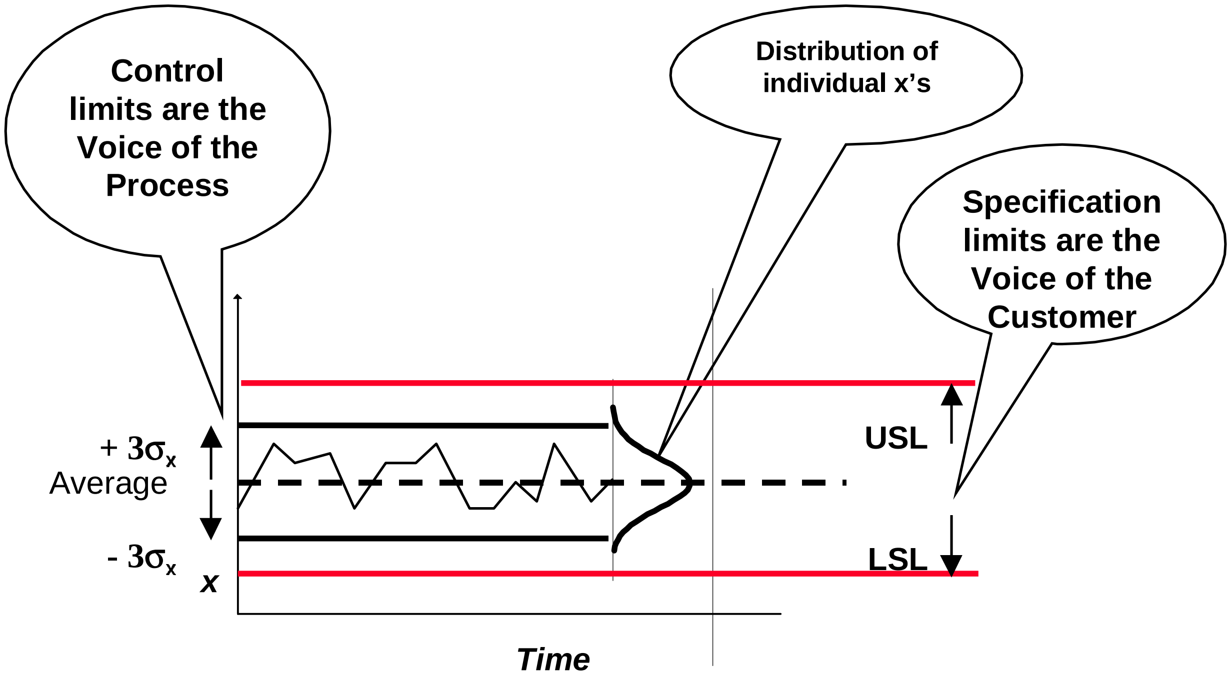
Control Charts & Process Variation

- Control charts provide a graphical depiction of the normal range of variation of a stable process
- Common cause variation is normal random variation in process performance
  - Don't over-react to common cause variation
  - Reduction requires a process change



- Special cause variation represents an exception to the process
  - Actions to correct special cause variation must eliminate a specific assignable cause
  - Special cause action eliminates a specific isolated event; does not necessarily involve a process change
- Avoid taking special cause action, designed as a one time event to correct an isolated incident, on a common cause problem that is inherent to the process

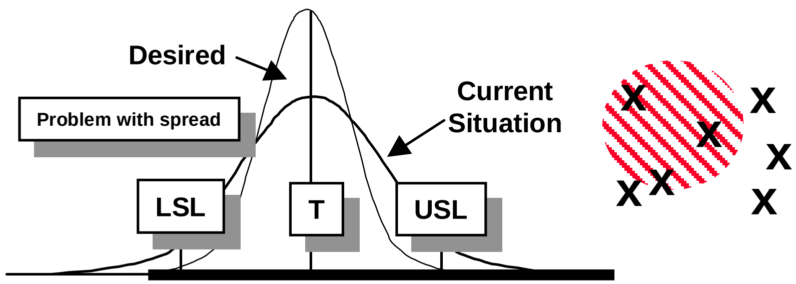
Reading XmR Charts



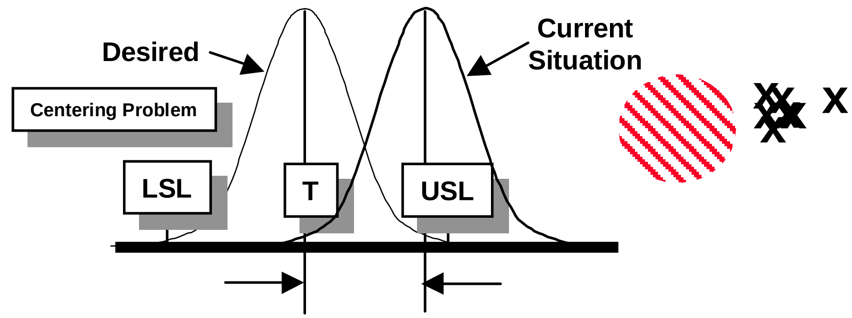
- There are many types of control charts in the Six Sigma Toolkit
- The XmR chart is most useful for software development
- Consists of two charts: X & mR (moving Range of X)
  - mR chart must be in control before you can interpret X chart
  - Sigma estimated from average moving range
- Special causes are indicated by points outside the control limits, runs of points to one side of the central line, and trends

Six Sigma Process Improvement

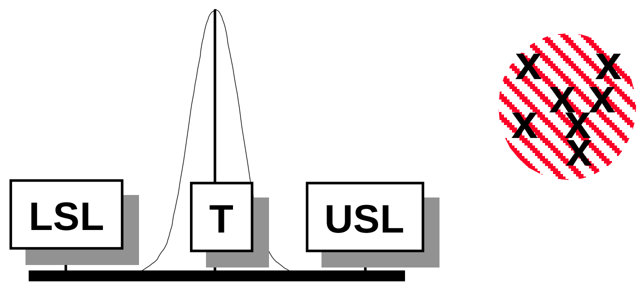
On Target but not consistent



Consistent but not on target

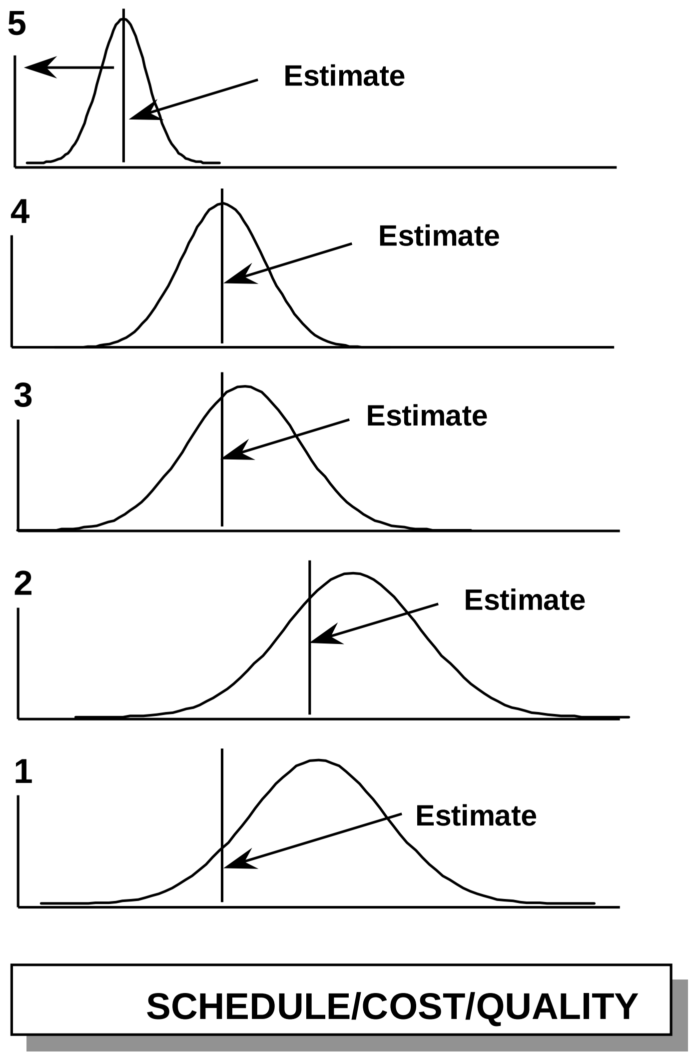


Consistently on target



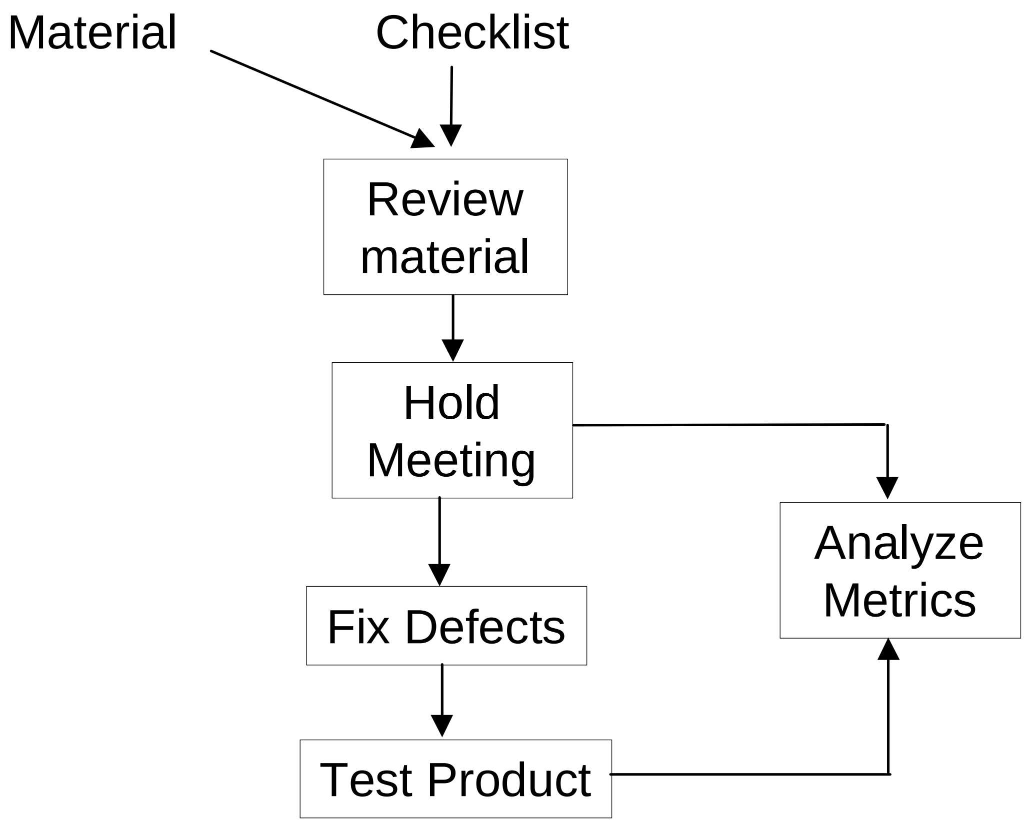
- **In order to improve a process**
  - **define it**
  - **measure it**
  - **stabilize it be eliminating common causes**
  - **systematically reduce variation and shift mean towards target**

CMM Levels – A Six Sigma Perspective



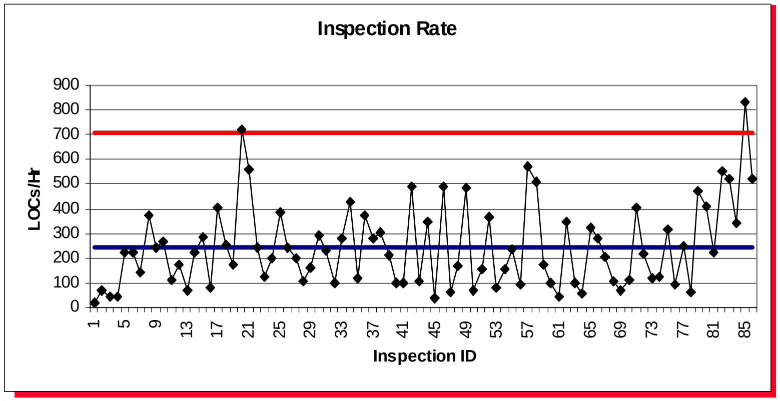
- From a business perspective, predictable process performance is a key aspect of process capability
  - Predictable performance requires a stable process
  - First step to a stable process is a "defined process"
- Moving up the CMM levels requires
  - first stabilizing the overall process,
  - centering on estimated performance,
  - reducing variation,
  - continuously improving the process by improving centering & variation
- The same cycle can be applied to any low level process at any CMM level

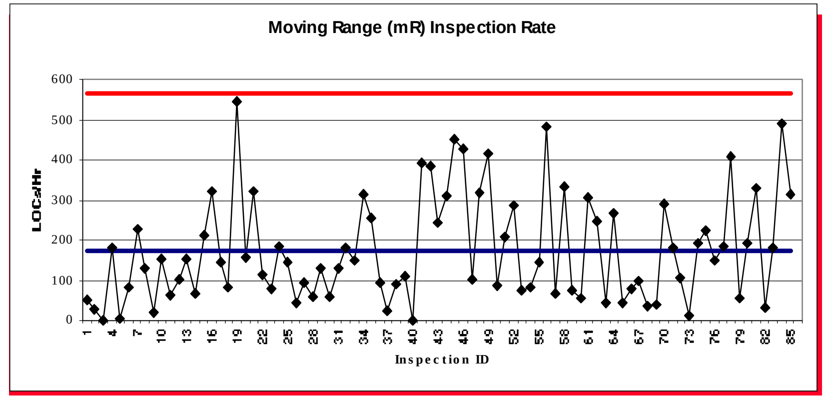
Example: Open Loop Inspection Process

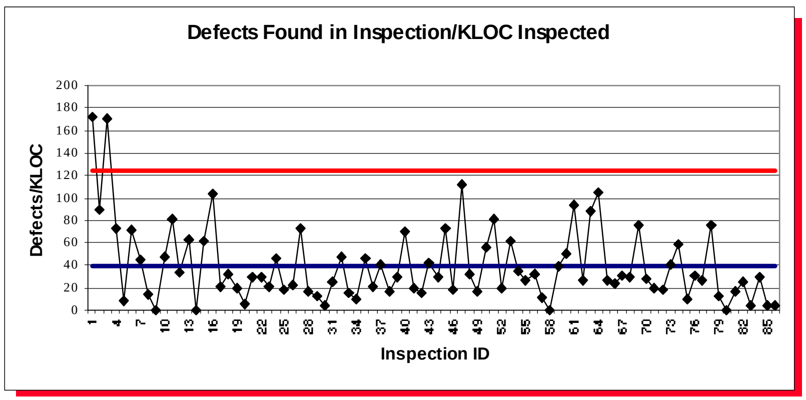


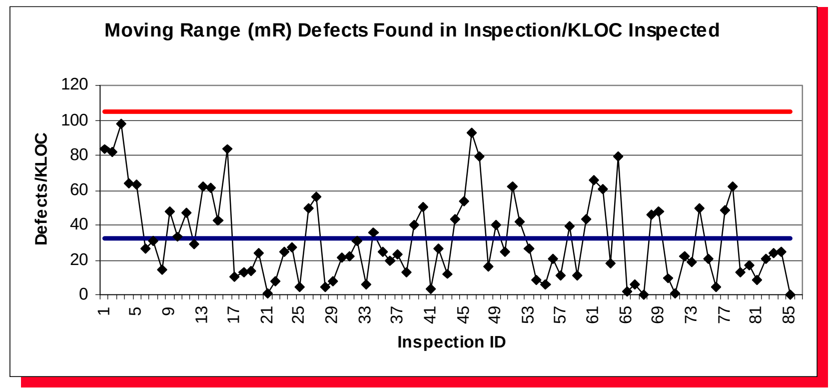
- **Optimizing the inspection process is a good place for an organization to try out a six sigma approach**

Open Loop Process Run Charts



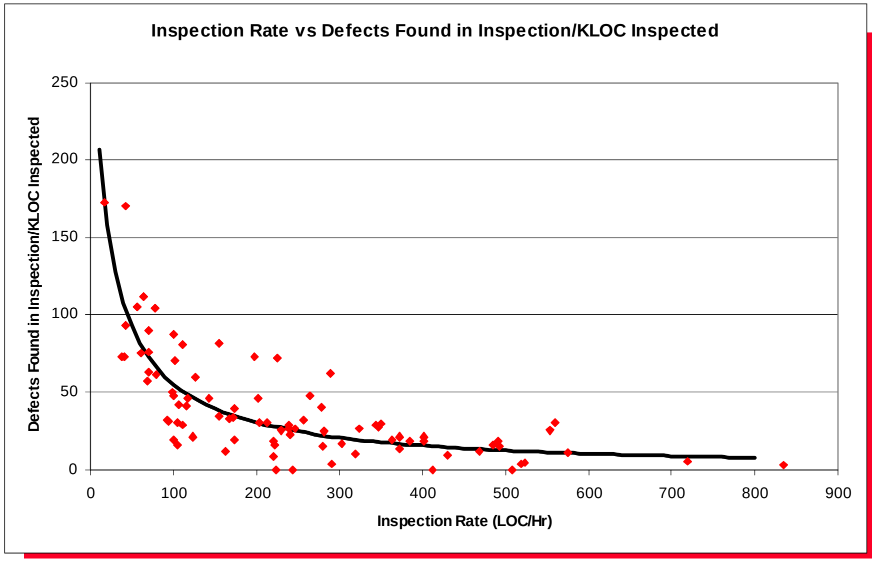




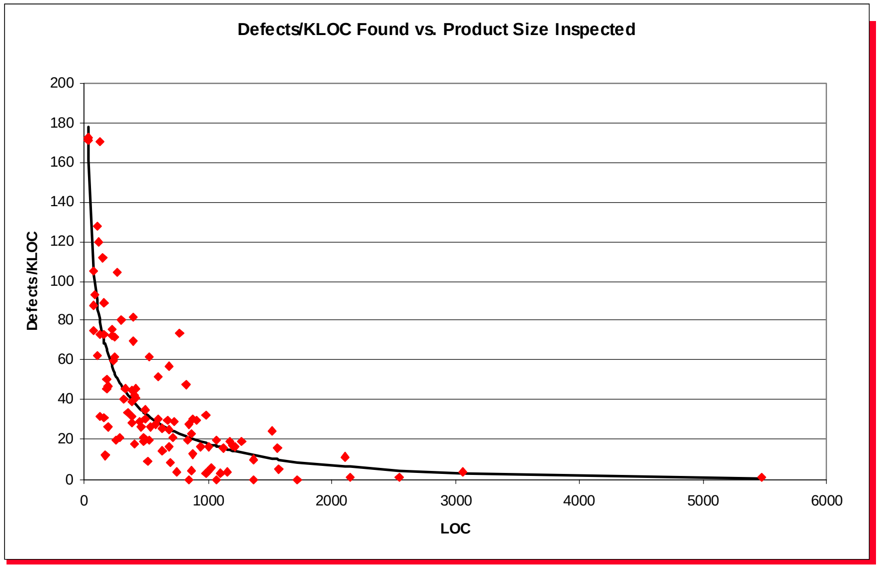


- **Average review rate 244 LOCs/Hr**
- **Average defect density 39 Defects/KLOC**
- **Average removal rate 6/Hr**

Correlation Analysis

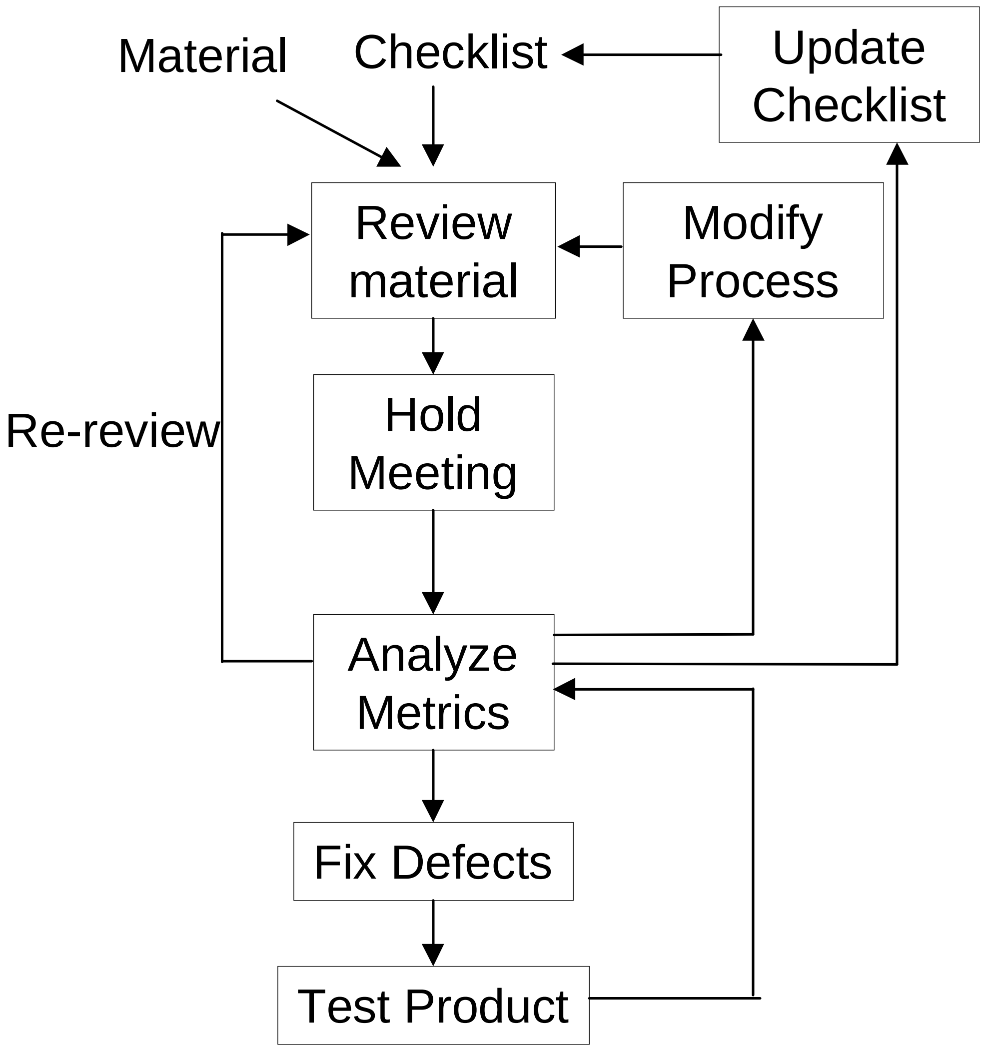


- To evaluate review rate for suitability as a control variable use correlation analysis
- $r^2 = 0.67$ – moderately good fit by hyperbola: $y = 1000/(0.1x + 3)$
- Chart suggests targeting review rate in the 100 – 200 LOCs hour range



- Similar analysis show dependency on size of product under review
- $r^2 = 0.68$ – moderately good fit by hyperbola: $y = 1000\exp(-x/2000)/ (x)^{1/2}$
- Charts suggests very little value in inspection review of large products
- Target product size < 500 LOCs

Closed Loop Inspection Process



Update Checklist

- **Remove questions that are not catching defects.**
- **Add questions to catch defects that are leaking out to test.**

Modify Process

- **Modify review rate**
- **Vary size of material reviewed**
- **Include test cases**

Analyze Metrics

- **Process metrics:**
  - **Rate vs Yield**
- **Product metrics:**
  - **Compare yields to quality plan**
  - **Re-review of products that fall outside quality thresholds**
  - **Buggiest products list**

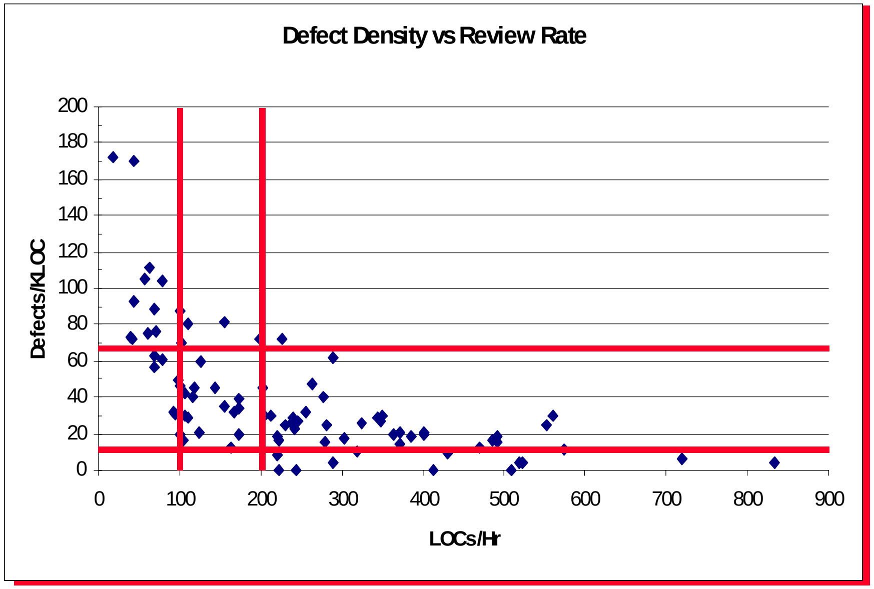
Inspection Action Plan

<u>Slow Review Rate & Many Defects</u>

Is the product really buggy?
Was the review really effective?
Was the review cost efficient?

<u>Fast Review Rate & Many Defects => Buggy Product</u>

The product is buggy.
Return to author for rework
Ask someone else to rewrite



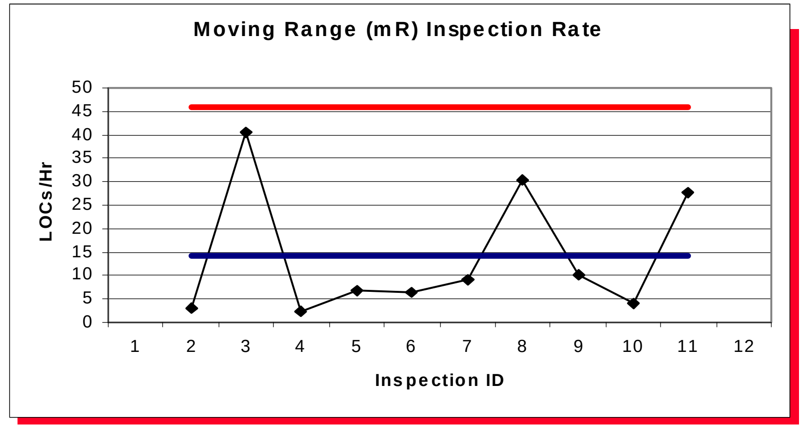
<u>Slow Review Rate & Few Defects</u>

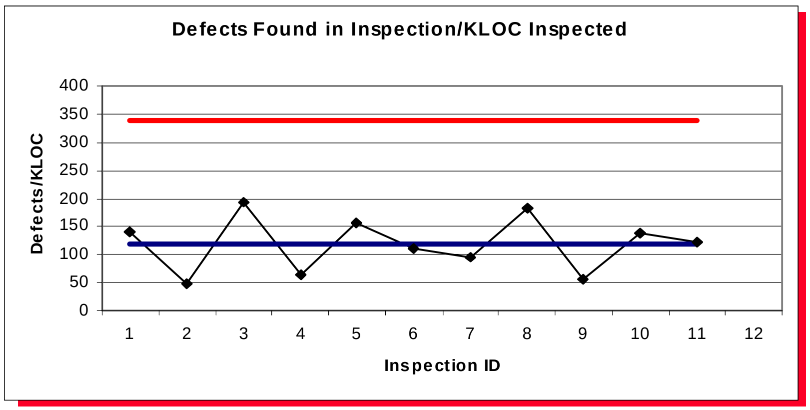
Is the product really good?
Was the review really ineffective?
Was the review cost efficient?

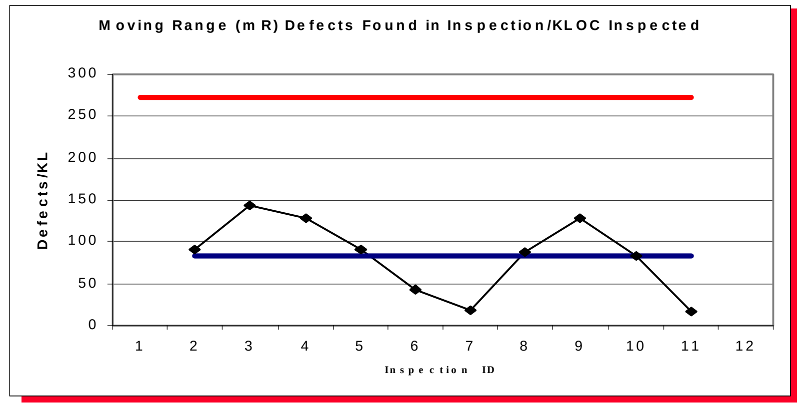
<u>Fast Review Rate & Few Defects => Poor Review</u>

Is the product really good?
Re-review at a slower rate
Make sure reviewers are using the checklist

Closed Loop Run Charts







- **Targeting rate yielded major decrease in variation**
- **Closed loop process achieved significant improvements**
  - **Average Review Rate 138 LOCs/hr**
  - **Average Defect Density 118 Defects/KLOC**
  - **Average Defect Removal Rate 15/hr**

Why Adopt Six Sigma?

- Achieve bigger savings, lower cycle times, and better predictability for the same investment
  - Initial estimates typically accurate to better than 20%
  - Estimates to go typically good to under 10%
  - Productivity up 30% - 50%
  - Product Quality better by at least a factor of 4
- Demonstrate a quantitative connection between process improvement and business goals
- Maintain sponsorship through reorganizations and changes in senior management
- Exploit corporate Six Sigma sponsorship to boost your SPI initiative
- Accelerate progress to higher CMM levels

Summary

- Six Sigma is a philosophy of doing business encompassing the methodologies of continuous improvement, statistical process control, and defect prevention
- Six Sigma uses a metrics driven approach to continuous improvement that starts with understanding business objectives
- Six Sigma demonstrates a quantitative connection between process improvement and business goals
- Six Sigma techniques can produce a software product of predictable quality at a predictable cost that meets the business and customer objectives
- Six Sigma can be used by software organizations at any level of CMM maturity.
  - Organizations that delay until CMM level 4 may miss the opportunity to make their CMM effort more likely to achieve measurable business results
  - Consider combining a Six Sigma approach to SPI at the tactical level with a CMM approach at the strategic level

References

- For additional information see our web site or for questions contact:

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- For more on statistical process control see
  - *Understanding Statistical Process Control*, Donald J. Wheeler & David S. Chambers, SPC Press, 1992

www.SoftwareSixSigma.com