Process Improvement Based on Analytics

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Carnegie Mellon, MSE Analysis of Software Artifacts

Two Paradigms

Analytic
• based on measurement, principles

Best Practice Frameworks
• practices that consistently demonstrate significant improvements to the bottom line

Important analytic approaches
• Goal-driven measurement
• Deming
• Juran
• Crosby
• Statistical thinking, statistical process control
• Lean methods
• Six Sigma
Wheeler’s Three Questions

What do you want to accomplish?

By what method will you accomplish your objective?

How will you know when you have accomplished your objective?

From Scientific Management (Hays, 1994)

• Quality improvement concepts originated in Frederick W. Taylor’s and Frank B. Gilbreth’s school of scientific management and in the work of Walter A. Shewhart in the early 1900s.
• Taylor believed that stabilizing processes would reduce labor-management conflict by leaving little discretion for labor or management.
• One drawback... employees thought they would lose their jobs if productivity increased dramatically.
• Quality improvement and scientific management share the same objective of stabilizing processes.
  - QI seeks to stabilize processes by eliminating special causes of variation.
  - Scientific management seeks to stabilize processes by breaking down jobs into simple steps to be performed repeatedly without deviation.
Evolving Quality Philosophies

Taylor's Scientific Management

*Industrial engineering*

Shewhart's statistical process control

*World War II quality initiatives*

Deming, Juran, ... in Japan

Quality rediscovered as TQM in USA

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Defining Quality

(Reeves, 1994)

Quality defined as *excellence* can provide powerful motivation to a workforce.

Quality defined as *value* or *conformance* to specifications can lead an organization to focus on efficiency.

Quality defined as meeting and/or exceeding *expectations* compels management to keep abreast of changes in consumer demands.

Excellence provides limited practical guidance.

Value and quality typically represent different concepts.

Conformance to specifications may cause managers to focus on internal efficiencies while neglecting external effectiveness.

Understanding and measuring consumers’ expectations is problematic.
Juran – Quality as Fitness for Use

Quality of design
• distinguish a Rolls Royce from a Chevy

Quality of conformance
• matching actual product and design intent

Availability

Safety

Field use
• a product’s conformance and condition after it reaches the customer’s hands

Dimensions of Quality

• Performance
• Features
• Reliability
• Conformance
• Durability
• Serviceability
• Aesthetics
• Perceived quality

ISO/IEC 9126 (Software Quality Characteristics)
• Functionality
• Reliability
• Usability
• Efficiency
• Maintainability
• Portability
One of the dangers in enterprises as complex as software engineering is that there are potentially so many things to measure...

In goal-driven measurement, the primary question is not

“What measures should I use?”

Rather, it is

“What do I want to know or learn?”

Goal-driven measurement is not based on a predefined set of measures.
Reasons for Measuring

Characterize – to gain understanding of processes, products, resources, and environments and to establish baselines for comparison with future assessments

Evaluate – to determine status with respect to plans

Predict – so that we can plan; involves understanding relationships

Improve – identify roadblocks, root causes, inefficiencies, and other opportunities for improving product quality and process performance

Ten Steps of Goal-Driven Measurement

1. Identify your business goals.
2. Identify what you want to know or learn.
3. Identify your subgoals.
4. Identify the entities and attributes related to your subgoals.
5. Formalize your measurement goals.
6. Identify quantifiable questions and the related indicators that you will use to help you achieve your measurement goals.
7. Identify the data elements that you will collect to construct the indicators that help answer your questions.
8. Define the measures to be used, and make these definitions operational.
9. Identify the actions that you will take to implement the measures.
10. Prepare a plan for implementing the measures.
Measurement Goals

Translate issues and questions into clearly stated measurement goals.

Steps 1-4 are to get to point where GQM paradigm can be applied effectively.

Adding an “indicator” step is helpful...
• a picture or display of the kind one would like to have to help answer the question

Active measurement goals – directed toward controlling processes or causing changes to products, processes, resources, or environments.

Passive measurement goals – enable learning or understanding.

Operational Definitions

The rules and procedures used to capture and record data

What the reported values include and exclude

Operational definitions should meet two criteria
• Communication – will others know what has been measured and what has been included and excluded?
• Repeatability – would others be able to repeat the measurements and get the same results?
“An operational definition [is one] which reasonable men can agree on and do business with.”

“Shewhart believed his work on operational definitions to have been of greater importance than his development of the theory of variation and of the control chart.”

“There is no true value of anything.”

Chapter 7 in Henry R. Neave, The Deming Dimension.

Deming’s Operational Definitions

A criterion to be applied
  • What do you want to accomplish?

A test of compliance to be applied
  • By what test method?

A decision rule for interpreting the test results
  • How will you know?
**Measurement Scales**

Derived from the rules that we use for assigning values to attributes.

Admissible transformations limit the ways we can validly use the measurement results.

*Nominal* – classify entities

*Ordinal* – rank entities; distance has no meaning

*Interval* – concept of distance; no origin

*Ratio* – has origin of meaningful, nonarbitrary zero value

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**Appropriate Statistical Uses**

<table>
<thead>
<tr>
<th>Scale Type</th>
<th>Measures of Central Tendency</th>
<th>Measures of Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Mode</td>
<td>Information (H)</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Median</td>
<td>Percentiles</td>
</tr>
<tr>
<td>Interval</td>
<td>Arithmetic mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average deviation</td>
</tr>
<tr>
<td>Ratio</td>
<td>Geometric mean</td>
<td>Percent variation</td>
</tr>
<tr>
<td></td>
<td>Harmonic mean</td>
<td></td>
</tr>
</tbody>
</table>

Scale types are not fundamental attributes of data!
Goal – Question - (Indicator) - Measure

GQ(I)M is used to
• define measurement goals
• pose related, quantifiable questions
• derive measures that support the goals

GQ(I)M identifies
• the measures required
• the reasons why the data are being collected

The “why?” is important because it
• defines how the data should be interpreted
• provides a basis for reusing measurement plans and procedures in future projects

Measurement Principles for Project Managers

Know the strategic focus of the organization and emphasize measures that support the strategy.

Gain agreement with team(s) on measures to track.

Define measures in project plan.

Provide regular feedback about data collected.

Do not measure individuals.
General Measurement Principles

Software measurement must not be a strategy unto itself.

Integrate measurement with the overall strategy for software process improvement.

Start small with common goals and issues.

Develop a consistent measurement process that
• is linked to organizational goals and objectives
• includes rigorous definitions
• continuously evolves

Test the measures and processes you design before implementing them broadly.

Measure and monitor the effectiveness of the measures and measurement activities.

Dysfunctional Behavior

Austin’s Measuring and Managing Performance in Organizations
• motivational versus information measurement

Deming strongly opposed performance measurement, merit ratings, management by objectives, etc.

Dysfunctional behavior resulting from organizational measurement is inevitable unless
• measures are made “perfect” or
• motivational use impossible
SEI Core Measures

Checklist-based approach with strong emphasis on operational definitions

Measurement areas where checklists have been developed include:
• effort
• size
• schedule
• quality

Deming

Everyone doing his best is not the answer. It is necessary that people know what to do.

Quality and productivity are not to be traded off against each other.
• Productivity is a byproduct of quality and of doing the job right the first time.

The practical value of distinguishing random from nonrandom variation is enormous.
• Know when to intervene in a process and when to leave it alone.
Deming’s 14 Points

1. Create constancy of purpose for improvement of product and service.
2. Adopt the new philosophy.
3. Cease dependence on mass inspection.
4. End the practice of awarding business on price tag alone.
5. Constantly and forever improve the system of production and service.
6. Institute modern methods of training on the job.
7. Institute modern methods of supervising.
8. Drive out fear.
10. Eliminate numerical goals for the work force.
11. Eliminate work standards and numerical quotas.
12. Remove barriers that hinder the hourly workers.
13. Institute a vigorous program of education and training.
14. Create a structure in top management that will push every day on the above 13 points.

Juran’s Breakthrough Approach

Juran proposed a three-pronged approach: breakthrough projects, the control sequence, and annual quality programs.

Juran’s Breakthrough Sequence
• Breakthrough in attitudes.
• Identify the vital few projects.
• Organize for breakthrough in knowledge.
• Conduct the analysis.
• Determine how to overcome resistance to change.
• Institute the change.
• Institute controls.
The Cost of Quality

Internal failure costs
- costs from product defects before shipment to the customer

External failure costs
- costs associated with defects found after shipment to the customer

Appraisal costs
- costs associated with discovering the condition of products and raw materials

Prevention costs
- costs associated with preventing defects and limiting failure and appraisal costs

Crosby’s 14 Point Program
P. Crosby, Quality Is Free, 1976

1. Management commitment
2. Quality improvement team
3. Quality measurement
4. Cost of quality evaluation
5. Quality awareness
6. Corrective action
7. Zero defects planning
8. Supervisor training
9. Zero Defects Day
10. Goal setting
11. Error cause removal
12. Recognition
13. Quality councils
14. Do it all over again
Crosby’s Quality Management Maturity Grid

<table>
<thead>
<tr>
<th>Stage</th>
<th>Summation of quality posture</th>
<th>COQ as % of sales</th>
<th>Quality improvement actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>“We don’t know why we have quality problems.”</td>
<td>Reported: ???</td>
<td>No organized activities.</td>
</tr>
<tr>
<td></td>
<td>Actual: 20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>“Must we always have quality problems?”</td>
<td>Reported: 5%</td>
<td>Activities are motivational and short term.</td>
</tr>
<tr>
<td></td>
<td>Actual: 18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>“Because of management commitment and quality improvement programs, we are identifying and resolving our quality problems.”</td>
<td>Reported: 8%</td>
<td>Implements the 14-step program with full understanding.</td>
</tr>
<tr>
<td></td>
<td>Actual: 12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>“We routinely prevent defects from occurring.”</td>
<td>Reported: 6.5%</td>
<td>Continues the 14-step program and starts Make Certain.</td>
</tr>
<tr>
<td></td>
<td>Actual: 8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>“We know why we don’t have quality problems.”</td>
<td>Reported: 2.5%</td>
<td>Quality improvement is a regular and continuing activity.</td>
</tr>
<tr>
<td></td>
<td>Actual: 2.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Statistical Thinking

All work is a series of interconnected processes.

All processes are variable.

*Understanding variation is the basis for management by fact and systematic improvement.*

*Understand* the past.

*Control* the present.

*Predict* the future.

Quantitatively...
Six Sigma Methodologies

Process management
• managing existing processes

DMAIC
• improving existing processes

DMADV aka Design for Six Sigma
• designing new processes, products, and services

_Dana Ginn and Evelyn Varner, The Design for Six Sigma Memory Jogger, 2004._

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DMAIC

**Define** – improvement project, collect info on current process and customer needs/requirements

**Measure** – current situation

**Analyze** – identify root causes of defects, confirm with data

**Improve** – implement solutions, evaluate results

**Control** – maintain gains by standardizing, anticipate future improvements
DMADV – Design for Six Sigma

**Define** – org’l change plans, risk management plans, project plans

**Measure** – customer requirements (VOC), translate into critical to quality (CTQ)

**Analyze** – select concept that best meets CTQs within budget and resource constraints

**Design** – prepare to pilot and deploy

**Verify** – stress test and debug prototypes, deploy

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Contrasting Lean and Six Sigma

Lean is a relentless commitment to eliminate waste in all forms.

Six Sigma concentrates on reducing variation.

➔ Lean Six Sigma
  • combine the best of both philosophies

Continual Improvement Is...

... the ability to understand the messages contained in your data.

... the ability to differentiate between routine variation and exceptional variation.

... the difference between reacting to noise and understanding signals.

... ultimately an incredibly powerful way of thinking that will enable you to conduct your business more effectively.

Questions and Answers

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