Preface

Reliability improvement is an essential component of product development. Indeed, product development is an iterative process in which the design phase must be followed by reliability verification, and prototype production must be followed by reliability testing.

A solid understanding of failure modes and mechanisms, combined with knowledge of domain-independent principles to prevent them, is fundamental to ensuring the reliability of engineering products. This understanding strengthens design decisions early in the development cycle, preventing costly rework and redesign after the product enters operation.

The most critical mistake a design engineer can make is to overlook reliability during the design stage. The inevitable result is a poorly designed unreliable product, causing customer dissatisfaction, loss of market share, and ultimately, business failure. In today's competitive marketplace, product reliability is not optional, it is vital for survival.

While areas such as reliability and risk assessment are widely acknowledged as domain-independent, the equally critical areas of reliability improvement and risk reduction have not received the same cross-domain recognition. For decades, reliability and risk practitioners have largely failed to recognize that improvements in reliability, reductions in risk, and the management of uncertainty can be guided by general principles applicable across various domains.

With few exceptions, such as the widely recognized methods like introducing redundancy, strengthening and upgrading weak components, selecting better materials, simplifying components and systems, eliminating a common cause, and condition monitoring, there is a lack of a unified framework of domain-independent methods for reliability improvement and risk reduction. This gap has hindered the adoption of broadly applicable strategies that transcend domain boundaries.

Why has engineering design been so slow to embrace the domain-independent methods for reliability improvement and risk reduction?

One of the chief contributing factors is that the prevailing approach remains heavily dependent on domain-specific knowledge and expertise. Many practitioners view domain-independent methods as too generic to tackle the specific challenges unique to their fields. As a result, efforts to improve reliability remain fragmented, restricted to narrow technical areas and heavily dependent on domain experts.

In contrast, foundational sciences such as mathematics and physics, did not remain bound to the domain-specific solutions from which they emerged. Their transformation into powerful scientific disciplines was driven by the ability to generalize by extracting universal principles from diverse examples and forming structured frameworks with strong predictive power.

The persistent belief that reliability improvement must rely solely on domain-specific methods and experts has led to systemic inefficiencies. These include missed opportunities for cost-effective reliability gains, recurring design errors and the continued presence of unreliable products and processes. Consequently, industries often face suboptimal designs and failures that could have been prevented.

This siloed approach to risk reduction has also led to repeated reinvention, as practitioners independently arrive at the same solutions in isolation. In an era of rapid innovation, where domain-specific knowledge can quickly become obsolete, domain-independent methods offer a compelling alternative. These higher-level approaches are adaptable, capable of guiding effective risk reduction even in the absence of detailed failure histories, reliability data or exhaustive analyses.

Domain-independent methods do not rely on historical failure data or detailed knowledge of specific failure mechanisms, which makes them particularly valuable in the design of new products and processes. Often, they enable substantial risk reduction at minimal or no additional cost. A key principle of domain-independent reliability improvement and risk reduction is the recognition of recurring patterns in reliability problems and their solutions across different fields of human activity. To support this cross-domain application, this book proposes a general algorithm for enhancing reliability and reducing risk using universal methods that apply across a wide range of disciplines.

The proposed domain-independent methods are not intended to replace domain-specific approaches, but to complement them. When integrated with specialized knowledge, domain-independent methods lead to more robust and innovative design solutions.

This book introduces a selection of domain-independent methods for improving the reliability of engineering products and processes. Reliability, simply defined, is the absence of failure and the goal of this book is to present a general methodology for preventing product and process failures.

Through numerous case studies and tutorial exercises based on real-world examples, readers will learn to apply domain-independent principles to address practical reliability challenges. This text is intended as a foundational resource on reliability improvement and risk reduction through universal methods.

By following the methodology presented, readers will be able to systematically identify and eliminate failure modes in selected products and processes, thereby significantly enhancing their reliability. These methods have been tested extensively in classroom settings at both undergraduate and postgraduate levels and have consistently demonstrated their effectiveness. After learning the foundational principles, students have gone on to develop innovative reliability solutions, many of which have been considered patentable.

This book does not aim to provide exhaustive coverage of all known domain-independent methods for improving reliability and reducing risk. Instead, the purpose is to structure the material so that it can support an initial introduction to these methods and classroom instruction. This is achieved through a relatively small subset of domain-independent methods by demonstrating how they can be effectively applied to eliminate or mitigate failure modes from products and processes.

This book is designed to benefit academic researchers in engineering design, quality and reliability engineering, risk and safety, and quality management. It is also intended for professionals and researchers across multiple disciplines, including mechanical, civil, electrical, and environmental engineering. The primary audience includes undergraduate students studying engineering design, MSc students in taught programs, and postgraduate students in reliability engineering and risk management.

In conclusion, I would like to express my deep gratitude to Katya Seward, Mechanical Engineering Editor at CRC Press, Taylor & Francis Group, and Suriya Rajasekar, Senior Project Manager at Newgen KnowledgeWorks, for their invaluable assistance and support. I am also thankful to my academic colleagues for their insightful feedback on various aspects of this work.

Finally, I extend my deep gratitude to my wife, Prolet, for her unwavering support, strength, encouragement, and patience during the preparation of this book.

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Oxford, August 2025