RELIABILITY AND MAINTAINABILITY

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Contents

Summary

Life support systems have to be very reliable and reliability and maintainability studies have to be carried out to demonstrate this. Reliability analysis is aimed at acquiring *information* about a system of interest relative to *making decisions*. This is an important aspect of system modeling and analysis and essential in developing life support systems.

This chapter introduces the basic concepts in reliability, maintainability and availability studies. Methods and models for describing and analyzing complex systems are reviewed. Probability measures useful for determining maintenance policies for system structures are considered. Methods for failure data analysis are also presented. Finally, recent developments and the need for future developments in this field are discussed.

1. Introduction

The problem of reliability analysis of life support systems arises in many practical engineering areas. Some of these include communication networks, electrical power systems, water transmission systems and transportation systems. The purpose of a

system reliability analysis is to acquire *information* about a system of interest relative to *making decisions* based on considerations of availability, reliability and safety.

Historically, reliability theory has been concerned with non-distributed systems such as aircraft, space vehicles, nuclear reactors, weapon systems, stand-alone computer systems, etc. Usually a statement about a system's reliability has to be made. When the system is treated as a single object, it is called a component. In general, a component can be any device, unit, module, sub-system, or even a process, procedure, algorithm, etc. A system usually consists of a number of components, and given the reliability of all components and the system configuration, the reliability of the system can then be calculated.

Broadly speaking, there are two important stages in the process of analysis of a system: (1) An *Inductive Analysis* stage and (2) A *Deductive Analysis* stage. In the inductive analysis stage one should gather and organize available information on the system. One should define the system, describe its functional purpose and determine its critical components. It is well known that system failures often occur at subsystem *interfaces* and these should also be taken into account. At this stage, a question like this can be asked: *What* can happen to the system as a result of a component failure or a human error. Possible system failure scenarios are hypothesized or guessed.

The Deductive Analysis aspect of a system reliability analysis answers this question: *How* can a system fail (or succeed) or be unavailable? A logic tree (or fault tree for failure oriented analyses) is often the best device for deducing how a major system failure event could possibly occur. However, its construction depends on a thorough understanding of the system and the results of the system inductive analysis. A block diagram or a network graph is a useful device for representing a successfully functioning system.

In recent years, there has been considerable interest in the analysis of lifeline systems subjected to seismic risk. Highways, bridges, tunnels and pipelines are examples of such systems. These are essential for sustaining the life of a community after a catastrophic event such as a destructive earthquake. The purpose of seismic risk analysis is to provide insight into the risks associated with a particular design of a lifeline.

In reliability analysis, the given system may be represented by a probabilistic graph in which vertices and links have a joint failure probability distribution. In such a graph the vertices and links represent the relevant components of the system. Consider a simplified version of the water transmission system in the city of Los Angeles as shown in Figure 1. The underlying graph model for this pipeline system depends on the stipulated "probabilistic measure" of the system. One of the main probabilistic measures of interest is the probability that there exists at least one path from a specified vertex to another specified vertex along which all vertices and links are good after a catastrophic event.

Suppose it is of interest to find the probability that water reaches circle 9 from any of the three supply stations in the event of an earthquake. By connecting the three supply stations together to a hypothetical supply station, the problem becomes a terminal-pair

reliability problem. The probabilistic graph model of Figure 1 for the terminal-pair reliability is shown in Figure 2 except that the arc 9 to 10 is not included as it is irrelevant to this problem.
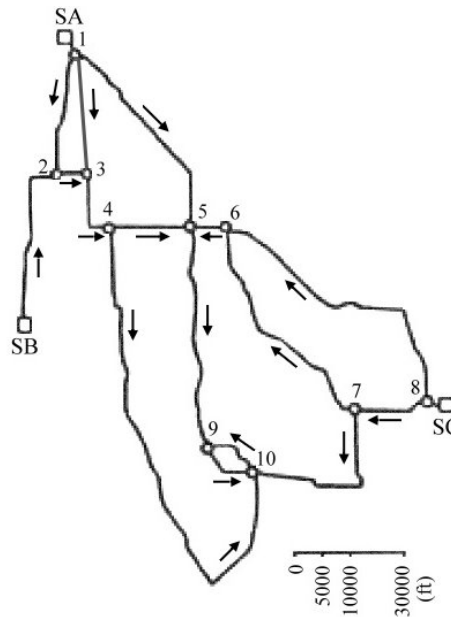

Figure 1. Simplified water distribution system in Los Angeles. The square boxes (SA, SB and SC) represent the supply stations and the circles 1-10 indicate junctions of transmission pipes or pumping stations.
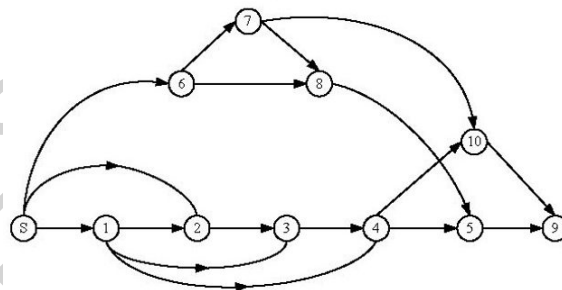

Figure 2. Graph model for terminal-pair reliability of Figure 1.

This chapter is structured as follows. In Section 2, the basic concepts in reliability are first introduced. Section 3 presents the basic ideas and computational techniques of network reliability. In Section 4 probability measures useful for determining maintenance policies for system structures are considered with the focus on system availability and maintainability. Section 5 presents some methods for failure data analysis for system components. Finally, in Section 6, recent developments and the need for future research in this field are discussed.

2. Some Reliability Concepts

There are different measures of reliability and these measures are useful in different contexts. Since component failure is usually a random event, subject to the use environment, its internal physical properties and the definition of failure, the concept of probability is used to describe component reliability. The most important quantity in component reliability analysis is the *lifetime T* which is the age of the component at failure.

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Biographical Sketches

Richard E. Barlow is a professor emeritus at the University of California, Berkeley. He is co-author with Frank Proschan of the book *Mathematical Theory of Reliability* first published in 1965 and re-issued in the SIAM classic series 1996. He is author of the recent book *Engineering Reliability* published by SIAM in 1998.

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