Preface

Incident reporting systems have been proposed as means of preserving safety in many industries, including aviation [310], chemical production [162], marine transportation [389], military acquisition [289] and operations [806], nuclear power production [384], railways [665] and healthcare [105]. Unfortunately, the lack of training material or other forms of guidance can make it very difficult for engineers and managers to set up and maintain reporting systems. These problems have been exacerbated by a proliferation of small-scale local initiatives, for example within individual departments in UK hospitals. This, in turn, has made it very difficult to collate national statistics for incidents within a single industry.

There are, of course, exceptions to this. For example, the Aviation Safety Reporting System (ASRS) has established national reporting procedures throughout the US aviation industry. Similarly, the UK Health and Safety Executive have supported national initiatives to gather data on Reportable Injuries, Diseases and Dangerous Occurrences (RIDDOR). In contrast to the local schemes, these national systems face problems of scale. It can become difficult to search databases of 500,000 records to determine whether similar incidents have occurred in the past.

This book, therefore, addresses two needs. The first is to provide engineers and managers with a practical guide on how to set up and maintain an incident reporting system. The second is to provide guidance on how to cope with the problems of scale that affect successful local and national incident reporting systems.

In 1999, I was asked to help draft guidelines for incident reporting in air traffic control throughout Europe. The problems of drafting these guidelines led directly to this book. I am, therefore, grateful to Gilles le Gallo and Martine Blaize of EUROCONTROL for helping me to focus on the problems of international incident reporting systems. Roger Bartlett, safety manager at the Maastricht upper air space Air Traffic Control center also provided valuable help during several stages in the writing of this book. Thanks are also due to Michael Holloway of NASA's Langley Research Center who encouraged me to analyze the mishap reporting procedures being developed within his organization. Mike O'Leary of British Airways and Neil Johnstone of Aer Lingus encouraged my early work on software development for incident reporting. Ludwig Benner, Peter Ladkin, Karsten Loer and Dmitri Zotov provided advice and critical guidance on the causal analysis sections. I would also like to thank Gordon Crick and Mark Bowell of the UK Health and Safety Executive, in particular, for their ideas on the future of national reporting systems.

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Chris Johnson, Glasgow, 2003.

Chapter 1

Abnormal Incidents

Every day we place our trust in a myriad of complex, heterogeneous systems. For the most part, we do this without ever explicitly considering that these systems might fail. This trust is largely based upon pragmatics. No individual is able to personally check that their food and drink is free from contamination, that their train is adequately maintained and protected by appropriate signalling equipment, that their domestic appliances continue to conform to the growing array of international safety regulations [280]. As a result we must place a degree of trust in the organisations who provide the services that we use and the products that we consume. We must also, indirectly, trust the regulatory framework that guides these organisations in their commercial practices. The behaviour of phobics provides us with a glimpse of what it might be like if we did not possess this trust. For instance, a fear of flying places us in a nineteenth century world in which it takes several days rather than a few hours to cross the Atlantic. The SS United States' record crossing took 3 days, 10 hours and 40 minutes in July 1952. Today, the scheduled crossings by Cunard's QEII now take approximately 6 days. In some senses, therefore, trust and profit are the primary lubricants of the modern world economy. Of course, this trust is implicit and may in some cases be viewed as a form of complicit ignorance. We do not usually pause to consider the regulatory processes that ensures our evening meal is free of contamination or that our destination airport is adequately equipped.

From time to time our trust is shaken by failures in the infrastructure that we depend upon [70]. These incidents and accidents force us to question the safety of the systems that surround us. We begin to consider whether the benefits provided by particular services and products justify the risks that they involve. For example, the Valujet accident claimed the lives of a DC-9's passengers and crew when it crashed after takeoff from Miami. National Transportation Safety Board (NTSB) investigators found that SabreTech employees had improperly labelled oxygen canisters that were carried on the flight. These cannisters created the necessary conditions for the fire, which in turn led to the crash. Prior to the accident, in the first quarter of 1996, Valujet reported a net income of $10.7 million. After the accident, in the final quarter of 1996, Valujet reported a loss of $20.6 million. These losses do not take into account the additional $262 million costs of settlements with the victims relatives.

The UK Nuclear Installations Inspectorate's report into the falsification of pellet diameter data in the MOX demonstration facility at Sellafield also illustrates the consequences of losing international confidence [642] In the wake of this document, Japan, Germany and Switzerland suspended their ships to and from the facility. The United States' government initiated a review of BNFL's participation in a £4.4bn contract to decommission former nuclear facilities. US Energy Secretary Bill Richardson sent a team to England to meet with British investigators. British Nuclear Fuel's issued a statement which stated that they had nothing to hide and were confident that the US Department of Energy would satisfy itself on this point [106].

The Channel Tunnel fire provides another example of the commercial consequences of such adverse events. In May 1997, the Channel Tunnel Safety Authority made 36 safety recommendations after finding that the fire had exposed weaknesses in underlying safety systems. Insufficient staff training had led to errors and delays in dealing with the fire. Eurotunnel, therefore, took steps to address these concerns by implementing the short-term recommendations and conducting further studies to consider those changes that involved longer-term infrastructure investment. However, the UK Consumer Association mirrored more general public anxiety when its representatives stated that it was 'still worried' about evacuation procedures and the non-segregation of passengers from cars on the tourist shuttle trains [97] Te fire closed the train link between the United Kingdom and France for approximately six months and served to exacerbate Eurotunnel's 1995 loss of £925 million.

This book introduces the many different incident reporting techniques that are intended to reduce the frequency and mitigate the consequences of accidents, such as those described in previous paragraphs. The intention is that by learning more from 'near misses' and minor incidents, these approaches can be used to avoid the losses associated with more serious mishaps. Similarly, if we can identify patterns of failure in these low consequence events we can also reduce the longer term costs associated with large numbers of minor mishaps. In order to justify why you should invest your time in reading the rest of this work it is important to provide some impression of the scale of the problems that we face. It is difficult to directly assess the negative impact that workplace accidents have upon safe and successful production [285]. Many low-criticality and 'near miss' events are not reported even though they incur significant cumulative costs. In spite of such caveats, it is possible to use epidemiological surveys and reports from national healthcare systems to assess the effects of incidents and accidents on worker welfare.

1.1 The Hazards

Employment brings with it numerous economic and health benefits. It can even improve our life expectancy over those of us who may be unfortunate enough not to find work. However, work exposes us to a range of occupational hazards. The World Health Organisation (WHO) estimate that there may be as many as 250 million occupational injuries each year, resulting in 330,000 fatalities [872]. If work-related diseases are included then this figure grows to 1.1 million deaths throughout the globe [873]. About the same number of people die from malaria each year. The following list summarises the main causes of occupational injury and disease.

- *Mechanical hazards.* Many workplace injuries occur because of poorly designed or poorly screened equipment. Others occur because people work on, or with, unsafe structures. Badly maintained tools also create hazards that may end in injury. Musculo-skeletal disorders and repetitive strain injury are now the main cause of work-related disability in most of the developed world. The consequent economic losses can be as much as 5% of the gross national product in some countries [872]. The Occupational Safety and Health Administration's (OSHA) ergonomics programme has argued that musculo-skeletal disorders are the most prevalent, expensive and preventable workplace injuries in the United States. They are estimated to cost $15 billion in workers' compensation costs each year. Other hazards of the working environment include noise, vibration, radiation, extremes of heat and cold.

- *Chemical Hazards.* Almost all industries involve exposure to chemical agents. The most obvious hazards arise from the intensive use of chemicals in the textile, healthcare, construction and manufacturing industries. However, people in most industries are exposed to cleaning chemicals. Others must handle petroleum derivatives and various fuel sources. Chemical hazards result in reproductive disorders, in various forms of cancer, respiratory problems and an increasing number of allergies. The WHO now ranks allergic skin diseases as one of the most prevalent occupational diseases [872]. These hazards can also lead to metal poisoning, damage to the central nervous system and liver problems caused by exposure to solvents and to various forms of pesticide poisoning.

- *Biological hazards.* A wide range of biological agents contribute to workplace diseases and infections. Viruses, bacteria, parasites, fungi, moulds and organic dusts affect many different industries. Healthcare workers are at some risk from tuberculosis infections, Hepatitis B and C as well as AIDS. For agricultural workers, the inhalation of grain dust can cause asthma and bronchitis. Grain dust also contains mould spores that, if inhaled, can cause fatal disease [323].

- *Psychological Hazards.* Absenteeism and reduced work performance are consequences of occupational stress. These problems have had an increasing impact over the last decade. In the United Kingdom, the cost to industry is estimated to be in excess of £6 billion with over 40 million working days lost each year [90]. There is considerable disagreement over the causes of such stress. People who work in the public sector or who are employed in the service industries seem to be most susceptible to psychological pressures from clients and customers. High workload, monotonous tasks, exposure to violence, isolated work have all been cited as contributory factors. The consequences include unstable personal relationships, sleep disturbances and depression. There can be physiological consequences including higher rates of coronary heart disease and hypertension. Post traumatic stress disorder is also increasingly recognised in workers who have been involved in, or witnessed, incidents and accidents.

This list describes some of the hazards that threaten workers' health and safety. Unfortunately, these items tell us little about the causes of these adverse events or about potential barriers. For example, OSHA report describes the way in which a sheet metal worker was injured by a mechanical hazard:

> "...employee #1 was working at station #18 (robot) of a Hitachi automatic welding line. She had been trained and was working on this line for about 2 months... The lifting arm then rises and a robot arm moves out from the operator's side of the welding line and performs its task. Then there is a few seconds delay between functions as the robot arm finishes welding, rises, returns to home and the lifting arm lowers to home, ready for the finished length of frame steel to move on and another to take it's place. During the course of this operation the welding line is shut down intermittently so that the welding tips on the robot arms can be lubricated, preventing material build up. This employee, without telling anyone else or shutting down the line, tried to perform the lubrication with the line still in automatic mode. She thought this could be done between the small amount of time it took all parts to complete their functions and return to home. The employee did not complete the task in time, as she had anticipated. Her right leg was located between the protruding rods on the lifting arm and the openings the rods rest in. Her leg was trapped. When other employees were alerted, they had trouble trying to switch the line to manual because the computer was trying to complete it's function and the lifting arm was trying to return to home. The result was that one employee used a crowbar to help relieve pressure on her leg and another used the cellenoid which enabled the lifting arm to rise. The employee received two puncture wounds in the thigh (requiring stitches) and abrasions to the lower leg. Management once again instructed employees working this line on the serious need to wait until all functions are complete, the line shut down and not in the automatic mode before attempting any maintenance." (OSHA Accident Report ID: 0352420).

It is possible to identify a number of factors that were intended to prevent this incident from occurring. Line management had trained the employees not to intervene until the robot welding cycle was complete. Lubrication was intended to be completed when the line was 'shut down' rather than in automated mode. It is also possible to identify potential factors that might have been changed to prevent the accident from occurring. For example, physical barriers might have been introduced into the working environment so that employees were prevented from intervening during automated operations. Similarly, established working practices may in some way have encouraged such risk taking as the report comments the management 'once again' instructed employees to wait until the line was shut down. These latent problems created the context in which the incident could occur [698]. The triggering event, or catalyst, was the employee's decision that she had enough time to lubricate the device. The lack of physical barriers then left her exposed to the potential hazard once she had decided to pursue this unsafe course of action. Observations about previously unsafe working practices in this operation may also have done little to dissuade her from this intervention.

Figure 1.1 provides a high level view of the ways in which incidents and accidents are caused by catalytic failures and weakened defences. The diagram on the left shows how the integration of working practices, working environment, line management and regulatory intervention together support a catalytic or triggering failure. Chapter 3 will provide a detailed analysis of the sources for such catalytic failures. For now, however, it is sufficient to observe that there a numerous potential causes ranging from human error through to stochastic equipment failures through to deliberate violations of regulations and working practices. It should also be apparent that there may be catalytic failures of such magnitude that it would be impossible for any combination of the existing structures to support, for any length of time. In contrast, the diagram on the right of Figure 1.1 is intended to illustrate how weaknesses in the integration of system components can increase an application's vulnerability to such catalytic failures. For example, management might strive to satisfy the requirements specified by a regulator but if those requirements are flawed then there is a danger that the system will be vulnerable to future incidents. These failures in the supporting infrastructure are liable to develop over a much longer timescale than the triggering events that place the system under more immediate stress.

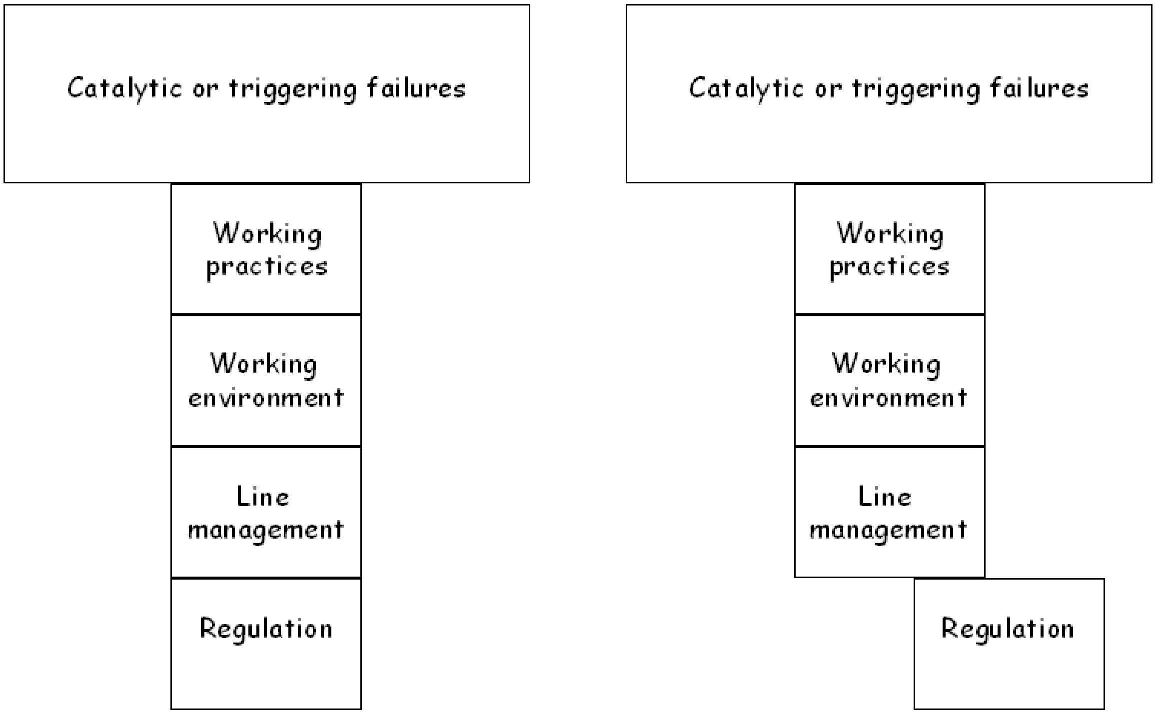

Figure 1.1: Components of Systems Failure

The diagrams in Figure 1.1 sketch out one view of the way in which specific failures place stress on the underlying defences that protect us from the hazards what were listed in previous paragraphs. A limitation of these sketches is that they provide an extremely static impression of a system as it is stressed by catalytic failures. In contrast, Figure 1.2 provides a more process oriented view of the development of an occurrence or critical incident. Initially, the systems is in a 'normal' state. Of course, this 'normal' state need not itself be safe if there are flaws in the working practices and procedures that govern everyday operation. The systems may survive through an incubation period in which any residual flaws are not exposed by catalytic failures. This phase represents a 'disaster waiting to happen'. However, at some point such an event does cause the onset of an incident or accident. These failures may, in turn, expose further flaws that trigger incidents elsewhere in the same system or in other interrelated applications. After the onset of a failure, protection equipment and other operators may intervene to mitigate any consequences. In some

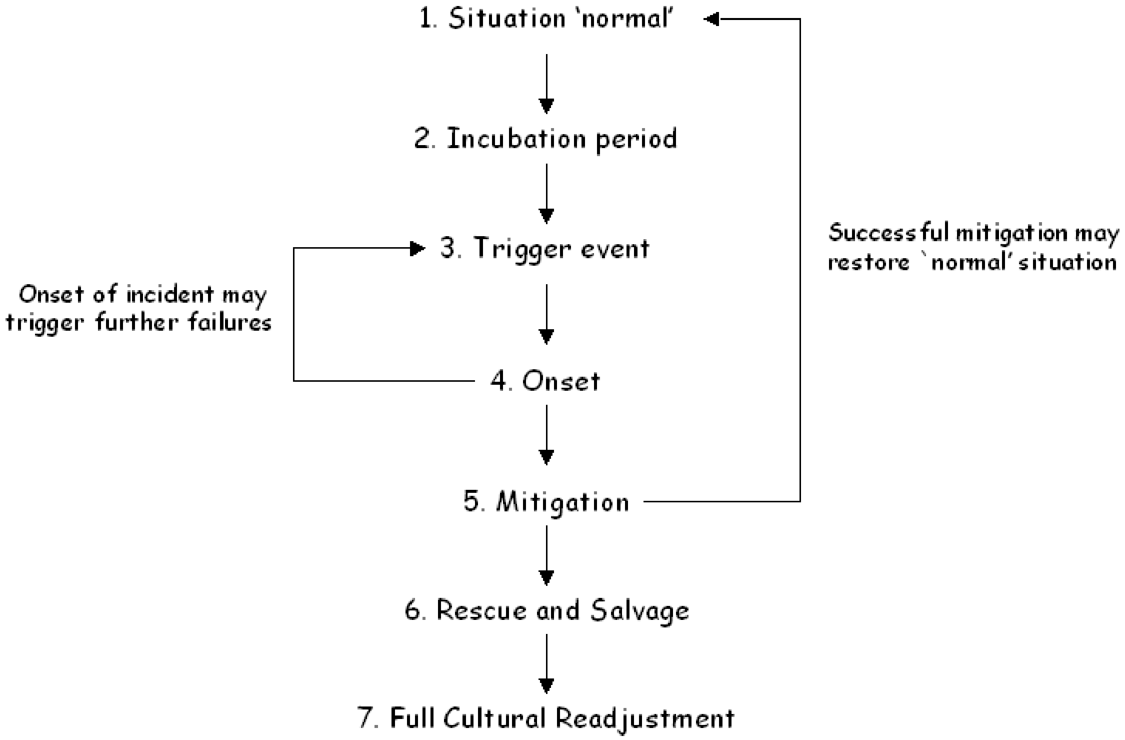

Figure 1.2: Process of Systems Failure

cases, this may return the system to a nominal state in which no repair actions are taken. This has potentially dangerous implications because the flaws that were initially exposed by the triggering event may still reside in the system. Alternatively, a rescue and salvage period may be initiated in which previous shortcomings are addressed. In particular, a process of cultural readjustment is likely if the potential consequences of the failure have threatened the continued success of the organisation as a whole. For example, the following passage comes from a report that was submitted to the European Commission's Major Accident Reporting System (MARS) [231]:

> "At 15:30 the crankcase of an URACA horizontal action 3 throw pump, used to boost liquid ammonia pressure from 300 psi to 3,400 psi, was punctured by fragments of the failed pump-ram crankshaft. The two operators investigating the previously reported noises from the pump were engulfed in ammonia and immediately overcome by fumes. Once the pump crackcase was broken, nothing could be done to prevent the release of the contents of the surge drum (10 tonnes were released in the first three minutes). The supply of ammonia from the ring main could only be stopped by switching off the supply pump locally. No one were able to do this as the two gas-tight suits available were preferentially used for search and rescue operations, and thus release of ammonia continued. Ammonia fumes quickly began to enter the plant control room and the operators hardly had the time to sound the alarms and start the plant shut-down before they had to leave the building using 10 minutes escape breathing apparatus sets. During the search and rescue operation the fire authorities did not use the gas-tight suits and fumes entered the gaps around the face piece and caused injuries to 5 men. The ammonia cloud generated by the initial release drifted off-site and remained at a relatively low level." (MARS report 814).

A period of normal operation led to an incubation period in which the pump-ram crankshaft was beginning to fail and required maintenance. The trigger event involved the puncture of the pump's crankcase when the ram crankshaft eventually failed. This led to the onset of the incident in which two operators were immediately overcome. This then triggered a number of further, knock-on failures. For instance, the injuries to the firemen were caused because they did not use gas tight suits during their response to the initial incident. In this case, only minimal mitigation was possible as operators did not have the gas tight suits that were necessary in order to isolate the ammonia supply from the ring main. Those suits that were available were instead deployed to search and rescue operations.

Many of the stages shown in Figure 1.2 are based on Turner's model for the development of a system failure [790]. The previous figure introduces a mitigation phase that was not part of this earlier model. This is specifically distinguished from Turner's rescue and salvage stage because it reflects the way in which operators often intervene to 'cover up' a potential failure by taking immediate action to restore a nominal state. In many instances, individuals may not even be aware that such necessary intervention should be reported as a focus for potential safety improvements. As Leveson points out, human intervention routinely prevents the adverse consequences of many more occurrences than are ever recorded in accident and incident reports [485]. This also explains our introduction of a feedback loop between the mitigation and the situation normal phases. These features were not necessary in Turner's work because his focus was on accidents rather than incidents. Figure 1.2 also introduces a feedback loop between the onset and trigger phases. This is intended to capture the ways in which an initial failure can often have knock-on effects throughout a system. It is very important to capture these incidents because are increasingly common as we move to more tightly integrated, heterogeneous application processes.

Previous paragraphs have sketched a number of ways in which particular hazards contribute to occupational injuries. They have also introduce a number of high-level models that can be used to explain some of the complex ways in which background failures and triggering events combine to expose individuals to those hazards. The following sections build on this analysis by examining the likelihood of injury to individuals in particular countries and industries. We also look at the costs of these adverse events to individuals and also to particular industries. The intention is to reiterate the importance of detecting potential injuries and illnesses before they occur.

1.1.1 The Likelihood of Injury and Disease

Work-place incidents and accidents are relatively rare. In the United Kingdom, approximately 1 in every 200 workers reports an occupational illness or injury resulting in more than three days of absence from employment every year [333]. OSHA estimates that the rate of work-related injuries and illnesses dropped from 7.1 per year for every 100 workers in 1997 to 6.7 in 1998 [653]. These figures reflect significant improvements over the last decade. For example, the OSHA statistics show that the number of work-related fatalities has almost been halved since it was established by Congress in 1971. The Australian National Occupational Health and Safety Commission report that the rate of fatality, permanent disability or a temporary disability resulting in an absence from work of one week or more was 2.2 per 100 in 1997-8, 2.5 in 1996-7, 2.7 in 1995-6, 2.9 in 1994-95, 3.0 in 1993-4, 2.8 in 1992-3 [44]. The following figures provide the same data per million hours worked: 13 in 1997-8, 14 in 1996-7, 16 in 1995-6, 16 in 1994-5, 17 in 1993-4, 19 in 1992-3.

These statistics hide a variety of factors that continue to concern governments, regulators, managers, operators and the general public. The first cause for concern stems from demographic and structural changes in the workforce. Many countries continue to experience a rising number of workers. This is both due to an increasing population and to structural changes in the workforce, for instance increasing opportunities for women. In the United Kingdom, the 1% fall between 1998 and 1999 in the over 3 day injury rate is being offset by a (small) rise in the total number of injuries from 132,295 to 132,307 in 1999-2000 [333]. Similarly the OSHA figures for injury and illness rates show a 40 % decline since 1971. At the same time, however, U.S. employment has risen from 56 million workers at 3.5 million worksites to 105 million workers at nearly 6.9 million sites [653]. Population aging will also have an impact upon occupational injury statistics. Many industrialised countries are experiencing the twin effects of a falling birth rate and a rising life expectancy. This will increase pressure on the workforce for higher productivity and greater contributions to retirement provision. Recent estimates place the number of people aged 60 and over at 590 million worldwide.

By 2020, this number is projected to exceed 1,000 million [873]. Of this number, over 700 million older people will live in developing counties. These projections are not simply significant for the burdens that they will place on those in work. Older elements of the workforce are often the most likely to suffer fatal work-related injuries. In 1997-98, the highest rate of work-related fatalities in Australia occurred in the 55 plus age group with 1.3 deaths per 100 employees. They were followed by the 45-49 and 50-54 age groups with approximately 0.8 fatalities per 100 employees. The lowest number of fatalities occurred in workers under that age of 20 with 0.2 deaths per 100 employees. It can be difficult to interpret such statistics. For example, they seem to indicate that the rising risks associated with aging outweigh any beneficial effects from greater expertise across the workforce. Alternatively, the statistics may indicate that younger workers are more likely to survive injuries that would prove fatal to older colleagues. The UK rate of reportable injury is lower in men aged 16-19 than all age groups except for those above 55 [328]. However, the HSE report that the differences between age groups are not statistically significant when allowing for the higher accident rates for those occupations that are mainly performed by younger men. There is also data that contradicts the Australian experience. Young men, aged 16-24, face a 40% higher relative risk of all workplace injury than men aged 45-54 even after allowing for occupations and other job characteristics.

The calculation of health and safety statistics has also been effected by social and economic change. Part-time work has important effects on the calculation of health and safety statistics per head of the working population [653, 328]. The rate of injury typically increases with the amount of time exposed to a workplace risk. However, it is possible to normalise the rate using an average number of weekly hours of work. The rate of all workplace injury in the UK is 8.0 per 100 for people working less than 16 hours per week. For people working between 16 and 29 hours per week it is 4.3, between 30 and 49 hours it is 3.8, between 50 and 59 it is 3.2 and people working 60 or more hours per week have an accident rate of 3.0 per 100 workers per annum. People who work a relatively low number of hours have substantially higher rates of all workplace and reportable injury than those working longer hours. The relatively high risk in workers with low hours remains after allowing for different occupational characteristics [328]. The growth of temporary work has similar implications for some economies. In the UK, the rate of injury to workers in the first 6 months is double that of their colleagues who have worked for at least a year. This relatively high risk for new workers remains after allowing for occupations and hours of work. 57% temporary workers have been with their employer for less than 12 months.

Figure 1.1 shows that accident rates are not uniformly distributed across industry sectors. For example, the three day rate for agriculture and fishing in the United Kingdom is 1.2 per 100 employees. The same rate for the services industries is approximately 0.4 per 100 workers.

Industry	UK		Germany		France	Spain		Italy
	1993	1994	1993	1994	1993	1992	1993	1991
Agriculture	7.3	8.5	6.0	6.7	9.8	9.1	5.4	18.4
Utilities	0.5	0.6	3.1	4.3	5.6	12.5	10.1	4.4
Manufacturing	1.6	1.2	2.3	1.6	2.3	6.7	4.9	3.3
Construction	8.9	6.9	7.9	8.0	17.6	21.0	19.3	12.8
Transport	2.2	2.0	7.2	7.5	6.5	13.0	10.7	11.2
Other services	0.3	0.4	1.0	1.2	1.9	1.4	1.5	0.9
All Industries	1.2	0.9	3.3	3.2	3.9	6.4	5.1	5.5

Table 1.1: Industry Fatality Rates in UK, Germany, France, Spain & Italy [326]

Accidents rates also different with gender. Positive employment practices are exposing increasing numbers of women to a greater variety of risks in the workplace. The overall Australian National Occupational Health and Safety Commission rate of 2.2 injuries and illnesses per 100 workers hides a considerable variance [44]. For males the rate was 2.9 per 100 workers whilst it was 1.3 for females.

In 1997-8, the industries with the highest number of male fatalities were Transport and Storage (66) and Manufacturing (64), while for females Accommodation, Cafes and Restaurants (4) and Property and Business Services (4) were the highest. The male fatalities were mainly employed as Plant and Machine Operators, and Drivers (91). Female fatalities were mainly employed as Managers and Administrators (5). These differences may decline with underlying changes in workplace demographics. However, UK statistics suggest some significant residual differences between the genders:

> "the rate of all workplace injury is over 75% higher in men than women, reflecting that men tend to be employed in higher risk occupations. After allowing for job characteristics, the relative risk of workplace injury is 20% higher in men compared with women. Job characteristics explain much of the higher rate of injury in men but not all because men still have an unexplained 20% higher relative risk". [328]

Table 1.1 illustrates how the rate of industrial injuries differs within Europe. Such differences are more marked when comparisons are extended throughout the globe. However, it is not always possible to find comparable data:

> "The evaluation of the global burden of occupational diseases and injuries is difficult. Reliable information for most developing countries is scarce, mainly due to serious limitations in the diagnosis of occupational illnesses and in the reporting systems. WHO estimates that in Latin America, for example, only between 1 and 4% of all occupational diseases are reported. Even in industrialised countries, the reporting systems are sometimes fragmented." [873]

For example, the Australian statistics cited in previous paragraphs include some cases of coronary failure that would not have been included within the UK statistics. These problems are further exacerbated by the way in which local practices affect the completion of death certifications and other reporting instruments. For instance, the death of a worker might have been indirectly caused by a long running coronary disease or by the immediate physical exertion that brings on a heart attack. It is important to emphasise that even if it were possible to implement a consistent global reporting system for workplace injuries, it would still not be possible to directly draw inferences about the number of incidents and accidents directly from that data. Many incidents still go unreported even if well-established reporting systems are available. A further limitation is that injury and fatality statistics tell us little or nothing about 'near miss' incidents that narrowly avoided physical harm.

1.1.2 The Costs of Failure

In 1996 the UK Health and Safety Executive estimated that workers and their families lost approximately £558 million per year in reduced income and additional expenditure from work-related injury and ill health [324]. They also estimated that the loss of welfare in the form of pain, grief and suffering to employees and their families was equivalent to a further £5.5 billion. These personal costs also have wider implications for employers, for the local economy and ultimately for national prosperity. The same study estimated that the direct cost to employers was approximately £2.5 billion a year; £0.9 billion for injuries and £1.6 billion for illness. In addition, the loss caused by avoidable accidental events that do not lead to injury was estimated at between £1.4 billion and £4.5 billion per year. This represents 4-8% of all UK industrial and commercial companies' gross trading profits.

Employers also incur costs through regulatory intervention. These actions are intended to ensure that a disregard for health and safety will be punished whether or not an incident has occurred. Tables 1.2 and 1.3 summarise the penalties imposed by United States' Federal and State inspectors in the fiscal year 1999 [653]. Regulatory actions imposed a cost of $151,361,442 beyond the immediate financial losses incurred from incidents and accidents. These figures do not account for the numerous competitive disadvantages that are incurred when organisations are associated with high-profile failures [676].

Violations	Percent	Type	Penalties
646	0.8	Willful	$24,460,318
50,567	66	Serious	$50,668,509
1,816	2	Repeat	$8,291,014
226	0.3	Failure to abate	$1,205,063
408	0.01	Unclassified	$3,740,082
23,533	30	Other	$1,722,338
77,196	Total		$90,087,324

Table 1.2: Federal Inspections Fiscal Year 1999

Violations	Percent	Type	Penalties
441	0.3	Willful	$12,406,050
57,010	40	Serious	$35,441,267
2,162	1.5	Repeat	$4,326,620
785	0.5	Failure to abate	$2,860,972
46	0.0002	Unclassified	$2,607,900
82,120	40	Other	$3,631,309
202,962	Total		$61,274,118

Table 1.3: State Inspections Fiscal Year 1999

1.2 Social and Organisational Influences

These statistics illustrate the likelihood and consequences of occupational injuries. It is important, however, to emphasise that this data suffers from a number of biases. Many of the organisations that are responsible for collaring the statistics are also responsible for ensuring that mishap frequencies are reduced over time. Problems of under-reporting can also complicate the interpretation of national figures. There is often a fear that some form of blame will attach itself to those organisations that return an occupational health reporting form. The OSHA record keeping guidelines stress that:

> "Recording an injury or illness under the OSHA system does not necessarily imply that management was at fault, that the worker was at fault, that a violation of an OSHA standard has occurred, or that the injury or illness is compensable under workers' compensation or other systems." [654]

However, in many counties including the United States, organisations that have a higher reported rate of occupational illness or injury become the focus of increasing levels of regulatory inspection and intervention. This has a certain irony because, as OSHA acknowledge, relatively low levels of reported injuries and illnesses may be an indicator of poor health and safety management:

> "...during the initial phases of identifying and correcting hazards and implementing a safety and health program an employer may find that its reported rate increases. This may occur because, as an employer improves its program, worker awareness and thus reporting of injuries and illnesses may increase. Over time, however, the employer's ... rate should decline if the employer has put into place an effective program." [649]

It is instructive to examine how our analysis relates to previous work on enhancing the safety of hazardous technologies. Two schools of thought can be identified; the first stems from the 'normal accident' work of Perrow [676]; the second stems from the idea of 'high reliability' organisations [718].

1.2.1 Normal Accidents?

Perrow argues that the characteristics of high-risk technologies make accidents inevitable, in spite of the effectiveness of conventional safety devices. These characteristics include complexity and tight coupling. Complexity arises from our limited understanding of some transformation stages in modern processing industries. It stems from complex feedback loops in systems that rely on multiple, interacting controls. Complexity also stems from many common-mode interconnections between subsystems that cannot easily be isolated. More complex systems produce unexpected interactions and so can provoke incidents that are harder to rectify.

Perrow also argues that tight coupling plays a greater role in the adverse consequences of many accidents than the complexity of modern technological systems. This arises because many applications are deliberately designed with narrow safety margins. For example, a tightly coupled system may only permit one method of achieving a goal. Access to additional equipment, raw materials and personnel is often limited. Any buffers and redundancy that are allowed in the system are deliberately designed only to meet a few specified contingencies. In contrast, Perrow argues that accidents can be avoided through loose coupling. This provides the time, resources and alternative paths to cope with a disturbance.

There is evidence to contradict parts of Perrow's argument [710, 684]. Some 'high reliability' organisations do seem to be able to sustain relatively low incident rates in spirit of operating complex processes. Viller [847] identifies a number of key features that contribute to the perceived success of these organisations:

- The leadership in an organisation places a high priority on safety.
- High levels of redundancy exist even under external pressures to trim budgets.
- Authority and responsibility are decentralised and key individuals can intervene to tackle potential incidents. These actions are supported by continuous training and by organisational support for the maintenance of an appropriate safety culture.
- Organisational learning takes place through a variety of means, including trial and error but also through simulation and hypothesis testing.

These characteristics illustrate the important role that incident reporting plays for 'high reliability' organisations. Such applications are an important means of supporting organisational learning. Table 1.4 summarises the main features of 'Normal Accident' theory and 'High Reliability' organisations. Sagan [718] used both of these approaches to analyse the history of nuclear weapons safety. His conclusions lend weight to Perrow's pessimistic assessment that some accidents are inevitable. They are significant because they hold important implications for the interpretation both of incident and accident reports. For example, Sagan argues that much of the evidence put forward to support high reliability organisations is based on data that those organisations help to produce. Accounts of good safety records in military installations are often dependent on data supplied by the military. This is an important caveat to consider during the following pages in which we will present incident and accident statistics. We may not always be able to rely upon the accuracy of information that organisations use to publicise improvements in their own safety record. Sagan also argues that social pressures act as brakes on organisational learning. He identifies ways in which stories about previous failures have been altered and falsified. He then goes on to show how the persuasive effects of such pressures can help to convince the originators of such stories that they are, in fact, truthful accounts of incidents and accidents. This reaches extremes when failures are re-painted as notable successes.

1.2.2 The Culture of Incident Reporting

Sagan's work shows that a variety of factors can affect whether or not adverse events are investigated. Thes factors affect both individuals and groups within safety-critical organisations. The impact of cultural influences, of social and legal obligations, cannot be assessed without regard to individual differences. Chapter 3 will describe how subjective attitudes to risk taking and to the violation of rules can have a profound impact upon our behaviour. For now it is sufficient to observe that each of the following influences will affect individuals in a number of different ways.

In some groups, it can be disloyal to admit that either you or your colleagues have made a mistake or have been involved in a 'failure'. These concerns take a number of complex forms. For example,

High Reliability Organisations	Normal Accidents Theory
Accidents can be prevented through good organisational design and management	Accidents are inevitable in complex and tightly coupled systems.
Safety is the priority organisational objective.	Safety is one of a number of competing objectives.
Redundancy enhances safety: duplication and overlap cam make a reliable system out of unreliable parts.	Redundancy often causes accidents: it creates interactive complexity and encourages risk taking.
Decentralised decision-making is needed to permit prompt and flexible operating responses to surprises	De-centralised control is needed for complex systems but centralised control is needed for tight coupling.
A culture of reliability enhances safety by encouraging uniform and appropriate responses by operators	A military model of intense discipline and isolation is incompatible with democratic values
Continuous operations, training and simulations can create and maintain high reliability operations.	Organisations cannot train for unimagined, highly dangerous or politically unpalatable operations
Trial and error learning from accidents can be effective and can be supplemented by anticipation and simulations	Denial of responsibility, faulty reporting and reconstruction of history cripples learning efforts.

Table 1.4: Competing Perspectives on Safety with Hazardous Technologies [718]

individuals may be prepared to report failures. However, individuals may be reluctant to face the retribution of their colleagues should their identity become known. These fears are compounded if they do not trust the reporting organisation to ensure their anonymity. For this reason, NASA go to great lengths to publicise the rules that protect the identity of contributors to the US Aviation Safety Reporting System.

Companies can support a good 'safety culture' by investing in and publicising workplace reporting systems. A number of factors can, however, undermine these initiatives. The more active a company is in seeking out information about previous failures then the worse its safety record may appear. It can also be difficult to sustain the employee protection that encourages contributions when incidents have economic as well as safety implications. Individuals can be offered re-training after a first violation, re-employment may be required after a second or third.

The social influence of a company's 'safety culture' is reinforced by the legal framework that governs particular industries. This is most apparent in the regulations that govern what should and what should not be reported to national safety agencies. For example, the OSHA regulations follow Part 1904.12(c) of the Code of Federal Regulations. These require that employers record information about every occupational death; every nonfatal occupational illness; and those nonfatal occupational injuries which involve one or more of the following: loss of consciousness, restriction of work or motion, transfer to another job, or medical treatment (other than first aid). [654] As we shall see, this focus on accidents rather than 'near-miss' incidents reflects an ongoing debate about the scope of Federal regulation and enforcement in the United States.

It is often argued that individuals will not contribute to reporting systems unless they are protected from self-incrimination through a 'no blame' policy [700]. It is difficult for organisations to preserve this 'no blame' approach if the information that they receive can subsequently be used during prosecutions. Conversely, a local culture of non-reporting can be reinforced or instigated by a fear of legal retribution if incidents are disclosed. These general concerns characterise a range of more detailed institutional arrangements. For example, some European Air Traffic Management providers operate under a legal system in which all incidents must be reported to the police. In neighbouring countries, the same incidents are investigated by the service providers themselves and, typically, fall under an informal non-prosecution agreement with state attorneys. Other countries have more complex legal situations in which specific industry arrangements also fall under more general regional and national legislation. For example, the Utah Public Officers and Employees' Ethics Act and the Illinois' Whistle Blower Protection Act are among a number of state instruments that have been passed to protect respondents. These local Acts provide for cases that are also covered by Federal statutes including the Federal False Claims Act or industry specific provision for Whistle Blowers such as section 405 of the Surface Transportation Assistance Act. This has created some disagreement about whether state legislation preempts federal law in this area; several cases have been conducted in which claimants have filed both common law and statutory suits at the same time. Cases in Texas and Minnesota have shown that Federal statutes provide a base-line and not a ceiling for protection in certain states. Such legal complexity can deter potential contributors to reporting systems.

There are other ways in which the legislative environment can affect reporting behaviour. For example, freedom of information and disclosure laws are increasing public access to the data that organisations can hold. The relatives or representatives of people involved in an accident can potentially use these laws to gain access to information about previous incidents. In such circumstances, there is an opportunity for punitive damages to be sought if previous, similar incidents were reported but not acted upon. These concerns arose in the aftermath of the 1998 Tobacco Settlement with cigarette manufacturers in the United States. Prior to this settlement, states alleged that companies had conspired to withhold information about the adverse health effects of tobacco [580].

The legislative environment for accident and incident reporting is partly shaped by higher-level political and social concerns. For example, both developed and developing nations have sought to deregulate many of their industries in an attempt to encourage growth and competition. Recent initiatives to liberalise the Indian economy have highlighted this conflict between the need to secure economic development whilst also coordinating health and safety policy. The Central Labour Institute has developed national standards for the reporting of major accidents. However, the Directorate General of Factory Advice Services and the Labour Institutes have not developed similar guidelines for incident and occurrence reporting. The focus has been on developing education and training programmes that can target specific health and safety issues after industries have become established within a region [156].

Some occupational health and safety reporting system have, however, been extended to explicitly collect data about both actual accidents and 'near-miss' incidents. For example, employers in the UK are guided by the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995. These cover accidents which result in an employee or a self-employed person dying, suffering a major injury, or being absent from work or unable to do their normal duties for more than three days. They also cover 'dangerous occurrences' that do not result in injury but have the potential to do significant harm [322]. These include:

- The collapse, overturning or failure of load-bearing parts of lifts and lifting equipment.
- The accidental release of a biological agent likely to cause severe human illness.
- The accidental release of any substance which may damage health.
- The explosion, collapse or bursting of any closed vessel or associated pipework.
- An electrical short circuit or overload causing fire or explosion.
- An explosion or fire causing suspension of normal work for over 24 hours.

Similarly, Singapore's Ministry of Manpower requires that both accidents and 'dangerous occurrences' must be reported. Under the fourth schedule of the national Factory Act, these may 'under other circumstances' have resulted in injury or death [742]. The detailed support that accompanies the act provide exhaustive guidance on the definition of such dangerous occurrences. These are taken to include incidents that involve bursting of a revolving vessel, wheel, grindstone or grinding wheel.

Dangerous occurrences also range from electrical short circuit or failure of electrical machinery, plant or apparatus, attended by explosion or fire or causing structural damage to an explosion or failure of structure of a steam boiler, or of a cast-iron vulcaniser.

A duty to report on incidents and accidents does not always imply that information about these occurrences will be successfully acted upon. This concern is at the heart of continuing attempts to impose a 'duty to investigate' upon UK employers. At present, the UK regulatory framework is one in which formal accident investigation of the most serious incidents is undertaken by specially trained investigators. Employers are not, in general, obliged to actively finding out what caused something to go wrong. Concern about this situation led to a 1998 discussion document that was published by the Health and Safety Commission (HSC). It was observed that:

> "At present, there is no law which explicitly requires employers to investigate the causes of workplace accidents. Many employers do undertake accident investigation when there has been an event in the workplace which has caused injury in order to ensure lessons are learnt, and although there is no explicit legal duty to investigate accidents there are duties under some health and safety law which may lead employers to undertake investigation. The objective of a duty to investigate accidents would be to ensure employers draw any appropriate lessons from them in the interests of taking action to prevent recurrence." [316]

There are many organisational reasons why a body such as the HSC would support such an initiative. The first is the face-value argument that such a duty to investigate accidents and incidents would encourage employers to adopt a more pro-active approach to safety. The second is that such a duty would help to focus finite regulatory resources by following the deregulation initiated in the UK under the Robens Committee [709]. This group responded to the mass of complex regulations that had emerged from the plethora of nineteenth century factory acts. As industries merged and emerged, it was difficult for employers to know which parts of each act actually applied to their business. As a result, the Robens Committee helped to propose what became the Health and Safety at Work Act (1974). Key sections of the Roben report [701] argued that:

> "We need a more effective self-regulating system... It calls for better systems of safety organisation, for more management initiatives, and for more involvement of work people themselves. The objectives of future policy must, therefore, include not only increasing the effectiveness of the state's contribution to safety and health at work but also, and more importantly, creating conditions for more effective self-regulation" [709]

The same concerns over the need to target finite regulatory resources and the need to encourage pro-active intervention by other organisations also inspired attempts in the United States to establish OSHA's Cooperative Compliance Programme. This focused on the 12,000 employers that had the highest reported mishap rates. Those companies that agreed to participate and invest in safety management programs were to be offered a reduced likelihood of OSHA inspection. This was estimated to be a reduction from an absolute certainty of inspection down to approximately 30% [649]. This policy was intended to leverage OSHA resources by encouraging commercial investment in safety. It was also intended to provide OSHA with a means of targeting finite inspection resources. However, employers' organisations claimed that it introduced new roles and responsibilities for the Federal organisation. The US Chamber of Commerce helped to present a case before the US Court of Appeals that succeeded in blocking OSHA's plans. The Assistant Secretary of Labour for Occupational Safety and Health argued:

> "The goal of Cooperative Compliance Programme (CCP) is to use OSHA's limited resources to identify dangerous work sites and work in partnership with management and labour to find and fix hazards. America's taxpayers expect nothing less for their continued support and funding of OSHA. This lawsuit is frivolous; it has no merit and aims only to hinder our ability to protect working men and women from often life-threatening hazards. The CCP is an enforcement program–not a regulation. We are confident that our program is lawful. Attempts by the National Association of Manufacturers and the

> U.S. Chamber of Commerce to throw-up legal roadblocks will only ensure that the most dangerous work sites in America remain that way, putting untold numbers of workers at risk." [399]

The CCP provides important insights into the regulatory environment in the United States. As a result of the legal action, OSHA was forced to build less formal partnerships with employers' organisations. The CCP is also instructive because OSHA produced detailed guidance on those measures that high-reporting organisations ought to introduce in order to address previous failures. Table 1.5 presents OSHA's guidelines [649] on how to assess the quality of accident investigation within an organisation. As can be seen, the investigation of 'near-miss' incidents, or occurrences in HSE terms, characterises an organisation at the highest level of safety management.

1	No investigation of accidents, injuries, near misses, or other incidents is conducted.
2	Some investigation of incidents takes place, but root cause may not be identified, and correction may be inconsistent. Supervisors prepare injury reports for lost time cases.
3	OSHA-101 (report form) is completed for all recordable incidents. Reports are generally prepared with cause identification and corrective measures prescribed.
4	OSHA-recordable incidents are always investigated, and effective prevention is implemented. Reports and recommendations are available to workers. Quality and completeness of investigations are systematically reviewed by trained safety personnel.
5	All loss-producing accidents and near-misses are investigated for root causes by teams or individuals that include trained safety personnel and workers.

Table 1.5: OSHA Levels of Accident and Incident Investigation

Different reporting systems have different definitions of what should and what should not be reported. These distinctions reflect national and international agreements about the nature of incidents and accidents. For instance, Table 1.6 embodies International Civil Aviation Organisation (ICAO) and EUROCONTROL requirements for incident and accident reporting in Air Traffic Control. As can be seen, this covers both specific safety-related incidents such as the loss of control in flight and also failures to provide adequate air traffic management services.

Table 1.6 provides domain dependent definitions of incidents and accidents. Each row provides explicit examples of occurrences in Air Traffic Management. It could not easily be used in the chemical or healthcare industries. It can still be difficult to apply these consequence based definitions of ATM incidents and accidents. For example, a loss of separation might be avoided if air crews spot each other and respond appropriately. Such an occurrence might be given a relatively low criticality assessment; no loss of separation occurred. However, it can also be argued that this incident ought to be treated *as if* an air proximity violation had occurred because air traffic control did not intervene to prevent it from happening. This approach is exploited within some European ATM service providers.

Further problems complicate the use of consequence based definitions of accidents and incidents, such as those illustrated in Table 1.6. Individuals may not be able to observe the consequences of the adverse events that they witness. For example, maintenance teams are often remote from the operational outcomes of their actions. As a result, organisations such as the UK Civil Aviation Authority approve specific lists of occurrences that must be reported. For instance, the Ground Occurrence Report Form E1022 is used for the notification of defects found during work on aircraft or aircraft components which are considered worthy of special attention [10]. In contrast to Table 1.6, the following list includes procedural errors and violations, such as incorrect assembly, as well as

Occurrence	Category	Definitions of an Occurrence
Accidents	Mandatory	Mid-air collision, controlled flight into terrain, ground collision between aircraft, ground collision between aircraft and obstruction. Other accidents of special interest including loss of control in flight due to VORTEX or meteorological conditions.
Incidents	Mandatory	Loss of air separation, near controlled flight into terrain, runway incursion, inability to provide ATM services, breach in ATM system security.
Other occurrences	Voluntary	Anything which has serious safety implications but which is neither an accident nor an incident.

Table 1.6: Distinctions between Accidents and Incidents in Air Traffic Control

observations of potential component failure, such as overheating of primary or secondary structure:

- Defects in aircraft structure such as cracks in primary or secondary structure, structural corrosion or deformation greater than expected
- Failures or damage likely to weaken attachments of major structural items including flying controls, landing gear, power plants, windows, doors, galleys, seats and heavy items of equipment
- When any component part of the aircraft is missing, believed to have become detached in flight
- Overheating of primary or secondary structure
- Incorrect assembly
- Failure of any emergency equipment that would prevent or seriously impair its use
- Critical failures or malfunction of equipment used to test aircraft systems or aircraft units
- Any other occurrence or defect considered to require such notification.

The ICAO list of air traffic incidents relied upon an analysis of the potential consequences of any failure. In contrast, the CAA definition of ground maintenance incidents was built from a list of errors, violations and observations of potential failures. These differences can be explained in terms of the intended purpose of these definitions. In the former case, the list of ATM accidents and incidents was intended as a guideline for safety managers in national service providers. They are assumed to have the necessary investigative resources, analytical insights and reconstruction capabilities to assess potential outcomes once incidents have been reported. However, the CAA reporting procedures provide direct guidance for maintenance personnel. These individuals are not expected to anticipate the many different potential outcomes that can stem from the failures that they observe. Such criticality assessments must be performed by the line management who receive and interpret the information from incident reporting systems. These differences illustrate the difficulty of developing a priori definitions of accidents and incidents that ignore the purpose to which those definitions will be put.

Some authors have constructed more general definitions of accidents and incidents. For instance, Perrow [676] proceeds by distinguishing between four levels of any system. Unlike most regulatory definitions, such as that illustrated in Table 1.6, Perrow does not focus directly on the likely consequences of a failure but rather looks at those portions of a system that were effected by an incident or accident:

1. *parts.* The first level of any system represent the smallest components that are likely to be considered during an accident investigation. They might include objects such as a valve.
2. *unit.* These are functionally related collections of parts. For example, a motor unit is built from several individual component parts.
3. *subsystem.* These are composed from individual units. For example, the secondary coolant system of a nuclear reactor will contain a steam generator and a water return unit.
4. *the plant or system.* This is the highest level involved in an accident. Beyond this it is only profitable to think in terms of the impact of an accident on the environment.

In Perrow's terms, accidents only involve those failures that affect levels three and four of this hierarchy. Incidents disrupt components at levels one and two. This definition is critical for the normal accidents argument that Perrow proposes in his book. He argues that 'engineered safety functions' cannot reliably be constructed to prevent some incidents from becoming accidents at levels three and four. Unfortunately, however, these distinctions raise a number of problems for our purposes. Definitions of incidents and accidents must serve the pragmatic role of helping individual workers to know what should, and what should not, be reported. It is unclear whether people would ever be able to make the distinctions between levels 2 and 3 that would be required under this scheme.

There are further practical problems in applying such structural distinctions between accidents and incidents. As with consequential definitions, it may be difficult for any individual to determine the scope of any failure as it occurs. They may fail to realise that the failure of a level one valve will create knock-on effects that compromise an entire level four system. The social and cultural issues that were introduced in previous sections also affect the interpretation of accidents and incidents. This is illustrated in Figure 1.3. From the viewpoint of person A, the system is operating 'abnormally' as soon as it moves from state 1 to state 2. Person B holds different beliefs about what is, and what is not, normal. As a result, they only consider that an incident has occurred when the system moves from state 2 to state 3. The different viewpoints shown in this sketch can arise for a number of reasons. For example, Person A may have been trained to identify the transition between states 1

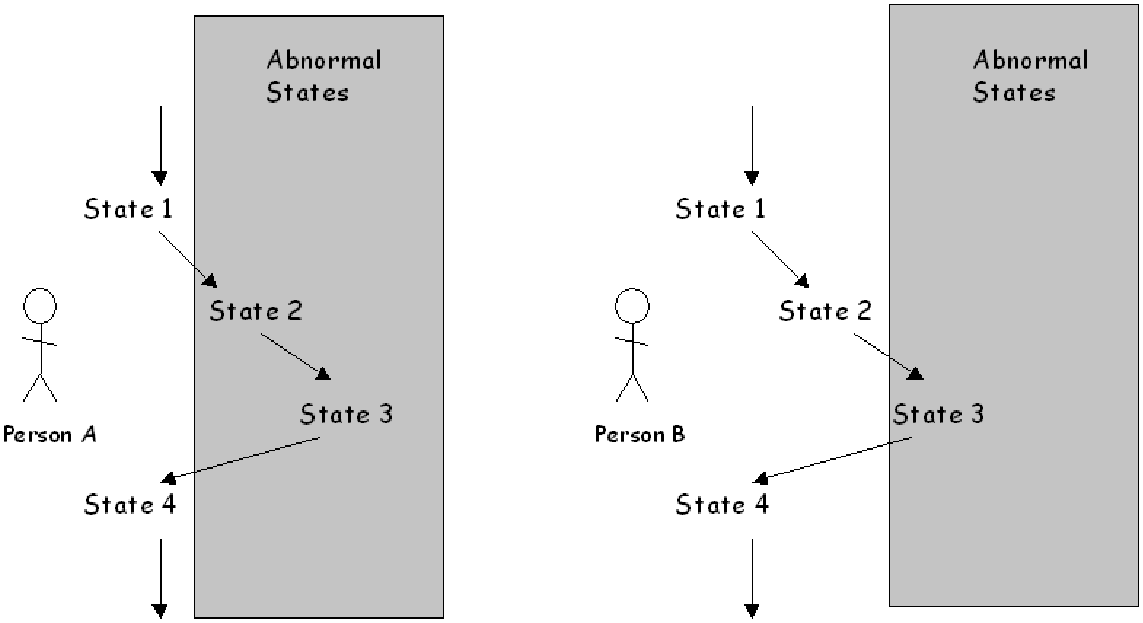

Figure 1.3: Normal and Abnormal States

and 2 as potentially hazardous. Alternatively, person B may exhibit individual attitudes to risk that can dispose them not to report hazardous incidents. Figure 1.3 can also illustrate how attitudes to hazards may change over time. For example, the figure on the left might represent an initial attitude when the system is initially installed. Over time, dangerous working practices can become the norm. It can be difficult for many individuals to question such established working practices even if they violate recognised rules and regulations. Over time, these dangerous practices may themselves become sanctioned by procedures and regulations. This is illustrated by what Diane Vaughan has called "normalised deviance" in the events leading to the Challenger accident [846]. Under such circumstances, the figure on the right might represent the prevailing view of normal and abnormal states.

The previous analysis helps to identify a number of possible approaches to the definition of what an incident actually is. These can be summarised as follows:

- *open definitions.* This approach encourages personnel to report any failure as a safety-related incident. It is exploited by the Air Navigation Services Division of the Swedish Civil Aviation Administration. As a result they receive several thousand reports per year ranging from the failure of lights or heating systems through to potential air proximity violations. The open approach to the definition of an incident avoids some of the problems with more restricted definitions, see below. However, it can also lead to a dilution of the safety reporting system with more general concerns. In the Air Navigation Services Division this approach is well supported by trained 'Gatekeepers' who filter low priority reports from more serious occurrences. The entire system is, however, dependent on the skill and insight of these personnel and their ability to perform a timely analysis of the initial reports.

- *closed definitions.* Closed systems lie at the other extreme from open definitions such as those exploited by the Swedish Air Traffic Control organisation. These systems provide rigid definitions or enumerations for those incidents that are to be reported to the system. All staff are trained to recognise these high priority occurrences and all other incidents are handled through alternative mechanisms. The difficulty with this approach is that the introduction of new equipment can have a profound impact upon the sorts of incidents that will occur. As a result, these enumerations must be revised over time. Otherwise, staff will not report new incidents but will instead continue to wait for occurrences that are now prevented by more secure defences.

- *consequential definitions.* These represent a subset of the closed approach, described above. Incidents and accidents are distinguished either by their actual outcomes or by the *probable worst case* consequences. For example, the US Army regulations distinguish between class A to D accidents whose consequences range from $1,000,000 or more (class A) to between $2,000 and $10,000 (class D) [806] Class E incidents result in less that $2,000 damage but interrupt an operational or maintenance mission. Class F incidents relate to Foreign Object Damage and are restricted to aviation operations. As we have seen, the problem here is that it can be difficult for operators to predict the possible consequences of a failure without further investigation and analysis. As a result, these definitions tend to be applied by investigators and analysts after an initial warning or report has been generated.

- *structural definitions.* This is a further example of a closed approach which has strong links to consequential definitions. The consequences of a failure are assessed for each of several layers of a system. Incidents affect the lower level components whilst accidents involve the system as a whole. There are a number of practical problems in applying this as a guide for incident reporting. there are also theoretical problems when individual component faults may cause a fatality, for example through electrocution, even though the system as a whole continues to satisfy its functional requirements. A strict interpretation of such events would rank them as an incident and not an accident in Perrow's terms [676].

- *procedural definitions.* This is another example of a closed approach. Rather than focusing on the anticipated outcome of a failure, procedural definitions look at violation of the prescribed methods. The problem here is that the individuals who witness violations may fail to recognise them as violations, especially if they have become part of standard working practices. Such problems also affect incident reporting systems that ask operators to comment on ‘anything unusual’.

- *pragmatic definitions.* Some incident reporting systems take a particularly pragmatic approach to the definition of what should and what should not be reported. They are often characterised by the phrase ‘target the doable’. This characterises systems that have been established within larger organisations that may not, as a whole, support the recommendations of the scheme. Some of the pioneering attempts to establish incident reporting systems within the UK National Health Service deliberately focused on those occurrences that individual consultants felt that they could address; incidents stemming from wider acquisitions policy or even from other clinical departments were deliberately excluded.

- *special issues.* Finally, some incident reporting systems deliberately focus on key issues. For instance, the European Turbulent Wake incident reporting system was established with help from the UK Meteorological Service in response to concerns about a number of occurrences involving commercial flights. Other systems are deliberately focused to elicit information from key personnel who may be under-represented in existing incident databases. For example, schemes have been initiated to encourage incident reporting from General Aviation and military pilots rather than commercial pilots. Other schemes have focused on eliciting information from medical and surgical staff rather than nursing personnel.

The preceding discussion should illustrates the difficulty of providing a single definition of accidents and incidents. These problems stem from the different ways in which different people must use these definitions. The person witnessing an adverse occurrence must know whether or not it is worthwhile reporting. Safety managers may apply different criteria when determining whether or not an incident report merits a full-scale investigation or whether it can be dealt with at a more local level. National authorities may apply further criteria when deciding whether national trends indicate a need for regulatory intervention.

It is important to emphasise that the distinction between an incident and an accident is not firm and cannot be made a priori. The same set of events may be reclassified at several stages in the investigation and analysis of an occurrence. These must not be arbitrary decisions. Later chapters will stress the need to provide a documented justification for such changing assessments. However, there are often important pragmatic reasons for such actions. For example, a number of European air traffic control agencies have not reported any major accidents in recent years. As a result, some air traffic service providers have begun to treat certain ‘critical incidents’ as-if they were accidents, even though no loss of life or property has occurred. The intention is to rehearse internal procedures for dealing with more critical events when, and if, they do occur. Such decisions also focus attention and resources on the causes of these incidents. To summarise, simple distinctions between accidents and incidents ignore the underlying complexity that characterises the ways in which different national and international organisations treat technological failure. Different definitions are used, and may indeed be necessary, to support different stages of an organisation’s response to incidents and accidents.

1.3 Summary

It is difficult to estimate the costs when human error, systems failure or managerial weakness threatens safety. Employers face a number of direct costs when their employees are injured. The UK Health and Safety Executive estimate that occupational injuries cost employers around 4-8% of their gross trading profit; currently approximately £6 billion. There are also indirect costs that accrue when regulators intervene. In the United States Federal and State inspectors levied penalties for health and safety violations that totalled $151,361,442 for the fiscal year 1999. Incident or occurrence reporting systems enable companies to identify potential failures before they occur. They provide insights that can be used to guide risk assessment during subsequent development.

Incident reporting systems provide regulators with data that can be used to guide any necessary intervention. They help to prioritise health and safety initiatives and awareness raising campaigns. They can also be used to address public concerns, for example the creation of a national incident reporting system for UK railways followed shortly after the Ladbroke Grove and Southall accidents. At an international level, incident reporting systems provide means of ensuring that lessons are effectively shared across national boundaries. The following chapter introduced the challenges that must be addressed if these claimed benefits are to be realised.