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8 Reliability Capability

The last decade of the twentieth century and the first decade of the twenty-first have witnessed the rapid globalization of many industries. Competitive and regulatory pressures have driven companies to low-cost manufacturing and to the evolution of a worldwide supply chain. Today, external sourcing of components and contract manufacturing is widespread. Companies are dependent upon worldwide suppliers who provide them with materials, parts, and subassemblies. Therefore, for any product design, it is essential that the reliability requirements be applied to all the incoming subcontracted elements so that reliability can be managed across all the tiers of the supply chain. The ultimate goal is that each supplier's reliability practices will be adequate to satisfy the end-product requirements of their customers.

System integrators, who are at the top of the supply chain, generally set the requirements for system reliability. Parts and manufacturing processes purchased on the market as commodities are selected based on information provided by suppliers. However, system integrators cannot wait until they receive purchased parts or subassemblies to assess whether they are reliable. This would lead to an expensive iterative process of part delivery, product assembly, and reliability testing followed by part respecification. An upfront evaluation of suppliers based on their ability to meet reliability requirements can provide a valuable competitive advantage. A company's capability to design for reliability and to implement a reliable design through manufacturing and testing can yield important information about the likelihood that the company will provide a reliable product.

8.1 Capability Maturity Models

The maturity approach to determining organizational abilities has roots in quality management. Crosby's quality management maturity grid (Crosby 1996) describes the typical behavior of a company, which evolves through five phases (uncertainty, regression, awakening, enlightenment, and certainty) in its ascent to quality management excellence. Consequently, maturity models have been proposed for a wide range of activities, including software development (Bamberger 1997; Bollinger and McGowan

Reliability Engineering, First Edition. Kailash C. Kapur and Michael Pecht.

1991; Paulk et al. 1993), supplier relationships (Macbeth and Fergusson 1994), research and development effectiveness (Szakonyi 1994a, 1994b), product development (McGrath 1996), innovation (Chiesa et al. 1996), collaboration (Fraser and Gregory 2002), product design (Fraser et al. 2001; Strutt 2001; Williams et al. 2003), and reliability information flows (Boersma et al. 2004; Brombacher 1999; Sander and Brombacher 1999, 2000). This leads to the following metric for reliability capability:

> A reliability capability maturity metric is a measure of the practices within an organization that contribute to the reliability of the final product, and the effectiveness of these practices in meeting the reliability requirements of customers.

8.2 Key Reliability Practices

The IEEE Reliability Program Standard 1332 (IEEE Standard 1332–1998; Pecht and Ramakrishnan 2000) defines broad guidelines for the development of a reliability program, based on three objectives:

1. The supplier, working with the customer, should determine and understand the customer's requirements and product needs so that a comprehensive design specification can be generated.
2. The supplier should structure and follow a series of engineering activities so that the resulting product satisfies the customer's requirements and product needs with regard to product reliability.
3. The supplier should include activities that adequately verify that the customer's reliability requirements and product needs have been satisfied.

For each of these reliability objectives, key practices for evaluating reliability capability can be assigned. Figure 8.1 presents eight key practices identified from a study of reliability standards from the industry and reliability literature. Each of the eight key reliability practices is described in the following sections.

8.2.1 Reliability Requirements and Planning

During product development, the customer's needs and operational conditions for all phases of the product life cycle must be understood to arrive at a set of customer reliability requirements. The different considerations for establishing reliability requirements for a product include the design and operational specifications (information about the manner in which the product will be used), regulatory and mandatory requirements, definition of failure, expected field life, criticality of application, cost and schedule limitations, and business constraints, such as potential market size.

Establishing reliability requirements and planning early incorporates activities needed to understand customers' requirements, generates reliability goals for products, and plans reliability activities to meet those goals. The inputs for generating reliability requirements for products include customer needs, reliability data specifications for competitive products, and lessons learned from the reliability experience with previous products, including test and field failure data.

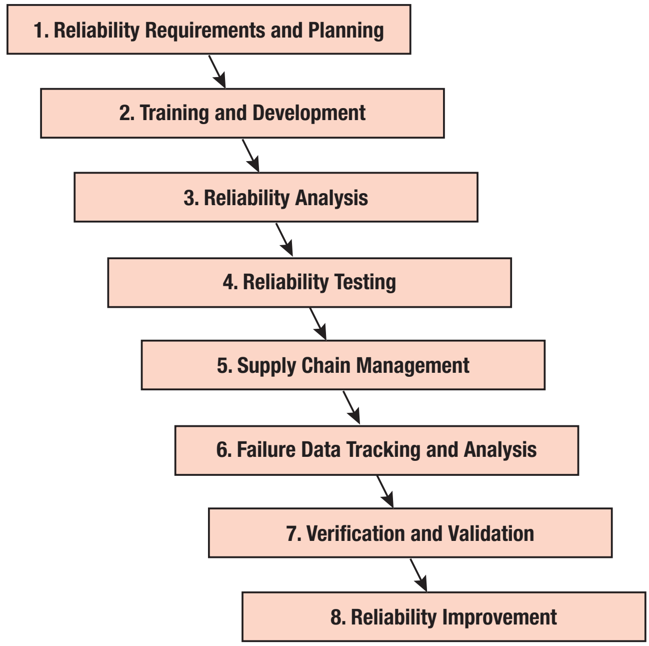

Figure 8.1 Key reliability practices.

Reliability planning is needed to establish and maintain plans that define reliability activities and manage the defined activities. The planning activity starts with identifying available resources, such as materials, human resources, and equipment, and determining the need for additional resources. Reliability analysis and testing needed for the product and the logistics to obtain feedback on the implementation of these activities can be identified.

The output from this key practice is a reliability plan. The reliability plan identifies and ties together all the reliability activities. The plan should allocate resources and responsibilities and include a schedule to follow. Decision criteria for altering reliability plans can also be included.

8.2.2 Training and Development

Training and development enhances the specialized skills and knowledge of people so that they can perform their roles in the development of a reliable product effectively and efficiently. The aim is to ensure that employees understand the reliability plans and goals for products, and have sufficient expertise in the methods required to achieve those goals. This includes the development of innovative technologies or methods to support business objectives.

Training and educating employees enhances the possibility of obtaining a better, more reliable product. Reliability managers must be aware of how specific reliability activities can impact or improve reliability, and business managers should appreciate the importance of reliability to ensure successful implementation of reliability practices within a company. The implementation of regular training programs indicates the willingness of business managers to spend time, effort, and money on training employees.

Effective training requires assessment of needs, planning, instructional design, and appropriate training media. The main components of employee training include a training development program with documented plans and means for measuring its effectiveness. The main activity for this key practice is the development of a training plan, including training needs for individual personnel, with a schedule. The implementation of the plan requires the procurement of a training infrastructure, including training instructors and training material.

The different modes of imparting training include in-class training, mentoring, web-based training, guided self-study, or a formal on-the-job training program. Employees must be trained in the life-cycle reliability management of products, including specific areas such as failure analysis, root cause analysis, and corrective action system. The training should incorporate an understanding of reliability concepts and statistical methods.

8.2.3 Reliability Analysis

Reliability analysis incorporates activities to identify potential failure modes and mechanisms, to make reliability predictions, and to quantify risks for critical components in order to optimize the life-cycle costs for a product. Prior experience and history can be helpful in this analysis. The data used to make reliability predictions may be historical, from previous testing of similar products, or from the reported field failures of similar products.

Reliability analysis activities include conducting failure modes, mechanisms, and effects analysis (FMMEA) to identify potential single points of failure, failure modes, and failure mechanisms for a product. The next step is to identify the criticality of these failure modes and mechanisms. Criticality may be based on complexity, application of emerging technologies, demand for maintenance and logistics support and, most importantly, the impact of potential failure on overall product success. Reliability analysis also includes identification of reliability logic for products as a system, and creating reliability models at the component and product levels in order to make reliability predictions. Assessing adherence to design rules, including derating, electrical, mechanical, and other guidelines, is also a part of reliability analysis.

The outputs from this analysis include an assessment of the reliability of the product, expected failure modes, and identification of design weaknesses to determine the suitability of the existing design for avoiding early-life failures and the product's susceptibility to wear-out failures. The information from reliability analysis can be used to create a list of reliability critical materials, parts, subassemblies, or processes, and to design reliability tests. Predictions regarding expected warranty costs and logistics support, including spares provisioning, can also be made.

8.2.4 Reliability Testing

Reliability testing can be used to explore the limits of a product, to screen products for design flaws, and to demonstrate (or qualify) the reliability of products. The tests may be conducted according to some industry standards or to required customer specifications. The reliability testing procedures may be generic—that is, common for all products—or the tests may be custom designed for specific products. The tests may or may not be used for the verification of known failure modes and mechanisms.

Detailed reliability testing plans can include the sample size for tests and the corresponding confidence level specifications.

Important considerations for any type of reliability testing include establishing the nature of the test (failure or time terminated), the definition of failure, the correct interpretation of the test results, and correlating the test results with the reliability requirements for the product. The information required for designing product-specific reliability tests includes the expected life-cycle conditions, the reliability plans and goals for a product, and the failure modes and mechanisms identified during reliability analysis. The different types of reliability tests that can be conducted include tests for design marginality, destruct limits determination, design verification testing before mass production, ongoing reliability testing, and accelerated testing.

The output from this key practice is the knowledge obtained from different types of tests. Test data analysis can be used as a basis for design changes prior to mass production, for identifying the failure models and model parameters, and for modification of reliability predictions for the product. Test data can also be used to create guidelines for manufacturing tests, including screens, and to create test requirements for materials, parts, and subassemblies obtained from suppliers.

8.2.5 Supply-Chain Management

Supply-chain management activities include monitoring a list of potential suppliers, conducting supplier assessment and audits, and selecting vendors or subcontractors for parts or processes. Other activities include part and process qualification through review of process, quality, reliability testing, or accelerated test data from the suppliers. Activities such as tracking product change notices, changes in the part traceability markings, and management of part obsolescence are also included under this key practice. These activities are essential for sustaining product reliability throughout its life cycle.

The decision criteria for supplier selection include their ability to provide reliable components effectively and their demonstrated ability to control their own supply chain. Possible control over the supplier's reliability practices through exchange of technological expertise and sharing of information also increases the possibility of achieving and maintaining product reliability. In some cases, multisourcing of parts may be necessary due to considerations of product manufacturing schedules, supplier capacity, or anticipated supply fluctuations.

Key outputs from this key practice are a list of preferred/qualified/approved parts, vendors and subcontractors, and a system for supplier rating. Other outputs include component qualification reports, supplier audit reports, and development of supply contracts that include contractual quality and reliability requirements.

8.2.6 Failure Data Tracking and Analysis

Failure tracking activities are used to collect manufacturing, test, and field-failed components, as well as related failure information. Failures must then be analyzed to identify the root causes of manufacturing defects and test or field failures and to generate failure analysis reports. These records can include the date and lot code of the returned product, the failure point (quality testing, reliability testing, or field), the return date, the failure site, the failure mode and mechanism, and recommendations for avoiding the failure mode in existing and future products. For each product category, a Pareto chart of failure causes can be created and continually updated.

The failure sources that initiate failure analysis of a product include manufacturing, production testing, reliability testing, pre- and postwarranty field returns, and customer complaints. Failure analysis includes statistical analyses of failure data and analysis of the cause of failure at various levels down to the identification of the root cause of failure.

The outputs for this key practice are a failure summary report arranged in groups of similar functional failures, forward and backward traceability of failed components through date and lot code information, actual times to failure of components based on time-specific part returns, and a documented summary of corrective action implementation and effectiveness. All the lessons learned from failure analysis can be included in a corrective actions database for future reference. This database can help save the considerable cost in fault isolation and rework associated with problems that may be encountered.

8.2.7 Verification and Validation

Verification and validation through an internal review/audit of reliability planning, testing and analysis activities helps to ensure that planned reliability activities are implemented so that the product fulfills the specified reliability requirements. Benchmarking can be used to study the best internal practices that produce superior reliability performance and for ensuring that noncompliance is addressed. Part of the process is to understand how some practices are better than others and to find ways to improve others by pushing for improved facilities, equipment, and methodologies.

The inputs for this key practice are the outputs from previous practices like planning, analysis, testing, and failure data tracking. The inputs include reliability plans and goals for products, potential failure modes and mechanisms identified during reliability analysis, information on failure mechanisms from reliability testing, specific reliability test plans and specifications, and the corrective actions database.

Verification and validation activities include comparison of identified potential problems against those experienced in the field. This includes comparison of expected and field failure modes and mechanisms and of reliability prediction models for a product against field failure distributions.

The outputs from this key practice include an updated failure modes and mechanisms database, modification of reliability predictions and failure models for a product, and modification of warranty costs and spares provisioning. Reliability test conditions may also be modified based on field information on products.

8.2.8 Reliability Improvement

Reliability improvement is concerned with applying lessons learned from testing, reported field failures, technological improvements, and any additional information from previous tests or experiences. This key practice primarily involves implementing corrective actions based on failure analysis. It also involves initiating design changes in products or processes due to changes in reliability requirements or in life-cycle application conditions (operating and nonoperating).

Reliability improvements can be affected either by making design changes in products or by using alternative parts, processes, or suppliers. Design changes can include an improved design using an established technology, or implementing developing technologies within an older design. New modeling and analysis techniques and trends that could improve reliability can also be used.

The inputs required to initiate reliability improvement also come from previous key practices. Such information includes Pareto charts for field failure modes and mechanisms, recommendations from the corrective actions database, and documented anomalies from verification and validation. Other factors that can initiate a reliability improvement process are changes in life-cycle usage conditions for a product or changes in reliability requirements due to business or other considerations.

The outputs from this practice include methods to prevent the recurrence of identified failures and implementation of corrective actions stemming from failure analysis. Corrective actions can be implemented by issuing engineering change notices, or through modifications in manufacturing and design guidelines for future products.

8.3 Summary

In the last 20 years, competitive and regulatory pressures have driven many companies to develop low-cost manufacturing processes and a worldwide supply chain. Since reliability represents a risk factor associated with profit-making, it is essential that reliability is managed across all the tiers of the supply chain. System integrators need an upfront evaluation of suppliers' ability to meet reliability requirements to effectively manage reliability and provide competitive advantage.

Reliability capability maturity assesses the effectiveness of the organizational practices that contribute to the reliability of the final product. Eight key reliability practices are essential to a strategy for reliability management and form the basis for reliability capability evaluation. These practices underlie the development of a reliability capability maturity model that can help companies assess their potential suppliers or help suppliers to assess themselves. Reliability tasks under each key practice can be used as evaluation items to assign maturity scores that provide a quantitative metric for grading companies.

The reliability capability maturity model can also help to establish reliability management practices for designers, suppliers, customers, and independent authorities. It can produce increased customer satisfaction, provide competitive opportunities, and shorten the product development cycle. It is expected that this model can also be used to identify shortcomings in a company's reliability program, which can then be overcome by improvement actions.

Problems

8.1 What are the three reliability objectives established for suppliers and customers by IEEE Reliability Program Standard 1332? How do they relate to the key reliability practices in reliability capability evaluation?

8.2 A reliability capability assessment is useful to the organization being evaluated because it can help identify the blind spots where a company can make improvements. List three possible blind spots for an emergency dispatch service (like police or ambulance), a gas station, or a manufacturer of pipes that can be identified by a reliability capability assessment. Relate each one of those possible blind spots to a unique key reliability practice and justify why each blind spot correlates to that key practice.

8.3 Discuss the benefits of conducting a reliability capability evaluation for an organization. What is the outcome of the evaluation, and can it be used to ensure delivery of reliable products?

8.4 List the eight key reliability practices in order and provide a brief description of each.