Appendix B

Software Quality Management Standards and Models

B.1 ABC Software Ltd – an unnecessary loss – a mini-case

2015 was ABC Software's worst year since being founded in 1985. The company lost almost $2.1 million, sales dropped 35%, and it had to let go of 145 out of its 390 personnel.

ABC Software specializes in the development of custom-made information systems for governments and government agencies. Only a very small part of the company's activities was directed toward the development of COTS software packages. By 2013, the company's annual sales reached over $65 million.

"A clear case of negligence caused unnecessary losses and severe damage to the company's reputation – that will need at least 5 years to recover," Sam Baron, the company's deputy manager operations and quality, explained.

"It all began in 2005, when management realized that in order to further grow the company business, it would need to become ISO 90003 certified. It took us about a year to get organized with a full set of procedures and written work instructions, and to train our staff in implementing the procedures. National Standard Institute experts reviewed our procedures and performed a comprehensive audit to verify staff compliance with our procedures. A few days after the audit, we received the much anticipated ISO 90003 standard certification document, which I proudly presented at the following management and board meeting, and to which the participants expressed their appreciation. The original framed certification document is still hanging in the board meeting room. In the following years, the ISO 90003 certification proved very helpful in winning government tenders."

Software Quality: Concepts and Practice, First Edition. Daniel Galin.

"It sounds like you made a very good decision, and that the organization performed exceptionally well to adapt to the needed changes for the certification. So what went wrong?" We asked Baron.

"I believe that the cause of our current trouble is rooted in one line of the certification document – a line stating that the certification is valid for one year only, a line which was overlooked by management. In other words, the National Standards Institute (NSI) needs to re-audit the organization every year to verify continued conformance to procedures and work instructions." Baron then suggested that the head of the SQA unit explain the events that took place from that time till December 2015.

The head of the SQA unit started to recap the chain of events. "The audits conducted by the National Standard Institute (NSI) annual certification in the following years had high evaluation scores – well, at least at the beginning. But gradually the audit scores became less and less positive and the number of 'topics for required attention' quickly grew. Nevertheless, a renewed certification was granted to ABC Software each year. In December 2014, a change came about and the audit ended with a warning; unless a substantial improvement of in the company's SQA performance is evident by in the next audit, the ISO 90003 certification will be cancelled." He paused for a minute, and the following questions were raised.

"What caused the decline of your SQA system?" "What changed in the company?"

The SQA manager picked up where he had left off, "During the last few years management has been putting a great deal of pressure on the software development department to make substantial resource savings and stick to the schedules. These directives forced the project staff to skip reviews and cut tests plans. And all this happened despite my repeated requests to follow procedures in order to avoid any negative outcomes. Actually, several of these projects failed the system tests, and two projects were even rejected in acceptance tests performed by customers. The worst situation evolved closely after February 2015, when ABC Software won the Treasury project, the company's largest ever project. The win was achieved mainly due to proposing the lowest price and the shortest schedule. It took just a few weeks for the project manager to realize that the proposed project budget and schedule were unrealistic. From this moment on, the Treasury project team came under immense pressure to cope with the meager budget and tight schedule. Round about this time, the December 2015 ISO 90003 audit took place. As unfortunately expected, during their review of the Treasury project, the auditors found a handful of nonconformance issues, some examples are:

- The contract review was only partly performed, and worse, there was no sign of discussions on its findings, nor for changing the proposal accordingly.
- The design review of the design document listed 23 action items. None of which were implemented.

- No corrective or preventive actions were initiated during 2015, and no minutes of meeting of the CAB were found for this period.
- Half of the planned unit tests were not performed, while no record was found for the defects correction process, including the testing of the corrected software, for the remaining unit tests.
- The joint customer–supplier committee required the procedure to take place once in 2 weeks but was conducted every 4–6 weeks.

A total of 43 audit team findings, all of them negative, led to the inevitable result of the certification being cancelled, and management requests for a reaudit were denied. The NSI also denied a request to hold the next planned audit earlier when the company may present corrected SQA behavior and gain back its ISO 90003 certificating. The next NSI audit was scheduled for December 2016.

"The full impact of losing the certification was felt just a few weeks later," the head of the SQA unit continued, "When the management found out that the company could not participate in about two thirds of the tenders; those requiring the participants hold valid ISO 90003 certification. Following this discovery, a decision was made to submit the remaining tenders with minimal profit margins, in order to improve winning prospects." By May 2016, when most of the work on the Treasury project had been completed, it became clear to the company that no tasks at all could be allocated to a great many of the company professionals. This led to 145 staff members being let go.

The company expects an annual loss of over $2 million by the end of 2016. It is widely agreed among company management and employees alike that the major, if not the only, cause for this loss was the revoked certification.

"The lesson was learned, but not before paying high 'tuition fees.' Management was now committed to regain the certification, and invested efforts to promote SQA activities, and instruct members of staff to strictly conform to procedure requirements. In addition, a special consultant was hired to perform internal audits."

Jerry concluded his speech, "I hope that the coming NSI audit will note the significant change, created by the joint efforts of the SQA unit and professional staff, and restore our ISO 90003 certification."

We did not react to the ABC Software's sad "story," but only wish the deputy operations and quality manager, head of the SQA unit, and the company itself success in remembering the lessons learnt, and the substantial contribution of professional certification, but especially in never losing sight of the vast damages that could be caused by the loss of certification.

B.2 The scope of quality management standards

Quality management standards and methodologies focus on the software quality assurance system – its organization, infrastructure, and requirements

performance – yet leave the choice of the methods and tools to be used in the hands of the organization. In other words, these standards focus on the "what" of SQA and not on the "how." Compliance to quality management standards supports the organization's steady efforts to assure an acceptable quality level for its software products. The application of these standards is directed mainly as an assessment tool, but also as a certification tool. The standards of both routes, ISO/IEC 90003 and ISO/IEC 15504, are international standards and have also been adopted by the Institute of Electrical and Electronic Engineering (IEEE) and as national standards in many countries.

Standards for the software industry, belonging to the certification class – mainly ISO 90003, structure the SQA certification procedures applied to software developing organizations. Some standards and methodologies for the software industry of the assessment class, such as the Capability Maturity Model Integrated (CMMI) and ISO/IEC 15504, serve mainly for self-assessment of the organization's SQA achievements as guidance to the development of its SQA system.

Certification standards vary from assessment standards by content and emphasis.

The following are the aims of certification standards:

- To enable a software development organization to demonstrate consistent ability to ensure that its software products or maintenance services comply with acceptable quality requirements. This is achieved through certification granted by an external body.
- To serve as an agreed-upon basis for customer and supplier evaluation of the supplier's quality management system. This may be accomplished with a quality audit of the supplier's quality management system conducted by the customer. The audit will be based on the certification standard's requirements.
- To support the software development organization's efforts to improve quality management system performance and enhance customer satisfaction through compliance with the standard's requirements.

One indication of the importance of certification standards is the current trend in software development tenders, which requires certification of participants according to at least one of the dominant quality management standards.

The following are the aims of assessment standards:

- To serve software development and maintenance organizations as a tool for self-assessment of their ability to carry out software development projects.
- To serve as a tool for improvement of development and maintenance processes. The standard indicates directions for process improvements.

- To help purchasing organizations determine the capabilities of potential suppliers.
- To guide training of assessor by delineating qualifications and training program curricula.

To sum up, while the certification standards emphasis is external – to support the supplier–customer relationships – the emphasis of the assessment standards is internal and focuses on the improvement of the software process.

Comparison and evaluation of maturity process models for process improvement are the subject of several papers. A selection of these includes Helgesson et al. (2011), Salviano and Figueiredo (2006), and Bella et al. (2008).

The next section of the chapter presents the software process improvement aspects of quality management standards and their methodologies. Following this, the next three sections, Sections B.4–B.6, are dedicated to the scope of three major certification and assessment standards. These are followed by Section B.7 that presents two additional software quality management methodologies: TickIt and Bootstrap.

B.3 Software quality management standards as SPI standards

The concept of software process improvement (SPI) seeking to achieve process improvement throughout the software life cycle corresponds well to the SQA principle of continuous improvement. SPI, much like software quality management, promotes:

a. Software development organizations to focus more on improving the effectiveness and efficiency of the development process.

b. Software development organizations to assess their professional level of performance (termed also "maturity").

c. Use of quantitative and qualitative indicators to measure the level of improvement of software development processes of an organization.

One of the major approaches for managements to implement process improvement is by the adoption of appropriate quality management standards that support SPI.

These standards may be classified into two classes:

- *Certifying standards*. An example of this class of standards, ISO/IEC 90003, is discussed in this chapter.
- *Assessment standards*. CMMI, P-CMM, and ISO/IEC 15504, discussed in this chapter, are all examples of standards belonging to this class.

B.4 ISO/IEC 90003

The ISO/IEC 90003 international standard was developed for the application of the ISO 9001 standard to computer software. In other words, ISO/IEC 90003 presents implementation of the general methodology of quality management of ISO 9001 standards, which deals with product development, product production, and product services and maintenance, for the special case of software development and maintenance. Both ISO 9001 and ISO/IEC 90003 are separately reviewed and updated once every 5–8 years. The current ISO/IEC 90003:2014 international standard (ISO/IEC, 2014) is an application of ISO 9001:2008 to computer software.

The ISO/IEC 90003 international standard is planned to serve the entire population of software development and maintenance organizations by adopting a policy of comprehensiveness and standard redundancy. These features facilitate achieving universality that allows the ISO/IEC 90003 to fit the immense variety of organizations belonging to the software industry, and be especially suitable to serve as a tool for assessing and certifying organizations of the software industry.

There is a growing worldwide interest in ISO/IEC 9001 certification from organizations in many industries, including ISO/IEC 90003 in the worldwide software industry. Many national standard institutes, including the IEEE, have adopted the ISO/IEC 90003 standard.

One indication of the importance of these standards is the current trend in software development tenders requiring certification of participants according to at least one of the leading quality management standards.

In Section B.4.1, the principles underlying the 9001 and 90003 standards are reviewed. The contents of the current version of the standard are discussed in the following section, and the certification process according to ISO/IEC 90003 is the subject of the third section, Section B.4.3.

B.4.1 Guiding principles of ISO 9001 and ISO/IEC 90003 standards

Eight principles guide the ISO 9001 and ISO/IEC 90003 standards as follows:

1. Customer focus

   Organizations depend on their customers and therefore should understand current and future customer needs.

2. Leadership

   Leaders establish the organization's vision. They should create and maintain an environment in which people can become fully involved in achieving the organization's objectives in the designated route.

3. Involvement of people
   People are the essence of an organization; their full involvement, at all levels of the organization, enables their abilities to be applied for the organization's benefit.
4. Process approach
   A desired result is achieved more efficiently when activities and resources are managed as a process.
5. System approach to management
   Identifying, understanding, and managing processes, if viewed as a system, contributes to the organization's effectiveness and efficiency.
6. Continual improvement
   Ongoing improvement of overall performance should be high on the organization's agenda.
7. Factual approach to decision-making
   Effective decisions are based on the analysis of information.
8. Mutually supportive supplier relationships
   An organization and its suppliers are interdependent; a mutually supportive relationship enhances the ability of both to create added value.

B.4.2 ISO/IEC 90003: 2014 standard's content

The current standard edition of ISO/IEC 90003-2014 (ISO/IEC, 2014) presents the standard's requirement that is classified into the following five groups:

- Quality management system
- Management responsibilities
- Resource management
- Product realization
- Management, analysis, and improvement

Each of the requirement groups is further classified into requirement areas. The standard includes a total of 22 requirement areas.

Each of the requirement areas is further subdivided into several specific requirements.

Each of the specific requirements is followed by guidelines.

This standard structure provides detailed guidelines to the standard user. However, the standard presents detailed requirements listing "what" has to be done, but not "how" it should be performed.

The requirement groups and their requirement areas are presented in Table B.1. A typical example of the detailing level of the guidelines for a specific requirement is shown in Frame B.1.

Frame B.1: An example of ISO/IEC 90003 detailed requirements – maintenance requirements

Source: ISO/IEC 90003-2012

Guidelines for: Requirement area: Customer-related processes
Specific requirement: Review of requirements related to the product. Guidelines subject: Risks (Standard Sec. 7.2.2.2) The following risks may be included when reviewing requirements related to the product: **1.** Criticality, safety, and security issues **2.** Capabilities and experience of the organization or its suppliers **3.** Reliability of estimates of the resources and the duration required for each activity **4.** Significant difficulties between the times required to deliver product or service, and the times determined from plans through the optimization of cost and quality goals **5.** Significant geographical dispersion of the organization, customers, users, and suppliers **6.** High technical novelty including novel methods, tools, technologies, and supplied software **7.** Low quality or availability of supplied software and tools **8.** Low precision, accuracy, and stability of the definition of the customer requirements and external interfaces

B.4.3 Certification process according to ISO/IEC 90003

The ISO/IEC 90003 certification process verifies that an organization's software development and maintenance processes fully comply with the standard's requirements.

The certification service is organized by the International Organization for Standardization (ISO) through a worldwide network of certification services that are authorized by means of *accreditation bodies* and *certification bodies*. Each accreditation body is licensed by ISO to authorize other professional organizations as certification bodies. Certification bodies, whose number may vary by country, perform the actual certification audits and certify the organizations that qualify.

Obtaining certification. Organizations wishing to obtain ISO/IEC 90003 certification are required to complete the following:

- Develop the organization's SQA system
- Implement the organization's SQA system
- Undergo successfully the certification audits

Table B.1 ISO/IEC 90003–TOC – requirement areas and their classification

Requirement groups	Requirement areas
4. Quality management system	4.1 General requirements
	4.2 Documentation requirements
5. Management responsibilities	5.1 Management commitments
	5.2 Customer focus
	5.3 Quality policy
	5.4 Planning
	5.5 Responsibility, authority, and communication
	5.6 Management review
6. Resource management	6.1 Provision of resources
	6.2 Human resources
	6.3 Infrastructure
	6.4 Work environment
7. Product realization	7.1 Planning of product realization
	7.2 Customer-related processes
	7.3 Design and development
	7.4 Purchasing
	7.5 Production and service provision
	7.6 Control of monitoring and measuring devices
8. Measurement, analysis, and improvement	8.1 General
	8.2 Monitoring and measurement
	8.3 Control of nonconforming products
	8.4 Analysis of data
	8.5 Improvement

Source: ISO/IEC Std. 90003-2014.

Fulfillment of these requirements demands thorough planning of the structures and resources necessary to perform the activities culminating in certification.

Retaining certification. Once the organization has obtained the ISO/IEC certification, efforts should be invested to retain the organization's certification. The organization has to undergo successfully the periodical certification audits.

This process may vary somewhat from one organization to another, depending on the characteristics of the organization's design and maintenance activities as well as the certification bodies. The certification processes for obtaining and retaining certification are discussed in greater detail in the rest of this section and illustrated in Figure B.1.

The process for obtaining the certification includes the following activities:

a. Planning the process leading to certification

b. Development of the organization's SQA system and its procedures

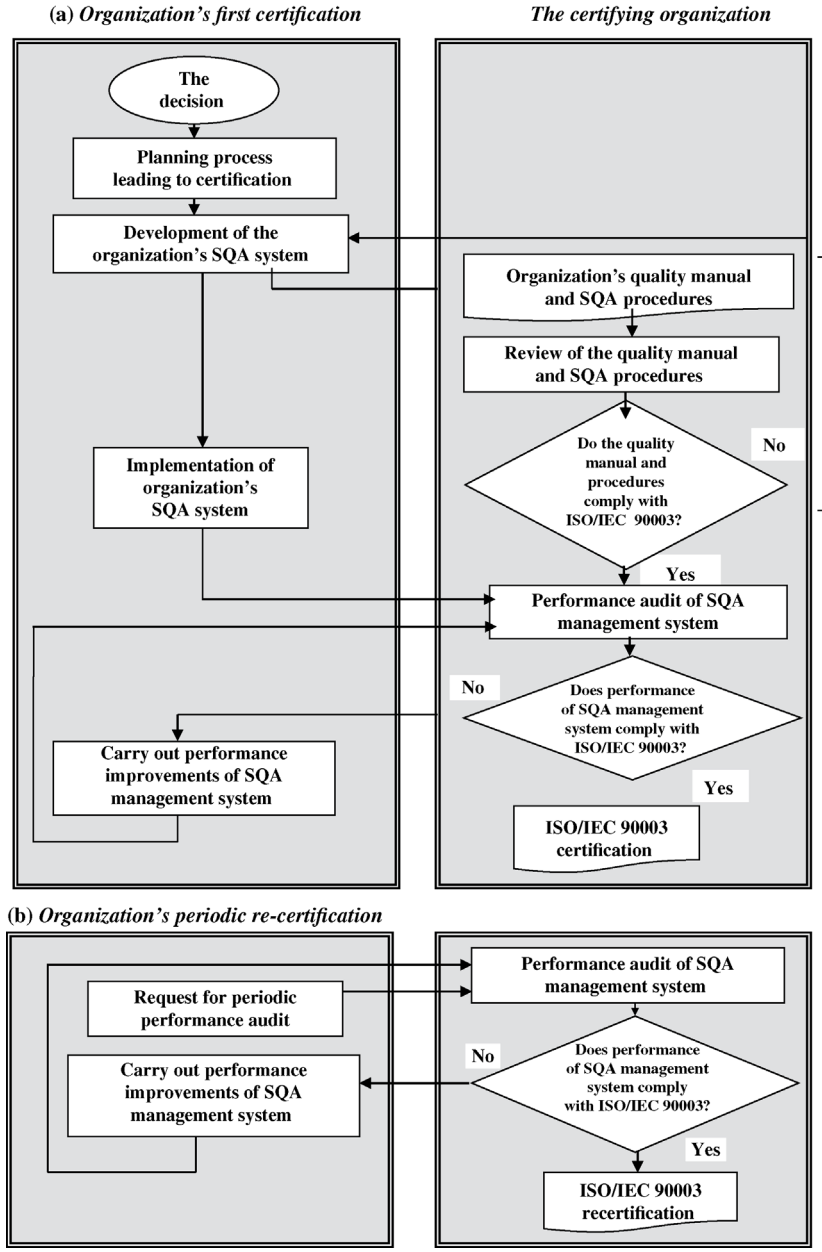

Figure B.1 The ISO 90003 certification process

c. Implementation of the organization's SQA system

d. Undergoing the certification audits

The process for retaining the certification includes the following activities:

e. Procedures for retaining ISO certification

a. Planning the process leading to certification

Once management has made its decision to obtain ISO 90003 certification for its software development and maintenance activities, an action plan is needed.

An internal survey of the current SQA system and how it is implemented is a good place to begin. The survey should supply information about:

- Gaps between currently employed SQA and required procedures: missing procedures in addition to inadequate procedures.
- Gaps between staff know-how and knowledge required regarding SQA procedures and SQA tools.
- Gaps regarding documentation of development as well as maintenance activities.
- Gaps/imparity regarding software configuration system capabilities and implementation.
- Gaps regarding managerial practices demanded for project progress control.
- Gaps regarding SQA unit organization and its capabilities.

After completing the above analysis, the plan for obtaining certification can be constructed. It should include:

- A list of activities to be performed, including schedules.
- Estimates of resources required to carry out each activity.
- Organizational resources: (a) Internal participants – SQA unit staff (including staff to be recruited) and senior software engineers; (b) SQA consultants.

b. Development of the organization's SQA system and its procedures

Before proceeding, the organization's SQA management system should be developed to a level adequate to meet ISO/IEC 90003 requirements. These efforts should include:

- Development of a quality manual and a comprehensive set of SQA procedures
- Development of additional SQA infrastructure:
  - Staff training and instruction programs, including staff certification programs
  - Preventive and corrective actions procedures, including the CAB committee
  - Configuration management services, including a software change control management unit

  - Documentation and quality record controls
- Development of a project progress control system

c. Implementation of the organization's SQA system

Once the components of the SQA management system conform to certification requirements, efforts are shifted toward implementing the system. These efforts include setting up a staff instruction program and support services appropriate for the task of solving problems that may arise when implementing SQA tools. These arrangements are targeted especially at team leaders and unit managers, who are expected to follow up and support the implementation efforts made by their units.

Throughout this stage, internal quality audits are carried out to verify the success of implementation and to identify units and SQA issues that require additional attention. The internal quality audit findings will enable determining whether the organization has reached a satisfactory level of implementation.

d. Undergoing the certification audits

The certification audits are carried out in two stages:

a. *Review of the quality manual and SQA procedures developed by the organization*. The review ascertains completeness and accuracy. In cases of noncompliance with standards, the organization is obligated to complete the corrections prior to advancing to the second stage of certification.

b. *Verification audits of compliance with the requirements defined by the organization in its quality manual and SQA procedures*. The main questions to be answered are:

- Has the staffs been adequately instructed on SQA topics and does it display a satisfactory level of knowledge?
- Have the relevant procedures – project plans, design reviews, progress reports, and so on – been properly and fully implemented by the development teams?
- Have documentation requirements been fully observed?

The main sources of information for certification audits are: (a) interviews with members of the audited unit and (b) review of documents such as project plans, design documents and test plans and procedures, and design review records. In order to ensure reliable results and avoid biased conclusions, audits are based on a random selection of projects and/or teams.

e. Procedures for retaining ISO/IEC certification

Periodic recertification audits, usually carried out once or twice a year, are performed to verify continued compliance with ISO/IEC 90003 requirements. During these audits, the organization has to demonstrate continuing development of its SQA management system, which is indicated in quality and productivity performance improvements, regular

updates of procedures to reflect technological changes, as well as process improvement.

B.5 Capability maturity CMMI models – assessment methodology

Carnegie Mellon University's Software Engineering Institute (SEI) took the initial steps toward development of what is termed as a *capability maturity model* (CMM) in 1986, when it released the first brief description of the maturity process framework. The initial version of the CMM was released in 1992, mainly to receive feedback from the software community. The first version for public use was released in 1993 and was dedicated to the assessment of software development processes (Paulk et al., 1995). The current integrated CMMI methodology includes software development, software service, and acquisition models, integrated into the CMMI (CMMI Product Team, 2010a, 2010b, 2010c).

Another maturity model, P-CMM (People-CMM), was developed by the SEI team similarly to other maturity models, and dedicated to the process improvement of human resources management.

Several CMMI methodology implementation issues are presented by Ramanujan and Kesh (2004), Diaz et al. (2009), Trujillo et al. (2011), and Alyahya et al. (2012). The applicability of capability models for small software organizations is examined by Suominen and Makinen (2014).

B.5.1 The principles of CMMI

CMM assessment is based on the following concepts and principles:

- Application of elaborate management methods based on quantitative approaches increases the organization's capability to control the quality and improve the productivity of the software development process.
- The vehicle for enhancement of software development is composed of the five-level capability maturity model. The integrated models for software development, software services, and acquisition enable an organization to evaluate its achievements and determine the efforts needed to reach the next capability level by locating the process areas requiring improvement.
- Process areas are generic; they define the "what" – not the "how." This approach enables the model to be applied to a wide range of implementation organizations as:
  - It allows using any life cycle model.
  - It allows using any design methodology, software development tool, and programming language.
  - It does not specify any particular documentation standard.

B.5.2 The CMMI structure and processes areas

The three CMMI models share the same conceptual framework. The CMMI models, like the original CMM model, are composed of the following five levels:

- Capability maturity level 1: Initial
- Capability maturity level 2: Managed
- Capability maturity level 3: Defined
- Capability maturity level 4: Quantitatively managed
- Capability maturity level 5: Optimizing

Each of the CMMI models includes almost the same number of process areas (PAs): CMMI model for software development – 22 PAs, CMMI model for services – 23 PAs, and CMMI model for acquisition – 22 PAs. The organization is required to successfully perform a set of PAs in order to be awarded a higher maturity level.

The CMMI models share a great part of their PAs as follows:

- CMMI model for software development shares 14 PAs with CMMI model for services share
- CMMI model for software development shares 16 PAs with CMMI model for acquisition
- CMMI model for services shares 14 PAs with CMMI model for acquisition

Thirteen of the PAs are common to the three CMMI models.

The CMMI model for software development and its process areas (PAs) are presented in Figure B.2.

The CMMI assessment standards provide detailed guidance for the performance of each PA. This guidance includes:

- Purpose statement of the PA
- Specific goals for each PA
- Specific practices for each specific goal
- Examples of information sources, categories of practices, criteria, situations, selection considerations, and so on
- Examples of work products and subpractices for each specific practice

In addition, the CMMI assessment standards define generic goals for each PA, where

- Purpose statement of the PA is defined
- Generic goals are defined for each PA
- Generic practices are defined for each generic goal

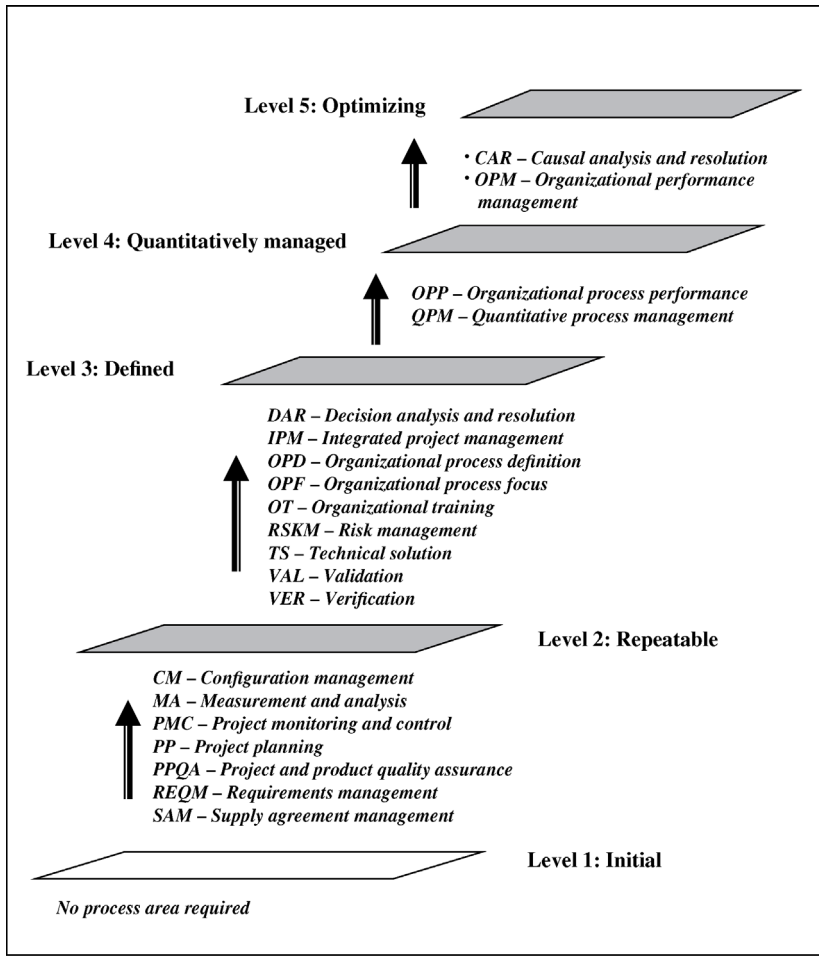

Figure B.2 The CMMI model for software development – model levels and process areas (PAs). (After Paulk et al., 1995.)

- Subpractices and generic practice elaborations and additions are provided for each generic practice

B.5.3 CMMI appraisal process

CMMI standards do not have a certification process, but enable the professional appraisal of the quality management achievement of the organization. The appraisal could be performed as a self-assessment or by an external assessor. The appraisal results determine the organization's capability level or its capability achievement profile.

The following are the main justifications for performing an appraisal:

- To determine the quality management performance achievements compared with CMMI requirements, in order to identify areas that need improvement.
- To present to customers the organization's capability level as a supplier of software development and services.
- To meet capability level requirement by customers.

CMMI methodology stresses the importance of the assessor's qualifications. A certified assessor is required to be SEI-trained and to be certified by the institute.

B.5.4 CMM implementation experience

In our discussion of CMMI implementation experience, we refer to:

- Performance improvements
- Time required for the transition from one CMMI level to the next

Performance improvements

Implementation of a CMMI program by an organization is a costly investment. Managers often wonder what the expected benefits of this investment are. A response to this request, based on quantitative measurements by 19 organizations, is provided by Galin and Avrahami (2006). It was found that "climbing" to a higher capability level (i.e., from CMM level 2 to CMM level 3) is followed by the following average performance improvements in Table B.2.

Even when considering the fact that the resulting benefits are somewhat biased, being based on CMM success stories, the benefits are still remarkable.

Table B.2 Performance improvement by transition to the next CMM level

Performance criterion	Average performance improvement (%)
Reduction of error density	48
Increase of productivity	52
Decrease of percentage of rework	39
Reduction of project cycle time	38
Increase of schedule fidelity	45
Increase of error detection effectiveness	63

Source: Galin and Avrahami (2006).

Table B.3 Time required to progress to the next CMM capability level

Capability level transition	Mean time (months)
Level 1 to level 2	24
Level 2 to level 3	21.5
Level 3 to level 4	33
Level 4 to level 5	18

Expected CMMI transition time

A report by Gartner Group Inc., a leading consulting company on information technology management, summarizes the firm's accumulated experience regarding the time required for progress from one capability level to the next (Gartner Group, 2001). The average time required for progress from one CMM capability level to the next is a measure of the efforts required for achievements in a CMMI project. As such, this information is of great interest to managers considering implementation of a CMMI project in their organization. These results for CMM projects are shown in Table B.3.

The results for performance improvement and time required for transition from one capability level to the next are based on studies of CMM project experience. No similar studies were found for CMMI projects. We expect that similar results will also be achieved in CMMI applications.

B.5.5 The People CMM model

The People-CMM (P-CMM) methodology (Curtis et al., 2009a) is an important complementary part to the CMMI methodology as it guides management of the human resources, whom are occupied with the development of the software systems and the provision of software services. In other words, implementing P-CMM increases the organizational capability to perform CMMI process areas and reach higher CMMI capability levels. The P-CMM process areas deal with HR management, skill and knowledge development, quantified managerial control of HR, and improvement of HR management practices.

The P-CMM model is a "traditional" 5-capability level model, dedicated to the HR-specific process areas. The P-CMM model levels and their process areas are presented in Figure B.3.

Several papers discuss the issues of People-CMM and the experience of its implementation in organizations: Gama et al. (2011) and Colomo-Palacios et al. (2010), to name but a few. A comprehensive discussion of the P-CMM methodology, possible uses of the model and experience gained by implementation of the model, can be found in a book by Curtis et al. (2009b).

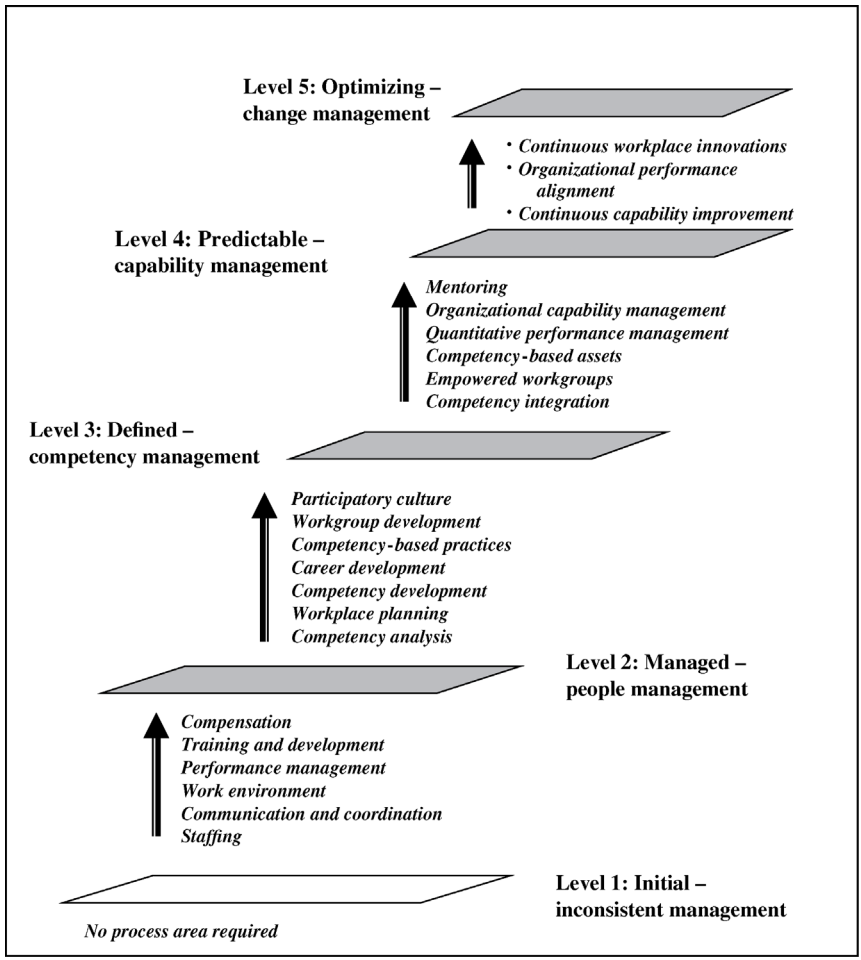

Figure B.3 P-CMM model – capability levels and process areas

B.6 The SPICE project and the ISO/IEC 15504 software process assessment standard

The success of CMM created parallel development of several software process assessment methodologies. The most important of these was a joint initiative by ISO and IEC, the SPICE (Software Process Improvement for Capability Determination) Project, established in 1993 by developing an international standard of software process assessment methodology.

The SPICE Project released its Version 1.0 report in 1995, which became the basis for the development of the TR (technical report) version of the ISO/IEC 15504 standard released in 1998.

The next stage in the development of the ISO/IEC 15504 standard will be its release as an international standard. An ISO/IEC working group has been assigned the responsibility of developing the standard and publishing its revisions. Each revision draft is examined and edited by the national standard institute members of ISO and IEC before being finally approved. Another route taken to identify features demanding revision was the conduct of a major three-phase trial within the framework of the SPICE Project.

The current ISO/IEC standard is composed of eight parts, four of which are technical specifications (TSs). The eight standard parts are dedicated to the following subjects:

- Part 2: Performing an assessment (ISO/IEC, 2003)
- Part 3: Guidance on performing an assessment (ISO/IEC, 2004a)
- Part 4: Guidance on use of process improvement and process capability determination (ISO/IEC, 2004b)
- Part 5: An exemplar process assessment process model (ISO/IEC, 2012a)
- Part 6: An exemplar system life cycle process assessment model (TS) (ISO/IEC, 2013)
- Part 8: An exemplar process assessment process model for IT service management (TS) (ISO/IEC, 2012b).
- Part 9: Target process profiles (TS) (ISO/IEC, 2011a).
- Part 10: Safety extension (TS) (ISO/IEC, 2011b)

Former parts 1 and 7 of the 15504 standard were replaced by a new standard: ISO/IEC 33001: Concepts and terminology.

This first replacement is part of the entire ISO/IEC 15504 set of standards being replaced by a new set of ISO/IEC 33000 series of standards as follows:

- ISO/IEC 33001: 2015 Information technology – Process assessment – Concepts and terminology (ISO/IEC, 2015a).
- ISO/IEC 33002: 2015 Information technology – Process assessment – Requirement for performing process assessment (ISO/IEC, 2015b).
- ISO/IEC 33003: 2015 Information technology – Process assessment – Requirement for process measurement framework (ISO/IEC, 2015c).
- ISO/IEC 33004: 2015 Information technology – Process assessment – Process reference, process assessment, and maturity models (ISO/IEC, 2015d).
- ISO/IEC 33014: 2015 Information technology – Process assessment – Guide for process improvement (ISO/IEC, 2015e).
- ISO/IEC 33063: 2015 Information technology – Process assessment – Process measurement framework for assessment of process capability.

B.6.1 Principles behind ISO/IEC 15504 assessment model

The initiators of the SPICE project and the ISO/IEC standard have defined the following guiding principles for the new assessment model:

- Harmonize the many existing "independent" assessment methodologies by providing a comprehensive framework model (instructing the users in "what" has to be accomplished rather than on "how" it has to be done).
- Be universal to serve all or almost all categories of software suppliers and customers as well as software categories.
- Be highly professional.
- Be worldwide accepted. Aim at reaching international acceptance to emerge as a real-world standard. Becoming a world standard is expected to save supplier resources by eliminating the need to perform several different capability assessments simultaneously in response to different customer requirements. The standard allows conformity of its process model with existing assessment models.

Comparative studies have already proved high conformity of the ISO/IEC 15504 standard with the CMM model and Bootstrap model.

B.6.2 Structure of the ISO/IEC 15504 assessment model

The 15504 process assessment model is a two-dimensional model:

- The capability dimension
- The process dimension

The capability dimension

The capability dimension model is composed of six levels of capability, where level 0 is the lowest and level 5 the highest. The model defines process attributes (PAs) that have to be attained to achieve each capability level. Process attributes are generic, defining "what," not "how,"

The model is composed of:

- Capability levels and process attribute requirements (PAs) for each level

- Indicators for each PA, which are used as a basis for collecting the objective evidence that enables an assessor to assign ratings
- Achievement grades scale for process attributes
- Accumulative achievement requirements for each capability level

Capability levels and process attribute requirements

Level 0: Incomplete process

No process attributes are expected. There is no (or only little) implementation of any planned or identified process.

Level 1: Performed process

PA1: **Process performance** includes identifying processes and their inputs and outputs.

Level 2: Managed process

PA2: **Performance management** – Processes performed according to procedures, their progress is controlled.

PA3: **Work product management** – Work products are controlled and documented, their compliance is verified.

Level 3: Established process

PA4: **Process definition** – The organization applies well-defined processes throughout. Processes tailored to any specific project originate in standard processes.

PA5: **Process deployment** – The organization controls use of project resources: human resources, infrastructure resources, and so on.

Level 4: Predictable process

PA6: **Process measurement** – Performance measurement supports achievement of project goals.

PA7: **Process control** – The organization controls processes by collection of data on performance and product measures, analysis and implementation of needed corrections of process performance to achieve process goals.

Level 5: Optimizing process

PA8: **Process innovation** – The organization initiates and controls processes and managerial systems to improve its effectiveness and efficiency for achievement of its business goals and assures continuous improvement of processes and management.

PA9: **Process optimization** – The organization persistently monitors the changes implemented through quantitative measurement to achieve optimization.

An example of indicators for a process attribute is presented in Frame B.2.

The capability dimension model and the process attributes required for each level are illustrated in Figure B.4.

Frame B.2: Indicator for process control attributes – an example
Source: ISO/IEC Std. 15504-2

Level 4: Predictable process.
PA7: Process control attribute. Indicators: **a.** Suitable analysis and control techniques determined and applied where applicable **b.** Control limits of variation are established for normal process performance **c.** Measurement data are analyzed for special cases of variation **d.** Corrective actions are taken to address special causes of variation **e.** Control limits are reestablished (as necessary) following corrective action

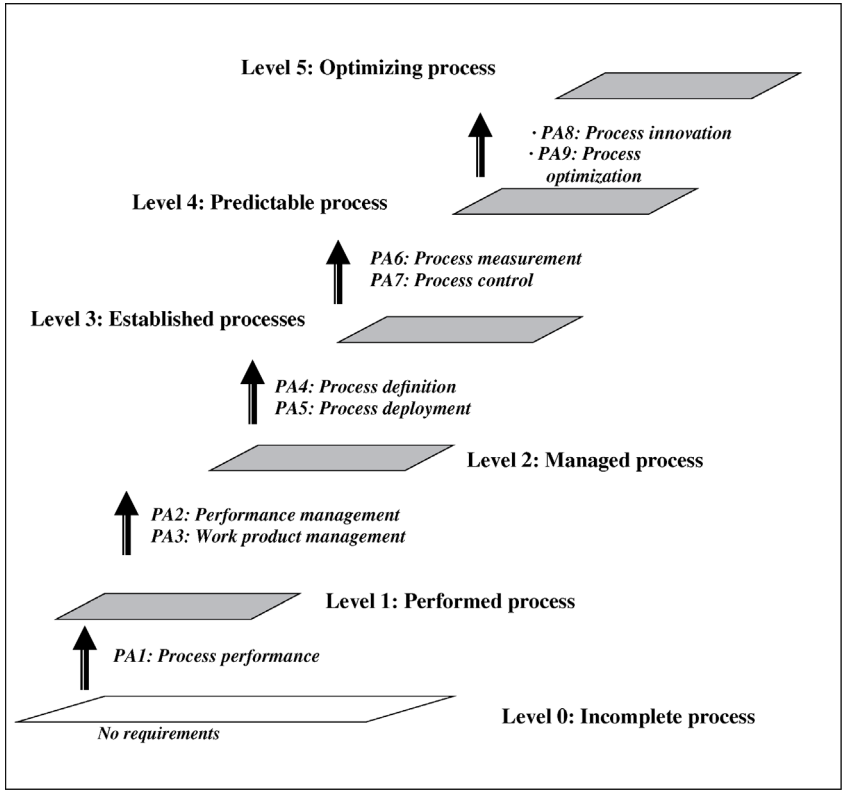

Figure B.4 The ISO/IEC 15504 capability dimension model

The process dimension

The 15504 process dimension fully adopts the process reference model of the 12207 standard presented in Figure A.1. The process dimension model is composed of more than 40 processes. (The number of processes varies slightly for the different versions of the 12207 standard.) The processes are classified into seven categories:

System life cycle category group:

- AGR: Agreement process
- ORG: Organization project-enabling processes
- PRO: Project processes
- ENG: Technical processes

Software life cycle category group:

- DEV: Software development processes
- SUP: Software support processes
- REU: Software reuse processes

The relationship between the capability dimension and the process dimension is defined by the standard in a table that indicates relevant PAs for each process. According to the table, a process could be relevant for one to four PAs. The two-dimensional process assessment model and the relationships between the dimensions are presented in Figure B.5.

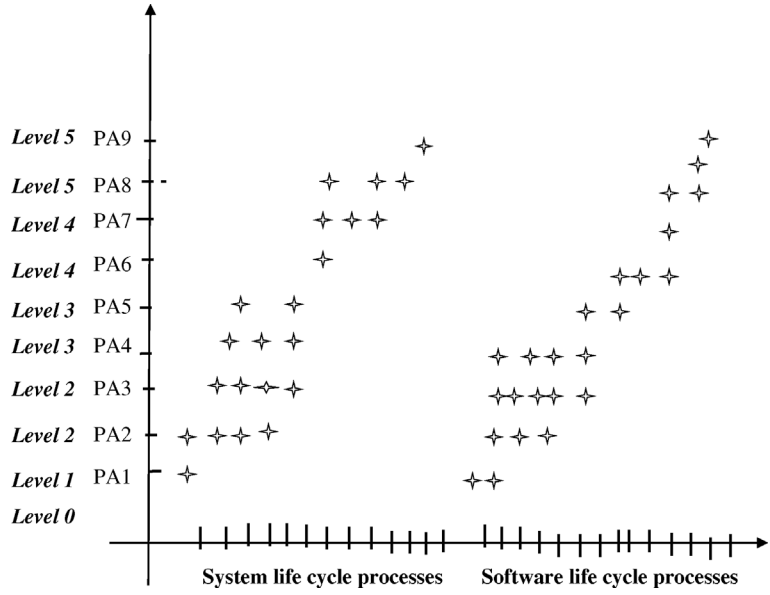

Figure B.5 The 15504 two-dimensional process assessment model

B.6.3 The ISO/IEC 15504 appraisal process

The standard allows performing the appraisal as a self-assessment or independent assessment. In both cases, the standard presents strict requirements regarding the qualifications of assessors:

a. Have adequate education, training, and experience on the relevant processes.

b. Have access to the guidance documentation on how to perform the relevant assessment activities.

c. Have the competence to use the tools to support the appraisal that are provided by the standard

The assessment result ratings for each PA are summarized by grades. A PA may be graded with one of the following four grades according to its evaluation:

- Fully achieved (F) for ratings in the range of 86–100%.
- Largely achieved (L) for ratings in the range of 51–85%
- Partially achieved (P) for ratings in the range of 16–50%
- Not achieved (N) for ratings in the range of 0–15%

The ISO/IEC 15504 model likewise determines the achievements required for each of the relevant process areas. An organization's SQA system capability maturity would be evaluated to a certain capability maturity level if (1) all level PAs are fully or largely achieved, and (2) all PAs of lower capability maturity levels are fully achieved. For example, an organization is evaluated as capability maturity level 3 if all PAs of level 3 are rated fully or largely achieved and all level 2 and level 1 PAs are fully achieved.

B.6.4 The SPICE project

The SPICE project operates the professional working groups that created the ISO/IEC 15504 standard in the mid-1990s and continue to conduct work to develop the standard.

Once the standard became public, the SPICE project management planned a large-scale trial of the ISO/IEC 15504 technical report version to facilitate its transformation into an effective standard. The trials had three goals:

- To validate the model's conformity with current standards
- To verify its usability in determining whether software satisfies user requirements
- To gain experience in applying the model

The three phases of the trial were carried out during 1995–2000. A database was built of data collected during full-scale assessments performed in organizational environments. Each volunteer organization agreed to carry out at least one full-scale assessment. Special efforts were invested to create a diversified database, including participants from every continent and a variety of software specializations. During these trials, more than 200 full-scale assessments were carried out with several technical reports that summarized the SPICE trials empirical experience published in the late 1990s. The analysis of the collected empirical data served as a major basis for the full version of the ISO/IEC international standard parts that were published during 2003–2006.

The SPICE project working group continued to develop and update the standard in the following years. Other activities within the SPICE project are the SPICE annual conferences dedicated to software development assessment research and experience with the application of the 15504 standard and other software development assessment models.

A new direction in the development of the SPICE project was the adaptation to individual domains by development of SPICE PRM, PAM, and OMM models. Another development was the automotive industry, with the 2005 release of the automotive SPICE standard.

Detailed descriptions of the history of the SPICE project can be found in Rout et al. (2007), Salviano et al. (2012), and Mesquida et al. (2014).

B.7 Additional software quality management standards

Several software quality management methodologies were developed in parallel to ISO/IEC 90003, CMMI, and ISO/IEC 15504 standards. TickIT and Bootstrap methodologies will be presented in this section.

TickIT

TickIT was launched in the late 1980s by the British software industry in cooperation with the British Department for Trade and Industry to promote development of a methodology for adapting ISO 9001 to the characteristics of the software industry known as *the TickIT initiative*. Currently, with the TickIT Plus methodology and TickIt standards, it provides a variety of consulting, auditing, and certification services, mainly to the British IT industry.

At the time of its launching, ISO 9001 had already been successfully applied in the manufacturing industry; however, no significant methodology for its application to the special characteristics of the software industry was yet available. In the years to follow, the TickIT initiative, together with efforts invested in the development of ISO/IEC 90003, achieved this goal.

TickIT activities include:

- Publication of the TickIt standards of software quality management and capability assessment.
- Publication of the *TickIT Guide* and other publications that support the software industry efforts to spread ISO 9001 and ISO/IEC 90003 certification. The current guide, which includes references to ISO/IEC 12207 and ISO/IEC 15504 and other TSO/IEC standards, is distributed to all TickIT customers.
- Performance of audit-based assessments of software quality systems and consultation to organizations on improvement of software development and maintenance processes in addition to their management.
- Conduct ISO/IEC 90003 and TickIT Plus in addition to certification audits and assessment audits. TickIT auditors who conduct audit-based assessments and certification audits are registered by the International Register of Certificated Auditors (IRCA).
- Provide consulting and training services.

The Bootstrap

The Bootstrap Institute, a nonprofit organization that operates in Europe as part of the European Strategic Program for Research in Information Technology (ESPRIT) in cooperation with the European Software Institute (ESI), offers another route for professional SQA support to organizations based on its Bootstrap methodology.

The Bootstrap Institute provides various types of support to its licensed members:

1. Access to the Bootstrap methodology for assessment and improvement of software development processes. The Institute constantly updates and improves its methodology.
2. Training and accreditation of assessors.
3. Access to the Bootstrap database.

The Bootstrap methodology measures the maturity of an organization and its projects on the basis of quality attributes grouped into three classes: process, organization, and technology. A five-grade scale is applied to each of the quality attributes separately. The methodology facilitates detailed assessment of the software development process by evaluating its achievements with respect to each attribute, and indicates the improvements required in the software development process and projects. The assessment options include:

- Evaluation of the current position of the software quality assurance system as a basis for improvement initiation.

- Evaluation of level of achievements according to the Capability Maturity Model Integrated (CMMI) models.
- Evaluation of achievements according to ISO 15504 (the SPICE project).
- ISO 90003 gap assessment to support preparations for a certification audit.

Training and accreditation of assessors. Bootstrap trains three levels of registered assessors, namely, trained assessor, assessor, and lead assessor. A person can become a registered lead assessor, having overall responsibility for planning and performing a Bootstrap assessment, only after successfully performing as a trained and then registered assessor. In order to become a trained assessor, a person has to successfully complete a basic assessor training program, after which she or he can participate in Bootstrap assessments. Trained assessors who have demonstrated knowledge in performance of assessments and have been recommended by a registered lead assessor may qualify as a registered assessor. Registered assessors are likewise required to demonstrate knowledge and competence in carrying out higher level assessments in addition to participation in a lead assessors training course. Only then they can apply for acceptance as lead assessors.

The Bootstrap database contains the findings of Bootstrap assessments conducted for its member organizations. Although the sources of the data are kept anonymous, the assessment results are classified according to the type of organization, country, type of product or service, market, and development effort. Members can obtain the following information:

- Members own assessments – retrieved from the database
- Aggregate assessments results from comparable organizations
- Data for surveys and research of software development to improve development processes and product quality

Summary

1. **The aims of certification standards**
   - Enable a software development organization to demonstrate consistent ability to perform software development and or maintenance services that comply with quality requirements.
   - Serve as an agreed-upon basis for customer and supplier evaluation of the supplier's quality management system.
   - Support the software development organization's efforts to improve quality management system performance and enhance customer satisfaction.

2. **The aims of capability assessment standards**
   - Serve software development and maintenance organizations as a tool for self-assessment of their capability level to carry out software development projects.
   - Serve as a tool for improvement of development and maintenance processes. The standard indicates directions for process improvements.
   - Help purchasing organizations determine the capabilities of potential suppliers.
   - Guide training of assessor by delineating qualifications and training program curricula.
3. **Ways by which continuous improvement principle of SPIs are achieved**
   - Serve software development and maintenance organizations as a tool for self-assessment of their ability to carry out software development projects.
   - Serve as a tool for improvement of development and maintenance processes. The standard indicates directions for process improvements.
   - Help purchasing organizations determine the capabilities of potential suppliers.
   - Guide training of assessor by delineating qualifications and training program curricula.
4. **Description of the general principles underlying quality management according to ISO/IEC 90003**
   - Customer focus – understanding a customer's current and future needs.
   - Leadership exercised in the creation and maintenance of a positive internal environment in order to achieve the organization's objectives.
   - Involvement of people at all levels to further organizational goals.
   - Process approach – activities and related resources are perceived and managed as a process.
   - Systems approach to management – managing processes as a system.
   - Continual improvement of the organization's overall performance.
   - Factual approach to decision-making – decisions are based on the analysis of data and information.
   - Mutually beneficial supplier relationships – emphasis on coordination and cooperation.
5. **Description of the ISO/IEC 90003 certification process**

   To acquire ISO/IEC 90003 certification, organizations must carry out the following:
   - Plan the organization's activities for gaining certification.
   - Development the organization's SQA system, including procedures.

- Obtain approval of procedures by the certifying organization.
- Implement the organization's SQA system.
- Undergoing certification audits of actual performance of the SQA system.

To retain the ISO/IEC certification, the organization

- must undergo certification audits of actual performance of the SQA system;
- is required to improve its performance in cases of low audits results to a level that complies with the standard requirements.
- undergo recurrent certification audits.

6. **Description of the principles embodied in the CMM**
   - Application of highly elaborated software quality management methods increases the organization's capability to control quality and improve software process productivity.
   - Application of the five levels of the capability maturity model enables the organization to evaluate its achievements and determine which additional efforts are needed to reach the next capability level.
   - Process areas are generic, with the model defining "what" and leaving the "how" to the implementing organizations, that is, the choice of life cycle model, design methodology, software development tool, programming language, and documentation standard.
7. **Description of the principles that guided the developers of ISO/IEC 15504**
   - Harmonization of independent assessment methodologies by providing a conceptual framework based on "what," not "how."
   - Universality of applicability to all or almost all categories of software suppliers and customer organizations as well as software categories.
   - Professionalism.
   - Worldwide acceptance.

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Review questions

B.1 Section B.2 presents classes of software quality management standards.

- **a.** Explain the differences between the two classes.
- **b.** Compare the scope of the two classes and discuss the differences with respect to the goals of software quality assurance.

B.2 The evolution and diversification of the CMM methodology have produced several specialized CMM products. At a certain point, SEI moved toward creation of integrated CMMI models.

- **a.** Explain the reasons for this move.
- **b.** List arguments for and against integration.

B.3 The SPICE project performed a comprehensive trial with the early versions of the ISO/IEC 15504 standard.

- Explain in your own words the contribution of the trial to development of the standard.

B.4 One of the main activities of the Bootstrap Institute is training and accreditation of assessors.
- Discuss the special role of assessors in implementation of the Bootstrap methodology.

Topics for discussion

B.1 ISO/IEC 90003 serves as a certification standard for interested software development organizations throughout the world.
- **a.** The ISO and the IEC are neither capable nor interested in carrying out certification audits. How do standards organizations ensure the performance of audits conducted with the same method and requiring the same level of achievement in the same subjects for organizations worldwide?
- **b.** Describe in your own words the certification for an organization.
- **c.** Explain the unique importance of each stage of a certification audit.

B.2 Organizations are usually interested to retain their ISO/IEC 90003 certification.
- **a.** Describe in your own words the recertification process of an organization.
- **b.** Describe situations when an organization does not retain its certification.

B.3 CMMI models are composed of almost identical capability maturity models. The models include 24 process areas.
- **a.** Explain the differences between the CMMI models process areas in relation to the respective subject matter.
- **b.** Indicate which of the capability levels present the most differences among the models.
- **c.** Can you characterize the observed differences among the models?

B.4 Section B.5.4 describes the CMM implementation experience.
- **a.** Discuss in your own words the experience presented in the section.
- **b.** What additional information could be helpful for organizations considering the adoption of the CMMI methodology in their decision making?