Process Improvement

Objectives

- To explain the principles of software process improvement
- To explain how software process factors influence software quality and productivity
- To introduce the SEI Capability Maturity Model and to explain why it is influential. To discuss the applicability of that model
- To explain why CMM-based improvement is not universally applicable

Process improvement

- Understanding existing processes
- Introducing process changes to achieve organizational objectives which are usually focused on quality improvement, cost reduction and schedule acceleration
- Most process improvement work so far has focused on defect reduction. This reflects the increasing attention paid by industry to quality
- However, other process attributes can be the focus of improvement

Why do process improvement?

- We want to build better products (cheaper, more dependable, quicker, …)
- We really don't know how to measure the product characteristics
- There, measure the process under the assumption – a better process will produce a better product.
  - When is this statement true or not true?

Process attributes

Process characteristic	Description
Understandability	To what extent is the process explicitly defined and how easy is it to understand the process definition?
Visibility	Do the process activities culminate in clear results so that the progress of the process is externally visible?
Supportability	To what extent can the process activities be supported by CASE tools?
Acceptability	Is the defined process acceptable to and usable by the engineers responsible for producing the software product?
Reliability	Is the process designed in such a way that process errors are avoided or trapped before they result in product errors?
Robustness	Can the process continue in spite of unexpected problems?
Maintainability	Can the process evolve to reflect changing organisational requirements or identified process improvements?
Rapidity	How fast can the process of delivering a system from a given specification be completed?

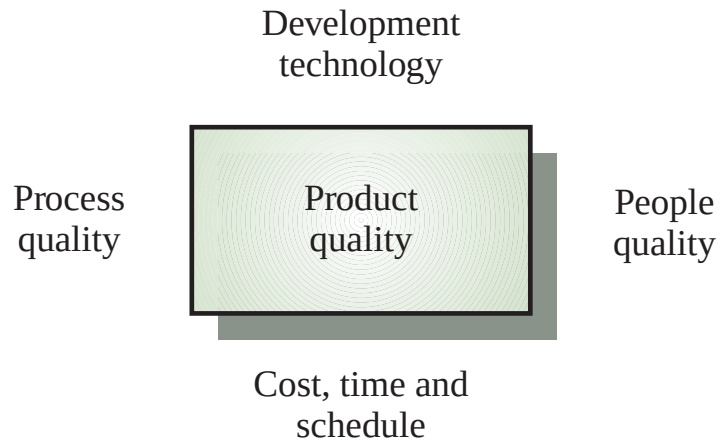
Process improvement stages

- Process analysis
  - Model and analyze (quantitatively if possible) existing processes
- Improvement identification
  - Identify quality, cost or schedule bottlenecks
- Process change introduction
  - Modify the process to remove identified bottlenecks
- Measure improvement
  - What happened? May need to tailor process.
- Process change training
  - Train staff involved in new process proposals
- Change tuning
  - Evolve and improve process improvements

Process and product quality

- Process quality and product quality are closely related (Are they?)
- A good process is usually required to produce a good product
- For manufactured goods, process is the principal quality determinant
- For design-based activity, other factors are also involved especially the capabilities of the designers

Principal product quality factors



Quality factors

- For large projects with 'average' capabilities, the development process determines product quality
- For small projects, the capabilities of the developers is the main determinant
- The development technology is particularly significant for small projects
- In all cases, if an unrealistic schedule is imposed then product quality will suffer

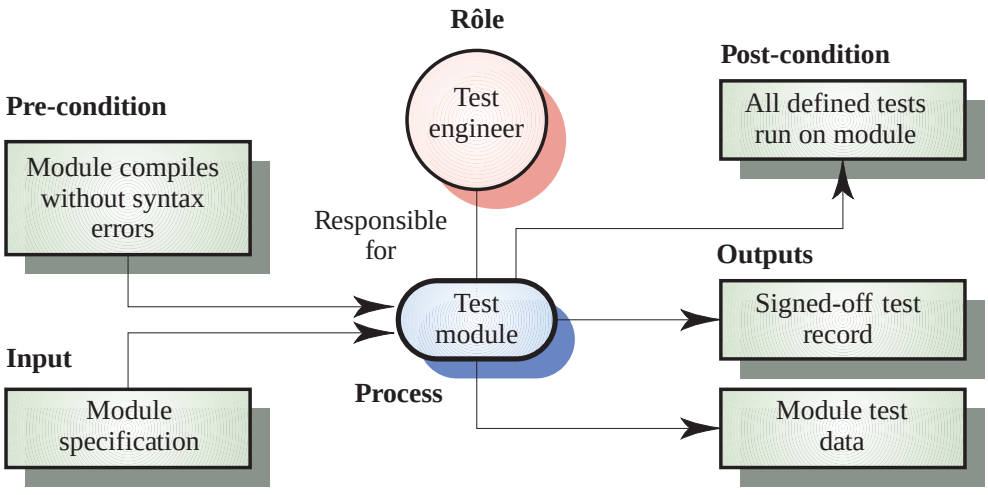
Process analysis and modelling

- Study an existing process to understand its activities
- Produce an abstract model of the process. You should normally represent this graphically. Several different views (e.g. activities, deliverables, etc.) may be required
- Analyze the model to discover process problems. Involves discussing activities with stakeholders

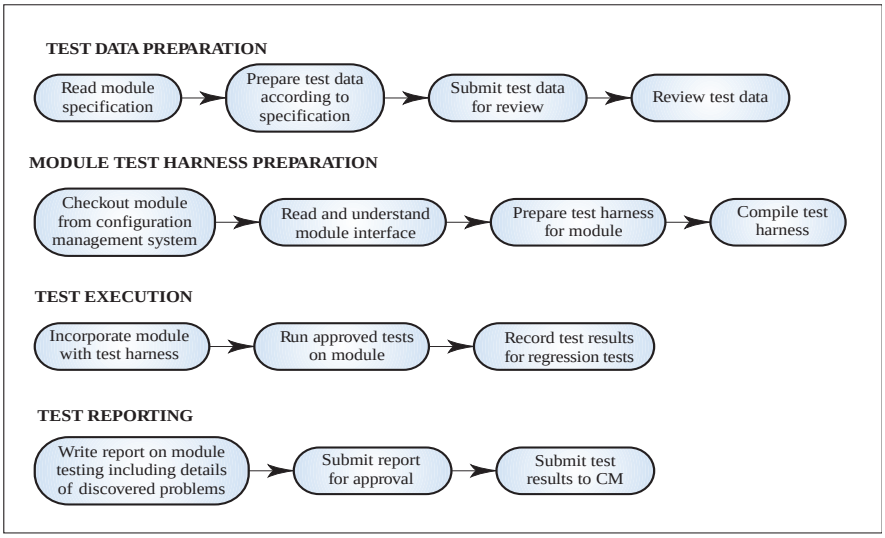
Process analysis techniques

- Published process models and process standards
  - It is always best to start process analysis with an existing model. People then may extend and change this.
- Questionnaires and interviews
  - Must be carefully designed. Participants may tell you what they think you want to hear
- Ethnographic analysis
  - Involves assimilating process knowledge by observation
  - Taxonomy of validation methods - Review "experimentation" notes from several weeks ago

The module testing activity



Activities in module testing



Process measurement

- Wherever possible, quantitative process data should be collected
  - However, where organizations do not have clearly defined process standards this is very difficult as you don't know what to measure. A process may have to be defined before any measurement is possible
- Process measurements should be used to assess process improvements
  - But this does not mean that measurements should drive the improvements. The improvement driver should be organizational objectives

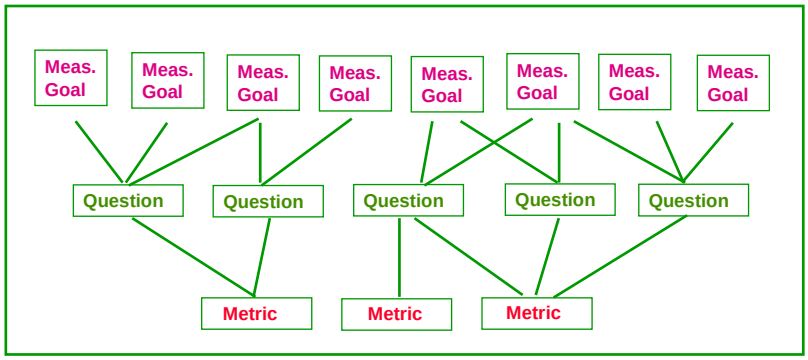
Classes of process measurement

- Time taken for process activities to be completed
  - E.g. Calendar time or effort to complete an activity or process
- Resources required for processes or activities
  - E.g. Total effort in person-days
- Number of occurrences of a particular event
  - E.g. Number of defects discovered

Goal-Question-Metric Paradigm

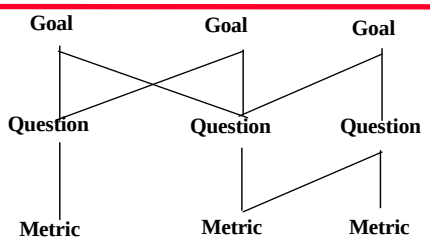
- Goals
  - What is the organization trying to achieve? The objective of process improvement is to satisfy these goals
- Questions
  - Questions about areas of uncertainty related to the goals. You need process knowledge to derive these
- Metrics
  - Measurements to be collected to answer the questions

THE MEASUREMENT INFRASTRUCTURE
Goal Based Measurement



- Each metric supports multiple goals
- Questions focus metric selection and in-process analysis

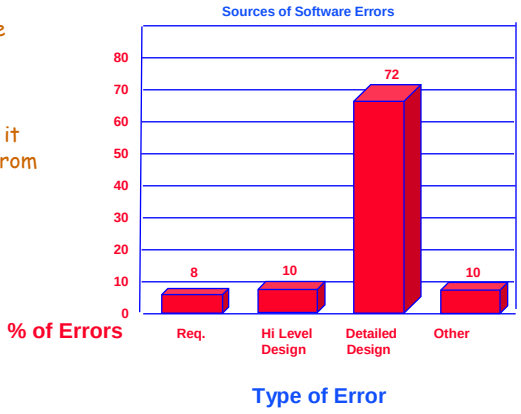
GOAL/QUESTION/METRIC PARADIGM
Goal and Model Based Measurement



- A Goal links two models: a model of the object of interest *and* a model of the focus and develops an integrated GQM model
- **Goal:** Analyze the final product to characterize it with respect to the various defect classes from the point of view of the organization
- **Question:** What is the error distribution by phase of entry
- **Metric:** Number of Requirements Errors, Number of Design Errors, ...

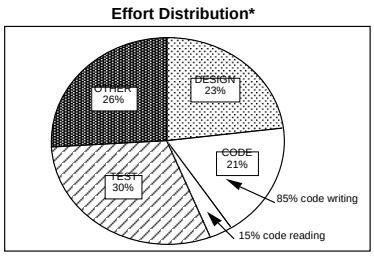
DEFINING MEASUREMENT GOALS
A GOAL/QUESTION/METRIC EXAMPLE

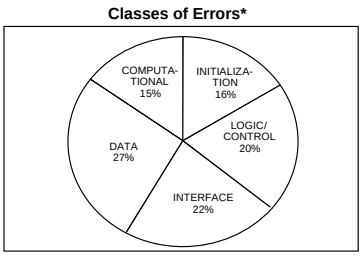
- **Business Goal**
  - Understand problem areas in the software business
- **A Measurement Goal**
  - Analyze the final product to characterize it with respect to the various defect classes from the point of view of the organization
- **Question**
  - What is the error distribution by type of error?
- **Metrics**
  - Number of Requirements Errors, Number of Design Errors, ...

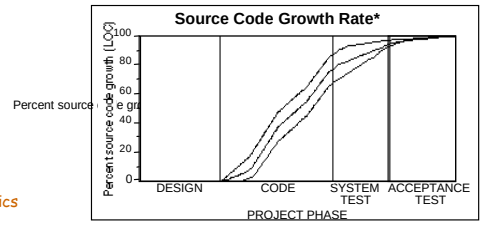


Importance of baseline studies

NASA/SEL PROCESS BASELINE EXAMPLE







*Data from 11 Flight Dynamics projects (mid 1980s)

Quality Improvement Paradigm

Developed by Basili as part of NASA/GSFC Software Engineering Laboratory (SEL) research

QIP – 6 step process:

- Characterize – Analyze and understand the environment. Need to understand current processes before improvement. Compare to CMM. Measurement crucial at beginning (not level 4) and each environment is unique.
- Set goals – Quantifiable goals must be based on discovered characteristics.
- Choose process – Based on characterization and goals, processes, methods, and tools have to be determined.
- Execute the process – Perform the processes constructing the required products.
- Analyze – At the end of each project, analyze the data gathered, determine problems, and make recommentations for improvement.
- Package – Structure knowledge and store it an experience base for future reuse.

Forms of Packaged Experience

Equations defining the relationship between variables,
e.g. Effort = $1.48*KSLOC^{.98}$,
Number of Runs = 108 + 150*KSLOC

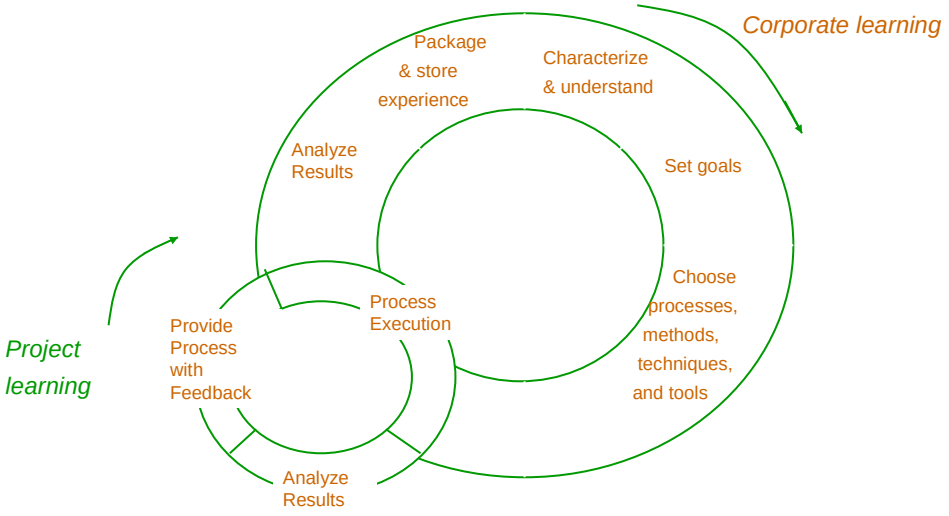
Histograms or pie charts of raw or analyzed data, e.g., Classes of Faults: 30% data, 24% interface, 16% control, 15% initialization, 15% computation
Effort Distribution: 23% design, 21% code, 30%test, 26% other

Graphs defining ranges of "normal" e.g.,
Fault Slippage Rate: halve faults after each test phase
(4, 2, 1, .5)

Specific lessons learned, e.g., an Ada design should use library units rather than a deeply nested structure;
minimize the use of tasking as its payoff is minimal in this environment;
size varies inversely with defect rate up to about 1KLOC per module

Processes descriptions (adapted to SEL), e.g., Recommended Approach, Manager's Handbook, Cleanroom Process Handbook,
Ada Developer's Guide, Ada Efficiency Guide

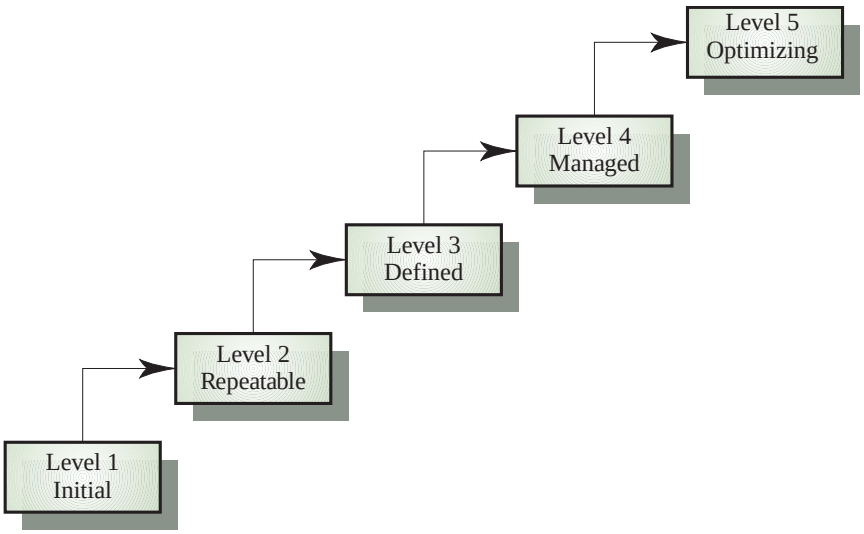
Quality Improvement Paradigm - 2



The Software Engineering Institute

- US Defense Dept. funded institute associated with Carnegie Mellon
- Mission is to promote software technology transfer particularly to defense contractors
- Maturity model proposed in 1987, refined in early 1990s.
  - Software Capability Evaluation (SCE) – a self assessment of an organization
  - Capability Maturity Model (CMM) – A mechanism to evaluate the "maturity" of a development group
  - Major developer Watts Humphrey
  - Soon merged into one process
- Work has been very influential in process improvement

The SEI process maturity model



CMM Overview

An evaluation is based upon a 5-level rating. Each level represents a more mature organization:

1. Initial – No predefined process. Development is ad hoc. No established rules. (Note: This does not mean bad practices, but usually means it can be greatly improved. There are good development practices followed by some level 1 organizations.)
2. Repeatable – Policies are in place to manage software development. Each project follows some process that is generally similar to others.
3. Defined – Processes for software development fit into a corporate standard for software development. Development processes are well documented.
4. Managed – Quantitative goals for products and processes are set. Software process attributes are quantifiable.
5. Optimizing – Goals for continuous process improvement are in place.

CMM Key Process Areas (KPAs)

CMM evaluations are based upon KPAs. 18 KPAs govern the CMM. In order to be at level N, all the KPAs up to that level must be satisfied.

Initial – None – This is the initial state.

Repeatable – Requirements management; Project planning; Project tracking; Subcontract management; Quality assurance; Software configuration management

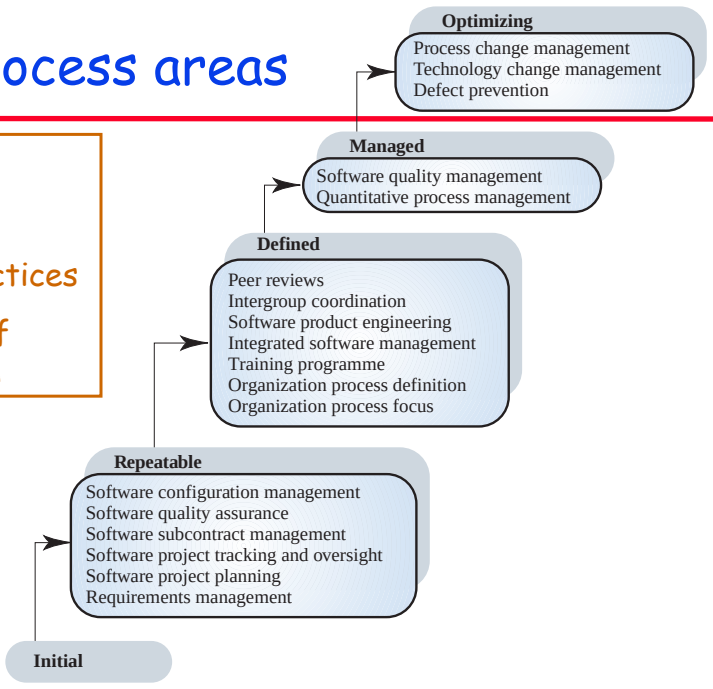
Defined – Organization process focus; Organization process definition; Training program; Integrated software management; Software product engineering; Intergroup coordination; Peer reviews

Managed – Software quality management; Quantitative process management [Is it really level 4?]

Optimizing – Defect prevention; Technology change management; Process change management

Key process areas

- 18 KPAs
- 52 goals
- 316 key practices
- 500 pages of documentation



For each KPA …

For each KPA, need to address commitment:

1. What is commitment to perform this KPA? What policies and management leadership are behind this KPA?
2. What is the ability to perform this KPA? What mechanisms are in place?
3. What activities are performed? What are the procedures in place to perform that KPA?
4. What is the measurement of the KPA and the analysis of its adherence?
5. What verifies the implementation? How to ensure compliance?

Required questions for level 2 of CMM

Question number	*Question*
1.1.3	Does the Software Quality Assurance function have a management reporting channel separate from the software development project management?
1.1.6	Is there a software configuration control function for each project that involves software development?
2.1.3	Is a formal process used in the management review of each software development prior to making contractual commitments?
2.1.14	Is a formal procedure used to make estimates of software size?
2.1.15	Is a formal procedure used to produce software development schedules?
2.1.16	Are formal procedures applied to estimating software development cost?
2.2.2	Are profiles of software size maintained for each software configuration item over time?
2.2.4	Are statistics on software code and test errors gathered?
2.4.1	Does senior management have a mechanism for the regular review of the status of software development projects?
2.4.7	Do software development first-line managers sign off on their schedule and cost estimates?
2.4.9	Is a mechanism used for controlling changes to the software requirements?
2.4.17	Is a mechanism used for controlling changes to the code?

SEI Process Improvement Cycle

Initialize

- Establish Sponsorship
- Create vision and strategy
- Establish improvement structure

For Each Maturity Level

- Characterize current practice in terms of key process areas
- Assessment recommendations
- Revise strategy (generate action plans and prioritize key process areas)

For Each key Process Area

- Establish process action teams
- Implement tactical plan, define processes, plan and execute pilot(s), plan and execute institutionalization
- Document and analyze lessons
- Revise organizational approach

Aggregate results from SEI benefits study

(Herbsleb et al 1994)

Category	*Range*	*Median*
Total yearly cost of software process improvement activities	$49,000 to $1,202,000	$245,000
Years engaged in software process improvement	1 to 9	3.5
Cost of software process improvement per engineer	$490 to $2004	$1375
Productivity gain per year	9% to 67%	35%
Early detection gain per year (faults discovered pre-test)	6% to 25%	22%
Yearly reduction in time to market	15% to 23%	19%
Yearly reduction in post-release fault reports	10% to 94%	39%
Business value of investment in software process improvement (value returned on each dollar invested)	4.0 to 8.8	5.0

What is a level 5 organization?

- It is an organization that can manipulate process to achieve various product characteristics.
- This requires that we have a process and an organizational structure to help us:
  - Understand our processes and products
  - Measure and model the project and the organization
  - Define and tailor process and product qualities explicitly
  - Understand the relationship between process and product qualities
  - Feedback information for project control
  - Experiment with methods and techniques
  - Evaluate our successes and failures
  - Learn from our experiences
  - Package successful experiences
  - Reuse successful experiences

KPA issues

Each KPA provides needed features for good development, but there are issues with CMM:

- Companies often look only one level ahead and ignore ultimate goal of level 5.
- Management only. Role of technology mostly ignored
- Expensive, especially for small companies
- Process is "bottom up." "One size fits all." (Contrast with QIP next.)
- "Level 3" is often a "requirement" for a DoD contract even though not fully demonstrated higher level is an accurate predictor of better quality products.

SEI model problems

- It focuses on project management rather than product development.
- Management often more interested in number than in improvement.
- It ignores the use of technologies such as rapid prototyping.
- It ignores measurement until level 4.
- It does not incorporate risk analysis as a key process area
- It does not define its domain of applicability.
- Is expensive to use. Too much overhead and reporting for a small company.
- Not very "agile." Hard to use if rapid turnaround needed.

CMM model value

- But it does impose a structure
  - Often any structure better than no structure.
- Some indications that levels 2 and 3 do help
- Not clear if levels 4 and 5 add much value
  - Some companies satisfied with a level 3 ranking.
  - Although level 5 is supposed to indicate agility in making changes, some companies are afraid to make a change in fear of losing their ranking.

ISO 9000 Certification

ISO standard 9001 (software component) for standard quality of a product. (Note that "good" quality is not required, only that quality can be accurately determined. Concrete life preservers can be "ISO certified," but not be very useful.)

- Companies want ISO certification as a requirement to sell in Europe.
- Based upon 20 clauses. "ISO certification" is comparable to CMM level 2 or level 3, but processes are different.

ISO 9000 clauses

Management	Design control
Quality team	Purchasing
Contract review	Process control
Training	Service
Control of customer supplied	Product identification and traceability
Document and data control	Inspection and test cases
Control of nonconforming products	Control of quality record
Integration and testing	Control of inspection, measuring, test
Corrective and preventative actions	Handling, storage, packaging, delivery
Interval quality audits	Statistical techniques

ISO 9000 tasks

- writing a quality manual, describing the organization's quality system at a high level
- writing procedure documents describing the work is carried out in the organization
- creating a system to control distribution and re-issue of documents
- identifying training needs for most positions in the organization
- training people in the organization on operation of the quality system
- planning and conducting internal audits

ISO 9000 standards

ISO 9000, "Quality management and quality assurance standards - Guidelines for selection and use," clarifies the distinctions and interrelationships between quality concepts and provides guidelines for the selection and use of a series of international standards on quality systems that can be used for internal quality management purposes (ISO 9004) and for external quality assurance purposes (ISO 9001, 9002 and 9003).

ISO 9001, "Quality systems - Model for quality assurance in design/development, production, installation, and servicing." Of the ISO 9000 series, it is the standard that is most pertinent to software development and maintenance.

ISO 9002, "Quality systems - Model for quality assurance in production and installation."

ISO 9003, "Quality systems - Model for quality assurance in final inspection and test"

ISO 9004, "Quality management and quality system elements – Guidelines."

ISO 9000-3, provides "Guidelines for the application of ISO 9001 to the development, supply, and maintenance of software."

Goals of ISO 9000

- An organization should achieve and sustain the quality of the product or service produced so as to meet continually the purchaser's stated or implied needs.
- An organization should provide confidence to its own management that the intended quality is being achieved and sustained.
- An organization should provide confidence to the purchaser that the intended quality is being, or will be, achieved in the delivered product or service provided.

The CMM and ISO 9000

- There is a clear correlation between the key processes in the CMM and the quality management processes in ISO 9000
- The CMM is more detailed and prescriptive and includes a framework for improvement
- Organizations rated as level 2 in the CMM are likely to be ISO 9000 compliant

People capability maturity model
(Curtis, Hefley and Miller 1995)

Level	*Focus*	*Key practices*
5: optimizing	Continuous knowledge and skills improvement	Continuous workforce innovation Coaching Personal competency development
4: managed	Effectiveness measured and managed, high performance teams developed	Organizational performance alignment Organizational competency management Team-based practices Team-building Mentoring
3: defined	Competency-based workforce practices	Participatory culture Competency-based practices Career development Competency development Workforce planning Knowledge and skills analysis
2: repeatable	Management takes responsibility for managing its people	Compensation Training Performance management Staffing Communication Work environment
1: initial		

CMMI -1

CMM have become a growth industry …

- SW-CMM - Capability Maturity Model for Software
- P-CMM - People Capability Maturity Model
- SA-CMM - Software Acquisition Capability Maturity Model
- SE-CMM - Systems Engineering Capability Maturity Model
- IPD-CMM - Integrated Product Development Capability Maturity Model

CMMI proposed to integrate various models

CMMI -2

The CMM Integration project was formed to address the problem of having to use multiple Capability Maturity Models. The initial mission of the project was to combine three source models:

1. Capability Maturity Model for Software (SW-CMM) v2.0 draft C
2. Electronic Industries Alliance Interim Standard (EIA/IS) 731, Systems Engineering Capability Model (SECM)
3. Integrated Product Development Capability Maturity Model (IPD-CMM) v0.98

into a single model for use by organizations pursuing enterprise-wide process improvement.

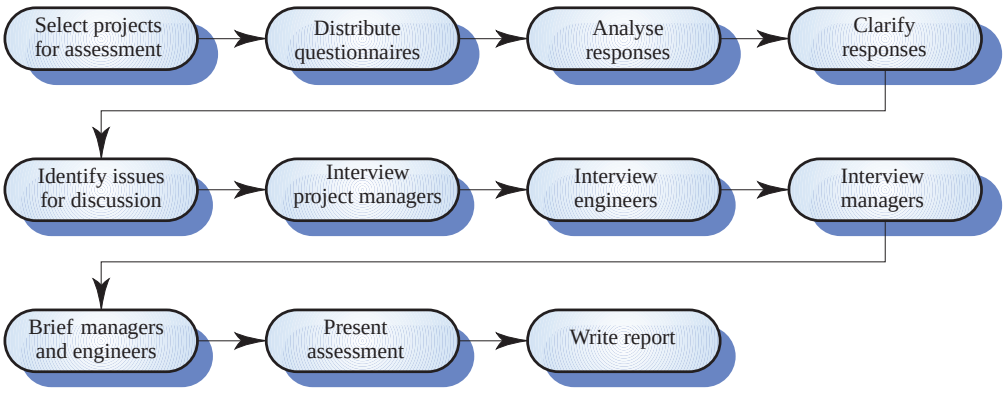
CMMI -3

- 24 process areas
- Each process area has a set of goals
- Up to seven practices are associated with each goal as a way to satisfy that goal
- 6 point measurement scale for each process area:
  - Not performed
  - Performed (goals satisfied)
  - Managed (Organizational policies define process)
  - Defined (Organizational standardization)
  - Quantitatively managed (Measurement involved)
  - Optimizing (Adaptive processes)
- Each maturity level has a set of process areas

Capability assessment

- An important role of the SEI is to use the CMM to assess the capabilities of contractors bidding for US government defence contracts
- The model is intended to represent organizational capability not the practices used in particular projects
- Within the same organization, there are often wide variations in processes used
- Capability assessment is questionnaire-based

The capability assessment process



Key points

- Process improvement involves process analysis, standardization, measurement and change
- Process models include descriptions of tasks, activities, roles, exceptions, communications, deliverables and other processes
- Measurement should be used to answer specific questions about the software process used
- The three types of process metrics which can be collected are time metrics, resource utilization metrics and event metrics
- The SEI model classifies software processes as initial, repeatable, defined, managed and optimising. It identifies key processes which should be used at each of these levels
- The SEI model is appropriate for large systems developed by large teams of engineers. It cannot be applied without modification in other situations