

Preface

Society is increasingly reliant on complex computer-based systems ranging from control systems in aircraft, trains and cars to business critical systems such as e-banking systems to systems that are an integral part of our critical national infrastructures. These systems have to be dependable—failures can have serious consequences, e.g. loss of life, loss of essential services or significant financial losses. Despite much progress having been made in technical approaches to achieving dependability—there is still a long way to go—many failures arise through the interactions of organisations, people and computer systems. It is possible to tackle these problems and make significant steps forward in improving dependability through an interdisciplinary approach.

This book draws on the *Interdisciplinary Research Collaboration in Dependability*—the DIRC project—a truly multidisciplinary project, bringing together researchers with backgrounds in computer science, mathematics, psychology, sociology and business. It involved researchers with an interest in dependable socio-technical systems from the Universities of Newcastle, York, Lancaster, Edinburgh and City University London. The long-term (six-year) research project supported the development of knowledge, methods and tools that enhance our understanding of socio-technical system dependability and support developers of dependable systems. This made remarkable progress across a number of areas. The interdisciplinary contribution has been increasingly recognised as an important insights into dependability research.

Interdisciplinary Research Themes

Interdisciplinary Research Themes within the DIRC project acted as a way of gathering, analysing and recording the lasting knowledge come out of research carried out during the collaboration. One of the motivations in selecting the themes was that it is possible (and interesting) to look at them from both a technical (system) and human (user) viewpoint. Furthermore, in order to progress on difficult

research themes, it is necessary to be able to deploy ideas, e.g. from the psychological or sociological research to the technical issues (and, of course, vice versa). The Interdisciplinary Research Collaboration in Dependability identified five major research themes: *Structure*, *Diversity*, *Timeliness*, *Responsibility* and *Risk*.

The structure of a system can contribute to its dependability, understandability and its ability to evolve. The *Structure* research theme studied the structure of both human organisations and technical systems (and the way they interact). An essential element of dependability is protective redundancy, or fault tolerance. But the risk of common-mode failures among redundant elements needs to be contained by actively pursuing diversity. The *Diversity* theme studied the advantages and difficulties of pursuing diversity both in systems and processes, including the socio-technical processes that develop technical and socio-technical systems. The work included empirical studies as well as probabilistic modelling.

Another characteristic of socio-technical systems is that they are required to function at many different time scales (from microseconds or less to hours or more). Time is clearly a crucial notion in the specification (or behavioural description) of socio-technical systems, but it has a wide range of technical, social and psychological properties. The *Timeliness* theme explored this rich set of issues.

The *Responsibility* theme explored one of the major differences between people and computers—people can be given or assume responsibilities. Many system failures are, at least partly, a consequence of responsibility failures. To reduce responsibility-related failures, it is necessary to develop a deeper understanding of these failures, to understand how responsibilities interact in complex socio-technical systems and to invent ways of making responsibilities explicit in models that can be used to inform system design.

Risk in socio-technical systems is more heterogeneous and difficult to capture than in conventional systems. This is due to the fact that socio-technical systems are deeply embedded in social and organisational contexts. The *Risk* theme emphasised the need to consider issues of risk perception since different participants in an organisation have very different views of the existence and severity of hazards. It is also important to consider mechanisms for handling risk arising from the ongoing process of change in organisational systems. This book draws on the research results contributing to the Risk theme.

Book Overview

Socio-technical systems carry a degree of risk. The traditional view is that risk relates to faults in systems. Risk management usually relies on the frequency of manifestation and severity of the consequences of system flaws. Socio-technical systems are deeply embedded in organisations. Hence, understanding risks associated with such systems is difficult and exposes the limitation of traditional approaches to risk. Organisations comprise many different groups, whose risk perception may differ radically and whose needs for and attitude to system change

also varies depending on role and environment. Thus, we have undertaken two important lines of work in the Risk theme: exploiting the Social Science literature (e.g. on risk perception) to highlight and to help manage socio-technical risk in complex organisations, and managing the risk of change in complex socio-technical systems. For instance, Social Science literature on Cultural Theory demonstrates how different constitutions of social groupings within organisations shape risk perception. We have, therefore, analysed potential risks in different organisations focusing on how the dominance of particular groups de-emphasises certain classes of risk. Our analysis provides the basis for a technique, complementing traditional approaches to risk, for identifying *emerging technological risk*. This is an outline of an *Interdisciplinary Risk Reader*. A multidisciplinary overview of risk motivates the approach to studying risk in an interdisciplinary fashion covering things such as the role of empirical studies, the extent to which theory is useful, how theories from one discipline inform work in others ones. The introduction motivates the selection of the studies and draws out some of the common concepts across the studies.

Case Studies

We have conducted several case studies in diverse domains in order to generalise and combine theories together with empirical findings into a comprehensive account of socio-technical risk. For example, in a large-scale study of dependable process transfer from one location to another, we discovered that the structure and modularity of organisations can pose significant risks for organisations. In particular, the loss of information across organisational boundaries can expose complex organisations to significant risks. In studying change, we have been particularly interested in exploring hybrid socio-technical approaches to mitigate the risk of change in complex organisations. Emerging evolutionary structures define technology trajectories, which characterise system evolution as the result of social negotiation processes. Our studies highlight how responsibility and trust are critical aspects affecting work practices as well as technological innovation. Misunderstanding responsibility and developing mistrust expose organisations to technological risk. We have, then, studied the role of trust in managing risk and as a potential source of risk arising from system failures or mistrust. At a macroscopic scale, a fascinating example of risk in large systems is drawn from the domain of economics. Our studies take into account lessons drawn from market mechanisms for the construction of large-scale socio-technical systems. The innovative use of a mathematical model, in particular for hedge funds, explores the connection between diversity in computer systems and diversity of portfolio together with social mechanisms that defeat attempts to maintain diversity in a changing market. Finally, we have extensively investigated different medical domains, which provided various accounts of complex socio-technical settings. The investigations of various medical settings allowed us to generalise common findings across different domains.

Risk Underpinnings

Our studies identify a set of socio-technical risk underpinnings, namely, *Boundary Hazards*, *Evolutionary Hazards* and *Performativity Hazards*. In this book we choose to focus on these three classes because they provide a characterisation of newly emerging technological risk in complex organisations that make extensive use of socio-technical systems. These underpinnings have their origins in and take into account multidisciplinary aspects of risk.

For example, *Boundary Hazards* arise at inter-, or intra-organisational boundaries. At organisational boundaries, different strategies are possible, in some situations attempts are made to establish a formal interface, in others the situation is so chaotic that internal structures require external scrutiny. Organisations are exposed to Boundary Hazards and consequently to risk. Boundary Objects arise as a key element in analysing complex organisations. For us, boundary objects are often a starting point for the analysis of Boundary Hazards.

A good example of a boundary object is a classification system, or simply classification. Classifications pervade organisations and capture agreed interpretations of action and information in organisations. They are the result of technical as well as political struggles addressed over the years. Classifications arise both locally as a result of bottom-up attempts to make sense of the organisation and globally in a top-down adoption of standards. In complex organisations, classifications are continually being reinterpreted in order to support intra-group working and to support inter-group interaction.

The process of developing classifications or adopting standard classifications differs across different communities of practice in an organisation. Interfaces between different communities of practice often give rise to knowledge, structured by classifications or standards, the interpretation of the shared knowledge by different communities of practice is critical to the operation of the organisation.

Classifications provide a structure for information, but its interpretation will depend on the mechanisms that shape the structure and the policies and practices of the communities involved in shaping the classification. The detailed processes involved in shaping and adopting classifications and standards give rise to risk, particularly in how information codified in a particular classification is interpreted in different communities of practice that share the codified information. Boundary hazards have potentially critical consequences for the activities of the organisation.

Our case studies analyse problems of working with and evolving classifications. These concerns are central to the organisational objectives of technology innovation in complex organisations. The studies allow us to reflect on the methodological implications of addressing the design and evolution of organisational technology innovations.

Technological risk arising from organisational technology innovation relates to uncertainty in engineering design knowledge with respect to technical, organisational and environmental factors. This uncertainty in engineering design knowledge represents a source of risk.

Discrepancies between standard schemes and local practices (rooted in existing heterogeneous information structures and practices) mean that the introduction of standardisation which can yield a sense of increasing general accountability, scrutiny and control over distant activities may also be accompanied by a loss of local focus and detail oversight. This can be a source of socio-technical undependabilities. The contradictory effects of standardisation efforts go to the heart of questions of trust and in particular the notion that standardised information structures and practices can resolve the problems of trust in complex and (spatially and culturally) dispersed organisational settings.

Emerging Technological Risk

Our case studies allow us to identify a set of risk underpinnings, or socio-technical hazards, which we can generalise across different application domains. These findings form the basis for guidelines complementing and extending traditional approaches to risk. The guidelines benefit from our multidisciplinary, eventually interdisciplinary, approach to risk. The extensive investigations of diverse medical case studies provided an application domain into which we could generalise and assess our findings. The empirical, as well as theoretical, nature of our work is such that other industry domains may benefit from our research findings.

Interdisciplinary Risk Reader

The original idea of this book was to collect a set of multidisciplinary literature that contributes towards the advancements of an interdisciplinary account of emerging technological risk. This gave rise to an *Interdisciplinary Risk Reader*—nicknamed within the DIRC project as—the *DIRC Risk Reader*, the *Risk Reader of the Interdisciplinary Research Collaboration in Dependability*. This book is, therefore, aimed at a multidisciplinary audience of researchers and practitioners, who would find benefits from learning about diverse perspectives on technology risk. Although many different books address technological risk, it is very difficult to find any guidance in understanding and assimilating diverse literature drawn from different backgrounds. This book represents a step towards bridging diverse contributions in order to sustain a fruitful debate about *emerging technological risk*.

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Emerging Technological Risk

Underpinning the Risk of Technology Innovation

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