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1. Introduction

General Introduction

This document was prepared with the aim of bringing up to date the disciplines associated with reliability prediction and analysis, and so overcome some of the problems associated with the techniques as performed over the last 20 years or so.

The opportunity has been taken to review those aspects of conventional reliability engineering and to provide a guide that can be used in a simple manner by those smaller companies that are required to provide larger customer organisations with reliability estimates and analyses for their equipment. It is also hoped that the techniques described herein will be of value to small- and medium-sized business enterprises when planning their own activities with respect to reliability. Reliable products enhance market position and protect company reputations.

The issue of this document has been timed to coincide with the spread of a new wave of thoughts and processes related to reliability engineering spreading from Europe to the rest of the world. It aims to support this wave of enthusiasm and to introduce a new and user friendly form of reliability prediction.

This document has been put together by a small team working under the auspices of Intellect with assistance from Relex Software Corporation, a worldwide leader in reliability analysis software tools. Supported by all Member Companies, this document updates an earlier UK Ministry of Defence document, RPM 80, which has been used worldwide.

The issue of this document is made even more important by the demise of many of the more traditional reliability prediction standards worldwide following the move towards commercial procurement of components and systems. There remains a need for companies to compete with one another in a reliability sense. Use of the reliability prediction and analysis techniques described in this document will allow them to compete from a common standpoint.

2. General Philosophy and Process of Reliability Prediction

Introduction

Reliability prediction is a continuing activity throughout the design and development of a project, from initial conception to production and beyond. The prediction methods that apply at any particular time may vary, but the general philosophy and principles remain common throughout. The primary objectives of this chapter are to:

- Describe the purposes of prediction and its application at different stages of a project.
- Consider the general philosophy and principles behind prediction methods.
- List the main activities comprising a prediction process.
- Indicate the main limitations of the general philosophy.

NOTE It is not the intention of this chapter to derive basic reliability expressions or to discuss probability and statistical theory. Information on these aspects is readily available in many standard textbooks.

Definitions

The definitions for those reliability terms most often used within this guide follow.

- **Reliability**.
  - The ability of an item to perform a required function without failure under stated conditions for a stated period of time.

    Or, as more commonly used in engineering applications:
  - The probability that an item can perform a required function under given conditions for a given time interval, $(t1,\ t2)$. This is normally denoted either by the letter R or by $R(t)$, with t denoting the interval $t1,\ t2$.

- **Failure**. The state of the item when it is unable to perform a required function. In the case of non-repairable items, it is the termination of the ability of an item to perform a required function.

  Note:
  1. After the occurrence of a failure, the item is in a faulty condition.
  2. An occurrence of a **failure** is an event (as distinguished from a **fault**, which is a state.
  3. This concept as defined does not apply to items consisting of software only.

- **(Instantaneous) Failure Rate**. The limit, if this exists, of the ratio of the conditional probability that the instant of time, t, of a failure of an item falls within a given time interval, (t, $t + \Delta t$), to the length of this interval, Δt, when Δt tends to zero, given that the item is in an up state at the beginning of the time interval. This limit is normally denoted by $\lambda(t)$. Failure rates are often given in terms of failures per million hours (fpmh); however, some industries use an alternative measure of failures per 10^9 known as FITs (Failures in Time). Such failure rates are given in terms of failures per billion hours.

- **Mean Time To Restore**, **Mean Time To Recovery** or **Mean Time to Repair (MTTR)**. The expectation of the time to restore.

NOTE In this document, the term MTTR is frequently used. This is to maintain a measure of consistency with other work. The term **Mean Active Corrective Maintenance Time (MACMT)** may often be interchanged with **Mean Active Repair Time (MART)**.

Purposes of Prediction

The aim of prediction is to provide a quantitative forecast of the reliability that may be eventually achieved by any particular design. Prediction is therefore a fundamental activity in the overall design evaluation process. The prediction process does not in itself contribute directly to the reliability of a system, but the values produced constitute essential criteria for selecting courses of action that affect the reliability of a design.

Also, by carrying out prediction in a detailed and systematic manner, the process will help to identify potential reliability problems, including:

- Misinterpretation of requirements.
- Sources of unreliability.
- Design imbalance (from a reliability viewpoint).

Primary Purposes

The primary purposes of prediction are to:

- Evaluate whether or not a particular design concept is likely to meet a specified reliability requirement under defined conditions.
- Compare alternative design solutions.
- Provide inputs to related project activities, such as:
  - Design evaluation.
  - Trade-off studies.
  - Life cycle costs.
  - Spares provisioning.
  - Logistic and maintenance support studies.
- Assist in the identification and elimination of any potential reliability problems by imposing a systematic discipline that ensures all reliability aspects of a design are examined.
- Measure progress towards achieving the specified reliability requirements.

The prediction process is a continuing activity throughout a project, with the prediction being regularly updated as more design, test and evaluation data become available. The accuracy of any prediction depends largely upon the availability of detailed design and operating data. This is seldom available during the early stages of a project.

However, the requirement for prediction must be used to force detailed information to be made available as early as possible, particularly in critical areas, so that a more thorough and realistic pre-design assessment can be produced. Clearly, therefore, prediction must be a part of the design process and not simply a parallel activity.

Project Definition

During the feasibility and early project definition stages of a project, predictions obviously cannot be based on detailed design information. In spite of this, major decisions are made and large-scale funding is committed at this time. It is at this stage that accurate predictions would be most valuable.

It is an unfortunate fact, therefore, that the greatest uncertainty is attached to predictions during the early stages of design. Despite this, the best available methods must be employed to identify critical design areas as early as possible. Examples of such methods include comparison with similar equipment and generic parts count assessments. Such methods are described more fully in Chapter 3, “Reliability Prediction Methods”.

Design Stages

It is during the early and detailed design stages that reliability prediction has its widest application. As more design information becomes available (e.g., component lists, application stresses, environmental conditions, etc.), more detailed predictions can be made progressively and design areas associated with potential unreliability can be identified. Examples of prediction methods used at these stages include generic parts count and parts stress analysis. These methods are also described more fully in Chapter 3, “Reliability Prediction Methods”.

Development Stages

During the development stages, there are two main types of reliability prediction activity:

- The continual updating of theoretical predictions as design changes are introduced due to shortcomings revealed by development testing and by early reliability predictions themselves.
- Predictions based on the practical results from any reliability development testing, demonstration testing, etc.. Often a **reliability growth model** is used, which enables future reliability achievement to be predicted based on cumulative test results.

Important! *It is important to note that a theoretical prediction will generally reflect the reliability of “mature” equipment (i.e., after some years in service). A prediction based on a reliability growth model, however, reflects the number of design shortcomings still present in the design of the build standard under test or in early service life.*

In-Service Stages

During in-service stages, theoretical predictions must be carried out to assess the effects on reliability of design changes introduced as modifications. Predictions based on in-service results may also be used to assess when the design may achieve **maturity** and how the achieved reliability at that stage may compare with the requirements. Such predictions are normally based on an appropriate reliability growth model as indicated above.