CHAPTER 5

SOFTWARE MAINTENANCE

ACRONYMS

MR	Modification Request
PR	Problem Report
SCM	Software Configuration Management
SLA	Service-Level Agreement
SQA	Software Quality Assurance
V&V	Verification and Validation

INTRODUCTION

Software development efforts result in the delivery of a software product that satisfies user requirements. Accordingly, the software product must change or evolve. Once in operation, defects are uncovered, operating environments change, and new user requirements surface. The maintenance phase of the life cycle begins following a warranty period or postimplementation support delivery, but maintenance activities occur much earlier.

Software maintenance is an integral part of a software life cycle. However, it has not received the same degree of attention that the other phases have. Historically, software development has had a much higher profile than software maintenance in most organizations. This is now changing, as organizations strive to squeeze the most out of their software development investment by keeping software operating as long as possible. The open source paradigm has brought further attention to the issue of maintaining software artifacts developed by others.

In this *Guide*, software maintenance is defined as the totality of activities required to provide cost-effective support to software. Activities are performed during the predelivery stage as well as during the postdelivery stage. Predelivery activities include planning for postdelivery operations, maintainability, and logistics determination for transition activities [1*, c6s9]. Postdelivery activities include software modification, training, and operating or interfacing to a help desk.

The Software Maintenance knowledge area (KA) is related to all other aspects of software engineering. Therefore, this KA description is linked to all other software engineering KAs of the *Guide*.

BREAKDOWN OF TOPICS FOR SOFTWARE MAINTENANCE

The breakdown of topics for the Software Maintenance KA is shown in Figure 5.1.

1. Software Maintenance Fundamentals

This first section introduces the concepts and terminology that form an underlying basis to understanding the role and scope of software maintenance. The topics provide definitions and emphasize why there is a need for maintenance. Categories of software maintenance are critical to understanding its underlying meaning.

1.1. Definitions and Terminology

[1*, c3] [2*, c1s2, c2s2]

The purpose of software maintenance is defined in the international standard for software maintenance: ISO/IEC/IEEE 14764 [1*].[1] In the context of software engineering, software maintenance is essentially one of the many technical processes.

1 For the purpose of conciseness and ease of reading, this standard is referred to simply as IEEE 14764 in the subsequent text of this KA.

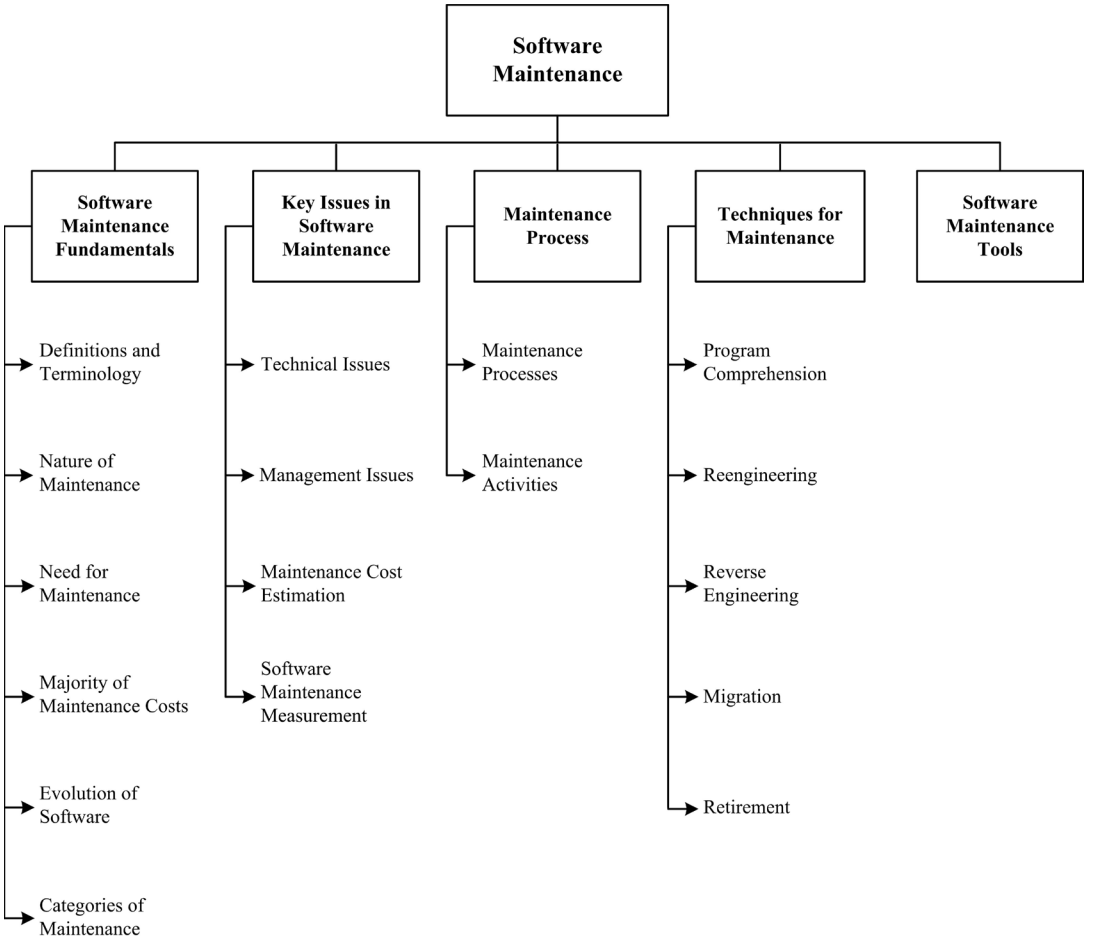

Figure 5.1. Breakdown of Topics for the Software Maintenance KA

The objective of software maintenance is to modify existing software while preserving its integrity. The international standard also states the importance of having some maintenance activities prior to the final delivery of software (predelivery activities). Notably, IEEE 14764 emphasizes the importance of the predelivery aspects of maintenance—planning, for example.

1.2. Nature of Maintenance

[2*, c1s3]

Software maintenance sustains the software product throughout its life cycle (from development to operations). Modification requests are logged and tracked, the impact of proposed changes is determined, code and other software artifacts are modified, testing is conducted, and a new version of the software product is released. Also, training and daily support are provided to users. The term *maintainer* is defined as an organization that performs maintenance activities. In this KA, the term will sometimes refer to individuals who perform those activities, contrasting them with the developers.

IEEE 14764 identifies the primary activities of software maintenance as process implementation, problem and modification analysis, modification implementation, maintenance review/acceptance, migration, and retirement. These activities are discussed in section 3.2, Maintenance Activities.

Maintainers can learn from the developers' knowledge of the software. Contact with the developers and early involvement by the

maintainer helps reduce the overall maintenance effort. In some instances, the initial developer cannot be reached or has moved on to other tasks, which creates an additional challenge for maintainers. Maintenance must take software artifacts from development (for example, code or documentation) and support them immediately, then progressively evolve/maintain them over a software life cycle.

1.3. Need for Maintenance

[2*, c1s5]

Maintenance is needed to ensure that the software continues to satisfy user requirements. Maintenance is applicable to software that is developed using any software life cycle model (for example, spiral or linear). Software products change due to corrective and noncorrective software actions. Maintenance must be performed in order to

- correct faults;
- improve the design;
- implement enhancements;
- interface with other software;
- adapt programs so that different hardware, software, system features, and telecommunications facilities can be used;
- migrate legacy software; and
- retire software.

Five key characteristics comprise the maintainer's activities:

- maintaining control over the software's day-to-day functions;
- maintaining control over software modification;
- perfecting existing functions;
- identifying security threats and fixing security vulnerabilities; and
- preventing software performance from degrading to unacceptable levels.

1.4. Majority of Maintenance Costs

[2*, c4s3, c5s5.2]

Maintenance consumes a major share of the financial resources in a software life cycle. A common perception of software maintenance is that it merely fixes faults. However, studies and surveys over the years have indicated that the majority, over 80 percent, of software maintenance is used for noncorrective actions [2*, figure 4.1]. Grouping enhancements and corrections together in management reports contributes to some misconceptions regarding the high cost of corrections. Understanding the categories of software maintenance helps to understand the structure of software maintenance costs. Also, understanding the factors that influence the maintainability of software can help to contain costs. Some environmental factors and their relationship to software maintenance costs include the following:

- Operating environment refers to hardware and software.
- Organizational environment refers to policies, competition, process, product, and personnel.

1.5. Evolution of Software

[2*, c3s5]

Software maintenance in terms of evolution was first addressed in the late 1960s. Over a period of twenty years, research led to the formulation of eight "Laws of Evolution." Key findings include a proposal that maintenance is evolutionary development and that maintenance decisions are aided by understanding what happens to software over time. Some state that maintenance is continued development, except that there is an extra input (or constraint)–in other words, existing large software is never complete and continues to evolve; as it evolves, it grows more complex unless some action is taken to reduce this complexity.

1.6. Categories of Maintenance

[1*, c3, c6s2] [2*, c3s3.1]

Three categories (types) of maintenance have been defined: corrective, adaptive, and perfective [2*, c4s3]. IEEE 14764 includes a fourth category–preventative.

- Corrective maintenance: reactive modification (or repairs) of a software product

performed after delivery to correct discovered problems. Included in this category is emergency maintenance, which is an unscheduled modification performed to temporarily keep a software product operational pending corrective maintenance.

- Adaptive maintenance: modification of a software product performed after delivery to keep a software product usable in a changed or changing environment. For example, the operating system might be upgraded and some changes to the software may be necessary.
- Perfective maintenance: modification of a software product after delivery to provide enhancements for users, improvement of program documentation, and recoding to improve software performance, maintainability, or other software attributes.
- Preventive maintenance: modification of a software product after delivery to detect and correct latent faults in the software product before they become operational faults.

IEEE 14764 classifies adaptive and perfective maintenance as maintenance enhancements. It also groups together the corrective and preventive maintenance categories into a correction category, as shown in Table 5.1.

Table 5.1. Software Maintenance Categories

	Correction	**Enhancement**
Proactive	Preventive	Perfective
Reactive	Corrective	Adaptive

2. Key Issues in Software Maintenance

A number of key issues must be dealt with to ensure the effective maintenance of software. Software maintenance provides unique technical and management challenges for software engineers—for example, trying to find a fault in software containing a large number of lines of code that another software engineer developed. Similarly, competing with software developers for resources is a constant battle. Planning for a future release, which often includes coding the next release while sending out emergency patches for the current release, also creates a challenge. The following section presents some of the technical and management issues related to software maintenance. They have been grouped under the following topic headings:

- technical issues,
- management issues,
- cost estimation, and
- measurement.

2.1. Technical Issues

2.1.1. Limited Understanding

[2*, c6]

Limited understanding refers to how quickly a software engineer can understand where to make a change or correction in software that he or she did not develop. Research indicates that about half of the total maintenance effort is devoted to understanding the software to be modified. Thus, the topic of software comprehension is of great interest to software engineers. Comprehension is more difficult in text-oriented representation—in source code, for example—where it is often difficult to trace the evolution of software through its releases/versions if changes are not documented and if the developers are not available to explain it, which is often the case. Thus, software engineers may initially have a limited understanding of the software; much has to be done to remedy this.

2.1.2. Testing

[1*, c6s2.2.2] [2*, c9]

The cost of repeating full testing on a major piece of software is significant in terms of time and money. In order to ensure that the requested problem reports are valid, the maintainer should replicate or verify problems by running the appropriate tests. Regression testing (the selective retesting of software or a component to verify that the modifications have not caused unintended effects) is an important testing concept in maintenance. Additionally, finding time to test is often difficult. Coordinating tests when different members of the maintenance team are working

on different problems at the same time remains a challenge. When software performs critical functions, it may be difficult to bring it offline to test. Tests cannot be executed in the most meaningful place–the production system. The Software Testing KA provides additional information and references on this matter in its subtopic on regression testing.

2.1.3. Impact Analysis

[1*, c5s2.5] [2*, c13s3]

Impact analysis describes how to conduct, cost-effectively, a complete analysis of the impact of a change in existing software. Maintainers must possess an intimate knowledge of the software's structure and content. They use that knowledge to perform impact analysis, which identifies all systems and software products affected by a software change request and develops an estimate of the resources needed to accomplish the change. Additionally, the risk of making the change is determined. The change request, sometimes called a modification request (MR) and often called a problem report (PR), must first be analyzed and translated into software terms. Impact analysis is performed after a change request enters the software configuration management process. IEEE 14764 states the impact analysis tasks:

- analyze MRs/PRs;
- replicate or verify the problem;
- develop options for implementing the modification;
- document the MR/PR, the results, and the execution options;
- obtain approval for the selected modification option.

The severity of a problem is often used to decide how and when it will be fixed. The software engineer then identifies the affected components. Several potential solutions are provided, followed by a recommendation as to the best course of action.

Software designed with maintainability in mind greatly facilitates impact analysis. More information can be found in the Software Configuration Management KA.

2.1.4. Maintainability

[1*, c6s8] [2*, c12s5.5]

IEEE 14764 [1*, c3s4] defines maintainability as the capability of the software product to be modified. Modifications may include corrections, improvements, or adaptation of the software to changes in environment as well as changes in requirements and functional specifications.

As a primary software quality characteristic, maintainability should be specified, reviewed, and controlled during software development activities in order to reduce maintenance costs. When done successfully, the software's maintainability will improve. Maintainability is often difficult to achieve because the subcharacteristics are often not an important focus during the process of software development. The developers are, typically, more preoccupied with many other activities and frequently prone to disregard the maintainer's requirements. This in turn can, and often does, result in a lack of software documentation and test environments, which is a leading cause of difficulties in program comprehension and subsequent impact analysis. The presence of systematic and mature processes, techniques, and tools helps to enhance the maintainability of software.

2.2. Management Issues

2.2.1. Alignment with Organizational Objectives

[2*, c4]

Organizational objectives describe how to demonstrate the return on investment of software maintenance activities. Initial software development is usually project-based, with a defined time scale and budget. The main emphasis is to deliver a product that meets user needs on time and within budget. In contrast, software maintenance often has the objective of extending the life of software for as long as possible. In addition, it may be driven by the need to meet user demand for software updates and enhancements. In both cases, the return on investment is much less clear, so that the view at the senior management level is often that of a major activity consuming significant resources with no clear quantifiable benefit for the organization.

2.2.2. Staffing

[2*, c4s5, c10s4]

Staffing refers to how to attract and keep software maintenance staff. Maintenance is not often viewed as glamorous work. As a result, software maintenance personnel are frequently viewed as "second-class citizens," and morale therefore suffers.

2.2.3. Process

[1*, c5] [2*, c5]

The software life cycle process is a set of activities, methods, practices, and transformations that people use to develop and maintain software and its associated products. At the process level, software maintenance activities share much in common with software development (for example, software configuration management is a crucial activity in both). Maintenance also requires several activities that are not found in software development (see section 3.2 on unique activities for details). These activities present challenges to management.

2.2.4. Organizational Aspects of Maintenance

[1*, c7s2.3] [2*, c10]

Organizational aspects describe how to identify which organization and/or function will be responsible for the maintenance of software. The team that develops the software is not necessarily assigned to maintain the software once it is operational.

In deciding where the software maintenance function will be located, software engineering organizations may, for example, stay with the original developer or go to a permanent maintenance-specific team (or maintainer). Having a permanent maintenance team has many benefits:

- allows for specialization;
- creates communication channels;
- promotes an egoless, collegiate atmosphere;
- reduces dependency on individuals;
- allows for periodic audit checks.

Since there are many pros and cons to each option, the decision should be made on a case-by-case basis. What is important is the delegation or assignment of the maintenance responsibility to a single group or person, regardless of the organization's structure.

2.2.5. Outsourcing

[3*]

Outsourcing and offshoring software maintenance has become a major industry. Organizations are outsourcing entire portfolios of software, including software maintenance. More often, the outsourcing option is selected for less mission-critical software, as organizations are unwilling to lose control of the software used in their core business. One of the major challenges for outsourcers is to determine the scope of the maintenance services required, the terms of a service-level agreement, and the contractual details. Outsourcers will need to invest in a maintenance infrastructure, and the help desk at the remote site should be staffed with native-language speakers. Outsourcing requires a significant initial investment and the setup of a maintenance process that will require automation.

2.3. Maintenance Cost Estimation

Software engineers must understand the different categories of software maintenance, discussed above, in order to address the question of estimating the cost of software maintenance. For planning purposes, cost estimation is an important aspect of planning for software maintenance.

2.3.1. Cost Estimation

[2*, c7s2.4]

Section 2.1.3 describes how impact analysis identifies all systems and software products affected by a software change request and develops an estimate of the resources needed to accomplish that change.

Maintenance cost estimates are affected by many technical and nontechnical factors. IEEE 14764 states that "the two most popular approaches to estimating resources for software maintenance are the use of parametric models and the use of experience" [1*, c7s4.1]. A combination of these two can also be used.

2.3.2. Parametric Models

[2*, c12s5.6]

Parametric cost modeling (mathematical models) has been applied to software maintenance. Of significance is that historical data from past maintenance are needed in order to use and calibrate the mathematical models. Cost driver attributes affect the estimates.

2.3.3. Experience

[2*, c12s5.5]

Experience, in the form of expert judgment, is often used to estimate maintenance effort. Clearly, the best approach to maintenance estimation is to combine historical data and experience. The cost to conduct a modification (in terms of number of people and amount of time) is then derived. Maintenance estimation historical data should be provided as a result of a measurement program.

2.4. Software Maintenance Measurement

[1*, c6s5] [2*, c12]

Entities related to software maintenance, whose attributes can be subjected to measurement, include process, resource, and product [2*, c12s3.1].

There are several software measures that can be derived from the attributes of the software, the maintenance process, and personnel, including size, complexity, quality, understandability, maintainability, and effort. Complexity measures of software can also be obtained using available commercial tools. These measures constitute a good starting point for the maintainer's measurement program. Discussion of software process and product measurement is also presented in the Software Engineering Process KA. The topic of a software measurement program is described in the Software Engineering Management KA.

2.4.1. Specific Measures

[2*, c12]

The maintainer must determine which measures are appropriate for a specific organization based on that organization's own context. The software quality model suggests measures that are specific for software maintenance. Measures for subcharacteristics of maintainability include the following [4*, p. 60]:

- Analyzability: measures of the maintainer's effort or resources expended in trying either to diagnose deficiencies or causes of failure or to identify parts to be modified.
- Changeability: measures of the maintainer's effort associated with implementing a specified modification.
- Stability: measures of the unexpected behavior of software, including that encountered during testing.
- Testability: measures of the maintainer's and users' effort in trying to test the modified software.
- Other measures that maintainers use include
- size of the software,
- complexity of the software ,
- understandability, and
- maintainability.

Providing software maintenance effort, by categories, for different applications provides business information to users and their organizations. It can also enable the comparison of software maintenance profiles internally within an organization.

3. Maintenance Process

In addition to standard software engineering processes and activities described in IEEE 14764, there are a number of activities that are unique to maintainers.

3.1. Maintenance Processes

[1*, c5] [2*, c5] [5, s5.5]

Maintenance processes provide needed activities and detailed inputs/outputs to those activities as described in IEEE 14764. The maintenance process activities of IEEE 14764 are shown in Figure 5.2. Software maintenance activities include

- process implementation,
- problem and modification analysis,
- modification implementation,

- maintenance review/acceptance,
- migration, and
- software retirement.

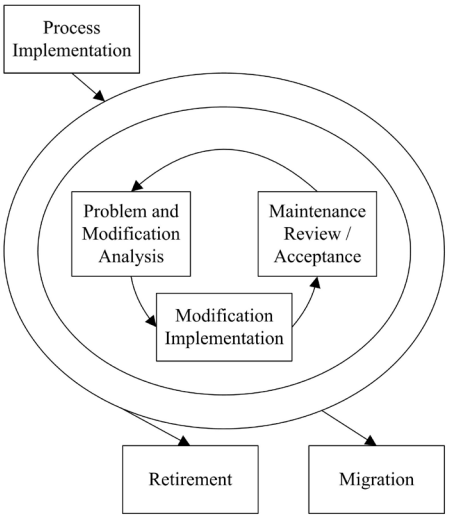

Figure 5.2. Software Maintenance Process

Other maintenance process models include:

- quick fix,
- spiral,
- Osborne's,
- iterative enhancement, and
- reuse-oriented.

Recently, agile methodologies, which promote light processes, have been also adapted to maintenance. This requirement emerges from the ever-increasing demand for fast turnaround of maintenance services. Improvement to the software maintenance process is supported by specialized software maintenance capability maturity models (see [6] and [7], which are briefly annotated in the Further Readings section).

3.2. Maintenance Activities

[1*, c5, c6s8.2, c7s3.3]

The maintenance process contains the activities and tasks necessary to modify an existing software product while preserving its integrity. These activities and tasks are the responsibility of the maintainer. As already noted, many maintenance activities are similar to those of software development. Maintainers perform analysis, design, coding, testing, and documentation. They must track requirements in their activities—just as is done in development—and update documentation as baselines change. IEEE 14764 recommends that when a maintainer uses a development process, it must be tailored to meet specific needs [1*, c5s3.2.2]. However, for software maintenance, some activities involve processes unique to software maintenance.

3.2.1. Unique Activities

[1*, c3s10, c6s9, c7s2, c7s3] [2*, c6, c7]

There are a number of processes, activities, and practices that are unique to software maintenance:

- Program understanding: activities needed to obtain a general knowledge of what a software product does and how the parts work together.
- Transition: a controlled and coordinated sequence of activities during which software is transferred progressively from the developer to the maintainer.
- Modification request acceptance/rejection: modifications requesting work beyond a certain size/effort/complexity may be rejected by maintainers and rerouted to a developer.
- Maintenance help desk: an end-user and maintenance coordinated support function that triggers the assessment, prioritization, and costing of modification requests.
- Impact analysis: a technique to identify areas impacted by a potential change;
- Maintenance Service-Level Agreements (SLAs) and maintenance licenses and contracts: contractual agreements that describe the services and quality objectives.

3.2.2. Supporting Activities

[1*, c4s1, c5, c6s7] [2*, c9]

Maintainers may also perform support activities, such as documentation, software configuration management, verification and validation, problem resolution, software quality assurance, reviews,

and audits. Another important support activity consists of training the maintainers and users.

3.2.3. Maintenance Planning Activities
[1*, c7s3]

An important activity for software maintenance is planning, and maintainers must address the issues associated with a number of planning perspectives, including

- business planning (organizational level),
- maintenance planning (transition level),
- release/version planning (software level), and
- individual software change request planning (request level).

At the individual request level, planning is carried out during the impact analysis (see section 2.1.3, Impact Analysis). The release/version planning activity requires that the maintainer:

- collect the dates of availability of individual requests,
- agree with users on the content of subsequent releases/versions,
- identify potential conflicts and develop alternatives,
- assess the risk of a given release and develop a back-out plan in case problems should arise, and
- inform all the stakeholders.

Whereas software development projects can typically last from some months to a few years, the maintenance phase usually lasts for many years. Making estimates of resources is a key element of maintenance planning. Software maintenance planning should begin with the decision to develop a new software product and should consider quality objectives. A concept document should be developed, followed by a maintenance plan. The maintenance concept for each software product needs to be documented in the plan [1*, c7s2] and should address the

- scope of the software maintenance,
- adaptation of the software maintenance process,
- identification of the software maintenance organization, and
- estimate of software maintenance costs.

The next step is to develop a corresponding software maintenance plan. This plan should be prepared during software development and should specify how users will request software modifications or report problems. Software maintenance planning is addressed in IEEE 14764. It provides guidelines for a maintenance plan. Finally, at the highest level, the maintenance organization will have to conduct business planning activities (budgetary, financial, and human resources) just like all the other divisions of the organization. Management is discussed in the chapter Related Disciplines of Software Engineering.

3.2.4. Software Configuration Management
[1*, c5s1.2.3] [2*, c11]

IEEE 14764 describes software configuration management as a critical element of the maintenance process. Software configuration management procedures should provide for the verification, validation, and audit of each step required to identify, authorize, implement, and release the software product.

It is not sufficient to simply track modification requests or problem reports. The software product and any changes made to it must be controlled. This control is established by implementing and enforcing an approved software configuration management (SCM) process. The Software Configuration Management KA provides details of SCM and discusses the process by which software change requests are submitted, evaluated, and approved. SCM for software maintenance is different from SCM for software development in the number of small changes that must be controlled on operational software. The SCM process is implemented by developing and following a software configuration management plan and operating procedures. Maintainers participate in Configuration Control Boards to determine the content of the next release/version.

3.2.5. Software Quality

[1*, c6s5, c6s7, c6s8] [2*, c12s5.3]

It is not sufficient to simply hope that increased quality will result from the maintenance of software. Maintainers should have a software quality program. It must be planned and processes must be implemented to support the maintenance process. The activities and techniques for Software Quality Assurance (SQA), V&V, reviews, and audits must be selected in concert with all the other processes to achieve the desired level of quality. It is also recommended that the maintainer adapt the software development processes, techniques and deliverables (for instance, testing documentation), and test results. More details can be found in the Software Quality KA.

4. Techniques for Maintenance

This topic introduces some of the generally accepted techniques used in software maintenance.

4.1. Program Comprehension

[2*, c6, c14s5]

Programmers spend considerable time reading and understanding programs in order to implement changes. Code browsers are key tools for program comprehension and are used to organize and present source code. Clear and concise documentation can also aid in program comprehension.

4.2. Reengineering

[2*, c7]

Reengineering is defined as the examination and alteration of software to reconstitute it in a new form, and includes the subsequent implementation of the new form. It is often not undertaken to improve maintainability but to replace aging legacy software. Refactoring is a reengineering technique that aims at reorganizing a program without changing its behavior. It seeks to improve a program structure and its maintainability. Refactoring techniques can be used during minor changes.

4.3. Reverse Engineering

[1*, c6s2] [2*, c7, c14s5]

Reverse engineering is the process of analyzing software to identify the software's components and their inter-relationships and to create representations of the software in another form or at higher levels of abstraction. Reverse engineering is passive; it does not change the software or result in new software. Reverse engineering efforts produce call graphs and control flow graphs from source code. One type of reverse engineering is redocumentation. Another type is design recovery. Finally, data reverse engineering, where logical schemas are recovered from physical databases, has grown in importance over the last few years. Tools are key for reverse engineering and related tasks such as redocumentation and design recovery.

4.4. Migration

[1*, c5s5]

During software's life, it may have to be modified to run in different environments. In order to migrate it to a new environment, the maintainer needs to determine the actions needed to accomplish the migration, and then develop and document the steps required to effect the migration in a migration plan that covers migration requirements, migration tools, conversion of product and data, execution, verification, and support. Migrating software can also entail a number of additional activities such as

- notification of intent: a statement of why the old environment is no longer to be supported, followed by a description of the new environment and its date of availability;
- parallel operations: make available the old and new environments so that the user experiences a smooth transition to the new environment;
- notification of completion: when the scheduled migration is completed, a notification is sent to all concerned;

- postoperation review: an assessment of parallel operation and the impact of changing to the new environment;
- data archival: storing the old software data.

4.5. Retirement

[1*, c5s6]

Once software has reached the end of its useful life, it must be retired. An analysis should be performed to assist in making the retirement decision. This analysis should be included in the retirement plan, which covers retirement requirements, impact, replacement, schedule, and effort. Accessibility of archive copies of data may also be included. Retiring software entails a number of activities similar to migration.

5. Software Maintenance Tools

[1*, c6s4] [2*, c14]

This topic encompasses tools that are particularly important in software maintenance where existing software is being modified. Examples regarding program comprehension include

- program slicers, which select only parts of a program affected by a change;
- static analyzers, which allow general viewing and summaries of a program content;
- dynamic analyzers, which allow the maintainer to trace the execution path of a program;
- data flow analyzers, which allow the maintainer to track all possible data flows of a program;
- cross-referencers, which generate indices of program components; and
- dependency analyzers, which help maintainers analyze and understand the interrelationships between components of a program.

Reverse engineering tools assist the process by working backwards from an existing product to create artifacts such as specification and design descriptions, which can then be transformed to generate a new product from an old one. Maintainers also use software test, software configuration management, software documentation, and software measurement tools.

MATRIX OF TOPICS VS. REFERENCE MATERIAL

	IEEE/ISO/IEC 14764 2006 [1*]	Grubb and Takang 2003 [2*]	Sneed 2008 [3*]
1. Software Maintenance Fundamentals			
1.1. Definitions and Terminology	c3	c1s2, c2s2	
1.2. Nature of Maintenance		c1s3	
1.3. Need for Maintenance		c1s5	
1.4. Majority of Maintenance Costs		c4s3, c5s5.2	
1.5. Evolution of Software		c3s5	
1.6. Categories of Maintenance	c3, c6s2	c3s3.1, c4s3	
2. Key Issues in Software Maintenance			
2.1. Technical Issues			
2.1.1. Limited Understanding		c6	
2.1.2. Testing	c6s2.2.2	c9	
2.1.3. Impact Analysis	c5s2.5	c13s3	
2.1.4. Maintainability	c6s8, c3s4	c12s5.5	
2.2. Management Issues			
2.2.1. Alignment with Organizational objectives		c4	
2.2.2. Staffing		c4s5, c10s4	
2.2.3. Process	c5	c5	
2.2.4. Organizational Aspects of Maintenance	c7s.2.3	c10	
2.2.5. Outsourcing/Offshoring			all
2.3. Maintenance Cost Estimation			
2.3.1. Cost Estimation	c7s4.1	c7s2.4	

	IEEE/ISO/IEC 14764 2006 [1*]	Grubb and Takang 2003 [2*]	Sneed 2008 [3*]
2.3.2. Parametric Models		c12s5.6	
2.3.3. Experience		c12s5.5	
2.4. Software Maintenance Measurement	c6s5	c12, c12s3.1	
2.4.1. Specific Measures		c12	
3. Maintenance Process			
3.1. Maintenance Processes	c5	c5	
3.2. Maintenance Activities	c5, c5s3.2.2, c6s8.2, c7s3.3		
3.2.1. Unique Activities	c3s10, c6s9, c7s2, c7s3	c6,c7	
3.2.2. Supporting Activities	c4s1, c5, c6s7	c9	
3.2.3. Maintenance Planning Activities	c7s2, c7s.3		
3.2.4. Software Configuration Management	c5s1.2.3	c11	
3.2.5. Software Quality	c6s5, c6s7, c6s8	c12s5.3	
4. Techniques for Maintenance			
4.1. Program Comprehension		c6,c14s5	
4.2. Reengineering		c7	
4.3. Reverse Engineering	c6s2	c7, c14s5	
4.4. Migration	c5s5		
4.5. Retirement	c5s6		
5. Software Maintenance Tools	c6s4	c14	

FURTHER READINGS

A. April and A. Abran, *Software Maintenance Management: Evaluation and Continuous Improvement* [6].

This book explores the domain of small software maintenance processes (S3M). It provides roadmaps for improving software maintenance processes in organizations. It describes a software maintenance specific maturity model organized by levels which allow for benchmarking and continuous improvement. Goals for each key practice area are provided, and the process model presented is fully aligned with the architecture and framework of international standards ISO12207, ISO14764 and ISO15504 and popular maturity models like ITIL, CoBIT, CMMI and CM3.

M. Kajko-Mattsson, "Towards a Business Maintenance Model," IEEE Int'l Conf. Software Maintenance [7].

This paper presents an overview of the Corrective Maintenance Maturity Model (CM3). In contrast to other process models, CM3 is a specialized model, entirely dedicated to corrective maintenance of software. It views maintenance in terms of the activities to be performed and their order, in terms of the information used by these activities, goals, rules and motivations for their execution, and organizational levels and roles involved at various stages of a typical corrective maintenance process.

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