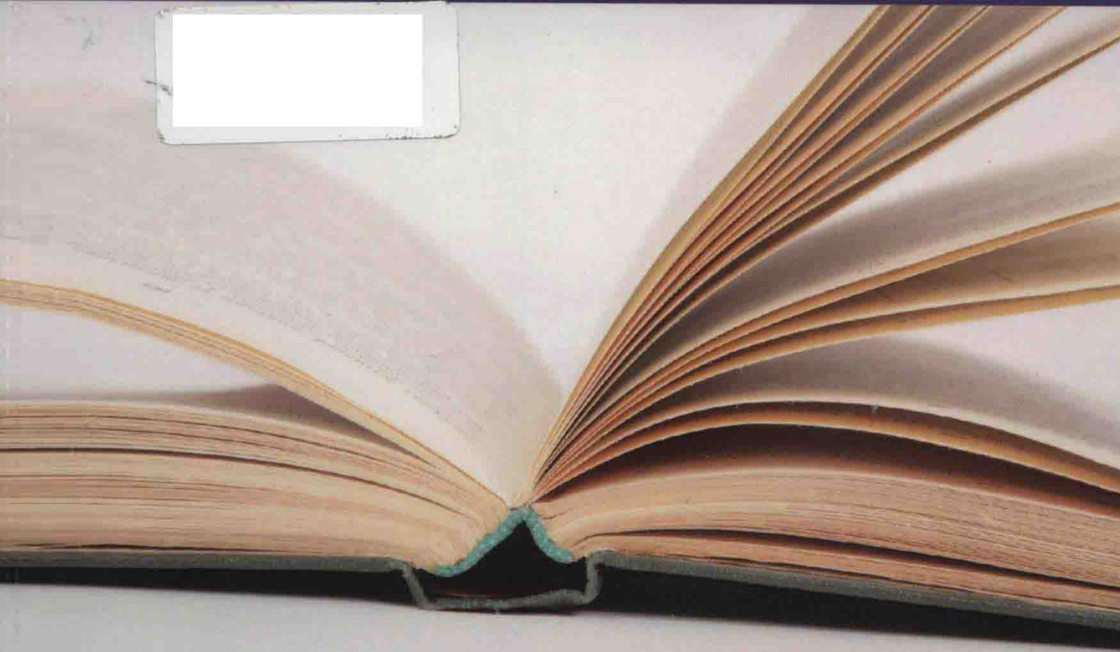

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Optimization modeling and mathematical analysis

OPTIMIZATION MODELING AND MATHEMATICAL ANALYSIS

By

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CONTENTS

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PREFACE

Quality and Reliability have assumed greater importance in the present days where competitiveness is the key element. Reliability considerations are playing an increased role in almost all-engineering disciplines. The effort in engineering is concerned with designing and constructions of systems/products with improved performance. In this direction demand for cost –effective system, which performs better, is always increasing on a higher note. Rapid progress in science and technology has made many of the day's engineering systems more versatile and powerful. The increasing level of sophistication in Hi-tech industrial processes leads to reliability related problems. Thus reliability problems not only continue to exist but are likely to require more complex solutions. The reliability problems not only of the system depend on performance of its constituent components. Hence in the recent time mathematical and statistical models were developed for evaluating system reliability and related measures. Thus the system reliability analysis and modeling is one of the interesting areas of the reliability analyses.

Conventionally in the reliability analysis most of the reliability modeling assumes the event of individual failures that mean that the component in the system will fail singly and individually, which are known as intrinsic failure [62]. Therefore most of the modeling and solutions considered in the literature of reliability was confined to individual / intrinsic failure category. However in practice we observe that probability of failure of one, two or more order of magnitude is predicted and the concept of common cause failures identified to be one of the most dominant causes of failures in many real line applications. Thus in most of the real situations systems are affected by external causes of failures (viz., temperature, pressure environment, moisture etc.) causing multiple component failures simultaneously. The more examples come from nuclear industry.

Some of the practical and typical examples of common cause failures are: Multiple loss of air-craft, Jet engines failures due to bird ingestion, loss of power station emergency fuel system due to inadequate maintenance of valves and multiple failures due to stress corrosion in redundant structures, common fuel supply failures which are leading to diesel generator failures, sudden appearance of high temperature computer chips (60). Thus one must say that reliability analysis have failed to recognize this dominant cause of system failures which appear in many real applications till 1980's. Therefore reliability analysis has started accounting for such failures in reliability modeling and analysis during 1980's.

The thesis is organized as follows. Chapter 1 covers an introduction and the basics and concept of reliability and related important measures. The concepts like Reliability, Availability, mean time between failures (MTBF), mean time to failure (MTTF), and frequency of encountering states of the system were discussed. Different types of redundant configurations and related measures were discussed. A brief discussion about common cause failures is also defined. In chapter 2, a comprehensive survey of literature on common cause failures and spares. The rule and concept of common cause failures briefed with some real applications. The review of literatures and several research papers connecting with the present work have been discussed and reported in this chapter. Motivation of the present research work and overview of the thesis is emphasized. Chapter 3 consists of the actual contribution of the research investigation of few models. This chapter covers optimum redundant design aspect of k-out-of-n: G systems. The author proposes an alternative modified and improved optimum design modeling of k-out-of-n: G redundant compared to a few earlier models namely Nakagawa [20] and Bai-et-al [5]. The deficiencies of the previous models were highlighted and modified and improved models were developed and presented in this chapter. Some examples were provided to establish the improvement of the present models. The results were tabulated and graphs were plotted for demonstration of the research results. Chapter 4 covers the new and improved optimum spare redundancy model for various redundant systems viz. N-modular redundant system (NMR), Triple modular redundant system (TMR) and General k-out-of-n: G redundant systems. In this chapter author proposes the new optimum sparing redundancy in place of Pham model [23] as an improvement involving the optimum suggestion of redundant spare (s*) as a function of failure rate, cost of components and time operating the system unlike the earlier models. The results were presented for some examples systems to establish the significance of the present models.

CHAPTER – 1

RELIABILITY MODELING: CONCEPTS & BASICS

1.1 INTRODUCTION:

Reliability is a popular concept that has been celebrated for years as a commendable attribute of a person or an artifact. From its modest beginning in 1816 the world reliability was first coined by **SAMUEL T. COLERIDGE** - reliability grew into an omnipresent attribute with qualitative and quantitative connotations that pervades every aspect of our present day technologically intensive world.

The field of Reliability had its origin popularly in the early 1940's during world war-II. Since then it grows gradually and in the recent times reliability field plays a vital role in system development and decision process. Reliability Engineering aims to develop methods and tools to evaluate and demonstrate reliability, maintainability, availability and safety of components, sub systems and systems. The increasing level of sophistication in high-tech industrial process makes the reliability problems continues to exist and requires ever more complex solutions. Further system failures have more significant effect on society ever before.

Reliability Engineering is an important branch of activity in industrial automotives, electronic and electrical field, which is figured popularly during the

World War-II. It was just emerged during World War–I and connected with comparing operational safety of one, two three and four jet engines in aero plane technology. The reliability analyses play a key role in planning, designing, testing, manufacturing, acceptance and use of product obtaining for effectiveness of the product.

The theory of reliability is a vital part of quality control. After industrial revolution, theory of reliability analysis was drastically developed during the last seven decades in the fields of space, missile, electrical and electronics. The reliability theory provides us an optimistic, perspective on the opportunities for life extension of the component. According to reliability theory life span is not fixed and could bi further increased through better maintenance, repair and replacement of the failed parts in the system.

Towards the end of 1950's and the beginning of 1960's the US Government has concentrated on inter-continental ballistic missile and space research program especially connected to the mercury and Gemini programs. In the race with, USSR it was the first nation to put the man on the moon. (It was very important program for launching of manned spacecraft to be successful). An association of engineers who were working with reliability techniques, has established and international journal of IEEE Transaction on Reliability in 1963. Later on many books were published on theory of Reliability.

During 1970's the US government was much more interested in other parts of world, in risk and safety aspects on buildings and operations of Nuclear power plants. Also it is established a large research commission laid by Prof. Norman Rosmussen.

The US Defense setup a major committee on reliability theory. This was later called as "AGREE" i.e. (ADVISORY GROUP ON RELIABILITY OF ELECTRONIC EQUIPMENT). This committee defines reliability as "*the probability of a product performing its intended function satisfactorily under given conditions for a specified period of time*". According to the definition, the basic elements of reliability are probability, adequate performance, time and operating conditions [2].

1.2 CONCEPT OF RELIABILITY

The concept of reliability is as old as man himself. Customer always confronts questions like,

- Will the product purchased function satisfactorily?
- Will that last long?
- Ever since long?

Of course its science, "Reliability" is new and has been progressing rapidly since after World war-II. Reliability in its simplest form, means the probability that a failure may not occur in a given time interval. More generally reliability is defined as "The probability that the unit/product perform its intended function adequately for a given period of time under the stated operating conditions or environment."

The definition emphasizes the four elements (1) probability (2) intended function (3) time and (4) operating (environment) conditions.

If "X" indicates time till the failure or life, which is always a random variable, then the probability that it does not fail before time 't' in a given environment is the reliability, i.e., R (t) = P (X > t).

Therefore reliability is always a function of time t. It also depends on environmental conditions under which it is operating. Since R (t) is a probability measure, it always satisfies the condition.

$0 < R(t) < 1$ and $R(t) = 0$ if $t \rightarrow \infty$ $R(t) = 1$ if $t = 0$.

Reliability is quality measurement, which is under the influence of time and environment unlike quality, which is degree of conformation alone not considering the time length and environment of operation.

Therefore reliability and quality slightly differ. Quality is associated simply with manufacturing ability where as reliability is associated with fields performance and design. In fact, reliability is the ability of the product to maintain its quality under specified time and specified environmental conditions.

1.2.1 FAILURES AND CAUSES:

A failure is the defined status of the unit/product the functioning of which is seriously impeded/completely stopped. The concept of failures and their details help the evaluation of quantitative reliability of a device. Some times components have well defined failures and some other times do not. For example switches and electrical bulbs have well defined failures that they are either in good or bad state. These are known as two state devices, where as the devices like voltage stabilizers, resistors etc., have a different way of operating conditions. For example voltage stabilizer is said to have failed if the input the voltage exceeds the limit $V \pm v$.

The concept of failure and its consequences will help in the process of evaluation of reliability of devices. From the examination of failure data, which is observed since long, the failures can be broadly classified into three ways. The first category of failures is early failures, which are known as initial failures or infant mortality. These are generally due to manufacturing defects and are very high at initial stages and gradually come down. The second category of failures is random failures. After a long period of operation a small number of failures occur which generally could be attributed to any cause. These categories of failures are known as random failures which normally occur a fewer number of times and characterized by constant number of failures per unit time. The third category is wear-out failures. As time cruises on, the unit/component gets worn out and begins to deteriorate. This stage is known as wear-out failures.

At this stage failure rate seems to be very high due to deterioration. Therefore the whole pattern of failures could be depicted by a bathtub curve as shown in fig.1.1.

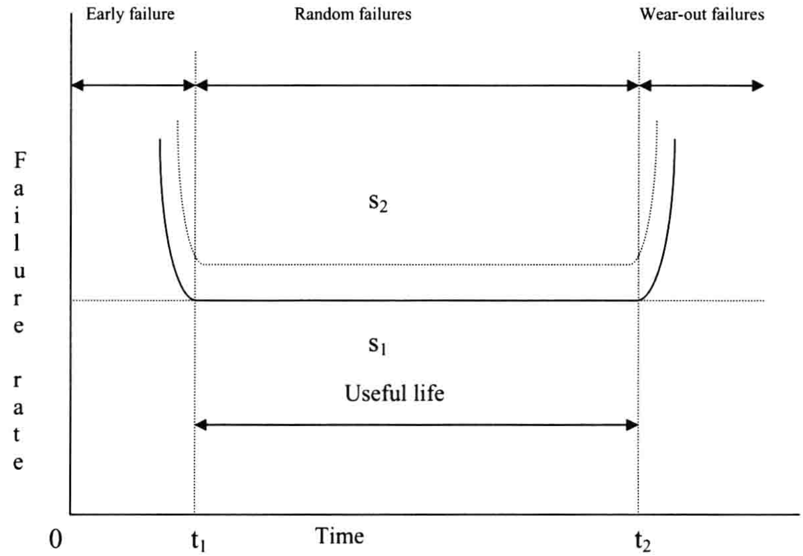

Fig.1.1: Failure rate Curve

—— **Operating stress S_1;** ········ **Operating stress S_2; ($S_2 > S_1$)**

1.3 DESIGN FOR RELIABILITY:

The system designer is encountered with several problems while planning and designing the system with reasonable level of reliability. Therefore a thorough reliability analysis needs to be attended to at the design stage itself. The various means of increasing the system reliability and the constraints associated with them must be known. A number of techniques are available to enhance the system reliability.