Affordable Reliability Engineering

Life-Cycle Cost Analysis for Sustainability and Logistical Support

William R. Wessels • Daniel S. Sillivant

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To my O.A.O., and the love of my life, Tudor.

Bill Wessels

To my parents who were concerned with my writing ability when I was younger. I would not have made it this far without them.

Daniel Sillivant

Preface

The book is written for engineers and managers. It presents procedures that use reliability information to determine life-cycle costs for part selection and logistical support analysis performed in system design and sustainment alternatives.

Organizations must be economically efficient to survive in the global competitive markets they serve. A reputation for high reliability and best costs of acquisition and life-cycle sustainability provides organizations with a competitive advantage that increases sales revenues and market share. Reliability-based life-cycle economic analysis enables an organization to be economically efficient and achieve a reputation for high reliability at best cost.

This book seeks to achieve two objectives:

1. Provide managers with an understanding of a reliability engineering program so that they can justify and fund reliability analyses
2. Provide engineers with an understanding of a reliability engineering program so that they can perform reliability analyses

Many engineers and managers believe that reliability is a discipline that requires specialists in the field. This book demonstrates that every organization already employs "reliability engineers" and "reliability managers." They are the organization's employees who have an intimate knowledge of the organization's products, capital equipment and machinery, culture, and customers. Engineers have a knowledge base from education and experience that is focused on achieving part functionality; reliability engineering uses the same knowledge base to focus on understanding part failure. Managers have a knowledge base from education and experience that is focused on allocation of scarce resources to implement part functionality; reliability management uses the same knowledge base to make cost optimum decisions to mitigate part failure.

Time-value of money is the essential principle for life-cycle economic analysis. Economic analysis requires information that estimates the magnitude of cost events and when the cost events will occur. This book shows how reliability analysis provides estimates of what the cost events will be, the duration of the cost events, and when the cost events will occur.

A final observation: All life-cycle sustainability costs for a system have a single cause—part failure. Absent part failure, an organization has no need for capital and operating investment to sustain a system. Understanding part failure in design and sustainment of fielded parts enables engineers and managers to optimize capital and operating investment.

About the Authors

Bill Wessels has over 40 years of experience in system design and sustainability. From 1975 to 1989, Bill worked as a field engineer for mining companies throughout the United States, Australia, Canada, Africa, and Europe to implement innovations in system sustainability for excavators, haul trucks, and process machinery. From 1989 to 2005, Bill worked as a reliability engineer for companies that performed research and design for aerospace payloads, defense aviation and weapons systems, chemical processes, and biomedical devices. Since 2005, Bill works at the University of Alabama in Huntsville, where he cofounded the Reliability and Failure Analysis Laboratory and performs basic and applied research in design-for-reliability, reliability-based maintainability, and reliability-based life-cycle economic analysis. Bill teaches professional development tutorials and consults in the United States and the Pacific Rim. He has a BS degree in engineering from the United States Military Academy at West Point, an MBA in decisions sciences from the University of Alabama in Tuscaloosa, and a PhD in systems engineering from the University of Alabama in Huntsville. He is a registered professional engineer in mechanical engineering and a certified reliability engineer. Bill and Tudor live on a small farm in North Alabama where they raise guard donkeys, chickens, worms, and dogs.

Daniel Sillivant is a researcher in the Research Institute at the University of Alabama in Huntsville (UAH) performing basic and applied research and investigations in reliability life-cycle modeling for aviation and sensors systems. He is published in peer-reviewed proceedings for the *International Mechanical Engineering Congress and Exposition; Reliability, Availability, Maintainability Workshop*; and *Industry, Engineering, and Management Systems.* Daniel has completed the requirements and has begun his dissertation research in reliability based life-cycle economic modeling for implementation of reliability-centered maintenance. He has a bachelor's degree in Chemical Engineering and a master's degree in Industrial/Reliability Engineering from UAH. His other certificates include Lean Concepts Training and Six Sigma Green Belt; and he passed the Fundamentals of Engineering Exam.

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Scope of Reliability-Based Life-Cycle Economical Analysis

The objective of this book is to provide a framework to managers and engineers to develop and implement a reliability program for their organization that provides information that goes beyond verification that reliability requirements are met. Reliability analysis also provides information that defines life-cycle cost events that enables performance of engineering economic analyses. Engineering economic analyses investigate design and sustainability alternatives to enable engineers and managers to make life-cycle economic decisions under uncertainty. Engineering economic analysis is no different than financial analysis taught in business schools. Engineering economic analyses characterize

1. Cash flows over an evaluation period

   [Cash flows are cost estimates made for present, recurring, and future amounts.]

2. Equivalent financial metrics based on the time value of money

   [Equivalent financial metrics are present values of cash transactions in a specific time period, net present values for all present values, and equivalent recurring values of net present values.]

Engineering economic analysis applies to

1. Design of systems
2. Systems engineering and integration
3. Maintenance and sustainability of systems

It enables engineers and managers to determine the lowest life-cycle costs for part selection, design configuration options, implementation of maintenance practices, spare parts strategies, and logistical resources.

[Maintainability is defined as repair and logistics events associated with a system downing event. Sustainability is defined as maintainability and logistical support analysis.]

Implementation of reliability-based life-cycle economic analysis requires that

1. Managers understand methods and procedures that must be employed in a reliability program, and the cost benefit for investment in reliability analyses
2. Engineers understand the analytical investigations required within the context of a reliability program that provides value to management

This book is based on the premise that all system sustainment costs have a single cause: part failure. Not a plurality of system sustainment costs, not the majority of system sustainment costs—ALL! If parts do not fail then there will be no need for maintenance actions, no maintenance facility requirements, no spare parts requirements, and no logistical support requirements.

Background

An organization or consumer that owns and operates capital assets, a system, incurs three categories of costs: acquisition, operations, and maintenance. The operations and maintenance costs are referred to as O&M costs, also known as operations and sustainment. Operational costs include labor, materials, and overhead expenses for system functionality and servicing. Sustainment costs include labor, materials, and overhead expenses for maintenance and logistical support. Maintenance includes all events that are performed to

1. Restore a system to functionality following a system downing event
2. Prevent an unscheduled system downing event during scheduled system operation

Logistical support includes all events that provide the resources required to perform maintenance events. Maintenance personnel, tools, facilities, spare parts, specialty equipment, and contracted maintenance services are just a few items involved in logistical support events.

Servicing is not maintenance. It is the replenishment of expendable items: fuel, lubricants, and coolants, to name a few. Servicing is not a repair task and may be performed with equal skill by operators or maintainers. If an organization assigns system servicing to the maintenance organization it does not change the fact that servicing is an operational event. Similarly, although the costs of fuels, lubricants, and coolants are budgeted for production expenses, they are still operational expenses. Alice Roosevelt Longworth best described servicing as, "Fill what's empty, empty what's full, and scratch where it itches."

Reliability engineering is a discipline that investigates and analyzes part failure. It is a multidiscipline practice of engineering as it applies to all basic engineering disciplines: mechanical, civil, and electrical, and their subdisciplines: chemical, nuclear, mining, aerospace systems, industrial, etc. As with all engineering disciplines, the application of reliability engineering falls in design and development, systems engineering and integration, and system sustainment.

Engineers who perform design and development are provided

1. System requirements, typically functional, that have been allocated down through a work breakdown structure to the lowest design hierarchical level, typically an assembly concept
2. A blank sheet of paper

They perform part design analysis that yields design art and a bill of materials, for the assembly concept. They create a tangible assembly that is comprised of parts from a concept. The objective of design engineers is to achieve functionality. Design for reliability performed by design engineers applies the same methods for design analysis that achieve functionality to then understand and model failure mechanisms and modes for part failure. It should be intuitively obvious that no one is better qualified or capable of analyzing the failure mechanisms acting on a part than the engineer who designed that part.

Engineers who perform system sustainment must understand

1. Part design analysis; although they do not perform, nor do they influence system design, they often evaluate third-party vendors for spare parts.
2. Systems engineering and integration; although they do not perform or influence system engineering and integration, they apply their understanding of design and systems engineering and integration to define and implement maintenance policies and practices that enable the O&M organization to achieve the optimum functional and economic performance of the system.

Sustainability engineers apply their understanding of part design and systems engineering to restore systems to full functionality following a downing event caused by a part failure. Reliability-trained sustainability engineers preserve system functionality, improve maintenance policy and practices, and optimize life-cycle economics of the system. The former is reactive; the latter is proactive. The former cannot influence system availability; the latter can.

Engineers who perform systems engineering and integration provide the design engineers with the allocation of the system requirements and the work breakdown structure, integrate the design analysis, design art and bill of materials, and determine whether the system requirement has been