Chapter 1
Introduction

1 The Field of Human Factors

Human Factors encompasses a large area of study within the realm of engineering and design. The basic premise of the research in this area is to increase performance and, especially in the last two decades, performance in increasingly complex socio-technical systems.

‘Performance’ is a term that needs clarification due to its catch-all meaning. Simply to increase performance within a system does not tell us too much; rather, performance may be improved through increasing two main factors: safety and productivity. Increasingly, these two factors are seen as mutually exclusive; indeed Reason (1997) revisits several times the idea that the battle between productivity and the protection of a system (depicted in Figure 1.1) tends to be resolved in favour of the former due to the innate commercial nature of the areas where these systems exist, for example in the aviation, rail, nuclear, chemical, oil and gas industries. This is not surprising in light of the discussions throughout Reason’s book of the aspect of human nature which means that increases in productivity have very positive results for the individual and to the collective mind, but ‘by contrast, successful protection is indicated by absence of negative outcomes’ (Reason 1997: 4). To management at all levels, successful protection is the more aspirational aim. In the system itself, however, successful protection and negative outcomes, far from being mutually exclusive are, rather, one and the same. As one increases, the other will by default decrease – but this does not guarantee a negative. Rather, the level of ‘absence’ noted by Reason is diminished.
In light of this, Human Factors has a very important role to play when looking at accident causation and investigation. As technology has become more reliable over time, the role of the human in the system has started to become the weak link in a complex system, that is, the human can be pivotal between safety and productivity. This is nowhere better illustrated than by the rapid development of aviation since its inception a century ago. For many years the accident rate was reduced as a result of increases in technological and industrial ability, the improvement of the structural integrity and reliability of the aircraft being flown and, in particular, the development of their propulsion, avionic and safety systems. However, in the last two decades, the serious accident rate\(^1\) in commercial aviation has remained relatively stable at approximately 1 per 1 million departures (Boeing 2000) and, as the continual increases in reliability and other factors do not appear to be moving the statistics from this equilibrium, the focus to reduce these figures still further has required human involvement. For this reason, the field of Human Factors has evolved to play a major role in aviation accident investigation and its sole aim, as stated in ICAO Annexe 13, ‘The prevention of accidents and incidents’.\(^2\)

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1. The ICAO defines a serious accident as one involving at least one serious injury/fatality, substantial damage or complete destruction of aircraft, and fire (pre- or post-crash).
2. The term ‘incident’ is taken to include near misses and non-fatal/lesser-damage occurrences.
Introduction

The ‘accident pyramid’ in Figure 1.2 was first developed by the American industrial safety pioneer Herbert William Heinrich (1931) and illustrates the comparable frequency of events in terms of magnitude. From this the human factors literature has developed comparisons a view of fatal accidents as being at the tip of the an iceberg, and so the focus has been on attempts to control the events at the larger base of the triangle in order to reduce the numbers of fatalities occurring at the upper levels. The lower level of ‘no-injury’ accidents includes the largest group, the ‘near misses’, which have become a larger and more important part of safety systems recently, whereas the often fatal accidents at the very tip have thankfully reduced in numbers over time.

This Human Factors evolution primarily hinged on the term ‘human error’, that is, the errors committed by the operator of the system that ‘caused’ the accident or incident. The term has been well defined by Reason (1997) as ‘failure of planned actions to achieve their desired ends – without the intervention of some unforeseeable event’. This limits the areas of interest to those which can be affected directly by humans and possibly those which are proximal enough to make remedial actions possible and immediately effective. It is within this field that this project is based.

This book aims to address how we might go about improving the way in which we attempt to understand and investigate the complex world of aviation accidents and safety. More specifically, the book explores the use of information networks to support improved risk mitigation.

Figure 1.2  Heinrich’s accident pyramid

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2 Objectives and Aims of the Book

As is highlighted above and further discussed in the subsequent chapters, the complexity of aviation accidents presents significant challenges, both in academia and industry. Traditional models will be shown to be too linear, so that any representation of the real world is artificial and limits usefulness. There needs to be a shift in understanding the system in which accidents (and, equally, normal work events) take place, rather than an improper emphasis on the end result.

The book aims to address how information networks can be used to develop our understanding of complex system accidents and, in particular, those within the aviation domain. Through its holistic focus on the system, and on elements that are present within normal work incidents and accidents, it is hoped that artificial limitations can be reduced and ultimately removed from risk mitigation methods.

The aims of this book are threefold. Firstly, a new method is to be developed and tested that moves away from the linear models that currently dominate aviation risk investigation and reduction. Full and real understanding of the complex aviation domain can only truly be realised if the models used in investigation reflect the non-linear complexities of the real world.

Secondly, the book looks to incorporate general aviation and make any method usable within this part of aviation equally, as well as within the more heavily studied and discussed commercial world. Any new method would need to be able to address the sometimes very different issues which underlie these aviation types.

Thirdly, the book sets out to address whether there is a fundamental difference between accidents and incidents. Due to the reduction in aviation accidents, data are often not sufficient to develop system understanding. For this reason it would seem appropriate to turn to the more common incidents. However, it is important that any method is able to cope with each type of event and does not preclude the use of incidents or oversimplify any relationship that they may have with actual aviation accidents.

A singular method is sought, therefore, that can address all of these issues. Complex network models are central to the work within this book and their many facets investigated in order to determine their true value within the field.

3 Structure of the Book

This book has been constructed so that it can be read from beginning to end by readers new to this specific subject area. An attempt has also been made to maintain a simple writing style to aid understanding and inclusiveness. Later chapters are also designed to be read individually for those readers interested in specific areas of the research. In order to aid the reading of this book, signposting is included at the beginning of each chapter and in other positions as required. Figure 1.3 illustrates the outline of the book and helps in maintaining the central themes expanded upon below.
Introduction

The themes developed in Chapter 2 of the book, in which the literature is reviewed, are continued through the remaining chapters. In particular, the central crux of this work is the movement away from linear analysis of aviation events in Chapters 3 to 8 (book aim). Chapters 3 and 4 identify information networks as a suitable tool to apply to aviation, with the potential for integration with complex mathematics to provide both a qualitative and a quantitative element (book aim). Chapters 5 and 6 build on the research and development from previous chapters in applying Bayesian mathematics to the information networks and testing this. In particular general aviation is the domain tested in order to provide a more comprehensive view of aviation that does not just centre on commercial operations (book aim). Chapter 7 then firmly places the work in an industrial context (book aim) by working with a legacy airline and developing a brand new risk rating methodology based on a model consisting of networks. Finally Chapter 8 ties up some loose ends, looks at possible further work and concludes the central thread of the book.

An overview of each chapter in slightly more detail is provided for the reader below.

Chapter 2 ‘Modelling a Dynamic World’

The book commences with a scene-setting chapter that sets out to explain the development of accident investigation models to date. Some of the key issues associated with these models and ways of thinking are explained and the foundations for the aims of the book identified.

Chapter 3 ‘A Complex Approach to a Complex Scenario’

In order to illustrate the usefulness of the information network approach, two polarised aircraft accident case studies are investigated with the technique. These case studies were selected as they illustrate two very different situations which
led to very different events. It was considered important to show how applicable the method is to aviation accidents in their many guises. Each analysis, in this and subsequent chapters, may not be fully comprehensive on its own but throughout the book different aspects of the novel methodology are brought to the reader’s attention and expanded upon.

Chapter 4 ‘Development of a Study’

In this chapter the methods of developing information networks into a more comprehensive and useful approach are investigated. The chapter aims to draw quantitative measures to work collaboratively with qualitative aspects of the information networks. Bayesian mathematics are introduced as a potentially powerful ally of information networks and this forms the basis for the subsequent two chapters.

Chapter 5 ‘Extending the Potential of Information Networks: A Bayesian Approach’

This chapter introduces the integration of Bayesian mathematics with the information network approach. A program was written to allow for a network to be investigated and potential error migration calculated in a novel way. Central to this chapter is addressing the book aim of developing a method that can be applied not only to commercial aviation, which is so often the focus of safety management, but also to general aviation. For this reason, data from general aviation accidents are used to populate probability information networks and potential uses are investigated.

Chapter 6 ‘Can we Validate Networks Derived from Incident Data Through Simulation? A Pilot Study’

Following on from the promising results of Chapter 5, a flight simulator study was developed to validate the possible use and effectiveness of the Bayesian information network approach. Chapter 6 focusses on the planning and implementation of this flight simulator study together with statistical analysis of the resulting data. These data allow predictions of error migration to be tested and results discussed. Despite the study size being limited the emphasis is on the validation of the approach.

Chapter 7 ‘Incidents versus Accidents: An Industrial Study’

A central tenet of this book is the applicability of any developed methodology to industry. The key to applicability in a domain that is suffering from the sheer number of complex and time-consuming methods available is one that can be seen by industry to be of benefit and implementable. This chapter addresses these issues and reports on two years’ work with an international legacy airline.
The applicability of the information network approach to incidents and accidents allows for the development of a long-term plan to integrate the method into the airline’s safety management system. Limitations of working in industry are also discussed and the past, present and future methods of risk management for the airline outlined. An interim method is tested against commercial aviation incident data to highlight the pertinence and usefulness of the approach. The method has now formed the core of the working practices of a new safety management system.

Chapter 8 ‘Conclusions’

The final chapter concludes the study with discussion of the aims and objectives. Areas for further research are also identified.