Organisational failure

An exploratory study in the steel industry and the medical domain

Organisational failure

An exploratory study in the steel industry and the medical domain

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de Rector Magnificus, prof.dr. M. Rem, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen op dinsdag 17 maart 1998 om 16.00 uur

door

Wim van Vuuren

geboren te Almkerk

Dit proefschrift is goedgekeurd door de promotoren:

prof.dr. P.M. Bagchus
en
prof.dr. P.C. Sander

en de copromotor:
dr. T.W. van der Schaaf

CIP-data Library Technische Universiteit Eindhoven

Vuuren, Wim van

Organisational failure: an exploratory study in the steel industry
and the medical domain / by Wim van Vuuren. - Eindhoven:
Eindhoven University of Technology, 1998. - Proefschrift. -

ISBN 90-386-0589-7
NUGI 684

Subject headings: Organisational failure / Safety / Risk management /
Medical domain / Steel industry

Layout and cover design: Hans-Anton Verschoor

BETA Central Secretary, pav. A03, PO Box 513, 5600 MB Eindhoven,
The Netherlands. Phone: +31 40 247 3983. Fax: +31 40 245 0258.
E-mail: BETA@tm.tue.nl

Contents

Preface

The past four years have, in many ways, been a wonderful time. Not only have I enjoyed doing this study, my colleagues in the department of Technology and Work and the people I have met along the way have also made these four years a time to remember. I would like to use this preface to thank those who in one way or another have contributed to this book.

From the start of this study, I have been supervised and supported by Paul Bagchus, Peter Sander, Tjerk van der Schaaf and Hans van der Bij. For three and a half years we met on a monthly basis to discuss my work. It is impossible to imagine how I would have reached the same results without these discussions. The last six months I have used to write this thesis. During these months, Paul and Tjerk provided me with all the help and support needed to get through this sometimes difficult process. I want to thank Paul for his constructive criticism concerning the structure and contents of this thesis. To Tjerk I am grateful for his continuous stream of ideas and for always having time for me. I am also grateful to Andrew Hale and Onno Buruma for participating in the dissertation committee and the many useful comments they made in the final stage of the writing up phase.

Conducting this study would have been impossible without the help of organisations. I want to thank the organisations that were willing to have me around, introduce me to their daily practice, and most importantly inform me about their incidents. Special thanks go to those who participated actively in the case studies.

Special thanks also go to Hans-Anton Verschoor for all the hours he spent on the design of the cover and layout of this thesis, while starting his own company, and to Christine Shea for proof reading this thesis and trying to make the best of my English.

Finally, I want to thank those who along the way have provided me with their moral support. First of all my parents who have always put aside their own interests to provide a wonderful home and the best possible environment for me to work in. I want to thank Jacco, Ria and all my friends for expressing interest in my work. Last but not least I want to thank Gemma. From the moment we met during one of my case studies in England, she has always supported and stimulated me. She has also been an example in devotion to a PhD study, though her own working conditions are from perfect. I want to dedicate this thesis to her and hope to read hers soon.

Almkerk, January 1998
Wim van Vuuren

1 Introduction

The study described in this thesis deals with risk management in complex and high-risk organisations and in particular with the analysis and categorising of organisational causes of safety related incidents. Without any doubt thoroughly analysed incidents can lead to valuable insights into a system's safety performance and possibilities for improvement. However, effective improvements can only be made when the investigating organisation is provided with the right models, tools and insights to reach the required level of analysis. If not, superficial analyses result, leading to limited insight into an organisation's problem areas and sub-optimal efforts to improve the system's safety performance.

This chapter will introduce the goals of the study described in this thesis, provide a general characterisation of the study and explain most of the background and concepts used in this thesis.

1.1 A classical approach

The last two decades have provided numerous serious accidents that exemplify the focus of incident analysis during these years. To give the reader a 'feeling' of the background and need for this study, one accidents is discussed in this paragraph. Although the following description is a simplified version of events, it provides insight into the causes of the accident and its investigation[1].

On Sunday January 8th, 1989 a new British Midland Boeing 737-400 took off from London Heathrow on a shuttle run to Belfast. On board were 118 passengers on their way home and 8 crew members, including one of the airline's most experienced pilots. Just 10 - 12 minutes after take off, climbing to a cruising altitude through 28,000 feet, a loud bang was heard. The plane started to shudder and smoke was detected in the cabin. The pilot and his co-pilot concluded that this was caused by fire in one of the engines. Although aware of the emergency, they stayed calm and did not panic. They knew that the plane was designed to fly on one engine and that their main concern was to shut down the burning engine. The co-pilot notified ground control about the emergency and the shut down procedure was started. However, to shut down the burning engine, they had to find out which engine was on fire first. Since there were no indicators in the cockpit to alert the pilots to which one was at fault, they had to throttle back one engine and hope this would resolve the problems. If this did not work, it indicated that they had apparently chosen the wrong one and the same routine had to be repeated for the other engine. Since both pilots suspected the right-hand engine was on fire, they started

[1] Based on a documentary on Fatal Error by David Jessel in the BBC programme "Taking Liberties", 1991.

this 'trial and error approach' on the right-hand engine first. After throttling back the engine, the plane stopped shuddering and the pilots concluded that they had shut down the correct engine. In fact, this action had stopped the shuddering of the damaged left-hand engine only. The passengers were notified by the pilot of the problems with the right-hand engine and told that everything was under control. The only repercussion was a diversion to the nearest airport. Although several passengers were convinced they had heard a bang in the left-hand engine no one stepped forward to question the pilot. They presumed the pilot was talking about the same engine, assuming there was simply a difference in perspective.
For the next 20 minutes the plane behaved normally flying on one engine and a new course was set to the nearest airport: East Midlands International Airport. During these 20 minutes the pilots tried to ensure they had correctly diagnosed and remedied the problem. During this time, they were frequently interrupted by ground control and there was also no apparent need to reconsider their actions. All seemed well.
With the extra stress on the already damaged left-hand engine during final approach, a broken fan blade was sucked into the engine, ripping it to shreds. The plane again started to shudder and the pilots realised that they had also lost the left-hand engine. The plane crashed on the right-hand carriageway of the M1 motorway, only yards away from the runway. 39 passengers died outright, 8 more the following days because of their injuries.

For the accident investigators, daybreak brought a dawning recognition of its cause. The pilots, who had both survived the crash, had shut down the healthy engine. Soon their private assessment had become a public verdict. How could two experienced pilots have made such a mistake? At the inquest the pilots admitted both their error and their bafflement at how they could have made this error. The question why was largely ignored, because simply allocating blame was so much easier. According to the official report, the pilots had acted contrary to training. The pilot was urged to retire, the co-pilot was sacked. Problem solved, case closed…

Fortunately, not everyone was satisfied with this conclusion. Was it really human error or rather a case of mischance? Would a different crew have shut down the correct engine or would they have made the same mistake? A closer look at the technology used in this new Boeing, the lessons learned from previous similar incidents and the training of the pilots provides a clear indication of the answers to these questions.

As the plane was climbing to its cruising altitude, one of the engine's fan blades snapped. The first indications were rapid vibrations and smoke in the cabin. As training had not prepared them to identify this set of symptoms and instruments did not alert them to which engine was at fault, they had to rely on a trial and error routine. By throttling back the right-hand engine, vibrations were stopped and the pilots thought they had cured the problem. However, the plane had an auto-throttle that automatically adjusts the flow of fuel to both engines, to equalise their performance. Because the left-hand engine was damaged, it was less efficient. The auto-throttle therefore pumped more fuel into this engine, resulting in vibrations and smoke. Shutting down the right-hand engine only disengaged the auto-throttle and therefore stopped the oversupply of fuel to the damaged left engine. This took away the symptoms but did not cure the problem.

The new Boeing 737-400 was bigger than its predecessor and required a larger engine. Since only a small increase of speed was necessary to achieve the increase of thrust needed, the manufacturer simply decided to upgrade the existing engine. To save time and money, the upgraded engine was tested at ground level only. The snapping of the fan blade was caused by a phenomenon called 'flutter'. Depending on the speed of the plane, the outside temperature and the altitude, flutter stresses the fan blades. Because flutter is still a relatively unknown phenomenon, it cannot be accurately predicted. Only tests at altitude could have shown the influence of flutter on the new engine, however, these tests were never performed. The official accident report stated that engines should be tested at high altitude. The Civil Aviation Authority (CAA) however reserved its position.

Another new feature of the new Boeing 737-400 was the completely computer driven cockpit. The old-fashioned dials with a big white needle were replaced by colourful cursors, which were only 1/3 the size of the original needles. It had been a selling point of the new 737 that the new instruments were just a more sophisticated version of those in the old plane. It was said that only a minimal pilot conversion course was needed to get used to them, although research had shown that the smaller cursors were harder to read and easier to misinterpret. The training given to the pilots took only one morning and part of an afternoon. Because there was no simulator available, hands-on training was acquired on regular scheduled flights. The official report stressed the importance of simulator training. However, since there were no such facilities in England, the CAA supported the idea but in the end rejected the request.

The only indicator that could have triggered the pilots to reconsider their decision, was a small vibration gauge. This vibration gauge showed a high reading on the left-hand engine but was not noticed by the pilots. The gauge was located in a secondary position and was only the size of a twenty pence coin. There were also no markings or warning lights to indicate an out of range reading. However, even if they had noticed the vibration gauge, it is still questionable if this would have triggered the pilots. The vibration gauges of the old planes were known to be highly unreliable and pilots were even allowed to fly with them disconnected. In the new plane however, the vibration gauge was highly reliable but no one had been informed. The official report stated that vibration gauges should have an attention-getting facility. However, according to the CAA this would give the gauge disproportionate significance.

At that time, the Civil Aviation Authority had two main duties. One was to protect the travelling public. The other was to regulate and protect the interests of commercial aviation. It is highly questionable if one body should protect the often conflicting interests of both parties involved. Four years before this accident 55 people were killed in a plane fire at Manchester Airport. In this last accident the crew had also been unable to identify the burning engine. One of the recommendations was to install external cameras on the plane. This recommendation was not taken seriously by the CAA.
After the British Midland accident, three more planes were confronted with the same engine problem. Eventually, the engine was completely redesigned and tested at high altitude. The upgraded engines were never used again.

This accident investigation clearly shows, in an anecdotal way, that there is more than human pilot error contributing to an accident. A large number of technical and organisational factors also played an important role in accident causation. This emphasises that effective prevention of accidents can only occur when human, technical and organisational factors are taken into account.

1.2 A changing scope in incident investigation

Research into the causes of incidents in complex and high risk organisations has always played an important role in the improvement of these organisations. By analysing their incidents, organisations have always tried to learn from mistakes and this way prevent incidents from happening again. Some have been successful, however most organisations still suffer from a large number of incidents each year with varying consequences. Unfortunately, the differences in success can only be partly explained by the level of risk associated with the tasks involved. This changes the focus to the effectiveness of the learning process in organisations. What has been done to learn from incidents and what makes one organisation successful, while others have difficulties in improving their safety performance?

In an historical overview of British railroad accidents, Reason (1991) clearly shows a change in scope in incident investigation, which is at any time determined to a large extent by the kind of preventive measures preferred. In current incident investigation, it is common to subdivide the causes that lead to an incident into the following three groups of failure: technical, human and organisational failure. According to Reason's historical overview, until the 1930s incident investigation of British railroad accidents mainly focused on technical failure, leading to elaborate in-built defences and efforts to make technical systems error proof. These efforts did have their effect on safety, however they were not able to completely eliminate serious accidents. Extra defences are attractive but will never provide full protection. Wagenaar *et al.* (1990) explain that it is extremely difficult to anticipate all foolish things people will do, particularly when the foolishness may reside in the removal of the same defences.

When engineers were finding it increasingly difficult to reduce accidents by technical safeguards, attention shifted to the role of human behaviour as a causal factor in incidents. This resulted in elaborate efforts by psychologists to model human behaviour and its influence on safety. Human factors specialists started to look at the physical and psychological insults created by design engineers. For a long time, design engineers had created systems from a technical perspective only, without considering the needs and capabilities and restrictions of their users. These two ages of safety concern were repeated within the short span of nuclear power generation in the 1960s and early 1970s. In the early 1980s, the predominance of the human factor in accident research is clearly demonstrated in a research overview given by Wagenaar (1983). This overview shows that 80 to 100% of incident causes were attributed to human failure.
Reason concludes that only in this last decade, after serious accidents such as the capsizing of the Herald of Free Enterprise just outside the harbour of Zeebrugge, the fire at King's Cross underground railway station and the explosions in the nuclear power plant of Chernobyl, has the importance of organisational and management factors as a cause of incidents been accepted. This leads attention away from those at the 'sharp end' of incident causation (e.g. operators, maintenance personnel) and towards those who make decisions at a managerial and organisational level (the 'blunt end').

1.3 Some concepts defined

Before describing in detail the content of the study that is presented in this thesis, it is necessary to provide the best possible definition of the concepts that are used. Most of these concepts are very well known in safety related research but are interpreted differently in various situations. These differences can lead to unnecessary misinterpretations and confusion, which should be prevented at all costs. It should also be noted, that at this stage it is not possible to give an accurate definition of every individual concept used. In particular defining organisational failure is one of the goals of this study and will be based on its findings. For these concepts a preliminary definition or guideline will be given. Whenever possible and necessary, these preliminary definitions will be updated based on the available information.

1.3.1 Incidents, Accidents and Near Misses

In safety related research, the terms *incident*, *accident* and *near miss* are used frequently. Van der Schaaf (1992) explains and 'defines' these terms by giving a simple but useful model of incident causation (figure 1.1). This model indicates that dangerous situations are always preceded by a certain combination of technical, human operator and/or organisational failures. In many cases, the in-built defences of a system (e.g. automatic safety systems, standard safety procedures, etc.) will prevent dangerous situations from developing into an incident and make the system return to its normal status. If not, the incident is allowed to develop further. It is then usually up to the flexibility, experience

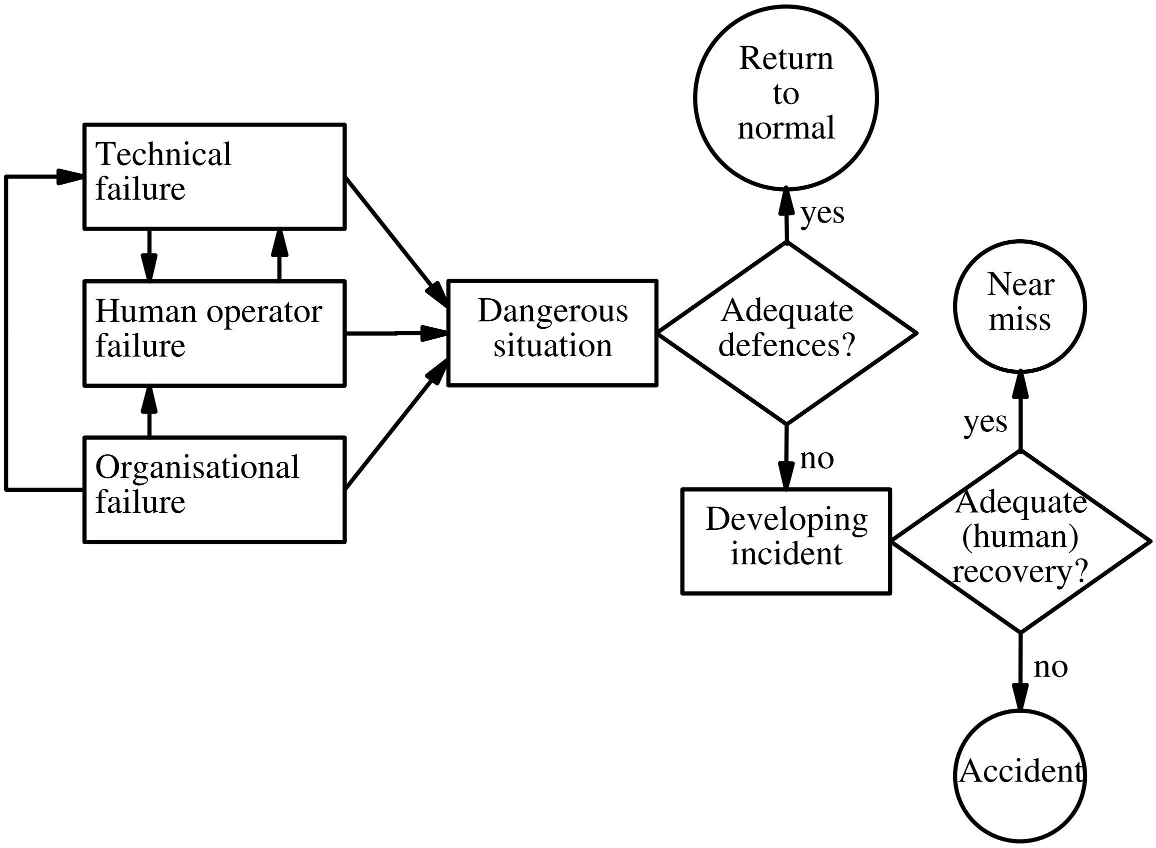


Figure 1.1: A simple model of incident causation (Van der Schaaf, 1992).

and intuition of the human operator to try to recover from this undesired chain of events. Successful (human) recovery will restore the original situation or at least prevent major injuries or damages. In this case, the incident becomes a near miss, that is any situation in which an ongoing sequence of events is prevented from developing further. This prevents the occurrence of potentially (safety related) consequences (Van der Schaaf, 1991). Unsuccessful or inadequate recovery will allow the incident to develop into a full-blown accident, that is an occurrence with actual adverse consequences (e.g. injuries and damages). According to this model, the term incident refers to the combined set of occurrences of both accidents and near misses. Consequently, both accidents and near misses are preceded by the same set of failure causes and only the presence or absence of defences and recovery mechanisms determines the actual outcome (e.g. normal situation, near miss or accident). Because the study presented in this thesis focuses on the causal side of the incident evolution process only, irrespective of its outcome, the term incident will be used to refer to both accidents and near misses.

1.3.2 Symptoms, Causes and Root Causes

When analysing incidents, it is also important to make a distinction between *symptoms*, *causes* and *root causes* of incidents. To visualise the difference between these concepts, part of the analysis of the East Midlands crash is presented in figure 1.2. The causal tree in figure 1.2 (see chapter 2 for an explanation of causal trees) shows one of the failure paths that resulted in the crash (see appendix 1 for the complete causal tree). In this study, the term symptom is used to refer to the detectable outcome of a chain of events. Symptoms are therefore found at the far end of incident causation and are the starting point for the analysis. In figure 1.2 the symptom is the plane crash, presented as the top of the causal tree. Root causes on the other hand, are presented at the bottom of the causal tree (i.e. underestimated effects of upgrade and reducing the development costs). All failures made following and triggered (directly or indirectly) by a root cause, leading to an incident are called causes. Failure to test the engine at altitude and the snapped fan blade are therefore called causes.
When the term root cause is used in this study it is not intended to imply that the absolute beginning of incident causation has been detected. During this study the

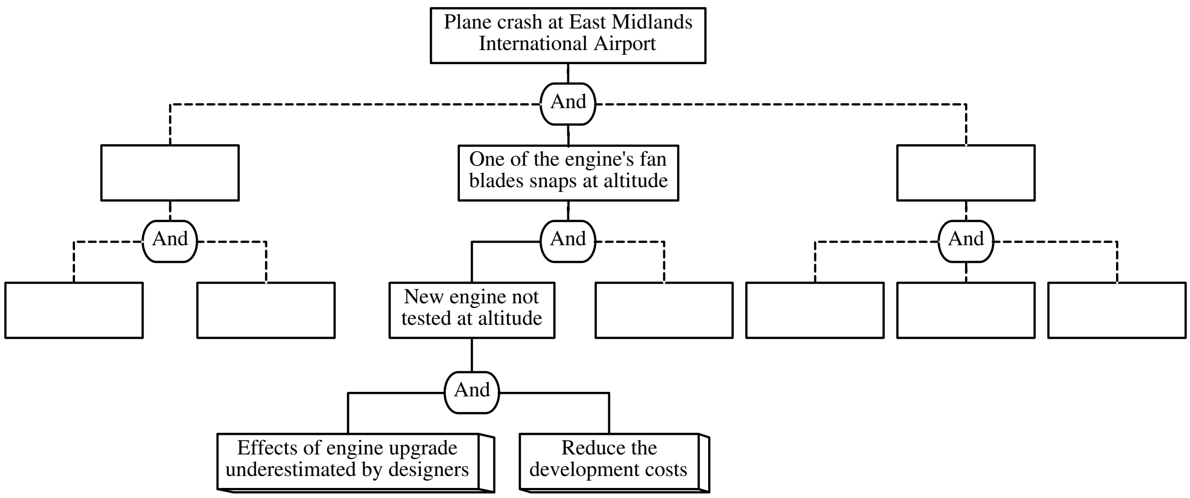


Figure 1.2: One of the failure paths leading to the East Midlands crash.

analysis of an incident was stopped when:

- information was lacking;
- information became unreliable;
- the outer boundaries of the responsibilities of the organisation investigated were reached.

For example, given the information in paragraph 1.1, it is not possible to determine why the effects are underestimated by the designers. A likely cause would be unfamiliarity with flutter, though no evidence is presented to draw this conclusion. The term root cause is therefore not necessarily related to the absolute beginning of the chain of events, even though it would be desirable to get to this point. It is merely a *practical* term to refer to those causes found at the bottom of the causal tree after the best possible in-depth analysis of the incident involved. The term root cause refers to the causal level from which fundamental corrective actions are derived, to be taken by the organisation itself. Root causes can be found both close to the top of the causal tree and several levels removed from the top.

At the same time, root causes must also be uniquely classifiable using the classification models discussed in this thesis. These classification models subdivide technical, human and organisational failure factors into a number of distinct categories. If the true nature of an alleged root cause is unclear, allowing classification in more than one category, it is likely that the cause describes a combination of underlying root causes, implying that additional information is needed to further refine the cause and clarify the underlying root causes. Causal trees that do not comply with this criterion have been excluded from this study, as failure to comply suggests that symptoms have been described and not root causes.

As indicated above, this study focused only on the root causes of the investigated incidents, in order to arrive at fundamental corrective actions. Therefore, the causes that were triggered by the root causes were not taken into account and will not be discussed in this thesis. This study included only failure factors and failed recovery actions as input. Recovery factors were not the focus of this study.

1.3.3 Technical, Human and Organisational failure

As shown in figure 1.1, incidents are always preceded by a certain combination of technical, human and/or organisational failures. The distinction between technical, human and organisational failure is well accepted in safety related research, however, generally accepted definitions are still lacking. For the research described in this thesis it is very important to make a clear distinction between these three failure types. In particular the definition of organisational failure plays an important role in the remainder of this study. This paragraph will give some practical guidelines to distinguish between the three failure types. Based on the literature review in section 1.4, paragraph 1.5.2 will give a working definition of organisational failure. A more precise definition of organisational failure, based on the outcomes of this study will be presented in chapter 5. It is beyond the scope of this study to define human and technical failure in detail. However, this section will provide the practical guidelines used to distinguish between the three failure types.

In this study the data was collected through a post-hoc and bottom-up analysis of real incidents. This means that for the analysis of an incident, the persons directly involved were taken as the starting point and the nature of the failure factors that contributed to the incident (i.e. technical, human or organisational) were determined from this perspective. In chapter 2 the analysis method is explained in detail. As stated earlier, only root causes are used in this study, since improvement can be made most effectively when the fundamental problems are the focus of investigation. The following practical guidelines are used to distinguish between the three failure types, when classifying the root causes found at the bottom of the causal tree:

- *Technical failure:* refers to failing or sub-optimal performance of technical equipment used prior to or during the incident, or failure related to the physical setting in which the incident occurred.
- *Human failure:* refers to errors made by those at the sharp end of incident causation that have directly triggered the incident.
- *Organisational failure:* refers to errors made by those at the blunt end of incident causation which in itself have not caused incidents directly but which triggered other failures leading to incidents.

These guidelines are based on practical experience in analysing incidents in pilot studies (Van Vuuren, 1993; Van Vuuren & Van der Schaaf, 1995) prior to the start of this study.

1.4 Status quo in safety related research

The distinction described above between technical, human and organisational causes of incidents is well accepted in safety related research. As stated in paragraph 1.2, there has been a change in focus in incident investigation from technical failure to human failure to organisational failure. Different domains seem to follow this cycle in incident investigation, though the cycle may begin at different times. The change in focus has influenced the status quo of safety related research and the number of models and tools that have resulted from this research. In this section, the three failure types are discussed briefly, followed by some conclusions for this study. It should be noted that although described separately, the three failure types are interrelated. Relations which involve organisational failure will be discussed in a later phase.

1.4.1 Technical failure

Technical failure has always been the area of designers and engineers and is probably the best understood part of incident causation. However, best understood does not automatically mean best controlled. In complex and high-risk environments such as the nuclear industry, the chemical process industry and aviation, numerous tools (e.g. Hazard and Operability Studies (Kletz, 1974), Probabilistic Risk Assessment and Failure Mode and Effects Analysis (e.g. Stamatis, 1995; Kirwan, 1994; Glendon & McKenna, 1995, Kumamoto & Henley, 1996)) are present and used to monitor the technical system's performance and to predict the probability of technical failure. Based on the findings, improvements are made to the system to decrease the likelihood of technical failures.

The focus on technological improvement becomes also apparent when the number of engineers working in most complex and high-risk organisations is considered. Maintenance and design engineers are a substantial part of the people employed by these organisations and are responsible for maintaining and improving the reliability of the technical system. Together they provide the organisation with a large technical knowledge base.
Given the existence of a large number of tools to monitor and predict technical problems and the large technical knowledge base provided by the technical employees, most complex and high-risk organisations are well able to effectively manage technical failure.

1.4.2 Human failure

Throughout their entire existence, humans have repeatedly shown their tendency and ability to make mistakes. For decades, researchers particularly in the field of psychology have tried to explain why humans behave the way they do and why they make mistakes. This has resulted in a large variety of models of human behaviour. One of the most well known models is Rasmussen's Skill-, Rule-, and Knowledge-based behaviour model (1976), whose influence is also visible in many more recent models (e.g. Reason, 1987; Hale and Glendon, 1987). Rasmussen distinguishes the following three levels of human behaviour that are hierarchically related:

- *Skill-Based behaviour*: referring to routine tasks, requiring little or no conscious attention during task execution;
- *Rule-Based behaviour*: referring to familiar procedures applied to frequent decision-making situations;
- *Knowledge-Based behaviour*: referring to problem solving activities.

Another important step in the understanding of human error is the distinction between *slips* and *mistakes* (Norman, 1981; Reason & Mycielska, 1982). A slip is a form of error in the execution of an otherwise perfect plan. A mistake is the perfect execution of an incorrect plan, originating in the planning phase. Reason (1987) has combined Rasmussen's SRK-model and the distinction between slips and mistakes in his 'Generic Error-Modelling System (GEMS). In the GEMS-model, slips occur at the skill-based level and are errors in the application of routine actions. There are two types of mistakes: rule-based mistakes and knowledge-based mistakes. Rule-based mistakes are of the 'strong-but-wrong' type, in which the actor strongly believes he has found the correct solution, without a full analysis of the problem. A knowledge-based mistake is 'wrong-but-weak', since it is the outcome of the analysis of a new problem. There is no guarantee that the adopted plan is correct, consequently the actor will not execute the plan without continuous checking.

Based on models like these, human behaviour can be explained and more importantly, provide insight into the kind of countermeasures that are likely to prevent recurrence. It is beyond the scope of this thesis to go into more detail about these models. They are only used to show the existence of useful models of human behaviour that can be used by organisations. Based on this existing knowledge about human behaviour, many organisations have already been able to identify and reduce error enforcing situations while human factors have been incorporated in the development or redesign of technical systems. Training and selection of personnel has also been improved, to guarantee a better fit between the employee and the job to be performed.

1.4.3 Organisational failure

Despite growing societal, industrial and scientific interest in the organisational causes of incidents, the concept of organisational failure is still only partly understood by researchers and hardly acknowledged by organisations (Van Vuuren & Van der Schaaf, 1995). However, some steps forward have been made.

Active versus latent failure
The most important step in research related to organisational failure, is the distinction between two kinds of failures: *active failures*, whose effects are felt almost immediately, and *latent failures,* whose adverse consequences may lie dormant within the system for a long time, only to become evident when combined with other factors to breach the system's defences (Reason, 1990). In general, active failures are made by those at the sharp end of incident causation (e.g. control room operators, maintenance personnel, the pilot who shuts down the perfectly healthy engine in the incident description). Failures made at the sharp end generally lead to direct consequences and the one making the failure is therefore also likely to experience the consequences. Latent failures, on the other hand, are made at the blunt end by those whose activities are removed in both time and space from the sharp end of incident causation (e.g. high level decision makers, designers, the CAA in the incident description). These latent failures however, create the conditions for active failures to be made.

The framework presented in figure 1.3 (Reason, 1990), shows the human elements of accident causation. The essence of figure 1.3 is that it portrays these human contributions as weaknesses or unwanted 'windows' in the defences of the system. A fallible management decision will only lead to an actual accident when there are holes (windows) in all the subsequent defences or when these holes are created by the management decision itself.

The causal sequence moves from fallible decisions through the windows of the intervening planes to an accident. The basic premise of the framework is that system accidents have their primary origins in fallible decisions made by designers and high-level (corporate or plant) managerial decision makers. Fallible decisions manifest

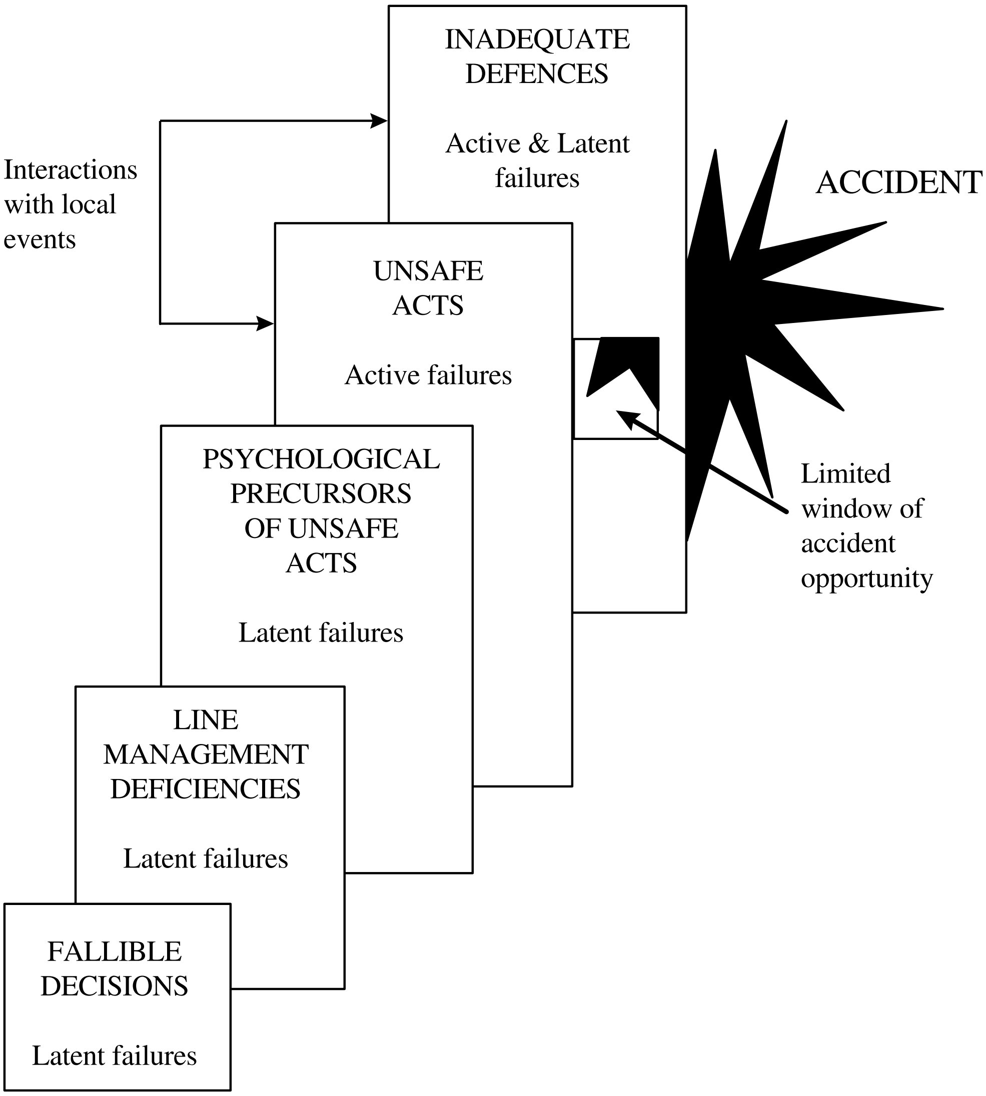


Figure 1.3: The human elements of accident causation (Reason, 1990).

themselves differently in various line management departments, since line management implements the strategies of the decision makers within their spheres of operation. Failures made at the level of line management are not only the consequence of higher-level decision making. The incompetence of any set of line managers can further exacerbate the adverse effects of high-level decision making or cause good decisions to have bad effects. The link between line management deficiencies and unsafe acts is formed by the psychological precursors of unsafe acts or the psychological states of mind elicited by both the fallible decisions and the line management deficiencies. Psychological precursors or preconditions create the potential for a wide variety of unsafe acts. Fallible decisions, line management deficiencies and the psychological precursors of unsafe acts are all latent in nature.

The unsafe acts are active failures, which can result in a real accident given a limited window of accident opportunity in the last line of defence. An inadequate state of defences can be caused by both active failures by those at the sharp end of accident causation and by latent failures at the level of corporate or plant management or designers.

That system failures develop over a period of time and are caused by a number of factors, rather than a single catastrophic event, is also acknowledged by Turner (1992). According to Turner, the development of a system failure can be characterised by the following sequence:

1. Situation 'notionally normal'
2. Incubation period
3. Trigger event
4. Onset
5. Rescue and salvage
6. Full cultural readjustment

From an initial situation when the circumstances are 'notionally normal', the incubation period starts to develop at the point at which circumstances start to deviate, covertly, from that which is believed to be the case. This state continues to develop until terminated by a 'trigger event' which combines the predisposing factors into a single occurrence, which provokes the 'onset' of a system failure. This system failure is usually followed by an immediate period of rescue and salvage, followed later by a full cultural readjustment. This includes identifying the reasons for the failure and attempts to prevent recurrence of similar incidents.
Turner sets out the predisposing features which typically associate and interact together in the various combinations during the incubation period as follows:

- Organisational rigidities of perception and belief.
- Decoy phenomena which distract attention from genuine hazards.
- A range of many types of information and communication difficulties associated with the ill-structured problem which eventually generates the accident.
- Failure to comply with existing safety regulations.
- A variety of modes of minimising or disregarding emergent danger, in particular in the final stages of the incubation period.

Up to the trigger event, the system is 'a disaster waiting to happen', as latent failures are waiting to coincide with the right conditions to become evident.

General failure types and TRIPOD

Based on the accident scenario presented in figure 1.3, Wagenaar *et al.* (1990) primarily focus on the influences that elicit the psychological precursors, which they call the 'general failure types' (GFTs). These general failure types are created by management decisions. Relating accidents to management decisions is not new. There are already some techniques to investigate management quality with an eye to accident prevention. Examples are the extensive Management Oversight and Risk Tree (MORT) analysis technique (Johnson, 1980) and the massive checklist produced by the International Loss Control Institute (ILCI, 1978). The two new elements provided by the discussion about the GFTs is that not all general failure types can be detected by scrutiny of a company's management and that the relationship to accidents via psychological precursors and unsafe acts is much more transparent (Wagenaar *et al.*, 1990). The term *types* is chosen to indicate that at this level sets of phenomena are considered and not individual phenomena, which are the *tokens* that make up the set. Tokens signal the types that are involved but are not themselves the primary target for prevention.

Somewhat arbitrarily, but after reading and analysing hundreds of accident scenarios, the following general failure types are summarised and divided over three groups (Wagenaar *et al.*, 1990):

Physical environment:	design failures, missing defences, hardware defects, negligent housekeeping, error enforcing conditions.
Human behaviour:	poor procedures, lack of training.
Management:	organisational failures, incompatible goals, lack of communication.

Although these failure types are created through human action, they are not called 'unsafe acts'. They are not immediately followed by a disaster, however, create inviting circumstances for unsafe acts to occur.

Based on the previously presented accident scenario and the GFTs, an audit tool called TRIPOD (Hudson *et al.*, 1991) was developed to transform incident data into so called 'Failure State Profiles', which are graphical representations of a company's score on each GFT on a scale from very poor to very good. The score on each individual GFT is based on a number of concrete indicators, each of which is relatively simple but agreed to be related to the specific activity being profiled. The indicators are collected from people with a specialist knowledge of the activity. For current TRIPOD applications, maintenance management was added to the list of GFTs, resulting in the following 11 GFTs (Hudson *et al.*, 1991; Wagenaar *et al.*, 1994):

- hardware
- design
- maintenance management
- operating procedures
- error-enforcing conditions
- housekeeping
- incompatible goals
- communication
- organisation

- training
- defence planning.

The constructed Failure State Profiles represent by means of bar graphs the extent to which each of these eleven GFTs can be expected to contribute to future incidents.

1.4.4 Conclusions for this study

In this section, a brief overview was given of literature on technical, human and organisational failure to give an indication of the current status quo in safety related research. This overview is and was not intended to be comprehensive. With regard to organisational failure, only literature that focuses on modelling organisational failure or providing insight into the influence of organisational failure on incident causation were the focus of study. Literature specifically aiming at developing and implementing comprehensive risk management tools has for the most part been excluded from this review.

The changing scope in incident investigation presented in section 1.2 and the overview given in the previous section have provided two good reasons to focus on the organisational causes of safety related incidents. Finally, after decades of research focusing on the technical and human side of incident causation, organisational factors as causes of incidents have been accepted. However, as shown in the previous paragraph, only a few small steps have been taken in a way to understand this new field of research and to provide useful models and theories about the organisational causes of safety related incidents.

The distinction between active and latent failure is the most important one in order to understand the difference in impact of different kinds of human failure. However, in his discussion Reason only focuses on the human contributions at different stages during accident causation, without providing insight into whether these human contributions result in technical, human or organisational problems. The same is true for TRIPOD, a management tool that is derived from the accident causation model presented by Reason. The eleven General Failure Types that are listed for TRIPOD are, given the definitions used for this study, a combination of technical, human and organisational factors, and are also a combination of causes/symptoms and root causes. For example, hardware problems are likely to be caused by incorrect design and the category 'organisation' refers to failures that can cause problems in communication, goal setting, etc. This might be acceptable for an audit tool, however, it is not for incident analysis. Although claiming to focus on management decisions, no definition of management or organisational failure is provided that can be useful for this study.

The lack of knowledge of how to model organisational failure in the area of safety related research states the importance of a bottom-up approach, using empirical incident data as a main input for new models and theories to be developed. The lack of knowledge also shows the importance of examining research areas not directly related to safety for models and theories that can be applied in this new field. An overview of the models and theories used is given in chapter 2.

1.5 General characterisation of the study presented in this thesis

1.5.1 Research goals

Although the influence of organisational factors on incident causation has been accepted, little is still known as discussed in the previous section. What is organisational failure and what is its influence on incident causation? Widely accepted theoretical and explanatory models to describe and explain this influence have not yet been developed. Without proper insight into the organisational causes of incidents and their influence on incident causation, recommendations for improvement will be largely based on wild guesses and good luck or focus on the wrong problem. In the incident description given in paragraph 1.1 it is clearly shown that by focusing on pilot error, the real problems (e.g. the training of the pilots, the design of the plane, the decisions made by the CAA) are not addressed.
A direct consequence of this lack of theories and models, is a lack of theory based tools for detecting, describing and classifying organisational causes of incidents. Without these tools, technical and human failure is very likely to remain the main focus of incident investigation, while underestimating the organisational influences on incident causation. Tools based on theory are also necessary to successfully make the link between organisational root causes of incidents and effective corrective actions.

A pilot study in the chemical process industry, carried out prior to starting the study described in this thesis (Van Vuuren & Van der Schaaf, 1995), and the incident description in paragraph 1.1, clearly showed the difficulty in detecting organisational causes of incidents. During the pilot study, two recent serious incidents, which had already been investigated by the organisation itself, were analysed again using the in-depth analysis method described in chapter 2. The re-analysis showed that not only the number but also the type of root causes detected differed from the initial investigation (see table 1.1). A considerable number of both organisational and technical root causes were found at the beginning of incident causation while left undetected in the initial investigation. Given its latent nature, organisational root causes in particular are far less visible than the active human causes. This often results, as it did in the investigation described in paragraph 1.1, in a superficial incident analysis leading to the highly visible active causes only, while the real root causes are left undetected.

	Results initial investigation			Results in-depth investigation		
	Technical root causes	Human root causes	Organisational root causes	Technical root causes	Human root causes	Organisational root causes
Inc. 1	1	2	0	4	4	4
Inc. 2	0	4	1	1	6	2
	1	6	1	5	10	6

Table 1.1: Two incident investigation methods compared.

Based on the limited insight into the organisational causes of incidents, as indicated in paragraph 1.4.3, the following main goal of the study described in this thesis is formulated:

- *To develop a taxonomy of the organisational causes of safety related incidents.*

Chapter 2 describes in detail how this is accomplished and which domains are used. However, as described earlier, insight into the organisational causes of safety related incidents is only the first step in creating safer systems. This insight needs to be transferred into tools and guidelines for organisations to actually make use of the newly gained knowledge. This results in the formulation of the following two sub-goals:

- *To develop tools for detecting, describing and classifying organisational root causes of incidents.*
- *To produce guidelines for organisations about how to analyse incidents in order to maximise the effectiveness of the analysis.*

The primary focus of this study is on the development of the taxonomy of the organisational causes of safety related incidents. However, the development of tools for detecting, describing and in particular for classifying organisational root causes also has a dominant place in this study. Based on the conclusions of this study, guidelines for managing organisational failure will be given.

1.5.2 Working definition of organisational failure

Another reason to give a description of an incident in this chapter, is to provide the reader with an idea of what organisational failure is about. Thus far, the term organisational failure has often been mentioned in this chapter while only a preliminary definition is provided. During the study it became clear that defining organisational failure in a useful way is not an easy job. Given the three failure types, technical, human and organisational, clear definitions are needed to separate one from the other. At a root cause level, technical failure appears to be the easiest one to distinguish, because this relates to failing equipment. However, problems arise with the distinction between human and organisational failure. Even at a root cause level, all errors are made by humans, so what makes one failure organisational and another human?

To answer this question, the previously described distinction between active and latent failures can be used. It should also be noted that in this study an incident is taken as a starting point for an investigation. From this point of view, active failures are made at the end of incident evolution and their consequences are felt almost immediately, in most cases by the individual making the failure. To date, these active failures have dominated incident investigation, mainly because they are so easy to detect. Wagenaar (1983) clearly shows that the majority (80 to 100%) of these active failures appear to be human error. The remaining active failures are technical in nature.

Organisational failure on the other hand, is latent in nature. Latent failures are made by those whose activities are removed in both time and space from the sharp end of accident causation. Their adverse consequences may lie dormant within the system for a long time, waiting for the right conditions to become evident. In most cases, the one(s) causing the failure is (are) not confronted with the consequences. Latent failures tend to create the right conditions for active failures to be made. The same latent failure, if undiscovered and uncorrected, can contribute to multiple active failures, while active failures tend to be unique to one incident. It should be noted that latent failures can also be technical in nature, because technical problems can also lie dormant within an organisation before becoming evident. Based on the distinction between active and latent failures table 1.2 is helpful in defining organisational failure.

	Active failures	*Latent failures*
Technical failure	X	X
Human failure	X	
Organisational failure		X

Table 1.2: Technical, human and organisational failure versus active and latent failure.

Based on these characteristics, organisational failure can be distinguished from active failure on the following aspects:

- *Time lag until consequences*: In the case of active failure the consequences are felt almost immediately. Organisational failure on the other hand creates conditions for active failures to be made. However, these conditions rarely lead to immediate consequences. There is normally a considerable time lag between the occurrence and the consequences of organisational failure.
- *The agent versus victim*: Because of the time lag and the fact that organisational failures are made at the blunt end of incident causation, the one(s) causing the organisational failure (the 'agents') are usually not the ones who are confronted with the consequences (the 'victims'). This is in contrast to active failure, where in most cases the same person is often both the agent and the victim.
- *Number of consequences*: In the case of active failure, there is a direct and one to one relation between the active failure and its consequences. Organisational failure on the other hand creates conditions for active failures to be made. If undetected, the

dangerous conditions may contribute to multiple active failures and therefore multiple consequences.

A second question that needs to be answered is: What is ‘organisational’? This question appears to be very difficult to answer, in particular when the outer boundaries are concerned. The inner boundary, i.e. the distinction between human failure and organisational failure, is discussed above but where does organisational failure end? The incident description given in the first paragraph of this chapter shows that it does not have to end at the boundaries of the organisation but instead regulating bodies from outside the organisation, such as the CAA, provide conditions that can lead to active failures inside the organisation. Therefore, organisational failure seems not to be limited to the organisation investigated. This raises the question of labelling it ‘organisational failure’ at all? In this study the term organisational failure is used, because the analysis of the incidents is limited to the responsibilities of the organisation investigated. It is the responsibility of the organisation to anticipate and safeguard against external influences. Failing to do so can and should be considered a failure of the organisation.

This leads to the following working definition of organisational failure:

Organisational failure refers to those non-technical latent failures by those at the blunt end of incident causation, which after a considerable time may trigger one or multiple active failures by those at the sharp end of incident causation.

In chapter 5 a more precise definition of organisational failure will be given based on the empirical results of this study.

1.5.3 A qualitative exploratory research design

There are many ways to distinguish between research designs and within these designs, numerous different research methods and techniques can be used. In this study, the selection of the research design and its accompanying methods and techniques is based on the previously described status quo in research into the organisational factors of safety related incidents and the goals of this study. The type of research design used in this study is discussed in this paragraph. The detailed set up of the research and the methods and techniques used within the design chosen are discussed extensively in chapter 2.

As described in paragraph 1.4.3, little is known about organisational failure. Theoretical and explanatory models to describe and explain organisational failure, similar to those available for human behaviour, are still lacking. Based on this lack of models and theories, a research design in which knowledge is gained from empirical data (i.e. induction) is needed.

A distinction between qualitative and quantitative research is a useful one, though it is often misinterpreted. Swanborn (1987) gives a number of distinctions between quantitative and qualitative research that are often used. Quantitative research is often related to natural sciences and seen as objective, focusing on causal relations. Qualitative research on the other hand, is often related to social sciences and considered to be subjective and not focusing on causal relations. This might give the impression that the two are completely different types of research and that both cannot be brought into line with the other. According to Swanborn (1987), it is merely a matter of accents than a clear distinction. Strauss & Corbin (1990) describe qualitative research as "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification". Some of the data may be quantified but the analysis itself is a qualitative one.

Qualitative research in this study means that:

1. Empirical data is collected to develop a taxonomy of organisational causes of safety related incidents.
2. The collected empirical data is semi-structured and qualitative in nature.
3. The research methods used and the way the data is analysed, focus on the interpretation and conceptualisation of the phenomenon organisational failure.

This closely resembles the method described by Strauss & Corbin (1990) as the Grounded Theory method. According to Strauss & Corbin (1990): "a grounded theory is one that is inductively derived from the study of the phenomenon it represents. It is discovered, developed and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon. Therefore, data collection, analysis and theory stand in a reciprocal relationship with each other. One does not begin with a theory, then prove it. Rather, one begins with an area of study and what is relevant to that area is allowed to emerge".

For this study, it is important to further specify the chosen research design. A distinction may be made between quantitative and qualitative research. It is also common to make a distinction between the following four types of research (e.g. Segers, 1987; Van der Zwaan, 1990):

- exploration;
- description;
- explanation;
- testing.

The main criterion underlying this division, is the level to which the phenomenon to be investigated has already been elaborated in theory. Exploration is needed when a theory is lacking and research is needed to find out which attributes (variables) of the phenomenon are important for further research. Description aims at the frequency of occurrence of the variables. In explanatory research, causal relations between variables are the area of interest. Finally, in the last type of research, hypotheses about the causal relations between variables are tested. Given the lack of theory about the organisational causes of safety related incidents, the study described in this thesis is mainly exploratory in nature. The main emphasis of this study is on collecting and analysing empirical incident data. Based on this empirical data, building blocks for future theory development are elaborated.

1.6 Outline of this thesis

Chapter 1 provided a brief introduction into the current state of incident analysis and discussed the lack of knowledge about organisational failure in the area of safety related research. Based on this lack of insight into organisational failure and the accompanying problems in detecting and preventing organisational failure, the goals of this study were described. The exploratory nature of the study described in this thesis was explained in this chapter.

Chapter 2 presents a detailed outline of the study. To achieve the goals described in chapter 1, both a top-down and a bottom-up path of development are followed. The top-down path is called the 'theoretical path' and starts with the development of a theoretical framework based on an overview of relevant literature. Both the literature review and the theoretical frame work are discussed in this chapter. Based on empirical incident data the theoretical framework will be modified into the final taxonomy. This step is discussed in chapter 5. The bottom-up path, called the 'empirical path', is also explained in chapter 2. The empirical path is based on empirical incident data only and aims at developing domain specific tools for classifying organisational root causes of incidents. The development of these tools is discussed in both chapter 3 and 4. Apart from giving an outline of the study presented in this thesis, the domains investigated and propositions formulated prior to starting the individual case studies are also described in detail in chapter 2.

In chapter 3, the results of the first two case studies carried out in the Dutch steel industry are described. Based on the results of these two case studies, a tool for classifying organisational root causes of safety related incidents in the steel industry is developed. This is the first product of the empirical path as described in chapter 2. Apart from the development of this classification tool, this chapter focuses on the organisational strengths and weaknesses of the domain investigated and the lessons learned about how to manage organisational failure. Based on the organisational strengths and weaknesses of the steel industry and the known characteristics of the medical domain, this chapter concludes with the formulation of propositions about differences between the two domains and about differences between individual cases in the medical domain.

In chapter 4, the results of the four case studies that were carried out in the medical domain are discussed. Based on the results of these four case studies, a tool for classifying organisational root causes of safety related incidents in the medical domain is developed. This is the second and last product of the empirical path. This chapter also focuses on the organisational strengths and weaknesses of the domain investigated and the lessons learned about how to manage organisational failure.

Following the two empirical chapters 3 and 4, chapter 5 returns to the theoretical path and focuses on the development of the taxonomy of the organisational causes of safety related incidents. The taxonomy is based on both the theoretical framework and the accumulated empirical data. The developed taxonomy is compared with the two classification tools developed in chapter 3 and 4. The differences in organisational strengths and weaknesses between the two domains and the propositions formulated in chapter 2 and 3 are evaluated. Guidelines about how to manage organisational failure are provided, using the practical lessons learned during this study. Finally, the position of organisational failure in relation to technical and human failure is discussed and a more precise definition of organisational failure is presented.

After discussing the case study results in chapter 5, chapter 6 reviews and assesses the study itself. First the contribution of this study to incident investigation and risk management is evaluated, followed by an extensive discussion about the implications of the research design for the results of this study. This chapter concludes with the formulation of research questions for future research.

2 Detailed outline of the study

Following the general introduction of the study in chapter 1, this chapter describes the outline of the study in more detail. This detailed outline describes and explains the two paths, called the *theoretical* and the *empirical* path, that have been followed. This is the main focus of paragraph 2.1. Paragraph 2.2 gives a review of literature used for the theoretical path. The domains investigated for the two paths and why these domains are chosen are described in paragraph 2.3, followed by a detailed description of the methodology used for both paths in paragraph 2.4. Finally, the planning of the case studies that were carried out in the Dutch steel industry is outlined in paragraph 2.5.

2.1 The theoretical and the empirical path

The study described in this thesis follows both a top-down and a bottom-up approach. The top-down approach is called the *theoretical* path, which is based on a theoretical framework of organisational failure and aims at developing a general taxonomy of organisational failure. The bottom-up approach is called the *empirical* path and aims at developing domain specific classification tools based on empirical incident data only. Both the two paths and their outcomes are visualised in figure 2.1. The two paths result directly in two of the three goals described in chapter 1 and also provide the opportunity to compare the results of both approaches. The third goal, regarding the guidelines for managing organisational failure, is derived from both paths indirectly.

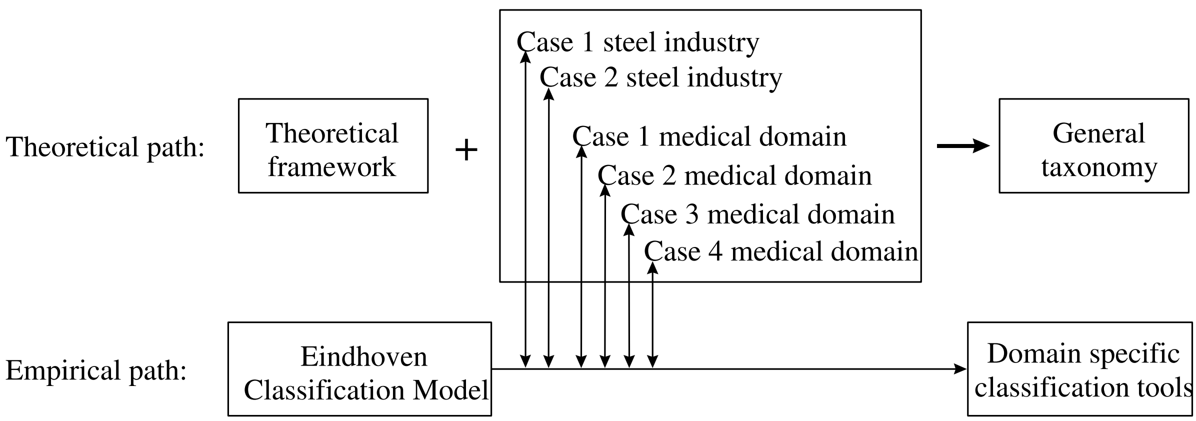


Figure 2.1: The theoretical versus the empirical path.

A taxonomy based on a theoretical framework is needed in order to make the first step towards explaining organisational failure and to predict the likelihood of occurrence of specific organisational factors given an organisation's characteristics.

For the development of domain specific classification tools the usability of the tool is a primary criterion. As a result, the categories of the classification tools will be defined at a higher level of abstraction to maximise their usability. The low abstraction level of the taxonomy is likely to exceed the level of detail needed for a classification tool.

The theoretical path starts with the development of a theoretical framework of organisational failure, based on organisational change and development literature. The development of this theoretical framework is discussed in paragraph 2.2. Since a general and not domain specific taxonomy is aimed for, the development is based on the empirical incident data of both the steel industry and the medical domain. Development of the taxonomy will take place after all case studies have been completed. Because of this post-hoc development strategy, the order in which the case studies have been carried out becomes irrelevant. For the development of the taxonomy, the case studies are selected for reasons of variety only. The methodology used for the development of the taxonomy is discussed in this chapter, while the final taxonomy of the organisational causes of safety related incidents is presented in chapter 5.

For the empirical path the Eindhoven Classification Model (ECM) of system failure (Van der Schaaf, 1992) is taken as a starting point. This model, discussed in paragraph 2.4.2, was originally developed to classify root causes of safety related incidents in the chemical process industry, but has also shown its usability in other domains such as the steel industry and medicine (Van Vuuren, 1993; Shea, 1996). The ECM was developed emphasising human failure. This study is intended to upgrade the organisational part of the model. For both the steel industry and medicine a domain specific classification tool is developed that also fully incorporates organisational failure factors. Differences in domains may result in different emphases on certain types of organisational failure factors. Therefore, a tailor-made classification tool for each domain will be developed. As shown in figure 2.1, a continuous development and testing strategy is used, in order to guarantee the quality and usability of the tool being developed. The methodology used will be discussed in detail in this chapter. The tools themselves are presented at the beginning of chapters 3 and 4.

2.2 Relevant literature

In chapter 1 it was explained that the emphasis on empirical data is a direct result of a lack of theoretical safety related models which can be built on in this study. However, a lack of useful safety related theory does not mean that this study will be based on empirical data only. Over the past decades the environment of organisations has changed rapidly, leading to both problems and opportunities for organisations. Based on these problems and opportunities organisations have tried to adapt to these changes in order to benefit or at least cope with them. This has resulted in extensive research into organisational change and development.

Lessons learned about how to run an organisation most effectively in a changing environment may also provide useful insights into how to manage an organisation's safety performance, since safety is also one of the factors that influences an organisation's success.
The literature discussed below provides a general theoretical framework of organisational failure. This theoretical framework serves as input to the theoretical path leading to the development of the taxonomy of organisational causes of safety related incidents.

2.2.1 Organisational change and development

Van de Bunt (1978) defines three organisational problem areas that cover the problems encountered by consultants in the area of organisational development. His division of problem areas is based on what he perceives as the three main themes in organisational science. The first theme is the structure of an organisation and deals with problems about how to divide tasks, authority, responsibilities, and resources to make the organisation function as efficiently as possible. The second theme deals with interpersonal relations between people working in the organisation. This second theme results from the notion that an efficiently organised structure in itself is no guarantee of positive results. Motivation of the people involved appears to be an important factor as well. The third theme deals with the strategy of an organisation. The goals of the organisation need to fit and adapt to the changing external environment to be able to survive. Based on these three themes, the following organisational problems areas are defined by Van de Bunt:

- *Structure:* refers to the configuration of an organisation.
- *Culture:* refers to the interpersonal relations inside an organisation.
- *Strategy:* refers to the organisation in its external environment.

Hoeksema and Van de Vliert (1989) observe a great diversity of ways in which organisational problem areas are categorised by consultants in the area of organisational development. Based on a literature review, they come to the following list of ten categories that are often used in organisational problem diagnosis:

- structure;
- co-ordination;
- goals;
- rewarding systems;
- management style;
- relations;
- significant norms and values;
- material resources;
- skills and knowledge;
- acceptance by society.

Based on this list they have identified a pattern of coherence between the ten categories, which resulted in the definition of a limited number of clear and well interpretable dimensions to categorise organisational problems. The following three dimensions, which closely resemble the problem areas that were pointed out by Van de Bunt (1978), were identified:

- *Structure:* refers to problems that are related to the structure of an organisation and to co-ordination.
- *Relations:* refers to interpersonal problems within an organisation.
- *Goals:* refers to problems that are related to the strategy of an organisation.

Porras (1987) describes a broad diagnostic model of organisations that is used in a tool (called 'Stream Analysis') to diagnose and manage organisational change. This diagnostic model distinguishes the following four dimensions to categorise organisational problems:

- *organising arrangements*, which contain all the parts of the organisation that are set up to co-ordinate formally both the behaviour of people and the functioning of various parts of the organisation.
- *social factors*, which encompass all things directly related to people in the organisation: their characteristics (individually and in small groups), their patterns and processes of interaction and their features as larger social groups.
- *technology*, which encompasses all of the factors that directly enter into the transformation of organisational inputs into organisational outputs.
- *physical setting*, includes the concrete structures and objects of the non-social/non-technical part of the environment in which people work.

Each of these four dimensions is further subdivided into a number of components. The technology and physical setting are beyond the scope of this study. The components of the organising arrangements can be summarised in two groups: 'strategy and goals' and 'formal structure'. One of the main components of the social factors is 'culture', which according to Porras is closely linked with the organising arrangements. The remaining social factors are not organisational and therefore beyond the scope of this study.

Looking back on this brief review of literature on organisational change and development, the recurring themes are summarised in table 2.1. It is concluded that a subdivision of organisational problems in structure, culture, and strategy and goal problems is well accepted in organisational change and development literature.
For the study described in this thesis, this subdivision is used in the theoretical framework for the development of the taxonomy of the organisational causes of safety related incidents. The remainder of the literature review will examine the possibility to further subdivide these three categories based on existing literature on these three themes separately.

Author	Recurring themes		
Van de Bunt	Structure	Culture	Strategy
Hoeksema & Van de Vliert	Structure	Relations	Goals
Porras	Formal structure	Culture	Strategy and Goals

Table 2.1: Recurring themes in literature review.

2.2.2 The structure of organisations

Structuring organisations is generally accepted to consist of the following two main aspects (De Leeuw, 1982; Mintzberg, 1983; Botter, 1988; Van Aken, 1994):

- subdividing tasks and responsibilities among departments, groups and persons;
- achieving co-ordination between these tasks.

These two aspects are also known as ‘decomposition’ and ‘co-ordination’. According to Mintzberg (1983), every organised human activity gives rise to two fundamental and opposing requirements: the division of labour into various tasks and the co-ordination of these tasks to accomplish the activity. Mintzberg describes the structure of an organisation as “the sum total of the ways in which its labor is divided into distinct tasks and then its coordination is achieved among these tasks”. This distinction between division of labour and co-ordination will be used as a first subdivision of organisational structure in this study. The remainder of the overview on structure will give some in-depth insight into the division of labour and co-ordination according to Mintzberg, since this insight will be used in this study.

According to Mintzberg, the elements of structure (i.e. the design parameters) should be selected to achieve an internal consistency or harmony, as well as a basic consistency with the organisation’s situation; its size, its age, the kind of environment in which it functions, the technical system it uses, and so on. Both the design parameters and the situational factors can be clustered to create a limited number of so called ‘configurations’ which explain most of the tendencies that drive effective organisations to structure themselves the way they do. In other words, the design of an effective organisational structure, even the diagnosis of problems in ineffective ones, involves the consideration of only a few basic configurations.

Mintzberg (1983) distinguishes the following five co-ordinating mechanisms which explain the fundamental ways in which organisations co-ordinate their work and which should be considered the most basic elements of structure:

- *Mutual adjustment*: achieves the co-ordination of work by the simple process of informal communication.
- *Direct supervision*: achieves co-ordination by having one person take responsibility for the work of others, issuing instructions to them and monitoring their actions.
- *Standardisation of work processes*: achieves co-ordination by specifying or programming the content of the work.
- *Standardisation of work outputs*: achieves co-ordination by specifying or programming

the results of the work; for example the dimensions of the product or performance.
- *Standardisation of worker skills*: achieves co-ordination by specifying the kind of training required to perform the work.

The five co-ordinating mechanisms seem to fall into a rough order. As organisational work becomes more complicated, the favoured means of co-ordination appears to shift from mutual adjustment to direct supervision to standardisation, finally reverting back to mutual adjustment. Within standardisation the emphasis shifts from standardisation of work processes to standardisation of outputs to standardisation of skills.

According to Mintzberg (1983), five basic parts of an organisation can be distinguished. The base of an organisation is formed by the *operating core*. The operating core consists of the operators, the people who perform the basic work of producing the products and rendering the services. In the simplest of organisations, the operators are largely self-sufficient and co-ordinating through mutual adjustment. The organisation needs little more than an operating core.
As the organisation grows and adopts a more complex division of labour among its operators, the need for direct supervision increases. It becomes mandatory to have a full-time manager who sits at the so called *strategic apex*. As the organisation is further elaborated, more managers are needed. Not only managers of operators but also managers of managers, creating a *middle line*, a hierarchy of authority between the operating core and the strategic apex.
As the process of elaboration continues, the organisation may turn increasingly to standardisation as a means of co-ordinating work. The responsibility for much of the standardisation falls on another group called the analysts. The analysts form the *technostructure*, outside the hierarchy of line authority. Finally, as it grows, the organisation tends to add staff units to provide indirect services to itself. These staff units, varying from a cafeteria, a mail room to a legal counsel or public relations department, form the *support staff*, which is also located outside the hierarchy of line authority.

In a later work, Mintzberg (1989) adds both a sixth co-ordination mechanism and a sixth basic part of the organisation to the ones discussed above. The sixth basic part is called *'ideology'* and encompasses the traditions and beliefs of an organisation that distinguishes it from other organisations and infuses a certain life into the skeleton of its structure. The accompanying co-ordinating mechanism is *standardisation of norms*, in which it is the norms infusing the work that are controlled, so that everyone functions according to the same set of beliefs.

To design effective organisations, Mintzberg (1983) suggests a set of nine design parameters (the basic components of organisational structure), which fall into the four broad groupings. The groups and design parameters are:

- *Design of positions*: job specialisation, behaviour formalisation, and training and indoctrination.
- *Design of superstructure*: unit grouping and unit size.
- *Design of lateral linkages*: planning and control systems and liaison devices.
- *Design of decision making system*: vertical decentralisation and horizontal decentralisation.

Based on the six co-ordinating mechanisms and the six basic parts of an organisation, Mintzberg (1989) formulates the following six configurations:

- *Entrepreneurial organisation*, based on direct supervision, in which the strategic apex is the key part.
- *Machine organisation*, based on standardisation of work processes, in which the technostructure is the key part.
- *Professional organisation*, based on standardisation of skills, in which the operating core is the key part.
- *Diversified organisation*, based on standardisation of outputs, in which the middle line is the key part.
- *Innovative organisation*, based on mutual adjustment, in which the support staff (sometimes with the operating core) is the key part.
- *Missionary organisation*, based on standardisation of norms, in which the ideology is the key part.

These configurations explain most of the tendencies that drive effective organisations to structure themselves the way they do. These configurations will be used in chapter 3 and 4 to characterise the organisations and departments that participated in this study. In chapter 5, the co-ordination mechanisms are used again to explain part of the differences found between the domains investigated and to predict organisational problems based on the type of co-ordinating mechanism used.

2.2.3 The culture of organisations

An organisation is more than its structure, its strategy (see paragraph 2.2.4), the people who work for the organisation and the technology used; more than just the visible elements. Organisations also possess a number of more intangible elements such as shared patterns of behaviour, rituals, a dress code, etc. Things that are not written down, however, give identity to an organisation, make people feel comfortable and influence decision making. These intangible elements make up what is called the culture of an organisation.

Research into the culture of organisations has gained popularity after publications by Peters & Waterman (1982) and Deal & Kennedy (1982), who show that the culture of an organisation can be used as a powerful management tool to improve a company's performance. Peters & Waterman, in their 'search of excellence', conclude that "without exception, the dominance and coherence of culture proved to be an essential quality of the excellent companies".

Many researchers have tried to define (organisational) culture. This brief review will present some common elements of culture, before moving on to the most important part for this study: the area of organisational culture that is concerned with safety. An often used, however poor, definition of culture is "the way we do things around here". A better definition is provided by Hofstede (1980), who defines culture as "the collective programming of the mind which distinguishes the members of one group from the other". This definition covers most of the basic elements of culture. A culture is something collective. One person cannot make up a culture. A culture belongs to a group and different groups can have different cultures. A culture is relatively stable ('programmed'). It does not change from one day to the other. However, stable does not mean static. According to Schein (1985), a culture develops by internal collective learning and external influences. A culture is holistic in nature. The elements that make up the culture are related and influence each other.
In attempts to model culture, values, beliefs and norms are often believed to make up the core of a culture (Van Hoewijk, 1988). Values can be defined as "a broad tendency to prefer a certain state of affairs above others" (Hofstede, 1980). Beliefs are ideas that a person holds about reality and are descriptive in nature. Norms on the other hand are prescriptive in nature and are the informal rules, prescribing desired behaviour.

According to Hofstede (1991) values are the core of culture and express themselves in the following three succeeding levels: rituals, heroes and symbols. Rituals are collective activities which are in essence superfluous, but are considered important in the given culture. Heroes are real or fictive persons with certain desirable characteristics who are considered role models. The last level is formed by symbols, which are concrete things that have a meaning within a culture because they refer to something else (e.g. a logo of a company). When moving from symbols, via heroes and rituals to values the visibility decreases. The ease in which they can be changed also decreases in the same direction. Similar levels can be found in the work of other authors mentioned earlier (Van Hoewijk, 1988; Schein, 1985).

The term 'safety culture' has gained popularity after the Chernobyl disaster in April 1986. After the Chernobyl accident, the development of an appropriate safety culture was seen within the western nuclear industry as an important human factors requirement in reactor operator training (Broadbent, 1989). Safety culture is now generally considered to be a part of organisational culture. Turner *et al* (1989) provide an initial characterisation of safety culture as "the set of beliefs, norms, attitudes, roles and social and technical practices that are concerned with minimising the exposure of employees, managers, customers and members of the public to conditions considered dangerous and injurious". A definition more in line with the discussion about culture is given by Cox & Cox (1991) who say that "safety culture reflects the attitudes, beliefs, perception and value that people share in relation to safety". In a cautious attempt to give a normative character to safety culture, Pidgeon (1991) describes the following three elements that might characterise a 'good' safety culture:

- *norms and rules for handling hazards*: the norms and rules governing safety within an organisation, whether explicit or tacit, are at the heart of safety culture. As corporate guidelines for action, these will shape the perceptions and actions of the individuals in the organisation in particular ways, defining what is and is not to be regarded as a significant risk, and what will represent an appropriate response.
- *attitudes toward safety*: safety attitudes refer to individual and collective beliefs about hazards and the importance of safety, together with the motivation to act on those beliefs.
- *reflexivity on safety practice*: a good safety culture can be characterised by an ongoing reflexivity over current safety practices and beliefs. This can be seen as a learning process and as such is a search for new meanings in the face of uncertainty and ambiguity about risk. Reflexivity acts as a precaution against the over-rigid application of existing rules to the neglect of unanticipated hazards.

For this study this characterisation given by Pidgeon is used as a template with which to compare the collected empirical incident data that relates to safety culture.

2.2.4 Strategy and goals

According to Mintzberg (1983), strategy may be viewed as a mediating force between the organisation and its environment. Strategy formulation therefore involves the interpretation of the environment and the development of consistent patterns in streams of organisational decisions (strategies) to deal with it.
In a later work, Mintzberg & Quinn (1991) provide a more elaborate definition of a strategy. "A strategy is the pattern or plan that integrates an organization's major goals, policies, and action sequences into a cohesive whole. A well-formulated strategy helps to marshal and allocate an organization's resources into a unique and viable posture based on its relative internal competencies and shortcomings, anticipated changes in the environment, and contingent moves by intelligent opponents".

Porras (1987) makes a distinction between goals and strategies, which remain strongly related. In short, goals indicate what the organisation is trying to achieve. Formal goals are usually spelled out and reviewed at least once a year. Closely linked with goals are strategies. Organisational strategies lay out the way of achieving the goals. Strategies can be externally oriented and have to do with the choice of markets, products to develop, advertising approaches to use, and so forth. Internally oriented strategies focus on types of people to hire, career development approaches, management development approaches and reward systems. According to Porras, both goals and strategies can exist at all levels of the organisation. Those at the top, dealing with the system as a whole, tend to be more formal and may take a written form. Those at the bottom often exist as an intuitive ideology.

When strategy is considered, the main focus is on the position of the organisation in its external environment. As indicated by Van der Bij *et al.* (1996), this external (corporate) strategy rarely directly leads to safety problems on the shop floor. However, it can result in conflicting internal goals and strategies, which can directly lead to dangerous situations. In industry for example, high production goals and maintenance plans often conflict, resulting in situations where maintenance takes place under unsafe conditions, since production must continue in order to achieve its (external) goals. The selection of personnel that is not fully qualified or demotivating reward systems are also likely to cause safety related problems. Therefore for this study, the focus is on internal goals and strategies only.

2.2.5 A theoretical framework

Looking back on the review of literature, the theoretical framework as shown in table 2.2 results as the first step of the theoretical path.

Concept	*Main categories*	*Subcategories*
Organisational failure	Structure	• the division of labour into distinct tasks; • the co-ordination among these tasks.
	Culture	• norms and rules for handling hazards; • attitudes towards safety; • reflexivity on safety practice.
	Strategy and goals	• internal goals; • internal strategies.

Table 2.2: The theoretical framework of organisational failure.

The second step of the theoretical path towards the development of the final taxonomy is based on the empirical incident data collected in the case studies, as indicated in figure 2.1. Section 2.4.3 explains how both the theoretical framework and the empirical incident data are used to arrive at the final taxonomy.

2.3 Domains investigated

The study presented in this thesis has been carried out in two different domains; the Dutch steel industry and the medical domain (both in England and The Netherlands). In this section, both a brief characterisation of the domains investigated and an explanation of why these domains participated in this study are given.

2.3.1 The steel industry

The steel industry has played an important role in the history of the industrial development of The Netherlands. Up to the 1920s the growing Dutch industry had to cope without its own basic industry. In 1918 the "Koninklijke Nederlandsche Hoogovens en Staalfabrieken" (the Royal Dutch Blast Furnace and Steel factories) was founded and has fulfilled the need for basic industry successfully ever since (Nieuwenhuys, 1993).

For years the Dutch steel industry has been involved in research projects to improve its safety performance. Over the years, the steel industry has been shown to be a high-risk environment, resulting in a considerable amount of incidents every year. In particular the combination of the amount of people directly involved in the production process and the characteristic dangers of this process (e.g. extremely high temperatures and the large quantities of product involved) are responsible for a high amount of risks. Fortunately, this situation has been recognised by the steel industry and projects have been started to improve its safety performance.

Prior to the start of the study presented in this thesis, a three year research project was carried out in two plants in the Dutch steel industry to develop and implement a system for reporting and analysing safety related incidents (Mulder, 1994). Based on the assumption that not only the limited number of real accidents but also the abundantly available near misses should be used as input for a learning process, a system needed to be developed that could deal with both types of incidents. The development of this system called "SAFER" (Systematic Analysis of Faults Errors and Recoveries) was financially supported by the European Committee for Coal and Steel and supervised by the Safety Management Group of the Eindhoven University of Technology. As part of this 'SAFER-project' a pilot study was carried out to investigate the possibilities for modelling the organisational causes of the safety related incidents in one of the two plants involved (Van Vuuren, 1993). This pilot study can be seen as the beginning of the study presented in this thesis.

2.3.2 The medical domain

As discussed earlier, initially the study was started in the Dutch steel industry. However, after two case studies in the steel industry the study enlarged its scope to include incidents in various departments in the medical domain. The move to the medical domain was made for methodological reasons. After two case studies in the steel industry a methodological choice had to be made. Whether to continue the development of the taxonomy in the steel industry or to move on to an apparently different domain to improve the general applicability of the taxonomy that had been developed. Based on the exploratory nature of the study and the limited added value of the second case study (see chapter 4), it was decided to move on to an apparently different domain. Based on known differences such as organisational structure, professionalism, self-regulation and patients as a risk factor, the medical domain fulfilled this criterion.

Risk management in the medical domain and medical accidents in particular are receiving growing interest from researchers in industrial engineering and management science, psychology and human factors. Historically there have been few systematic attempts to explore and assess safety for both staff and patients in the medical domain, particularly within a hospital setting (Vincent *et al.*, 1993). Though an interesting variety of quality assessment and audit methods have gained popularity, the scope of most systems excludes safety.

2.4 Set up of case studies

Both the development of the taxonomy and the tools are based on a post-hoc analysis of empirical incident data. In the previous section the domains investigated to collect the empirical incident data are discussed. Given the exploratory research design, there are still several different research strategies possible and within these strategies different methods and techniques that can be used to turn empirical incident data into a taxonomy of the organisational causes of safety related incidents or tools for classifying organisational root causes. This section focuses on the chosen research strategy and its accompanying methods and techniques.

2.4.1 Why case studies?

According to Yin (1994), the choice of a research strategy depends on the following three conditions:

1. the type of research question posed;
2. the extent of control an investigator has over actual behavioural events;
3. the degree of focus on contemporary as opposed to historical events.

A basic categorisation for the types of questions is the familiar series: 'who', 'what', 'where', 'how' and 'why'. In this exploratory study, reported incidents are used as input for further analysis. Two pilot studies in the Dutch steel industry and the chemical process industry (Van Vuuren, 1993; Van Vuuren & Van der Schaaf, 1995) have shown that the majority of these incident reports are descriptive in nature, focusing on the 'who', 'what' and 'where' of the incident. However, to develop a taxonomy of the organisational causes of safety related incidents, information about 'how' and 'why' is needed. Since organisational failure is latent in nature, in-depth information about the blunt end of incident evolution is required, as opposed to superficial and often highly visible information about its symptoms at the sharp end.

The fact that the study is based on a post-hoc analysis of reported incidents indicates that the investigator has no control over the actual behavioural events (assuming that the investigator is not part of the incident causation process). The incidents have already happened and only the type and quality of the analysis performed can be influenced by the investigator.

The incidents that are used must have occurred recently. There are two main reasons for this preference for contemporary events. To be able to acquire in-depth information about incident causation, the investigator is highly dependent on the memory of the people involved in the incident. Particularly, since the majority of the incident reports do not provide the information needed for this study, an additional investigation into each incident is needed. It is known however, that the ability to remember events strongly decreases over time. Therefore, to acquire complete and reliable information, the investigation of an incident needs to take place shortly after its occurrence.
The second reason is related to the relevance of the data collected. The taxonomy of organisational failure needs to represent contemporary organisational problems at the sites investigated and should be related to modern management theory. Therefore, only incidents that are relevant to the current situation are needed. Most historical events do not comply with this criterion.

Table 2.3 displays the three conditions and shows how each is related to five major research strategies in the social sciences: experiments, surveys, archival analysis, histories and case studies.

Strategy	*Form of research question*	*Control over behavioural events?*	*Focuses on contemporary events?*
Experiment	how, why	yes	yes
Survey	who, what, where, how many, how much	no	yes
Archival analysis	who, what, where, how many, how much	no	yes/no
History	how, why	no	no
Case study	how, why	no	yes

Table 2.3: Relevant situations for different research strategies (Yin, 1994).

When the conditions of this study are compared with the overview given in table 2.3, it can be concluded that a case study design is the best suitable strategy. According to Yin (1994) a case study has a distinct advantage when:

a 'how' or 'why' question is asked about a contemporary set of events over which the investigator has little or no control.

The study presented in this thesis complies with these criteria. Every single plant or department investigated is considered as a separate case study. The reported and analysed incidents in each plant or department are the set of events that make up each case study.

2.4.2 PRISMA

To collect the empirical incident data, a risk management approach called PRISMA was used. PRISMA (Prevention and Recovery Information System for Monitoring and Analysis) was developed to continuously and systematically monitor, analyse and interpret incidents and process deviations (Van der Schaaf 1992, 1996). PRISMA is an integrated approach that not only looks at errors, it also covers the whole range of root causes (technical, organisational and human) and provides tools not only to describe and analyse, but also to interpret incidents into suggestions for effective and efficient countermeasures.

Even a modern organisational structure, designed on the basis of acknowledged theories of management, does not guarantee flawless day to day business processes. Therefore, there will always be a need for risk management tools in order to (Van der Schaaf, 1996):

- *monitor* day-to-day activities and processes on the shop floor;
- *identify* weak and strong points in the production system; and
- *interpret* the above into suggestions for improvement and *evaluate* their effectiveness after implementation.

PRISMA provides these tools and aims at building a quantitative database of incident data, from which conclusions may be drawn to suggest optimal countermeasures. When using a quantitative database of incidents, the focus will be on the detection and prevention of structural problems, instead of spending too much time and money on incidental problems. The countermeasures may be directed not only at the prevention of errors and faults but also at the promotion of recovery factors to ensure timely corrective action. As such, PRISMA not only uses actual yet rare accidents as input, but also the abundantly available near misses. This discussion focuses on the main components of PRISMA, which are:

1. the causal tree incident description method;
2. the Eindhoven Classification Model (ECM) of system failure;
3. the classification/action matrix to suggest optimal countermeasures.

Causal trees (Van Vuuren and Van der Schaaf, 1995), derived from fault trees, are very useful to present critical activities and decisions during the development of an incident in chronological order and to show how activities and decisions are logically related to each other (figure 2.2). By using causal trees it becomes clear that incidents are never preceded by a single cause only, but always by a combination of technical, organisational and/or human causes.

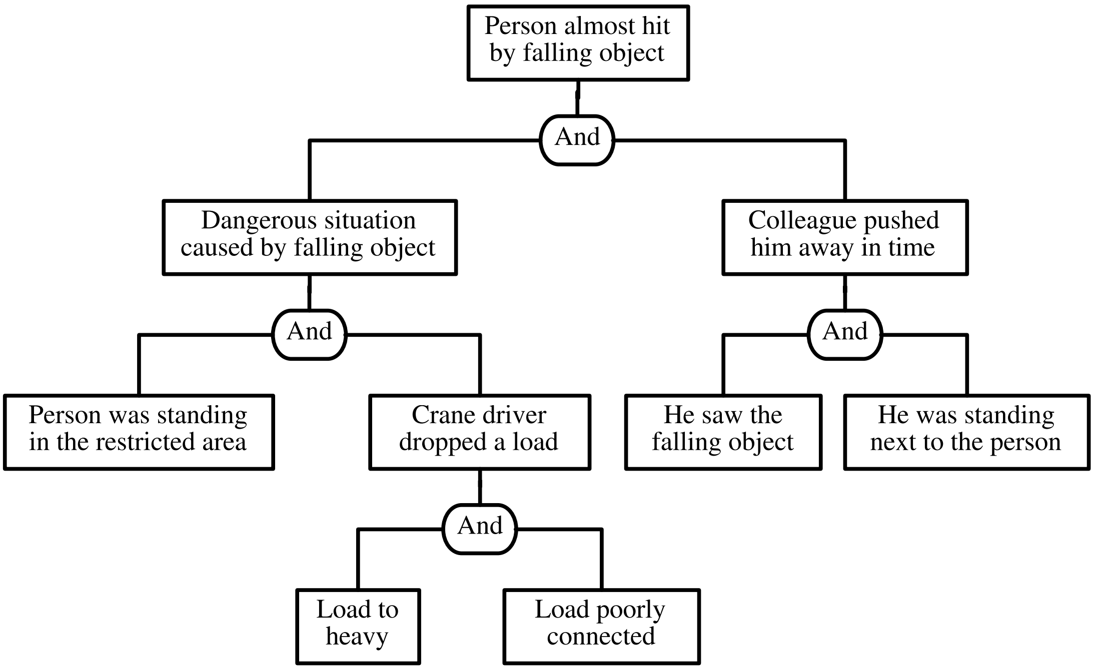


Figure 2.2: Example of a causal tree describing a near miss.

The main difference between a causal tree and a fault tree is that the top event in a causal tree is not a class of events but one particular incident, which actually occurred and for which the chain of incident causation must be discovered. The causal tree can, formally, be considered a sub-tree of a fault tree describing the class of events the incident belongs too. As opposed to fault trees, causal trees preferably do not include 'or-gates', since they indicate uncertainty about the true chain of events leading to the incident. Causal trees are used to get the best possible, and above all, reliable description of the chain of events leading to an incident, without hypothesising about possible causes. A causal tree of an incident is based on a combination of the following three sources of information: a verbal or written incident report, observations of the incident site if useful and critical incident interviews with those involved in the incident.

As indicated earlier, incident reports are generally descriptive in nature, focusing on 'who', 'what' and 'where', instead of 'how' and 'why'. Despite this lack of in-depth information, incident reports are still an important source of information, particularly since they trigger further incident analysis. An observation of the incident site can provide additional information about the physical setting in which the incident occurred.

In-depth information is acquired by conducting critical incident interviews with those involved in the incident. Critical incident interviews are derived from the critical incident technique developed by Flanagan (1954). The critical incident technique was originally developed to identify critical job requirements for purposes such as training and selection of personnel. The technique can be regarded as an outgrowth of studies in the Aviation Psychology Program of the United Air Forces in World War II. The Aviation Psychology Program was established in the summer of 1941 to develop procedures for the selection and classification of aircrews. Job analyses were used to determine critical requirements. These requirements include those which have been demonstrated to have made the difference between success and failure in carrying out an important part of the job assigned in a significant number of instances. To obtain valid information regarding critical requirements for success, procedures were developed for making a systematic analysis of causes of good and poor performance. Essentially, the procedure was to obtain first-hand reports, or reports from objective records, of satisfactory and unsatisfactory execution of the task assigned. The co-operating individual described a situation in which success or failure was determined by specific reported causes. In a similar way, it is possible to look at critical conditions, activities and decisions preceding an incident.

The next step in the PRISMA analysis is classifying the root causes of the failure side of the causal tree (left side of figure 2.2). Recovery factors (right side of figure 2.2) are not classified in PRISMA, but when present, are included in the causal tree to complete the incident description. Root causes are found at the bottom of the causal tree. To be able to classify root causes of safety related incidents, the Eindhoven Classification Model of system failure (figure 2.3) was developed by Van der Schaaf (1992), based on research into safety related incidents in the chemical process industry.

In the Eindhoven Classification Model of system failure (ECM), the three main categories of failure (technical, organisational and human) are further subdivided into a number of sub-categories, which are discussed in detail in Van der Schaaf (1992). Worth mentioning in this thesis are the two categories on the organisational level. The category ‘operating procedures’ refers to the (inadequate) quality of procedures (e.g. completeness and accuracy). The category ‘management priorities’ refers to any de facto pressure by top- or middle management to let production prevail over safety.
For every root cause the ECM is used to determine its classification. This is done in a fixed order. Firstly, one has to consider the adequacy of the technical work environment. Only when a technical cause has been ruled out, is the organisational context considered as a possible root cause. Secondly, when the technical and organisational aspects are found in order, human behaviour as a possible failure factor is considered. This is done in an attempt to counteract the sometimes strong bias within a company's culture to start and stop analysis at the level of the end-user and leave the technical and organisational context of any mishap unquestioned.

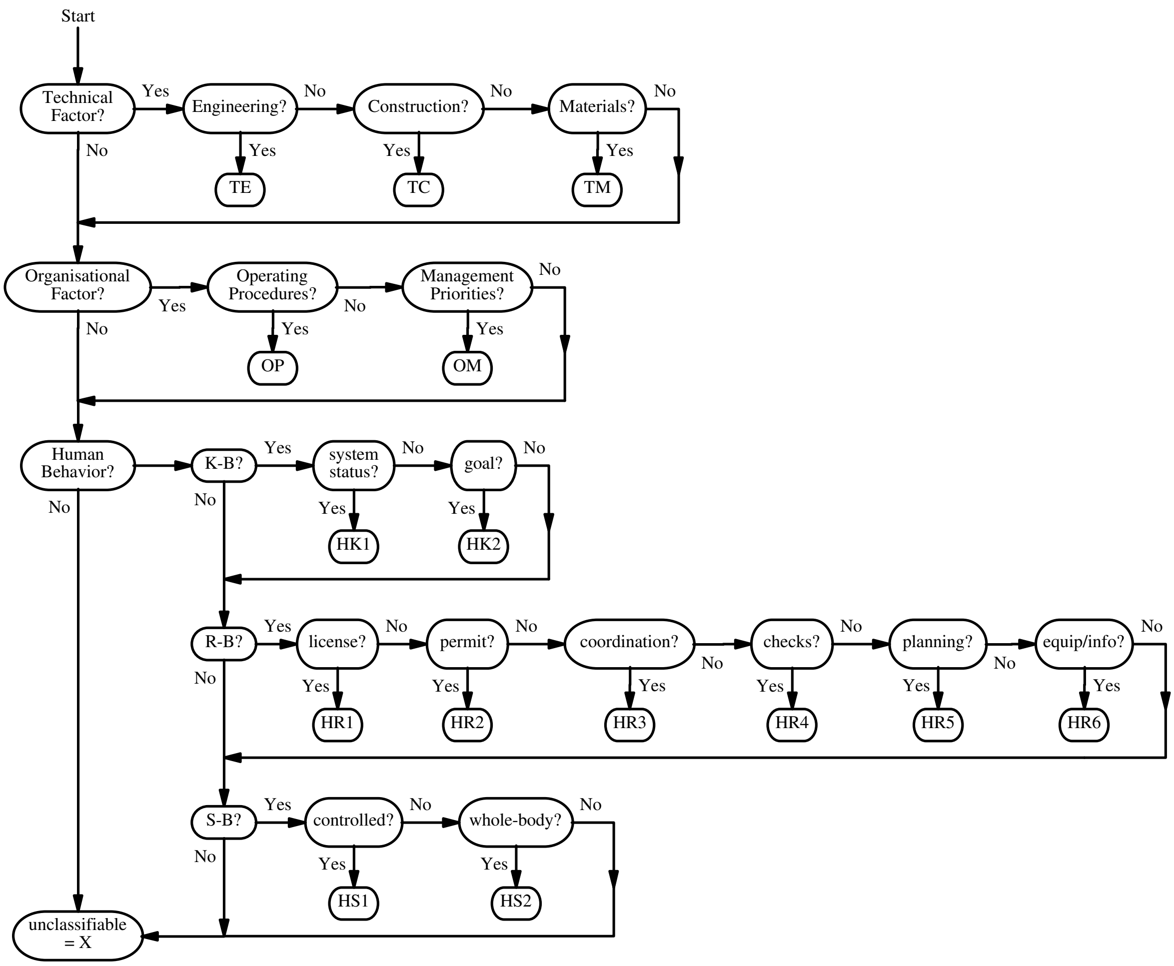


Figure 2.3: The Eindhoven Classification Model of system failure (Van der Schaaf, 1992).

The final step is to link the classified root causes and the most preferred countermeasures. For this purpose a classification/action matrix was developed by Van der Schaaf (1992). In this matrix, each category of the ECM is linked to a preferred action in terms of expected effectiveness. The actions suggested are related to equipment, procedures, information and communication, training, and motivation. The classification/action matrix was developed to provide an indication of the type of action that would fit a type of root cause, and perhaps even more important, what action would not fit at all. The final decision of what action to take depends on the circumstances (e.g. financial situation, culture) within the company.

2.4.3 From incident analysis to a taxonomy and tools

To develop both a taxonomy and tools, an analytic generalisation strategy is used (Yin, 1994). According to Yin, a fatal flaw in doing case studies is to conceive of statistical generalisation as the method of generalising the results of a case. In statistical generalisation, an inference is made about a population on the basis of empirical data collected about a sample. However, cases are not sampling units and should not be chosen for this reason. Rather, individual cases are to be selected as a laboratory investigator selects the topic of a new experiment. Multiple case studies should be considered like multiple experiments. Under these circumstances, the method is analytic generalisation, in which a previously developed theory or taxonomy is used as a template with which to compare the empirical results of the case study. If two or more case studies are shown to support the same theory or taxonomy, replication may be claimed. The empirical results may be considered even more potent if two or more case studies support the same theory or taxonomy but do not support an equally plausible rival one.

Within each case study, a similar iterative nature of 'explanation building' is used to develop a tool for classifying organisational root causes. This approach results in the following steps to be carried out:

- Make an initial tool for classifying organisational root causes of safety related incidents;
- compare the findings of an initial incident against this tool;
- revise the tool;
- compare the revision to the findings of the second, third or more incidents; and
- repeat this process as often as needed.

For each domain, the Eindhoven Classification Model presented in paragraph 2.4.2 will serve as the initial classification tool. However, instead of changing the ECM after every single incident, as indicated above, a set of 15 incidents is used for the first revision, followed by sets of 5 incidents. Since the classification tool is expected to cover all organisational problems, at least a variety of incidents from different departments or disciplines needs to be included in this study to increase the likelihood of complying to this criterion after the first revision. It is unlikely that one incident will highlight all organisational problems. The revision process is therefore started with a set of 15 incidents, which is enough to collect at least one or two incidents from each department involved. The additional sets of five incidents are needed to check if all types of organisational problems are indeed discovered. For each case study, the revision process is continued until new incidents do not lead to new insights and changes to the classification model. The results of the first case study will be used as the starting point (i.e. initial tool) for the second case study, and so forth. For every new domain this process is repeated, since domain specific classification tools are the objective of the empirical path.

For the development of the taxonomy the same approach as described for the development of the tools is followed, however, with the theoretical framework presented in paragraph 2.2.5 as the initial taxonomy. Since the development of the taxonomy takes place after all case studies have been carried out, a stop rule as presented above is not necessary. Every incident is considered individually and the development process is only stopped when all data has been considered.

Since the main objective of this study is to gain insight into the organisational causes of safety related incidents, the incidents to be included in this study will be selected in order to achieve a maximum of variety of the root causes involved with a minimum of incidents. It is not the main goal of this study to gain insight into the relative importance of the individual organisational failure factors, although some preliminary conclusions will be drawn based on the findings of the case studies. This means that recurring incidents, selected at a symptom level, will for the most part be excluded from the data analysis phase. Similar incidents are assumed to be preceded by the same set of root causes, although real evidence to support this assumption is lacking. Therefore, unless there are reasons to assume differently, only two or three incidents with the same symptom will be analysed and included in this study.

2.5 Multiple case studies

For multiple case studies, a replication logic and not a sampling logic should be used. Yin (1994) distinguishes between two types of replication which should be considered carefully when selecting and planning studies. Each case study must be selected so that it either (a) predicts similar results (a *literal replication*) or (b) produces contrasting results but for predictable reasons (a *theoretical replication*).

2.5.1 A theoretical replication logic

The case studies that are carried out for the study described in this thesis were all selected to create a maximum of variety among the cases in order to follow a theoretical replication logic. This does not only apply to the move from industry to the medical domain but also to the choice of each individual case study within the two domains. This decision is made for practical reasons only, since only a limited number of case studies can be carried out. To include a literal replication logic requires a larger number of case studies or less variety. Four case studies in the medical domain were used, as opposed to two for the steel industry, because of the greater diversity of this domain.

2.5.2 Propositions leading to the selection of the cases in the steel industry

For the steel industry two plants have been selected, a coke production plant and a steel production plant. The first case study was carried out in the coke production plant. As described earlier, one goal of the case studies is to transform the Eindhoven Classification Model into a tool that can also be used for classifying organisational root causes in the steel industry. The coke production plant was selected for the first case study because it resembled the chemical process industry, the domain in which the ECM was originally developed.

In short, the coke production plant can be characterised by a continuous and closed production process. The main emphasis of employees is on monitoring and maintaining the system. Apart from the input and output of the system, product handling activities are negligible. The organisational structure can be characterised by a traditional hierarchical structure, in which the three departments (production, maintenance and process control) are clearly separated from each other.

The steel production plant was selected for the second case study, because this plant differs in most characteristics from the coke production plant. The steel production plant can be characterised by an open production process, which operates in batches. Apart from monitoring and maintaining the system, product handling activities make up a considerable part of daily routine. The organisational structure is based on socio-technical design principles. In essence this means that instead of large 'mono-disciplinary' departments (e.g. production and maintenance), small multi-disciplinary and autonomous teams are formed with a maximum of authority to organise the work that is assigned to them.

Based on the known differences between the two plants, propositions about differences in the occurrence of organisational failure factors in each setting can be deduced. In this study, the selection of case studies was strongly determined by these expected differences, since a maximum of variety between the individual case studies was required. The following propositions about the occurrence of organisational failure in both plants are formulated prior to starting the two case studies in the steel industry:

Proposition 1

Due to the open production process and the higher amount of product handling activities in the steel production plant, employees in the steel production plant are more exposed to dangers than employees in the coke production plant. This will inevitably lead to a greater awareness of the risks of the working environment and fewer violations of safety procedures. At an organisational level, this will become visible in a decrease in unwanted group behaviour (culture) in the steel production plant.

Proposition 2

Due to the existence of autonomous teams in the steel production plant, communication problems between (individual) employees from different disciplines will decrease. However, structural co-ordination between teams, at an organisational level, will become more problematic due to teams' autonomy and the increased need for co-ordination. The 'straightforward' hierarchical structure of the coke production plant prevents most of these co-ordination problems.

Proposition 3

Since a maximum of authority is assigned to the teams in the steel production plant, less management involvement will be present, resulting in a lower score on management priorities in the steel production plant.

The propositions about organisational failure in the medical domain in general, and about the case studies in the medical domain specifically, are discussed following the case descriptions of the steel industry in chapter 3. This way, it is possible to relate outcomes of the steel industry cases to expected differences in the medical domain.

The propositions about the steel industry and the medical domain, as well as propositions about the differences between the two domains, are evaluated and discussed in chapter 5. Since propositions and not hypotheses or predictions are stated here, no statistical testing will be included in this study. The propositions are used only to state differences in organisational failure that are expected prior to starting the case studies and have determined the selection of individual case studies.

3 Case studies in the Dutch steel industry

In this chapter, the two case studies that were carried out in the Dutch steel industry are discussed. The two plants involved are both part of the same company but can, given the considerable size and organisational structure of the company, be considered as independent plants. For each case study, a description of the plant investigated, the specific set up of the case study and its results, followed by a discussion is given. Based on the empirical incident data collected in both case studies, a tool for classifying organisational root causes of safety related incidents in the Dutch steel industry is developed. The last section of this chapter will discuss some propositions about the case studies in the medical domain, based on the lessons learned in the steel industry and the known characteristics of the different medical settings involved in this study.

Figure 2.1 at the beginning of chapter 2 shows the continuous evolution and testing process to develop a domain specific classification tool from the Eindhoven Classification Model. The classification tool also provides a complete set of categories for classifying organisational root causes. However, in chapter 3 and 4, in which the case studies are described, this chronology is not followed. Both chapters will start with a description of the domain specific classification tool that was developed, followed by the case descriptions. At the end of each chapter, the development of the domain specific classification tool is justified based on the data collected. This way a logical description and justification of each domain specific tool is provided.

3.1 A classification tool for the steel industry

The case studies in the steel industry resulted in the classification tool shown in figure 3.1. The tool presented in figure 3.1 differs from the Eindhoven Classification Model in two areas. The most important difference is the increased number of classification categories for organisational root causes. A second major difference is the position of these organisational classification categories in relation to the technical and human classification categories. Both differences will be justified in section 3.4.1. Minor changes made to the human categories to facilitate use in the steel industry are also mentioned in section 3.4.1, although this is beyond the real scope of this thesis. The definitions of the organisational categories are presented first.

Transfer of knowledge: refers to failures resulting from inadequate measures taken to ensure that situational or domain specific knowledge or information is transferred to all new or inexperienced staff.

Working procedures: refers to failures related to the quality and availability of the working procedures within the plant (too complicated, inaccurate, unrealistic, absent, poorly presented).

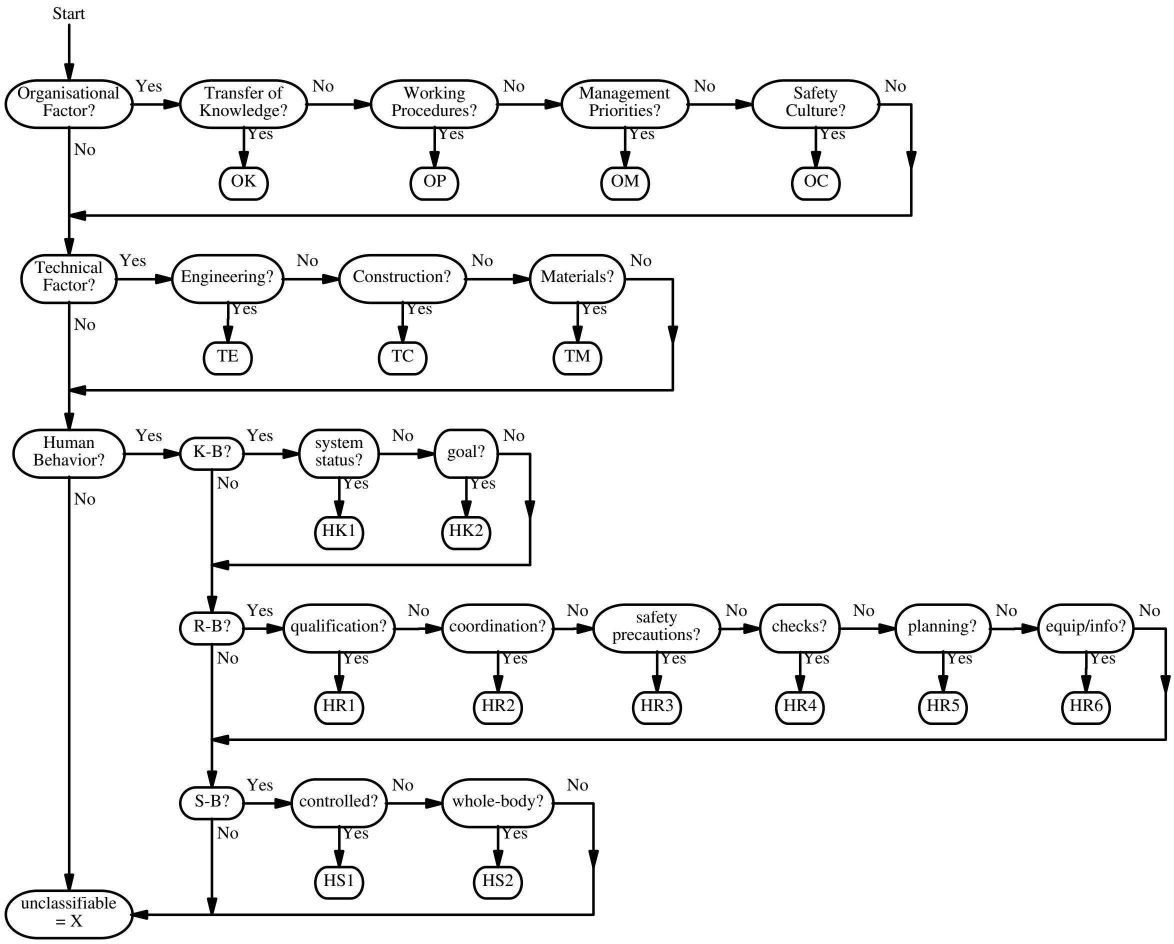


Figure 3.1: The classification tool for the steel industry.

Management priorities: refers to failures resulting from management decisions in which safety is relegated to an inferior position when faced with conflicting demands or objectives.

Safety culture: refers to failures related to collective beliefs and attendant modes of behaviour regarding risks and the importance of safety within the investigated organisation.

3.2 Case 1: Coke producing as part of the steel making process

The first case study in the Dutch steel industry was carried out in a plant that produces coke for the steel making process. The coke production plant is one of the two plants that participated in the SAFER project (Mulder, 1994) aimed at developing and implementing a system for reporting and analysing safety related incidents. The coke production plant is also the plant in which, as part of the SAFER project, a pilot study was carried out to investigate the possibilities of detecting and modelling organisational failure factors (Van Vuuren, 1993). After investigating the possibilities for detecting and modelling organisational failure factors during the pilot study, this first case study was carried out in this plant to start the actual modelling process.

3.2.1 Characterisation of the coke production plant

Coke is a solid substance that remains after gases have been extracted from coal and is primarily used as fuel for blast furnaces. With an annual production of approximately five million tons of pig-iron by the blast furnaces, over two million tons of coke are needed. Over a million tons of coke are produced by the plant that participated in this case study. A second coke production plant within the company produces the other half. Coke production is only part of the plant's job. Gases that are extracted from coal are also purified by the plant to regain valuable and useful substances and to keep air emissions below levels permitted by law.

The coke production plant is an integrated part of the total steel company, but can be considered as an independent plant. For practical reasons, such as the considerable size of the total steel company, only this plant participated in the study. The coke production plant employs about 300 people and has a traditional hierarchical organisational structure as shown in figure 3.2. The organisational structure shows that the employees are subdivided into three groups: production, maintenance and process control, which are discussed briefly.

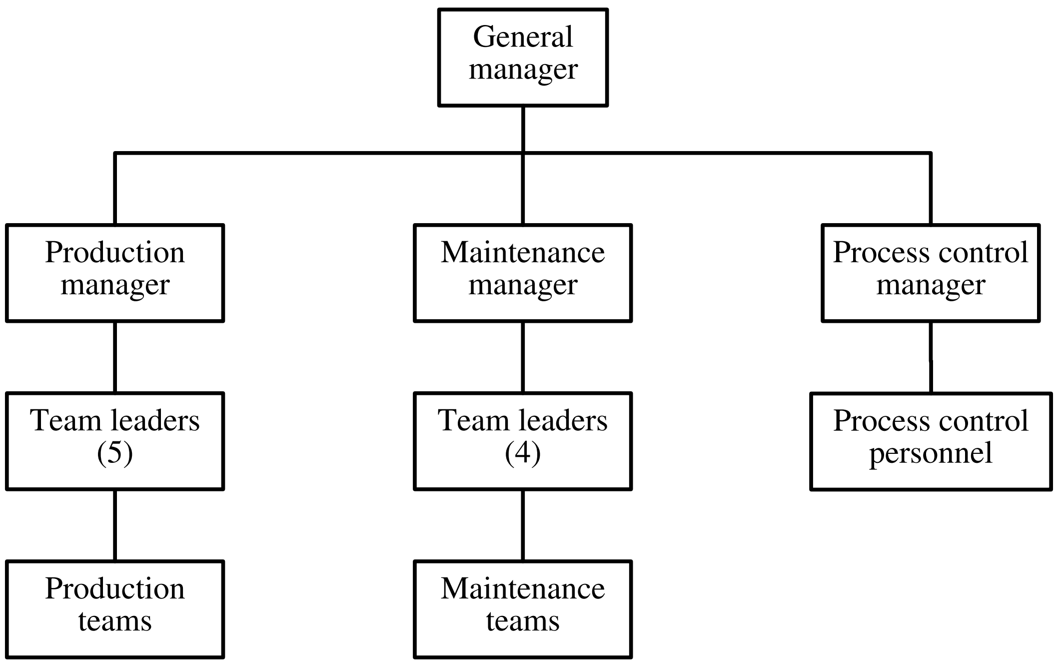


Figure 3.2: Organisational structure of the coke production plant.

Production is responsible for the production of coke. Coke is produced twenty-four hours a day, seven days a week. Coke is produced in ovens, which cannot be turned off, since the differences in temperature will result in enormous damage to the ovens. Since coke producing is a continuous process, production personnel is subdivided in 5 teams each with its own team leader. Within each team two groups exist, one responsible for the coke producing process, the other for purifying the gases extracted from the coal. Based on a shift system, the plant is operated twenty-four hours a day. Producing coke is a closed process, in which the ovens need only to be fed with coal and emptied when the coke is ready. Purifying the gases is also done in a closed process. Apart from filling, emptying the ovens and taking product samples, the majority of the production work consists of monitoring the process. This is done from one large control room at the centre of the plant.
Apart from these five teams, there is one team that is responsible for stoking up the ovens and maintaining the correct temperature. This is done only during the daytime.

The maintenance group is responsible for maintaining the technical state of the plant and solving technical problems with the installations. Maintenance is subdivided into four teams each with its own team leader. Each team has its own set of responsibilities. There are two teams of mechanical engineers. One of these teams is responsible for maintaining the part of the plant related to the ovens. The other team is responsible for the part of the plant related to the purifying of the gases extracted from the coal. The third team consists of electrical engineers, responsible for the electrical side of the entire plant. The fourth team is responsible for the maintenance of the process control instruments. These four teams work only during daytime hours, five days a weeks. Apart from these four teams there is a fifth group of all-round engineers. Based on a shift system, this group covers the same hours as production and is responsible for solving sudden breakdowns of the system. Although officially part of the maintenance department, this group is in practice supervised by the production team leader on duty.

The process control group is the smallest group of the plant. Its duty is to provide technical knowledge of the coke production plant to both production and maintenance and to investigate possibilities for optimising the production process. This is also the main difference between maintenance and process control. Maintenance should keep the plant running, while process control should optimise the system.

3.2.2 Background and set up of the case study

The case study at the coke production plant was part of the plant's attempt to further develop and implement a system for reporting and analysing incidents, building on the initial steps made during the SAFER project. Consequently, the steps undertaken for this case study were combined with guiding and supervising the development and implementation process. A work group of representatives from the three groups discussed earlier and from different levels inside the organisation, was assigned to develop and implement the incident reporting and analysis system. Guidance was particularly necessary to ensure the correct use of the incident analysis techniques as used in PRISMA (critical incident interviews, causal tree analysis and classifying root causes). The following three steps were carried out:

1. Guiding and supervising the process of developing and implementing a system for reporting and analysing safety related incidents.
2. Collecting empirical incident data following the PRISMA-techniques, which include:
   - critical incident interviews, following reported incidents;
   - causal tree analysis of the collected information;
   - classifying the root causes.
3. Feedback to management of the coke production plant about its organisational strengths and weaknesses and possibilities for improvement.

Weekly meetings with the work group were organised to evaluate progress made and to discuss the incidents that were collected to date. The final representation of each incident in a causal tree and the final classifications of its root causes were decided on during these work group meetings. Where possible, work group members were invited to participate in the data collection phase (step 2) and asked to perform a PRISMA analysis. During work group meetings, the completeness (e.g. are all root causes included?) and quality of the analysis (e.g. correct representation in a causal tree and correct classification of the root causes) was discussed to stimulate a learning process. Apart from being complete, the quality of causal trees is also determined by their logical accuracy. This means that causes preceding a higher level cause should have indeed contributed to that higher level cause and that all contributing causes preceding a higher level cause should be included in the causal tree. By checking this logic of causal trees, mistakes and lapses can easily be detected. Guidance was necessary to pinpoint these mistakes or lapses and by doing this to improve the quality of the causal trees and stimulate the learning process regarding how to build causal trees. Insights generated by the learning process of the work group that are relevant to this study are discussed in paragraph 3.2.4.

To achieve a maximum of variety, recurring incidents, selected at a symptom level, have for the most part been excluded from the data collection phase. In this study, similar incidents are assumed to be preceded by the same set of root causes. The main objective of this study is to gain insight into the types of organisational failure factors that cause incidents, and not to gain insight into the relative importance of the organisational failure factors. Therefore, only a limited number (two or three) of incidents with the same symptom have been included in this study.

3.2.3 Results

The case study in the coke production plant resulted in 52 incident descriptions of recent incidents, containing 317 classified root causes, giving an average of 6.1 root causes per incident. The root causes are classified using the classification tool for the steel industry. When the root causes are distributed over the main categories, i.e. technical, organisational, human and unclassifiable, this results in the distribution shown in table 3.1.

	Organisational	*Technical*	*Human*	*Unclassifiable*	*Total*
# root causes	111	67	126	13	317
Percentage	35%	21%	40%	4%	100%

Table 3.1: Distribution of root causes over main categories.

Table 3.1 shows that no less than 35% of the 317 root causes are organisational. The remaining 65% of the root causes are divided over technical root causes (21%), human root causes (40%) and unclassifiable root causes (4%). Contrary to the traditional focus on human and/or technical failure, as discussed in chapter 1, this distribution clearly shows the impact of organisational failure on incident causation in this plant. Figure 3.3 shows the distribution of the root causes over the categories of the classification tool for the steel industry.

The organisational failure factors are discussed in detail in this section. The technical, human and unclassifiable contribution are only discussed briefly, since they are beyond the scope of this study.

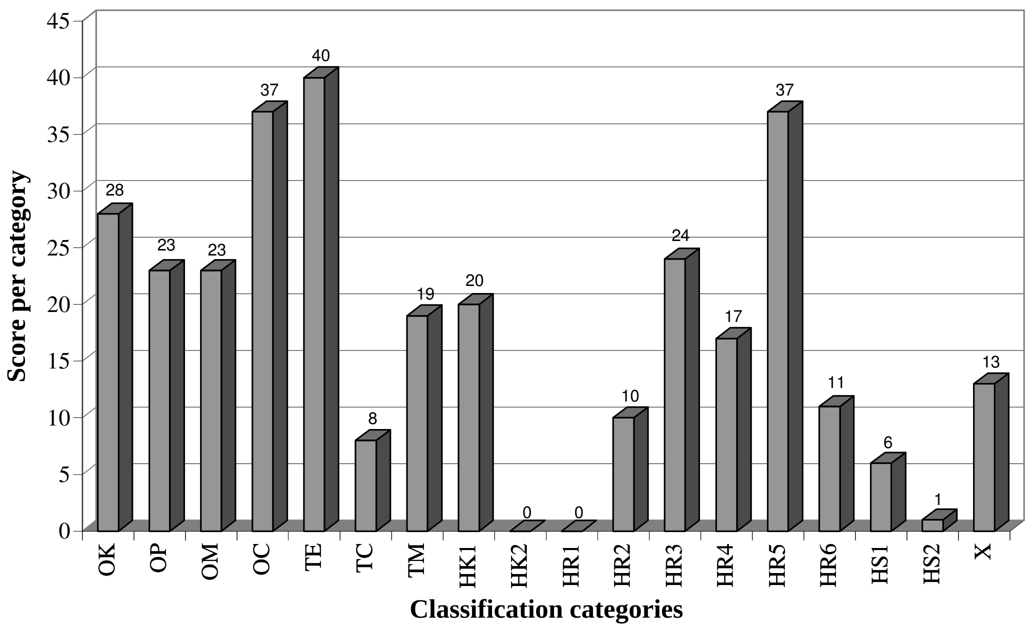


Figure 3.3: Distribution of root causes in the coke production plant (n = 317).

Organisational failure factors

Figure 3.3 shows the distribution of the 111 organisational root causes over the four organisational categories of the classification tool. This distribution shows that, apart from the somewhat higher total on organisational culture, the organisational root causes are equally divided over the four organisational categories. The 111 root causes represent 35% of the root causes detected, suggesting that all categories deserve attention by management and provide opportunities for improvement. For each organisational category, both the existing problems and the opportunities for improvement are discussed. This is done in order of importance for this specific situation.

The biggest category of the organisational root causes (37) is related to the prevailing safety culture(s) of the coke production plant. Frequently, enormous risks are deliberately taken simply to gain a few minutes. In these situations one is aware that safety precautions are violated, however, performing the job this way has become accepted by a group of employees and unfortunately, in many cases, also by their team leader. These collective beliefs about risks and the importance of following the safety rules are often explained by saying that “nothing ever happened” or “I know what I am doing”. Apparently an objective eye is needed to see that these statements are invalid.
Completely different but related to the safety culture of the coke production plant, is a recurring lack of action by management to known, mostly technical, problems, resulting in unnecessary incidents. This lack of action may be attributed to failing communication inside the organisation (the right person does not know about it), however, there also appears to be an unwillingness by management to learn from their own safety practice (the person responsible does not want to know about it).
It is up to the management of the coke production plant to try to take away the ‘blindness’ of both employees on the shop floor and management, and to make everyone realise the dangers they are exposed to daily. Implementing a system for reporting and analysing accidents, and in particular the abundantly available near misses, can be useful.

Secondly, 28 root causes are related to a lack of situational skills and knowledge, necessary to perform one’s job in a safe way. Every working environment has its own characteristics, rules and most important, dangers that one needs to be aware of in order to avoid dangerous situations. Problems related to this lack of knowledge occur with new employees who, after a brief period in which they are closely supervised, have to gain situational skills and knowledge on the job. Consequently and unfortunately, knowledge is gained ‘the hard way’ by making mistakes first.
To reduce the likelihood of incidents related to a lack of situational skills and knowledge, the organisation should invest in developing and implementing proper training programmes for new employees. Unfortunately, this often conflicts with short-term management priorities to spend the least possible time on training and to enter the actual production process as fast as possible.

In total 23 root causes are related to the quality and availability of working procedures. In some cases working procedures do exist, however, they are ill-adapted for use. According to these procedures a large number of activities have to be carried out (mostly safety precautions) of which many are generally considered to be unnecessary. Consequently, this perception results in staff not following the procedures at all. This clearly indicates that an overuse of rules outlined in procedures results in a situation where procedures are ignored. Proper procedures invite use. In the remaining cases procedures are lacking in situations that need guidance. Even though it might not be possible or desirable to proceduralise every task in detail, it is often possible to at least provide a 'best practice' that can be used as a guide in situations of doubt. Both the quality of existing procedures and the need for new ones need to be reviewed regularly.

A total of 23 root causes are classified as management priorities. All these root causes are related to conflicting situations where production prevails over safety by top- or middle management. In particular production and maintenance plans often conflict. To keep production at the required level, safety appears to be subordinated by management in situations where following safety procedures will negatively influence production. This clearly shows the danger of conflicting situations and the importance of a clear safety policy. Although aware of the importance of safe practice, management repeatedly refrains from acting accordingly.

Technical, human and unclassifiable failure factors

In figure 3.3 it is shown that 67 of the root causes are technical. The majority of these technical root causes (40) are related to the engineering or design of the coke production plant. Repeatedly, situations are encountered where the design of the plant does not fit the physical capabilities or properties of the employees, or is dangerous in itself. Valves are located out of reach, lighting is missing in places that have to be entered regularly and safety provisions are missing where needed most. These and many other situations result in hazardous attempts to cope with these limitations.

Of the 126 root causes that are classified as human, almost 50% are classified as either HR3, not taking the required safety precautions, or HR5, incorrect planning and execution of work. Classifying these causes as human error means that the person knows how work should be done correctly. However, for personal reasons (i.e. haste, overconfidence, etc.) it was decided not to follow the correct and accepted way of doing things.

A small proportion of the root causes (4%) appear to be unclassifiable with the given classification tool. Examples include: uncontrollable weather influences and private problems of an employee influencing his work.

3.2.4 Discussion

This first case study in the steel industry resulted in a large number of incidents, containing a large number of organisational root causes. Given the stop rule for the case studies outlined in paragraph 2.4.3, the case study could have been ended earlier. Replication of the different organisational failure types involved in this case study was found after 30 incidents. The case study was continued for two reasons. The first 30 incidents were collected in the pilot phase of the development and implementation process. For this pilot phase, only the maintenance department and one of the five production teams participated. The remaining incidents were collected when the other teams and the process control department were included. This, however, did not lead to any additional organisational failure types. In the second place, the process of guiding and supervising the development and implementation process provided valuable insights into how organisational failure is perceived by the work group members. The case study was continued after having collected 30 incidents to fully benefit from this learning experience.

During the work group meetings it became clear that the work group members had problems recognising organisational failure factors. Causal trees made by work group members mainly consisted of technical and human root causes. However, after discussing these incidents with the work group and following additional interviews conducted by the work group members, organisational failures were also detected. During the case study, a learning process was clearly noticeable.
As indicated in chapter 1, many companies are not used to investigating problems related to the organisation. In chapter 1 it was also shown that a superficial incident analysis is likely to be the main cause of this problem. In the coke production plant people were not used to analysing incidents in a structured and in-depth way. This problem was clearly represented in the problems work group members had building causal trees. Instead of using the causal tree technique to discover the root causes of the incidents, causal trees were used to display their private, mostly technical or human failure oriented, opinion of the causes of the incident. In this way the causal tree is not used as a means but as a goal in itself. Because of this unfamiliarity with in-depth incident analysis and the existing bias towards technical and human failure, mostly superficial incident analyses were produced by the work group members. Lucas (1991) listed the following five central problems with incident data collection systems:

1. *Technical myopia*: most approaches are oriented towards hardware failure.
2. *Action oriented*: there is often a strong tendency to focus on what happened rather than why the problem occurred. Data is often collated into classes based on the nature of the incident and/or the severity of the consequences.
3. *Event focused*: systems are usually restricted (in practice if not in theory) to looking at individual accidents rather than looking for more general patterns of causes.
4. *Consequence driven*: incidents with serious consequences are recorded and investigated, near misses and potential problems are often not perceived as necessary or worthy of analysis.

5. *Variable in quality*: reports vary considerably in the quality of description of the facts and in any attempted investigation of underlying causes.

Problem 1,2 and 5 appear to be equally true when identifying organisational failure factors in the coke production plant. Technical and human failure are the primary focus of investigation. Incident analyses are symptom oriented, meaning the focus is on what happened instead of why, and a structural and systematic method for reporting and analysing incidents is lacking in the coke production plant. This makes the eventual quality of the analysis highly dependent on the investigating and analytical capacities of the investigator. These three problems contribute to the problem of recognising organisational failure factors. Problem 3 and 4 are not related to recognising organisational failure factors.

An influencing factor that is not mentioned by Lucas but which was noticed in the coke production plant is the anticipated result of reporting a certain type of problem. During the confidential interviews the comment "there is no use in reporting these kinds of problems" was regularly noted and in particular related to organisational problems. So, if confidence in improvements at an organisational level is lacking, organisational problems are likely to be underreported. This means that incidents, apart from the recurrent incidents that are excluded by the researcher, are also 'screened' by the employees themselves. During the case study, the employees involved were strongly encouraged not to perform this private screening and report all known incidents, in order not to influence the outcomes of this study. In this way, bias (i.e. not reporting particular organisational problems) as a result of the screening by the employees was prevented.

3.3 Case 2: The steel production plant

The plant that participated in the first case study is situated at the beginning or preparation phase of the steel making process. The coke produced in the coke production plant is used as fuel for the blast furnaces, which produce pig-iron. In the plant that participated in the second case study, the pig-iron from the blast furnaces is transformed into steel. Together with the blast furnaces, this plant can therefore be considered the heart of the steel making process. The plants that are next in line in the steel making process all involve activities to transform steel into end-products for the customer.

3.3.1 Characterisation of the steel production plant

The main goal of the steel production plant is to transform pig-iron from the blast furnaces into different qualities of steel. The quality of steel is mainly determined by the percentage of carbon that is present in the steel. When all goes well, the lower the

percentage of carbon, the higher the quality of steel. In order to remove carbon from the pig-iron, oxygen is blown into a bath of liquid pig-iron, which results in burning most of the carbon and other unwanted elements. To regulate the temperature of this process, carefully selected scrap iron is added to the bath. Apart from scrap iron, a variety of supplements are added to achieve the required quality of steel.
Once the steel has reached the required quality, the liquid steel is poured into a mould. The finished product of this casting process is then cut into steel bars, approximately 20 meters long, which are either used as input for other plants in the steel company or sold directly to other companies.

The steel production plant employs approximately 1000 people. About 75% work on a shift system, to operate the plant twenty-four hours a day, seven days a week. The remaining 25% work during the daytime only and include management and support staff.
The steel production plant is subdivided in seven sections, which represent the seven phases of the steel production process. A detailed discussion of these seven sections is beyond the scope of this case study, since only the section responsible for the casting process participated in the case study. This section complies with the characteristics described in paragraph 2.5.2 and is also the section that participated in the SAFER project.

The casting section employs approximately 300 people. Similar to the coke production plant, the employees of the casting section are, apart from management and support staff, subdivided in three groups: production, maintenance and a group called QTD (Quality, Technology and Development). The somewhat simplified organisational structure, presented in figure 3.4, looks similar to the one of the coke production plant. However, there are some interesting differences.
The casting section consists of two casting installations. Each production team consists of 15 people assigned to only one installation. Together with the five teams that are

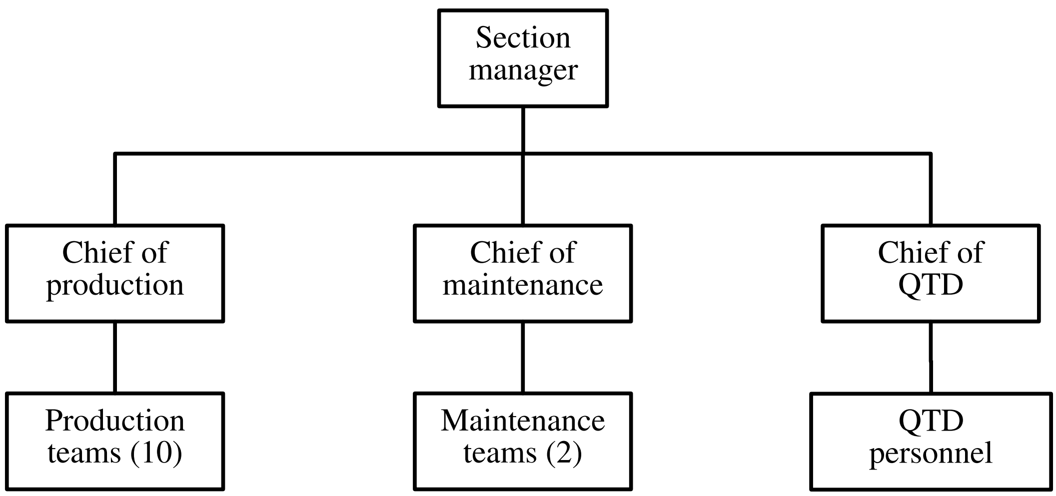


Figure 3.4: Organisational structure of the steel production plant.

needed to produce steel on a continuous basis, this makes up ten production teams. The most important difference between the production teams in the casting section and the coke production plant is that technical personnel is integrated into the production teams. Each production team has a number of mechanical and electrical engineers, who are responsible for dealing with breakdowns in the installation. This way, the production teams of the steel production plant depend less on the services provided by the maintenance group than the production teams of the coke production plant. Another important difference is that the team leader is completely integrated in the production team and a maximum of authority to organise their work is assigned to each team. Production in the steel production plant is organised with one less hierarchical layer, consists of multi-disciplinary teams with a maximum of authority assigned to the team, of which the team leader is only a part.
The production teams are responsible for producing steel bars according to customer specifications (inside or outside the steel company). Apart from monitoring and maintaining the system, this involves a large number of product handling activities on the input and output side of the system, including activities related to adapting the system to the specifications of the steel bars to be produced.

Since breakdowns of the installation are dealt with within the production teams, the maintenance group can focus primarily on structural maintenance and improvement of the technical status of the casting installations. This is done by two teams of approximately 60 people during the daytime only.

The QTD group is, similar to the process control group in the coke production plant, responsible for optimising the production process. The QTD groups consist of approximately 20 people and work only during the daytime.

3.3.2 Background and set up of the case study

The section has an incident reporting system up and running, because of its involvement in the SAFER project. However, unlike the coke production plant, the analysis of reported incidents is not carried out by members of a special work group but by a team that is created for the analysis of one particular incident only. Such a team consists of employees from both the shop floor and management, who have relevant knowledge about the circumstances in which the incident occurred. The SAFER system as a whole is co-ordinated by one person, who can also be consulted in case of difficulties during the analysis process and who manages and analyses the incident database. The advantage of this system is that over a few years a large amount of employees have been involved in one or more incident analysis teams, which provides them with valuable insight into incident causation. By organising the incident analysis process this way, it is hoped that the increased insight into incident causation will result in a positive change in the safety attitude of employees. A disadvantage of this system is that in the implementation phase of the system it requires a considerable effort to train every employee in the basic techniques used in incident analysis. In the coke production plant, only the work group had to be trained. More importantly for this study, since this study is not focusing on the implementation process of an incident reporting system, the approach followed in the steel production plant results in analyses of a lower quality than in the coke production plant (i.e. tree logically incorrect and superficial analysis of the incident). This is because the average employee is only occasionally involved in an incident analysis team and therefore does not get enough opportunity to become experienced in incident analysis and to further develop the necessary incident analysis skills.

The following set up for the case study was therefore followed:

1. Where possible, team meetings about recent incidents were attended to ensure the required depth of analysis for this study.
2. If team meetings could not be followed, the analysis was based on the analysis of the team and an additional interview with the co-ordinator of the SAFER system, who was familiar with the incidents involved.
3. After finalising the case study, feedback was provided to management about the organisational strengths and weaknesses and possibilities for improvement.

The most preferable option was to attend team meetings about recent incidents, because during these meetings the employees that were actually involved in the incident were interviewed by the incident investigation team. Therefore, first hand information about the incident could be collected. The incident investigation teams were provided with a guideline and checklist which needed to be used to perform the incident analysis. However, this guideline and checklist were restricting the scope of the analysis by fully structuring the analysis phase and by providing only a limited set of possible causes and root causes. Therefore, during the team meetings that were attended, guidance was provided to look beyond the restrictions and limitations of the checklist in order to perform a complete in-depth analysis of the incident.
Unfortunately, most additional interviews had to be conducted with the co-ordinator of the SAFER system, since the time that employees were supposed to spend on the analysis of the incidents was limited by management to the official team meetings. Together with the co-ordinator of the SAFER system, the final representation of each incident in a causal tree was agreed on as well as the classifications of the root causes. All incidents were analysed according to the PRISMA methodology.

3.3.3 Results

The case study in the steel production plant resulted in 26 incident descriptions of recent incidents, containing 181 root causes, giving an average of 6.9 root causes per incident. When the root causes are distributed over the main categories of the classification tool, the distribution shown in table 3.2 results.

	Organisational	*Technical*	*Human*	*Unclassifiable*	*Total*
# root causes	73	46	57	5	181
Percentage	40%	25%	32%	3%	100%

Table 3.2: Distribution of root causes over main categories.

Table 3.2 shows that 40% of the root causes are classified as organisational, which means that for this situation, organisational failure is the main contributor to incident causation. The remaining 60% of the root causes are divided over technical root causes (25%), human root causes (32%) and unclassifiable root causes (3%). Figure 3.5 shows the distribution of the root causes over the categories of the classification tool for the steel industry.

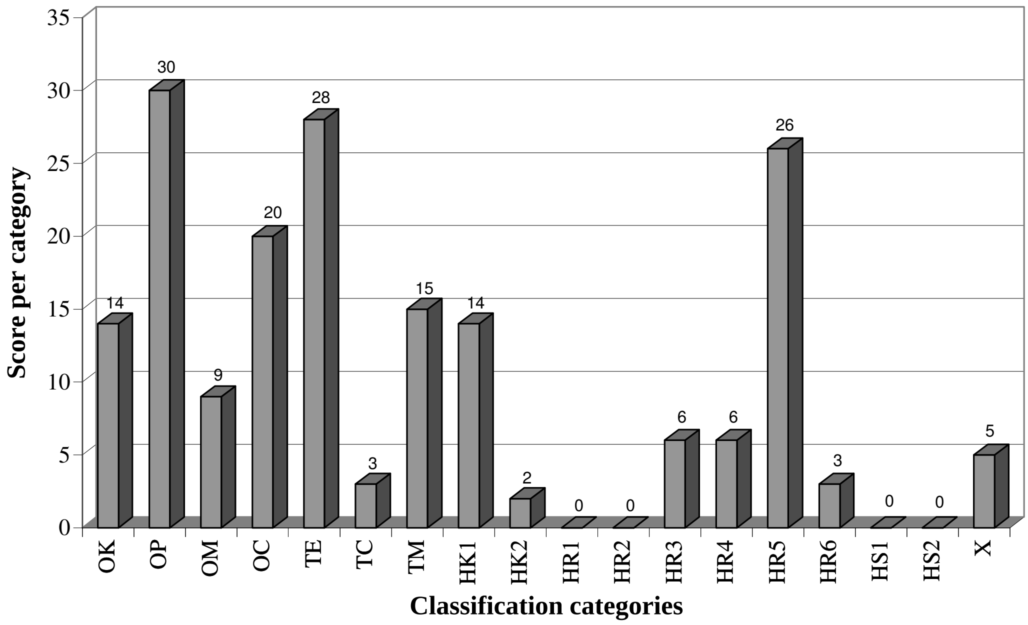


Figure 3.5: Distribution of root causes in the steel production plant (n = 181).

Organisational failure factors

Figure 3.5 shows the distribution of the 73 organisational root causes over the four organisational categories of the classification tool. Contrary to the coke production plant, the organisational failure factors are not equally distributed over the four categories. Two peaks (OP and OC) can be detected, which indicate two important areas for improvement. Both the peaks and the two other organisational categories will be discussed

A total of 30 root causes are classified as OP, which indicates problems with the quality and availability of working procedures. The 30 root causes are equally divided over problems with the availability, correctness and (over-) completeness of the working procedures. Working procedures were missing in situations where needed and regularly available working procedures appear to be incorrect or ill-adapted for use, incomplete or cumbersome. No problems were detected with the way the procedures are presented. The result of these three problems is often similar: confusion and uncertainty leading to incorrect execution of the task at hand or to an incomplete execution. Often this results in management blaming the employee or attempts to motivate employees to follow the working procedures correctly, while in fact the employees have done the best they possibly can given the circumstances. The only correct action is to continuously review both the availability and quality of the working procedures and update and adapt the procedures where needed.

The problems related to the safety culture of the steel production plant are also similar to the coke production plant. Often enormous risks are taken simply to gain some time. Specifically, reporting oneself before starting a job or isolating the system is regularly 'forgotten'. People are aware that in doing this safety rules and precautions are violated, however, the behaviour has become accepted by the group and risks are perceived to be negligible. Both overestimating ones skills, knowledge and experience and underestimating the risks involved, result in the risks that are taken. The organisation has to invest in systems to take away these incorrect perceptions of the risks that are encountered daily.

The vast majority of the knowledge and experience related problems occurred with new personnel. Both the combination of learning on the job and limited supervision while learning, regularly led to incorrect decisions or underestimating the risks at hand. In a few cases errors were made by fully qualified personnel through unfamiliarity with certain features of the system that were rarely used. Although training new personnel is time consuming and may interfere with production, in this plant the need for training was clearly demonstrated.

A total of 9 root causes are related to priorities of management, which resulted in dangerous situations. Again these management decisions are aimed at maintaining the required production level. In situations of a planned or unplanned turnaround the time available to check and carry out maintenance jobs is also limited to an absolute minimum to limit the loss of production time. The incidents show that this results in mistakes and checks not being carried out at all, with negative consequences occurring later.

Technical, human and unclassifiable failure factors

The majority of the technical factors in this case study are related to the engineering of the steel production plant. Due to these engineering failures, working safely is hindered or incorrect expectations about the system status are provoked. Examples are installation parts that are out of reach, a lack of possibilities to secure the installation and lacking possibilities to determine the status of the system. All of these problems require changes in the engineering and design of the system.

A total of 26 of the 57 human root causes are classified as HR5 (planning), which refers to incorrect planning and execution of the job to be performed. The individual knows how the job should be performed correctly and safely, however, for reasons such as haste, the execution of the wrong procedure in the wrong situation or by simply forgetting a vital step in the action sequence, the job is done otherwise. Given the rule-based character of this type of error, improvement should be accomplished by training the employees in the correct execution of the tasks to be performed.

The five unclassifiable root causes are all situational factors and not really failure factors, which are included to complete the incident descriptions.

3.3.4 Discussion

The incident data was collected in a very efficient way, given the set up chosen for this case study. The incident data was gathered 'from a distance' by interviewing the co-ordinator of the SAFER system, because only in a limited number of incidents could the people directly involved be interviewed. Both the short time span of the case study and the way the incident data was collected resulted in a less detailed view of what was really going on in the steel production plant than in the coke production plant. It is vital to spend a considerable time inside an organisation to gain proper insight into the safety culture of an organisation. Without this insight, it is difficult to correctly distinguish between individual human failure and collective cultural (organisational) failure. Only the opinion of the person interviewed can be used to make this distinction. Unfortunately, these opinions are often biased because of the particular culture in an organisation. It is therefore expected that a set-up similar to the previous case study would have resulted in a higher percentage of cultural factors.
As a result of the set up followed in this case study, less insight into how organisational failure is perceived by the employees was gained than in the coke production plant. Only a limited number of employees have been interviewed during this case study, since most interviews were conducted with the co-ordinator of the SAFER system. Consequently, less insight was also gained into whether or not all known incidents were indeed reported. The existence of a possible screening of incidents, as in the coke production plant, could not be checked given this set up.

As noted earlier, in the steel production plant the SAFER system was implemented with a different goal than in the coke production plant. In the coke production plant the system is now used as a management tool to monitor the organisation's strengths and weaknesses and to generate the best suitable countermeasures to improve the organisation's safety performance. In the steel production plant, SAFER is used to improve safety awareness by employees by involving the employees in the incident analysis process. Through this involvement, insight into incident causation is created, which is intended to lead to a positive change in the existing safety culture. It is therefore used as a tool to change the safety culture. Both are valid purposes to implement a system such as SAFER, however, conflict in many ways. It is therefore not advisable to pursue both goals at the same time.

When SAFER is used as a management tool only a small work group needs to be trained. Since this small work group is responsible for all the incident analyses, experience is gained quickly by the work group members, resulting in high quality incident analyses (i.e. in-depth analysis, logically correct, correct classifications). This quality information is needed for management to make well-informed decisions. The price to pay includes lower involvement of the employees that are not part of the work group. Since they are only expected to provide input to the system and are only given outcomes of the incident analyses, little insight is gained into incident causation.

When SAFER is used as a 'culture tool', every employee needs to be trained to be able to participate in an incident investigation. The employees involved in these incident investigations gain valuable insight into incident causation. This positively influences the behaviour of these employees, since it provides insight into the possible consequences of small deviations. The prices to pay however, include extensive training and a lower quality of incident analysis, given the limited experience in performing incident analysis. Management decisions based on this data should therefore be taken cautiously.

This discussion is not intended to imply that one approach is preferred over the other. However, it is necessary to consider the desired goal before implementing SAFER, since this will influence both the implementation strategy and the outcomes of the system. Pursuing both goals at the same time will definitely lead to sub-optimal results.

3.4 Lessons from industry

The lessons learned from the steel industry can now be summarised. The case studies provided valuable insight into both the domain's organisational strengths and weaknesses, which are discussed in this section. First the classification tool for the steel industry that is presented in section 3.1 and used for the case descriptions is discussed.

3.4.1 A classification tool for the steel industry

As outlined in chapter 2, the Eindhoven Classification Model of system failure is used as a starting point for the development of the domain specific classification tools. For the selection and definition of the organisational categories for the classification tool for the steel industry, the following four criteria are used:

- The classification tool must be able to classify all organisational root causes. The tool must therefore be *exhaustive*.
- Each organisational category must be unique, so that every organisational root cause can be classified according to one category only. Therefore, no *overlap* in categories is allowed in the tool.
- Every organisational category must lead to its own distinct set of *countermeasures*. If different categories lead to the same set of countermeasures, they can and should be combined to simplify the tool.
- The classification tool should strive for a minimum number of categories and each category should be easy to understand to maximise the *usability* of the tool.

The Eindhoven Classification Model already contains two categories for classifying organisational root causes. These two categories 'operating procedures' and 'management priorities' have clearly shown their value in both case studies in the steel industry and are therefore also incorporated in the new classification tool. The term 'operating procedures' is changed to 'working procedures' to give a more general and more accurate characterisation of the procedures that are referred to by this category. Not only procedures related to operating the technical systems involved but also procedures for maintaining and managing these systems correctly and safely are included.

The case study in the coke production plant resulted in adding the categories 'transfer of knowledge' and 'safety culture' to the two existing categories. Providing working procedures alone is not sufficient to guarantee safe day-to-day performance of the work. Only part of the work can and should be written down as rules. The rest should rely on the existing skills, knowledge and experience of the people employed by the organisation. This involves general knowledge about a certain area of expertise, applicable in different settings and different domains, but even more important, situational skills and knowledge (including knowledge of the existing working procedures) that are only needed for the particular setting the employee is working in. It is up to the organisation to train new employees in the skills needed and to provide the (situational) knowledge that is needed to carry out work safely. During the case study in the coke production plant it became clear that the organisation was relying heavily on working procedures and that the importance of transfer of skills and knowledge was underestimated. An employee should be allowed to enter the shop floor on its own only based on a complementary and comprehensive set of working procedures and available skills, knowledge and experience.

An additional organisational category was needed to manage cultural factors influencing the way work is carried out on the shop floor. To ascribe deviations from expected and prescribed behaviour to human failure only is unfortunately common practice. It is however, too simple and far from effective. The existing safety culture of a group also influences the collective beliefs about how to perceive and deal with the risks at work. These collective beliefs about how tasks should be carried out and what is acceptable or not appeared to strongly influence work in the coke production plant and also resulted in the greatest contribution to organisational failure factors. Therefore, the category 'safety culture' was added to the classification tool to cover failures related to collective behaviour as opposed to failures related to individual behaviour, which are covered by the human classification categories.

Although less dominant, the two new categories also clearly showed their use during the case study in the steel production plant, as well as the two original categories of the Eindhoven Classification Model. The incident data in the steel production plant indicated a possible need for a category specifically aimed at co-ordination problems between teams, departments or even suppliers and contractors. However, since these problems were not encountered in the coke production plant and given the small number of root causes (6) that could have been classified according to this category, it was decided not to add this category. The classification tool strives for a minimum number of categories and these co-ordination problems can be easily combined with procedural problems.

The position of the organisational categories in relation to human and technical failure has been changed, as well as adding two new organisational classification categories. The original Eindhoven Classification model starts with technical failure, followed by organisational failure and finally human failure is considered. This order is chosen to consider the less visible technical and organisational failure factors first and not start and stop the analysis at the level of the end-user and leave the technical and organisational context unquestioned. The causal trees of the incidents collected in both case studies clearly show that organisational failure factors are the least visible contributor to incident causation. This is related to the position in the causal tree. Human failure in particular and technical failure appear high in the causal tree, close to the actual incident. Organisational failure on the other hand is always found at the bottom of the causal tree and is never directly connected to the actual incident (the top of the causal tree). Organisational failures are never preceded by human or technical failure and always followed by one or more technical and/or human failure before resulting in an incident. This, of course, is not surprising given the latent nature of organisational failure. Since organisational failure is always found at the beginning of incident causation, it should also be considered at the beginning of each incident investigation. Only when an organisational failure is ruled out, should technical or human failure be considered as a possible classification of a root cause.

The order in which the organisational categories are placed in the classification tool is based on the increasing time and effort needed to achieve safety improvements. The first obligation of an organisation is to ensure that the required level of skills and knowledge necessary for its employees to carry out their job safely is available. This can be done by selecting qualified people but also involves in-house training. Second, an organisation has to provide working procedures for situations in which these skills and knowledge alone cannot be relied on. Once the employees are 'equipped' with the right set of skills, knowledge and working procedures, improvement can be achieved by creating a safe (organisational) environment to work in. This includes the priorities of management, and more difficult to change, the existing safety culture of the group the employee is working in.

At the human level a small modification of the tool has taken place to facilitate use in the steel industry. At a rule-based level the Eindhoven Classification Model included the categories 'license' and 'permit'. For the steel industry these two categories have been combined in a category called 'qualification'. The distinction between a license and a permit is far less common in the steel industry than it is in the chemical process industry. For the steel industry a category called 'safety precautions' is added, to deal specifically with failures as a result of not taking the necessary safety precautions.

3.4.2 Organisational strengths and weaknesses of the steel industry

Looking back on the case studies in the steel industry, some preliminary conclusions can be drawn about the organisational strengths and weaknesses of this domain. In general, organisational failure appears to be a main contributor to incident causation. For both cases, 35 and 40 percent of the root causes respectively are classified as organisational. Although some differences exist in how the organisational root causes are distributed over the four classification categories, all categories contribute significantly to incident causation in each setting and therefore improvements can and should be made on all categories. An exception can be made for the steel production plant, where only 12% of the root causes can be attributed to management priorities (against 21% in the coke production plant). This low total on management priorities in the steel production plant can be explained by the socio-technical design of the organisational structure. By assigning a maximum of authority to the teams, less management involvement will take place, resulting in fewer problems related to adverse management priorities.

When looking back on the configurations by Mintzberg (1983) discussed in chapter 2, it can be concluded that both settings in the steel industry rely heavily on a standardisation of work processes as a co-ordinating mechanism. The moderate level of skills and knowledge of the employees in both plants is compensated for by a great amount of working procedures used to organise work. Mintzberg's machine organisation therefore characterises both plants well.

3.5 Propositions about the medical domain

This chapter concludes with a brief preview of the case studies in the medical domain. Insight has been gained into the organisational factors leading to incidents in the steel industry and its organisational strengths and weaknesses. Propositions can now be formulated about differences with and within the medical domain. These propositions strongly determined the selection of the individual case studies and the move to the medical domain in the first place. For the medical domain four departments were selected, an accident & emergency department, an anaesthesia department, an intensive care unit and an institution for the care of the mentally handicapped.

The first case study in the medical domain was carried out in an accident & emergency (A&E) department, the second in an anaesthesia department. The A&E department can be characterised by its highly fluctuating, unpredictable and non-technical working conditions. It is mainly run by junior doctors. The anaesthesia department can be characterised by its well-planned and highly technical working conditions and is mainly run by experienced anaesthetists.

An intensive care unit (ICU) can be characterised by its complex patient management environment. The clinical skills of the care-providers are supplemented by sophisticated monitoring devices, life support systems and multiple drug administrations. Together with the critical condition of the patients visiting the ICU, this results in a high-risk environment, where minor changes in the condition of the patient or minor mishaps during treatment can lead to serious consequences for the patient. Another characteristic is that, although the medical strategy to be followed for a patient is determined by medical staff, the actual care (e.g. administering drugs) is mostly provided by nursing staff. Nursing staff are therefore a dominant presence in the ICU.

An institution for the care of the mentally handicapped has at least three main characteristics, which makes this field different from the ones discussed earlier. Two of these characteristics deal with the type of patient that is involved. The patients or residents, as they are called in the institution, are mentally handicapped and some also have a physical handicap. This type of institution therefore deals with a specific type of disease. Second, the term resident indicates that the patients live in the institution. Because of their handicap they need permanent care. This leads directly to the third characteristic. The care provided does not focus on curing the resident, which unfortunately is still not possible, but primarily on maintaining and improving the quality of life of the resident. This explains the minimal involvement of medical staff in this type of institution.

Two sets of propositions have been deduced from the existing knowledge about the organisational factors leading to incidents in the Dutch steel industry and the known characteristics of the four medical settings. These propositions are formulated in addition to those formulated in chapter 2. The first set of propositions deals with differences between the two domains. The second set of propositions deals with the occurrence of organisational failure factors within the four different medical settings.

The following propositions are formulated about differences in organisational failure factors between the two domains:

Proposition 4
In industry, routine tasks are performed according to rules and procedures and independent decision-making is frequently discouraged, in particular in a hierarchical environment. In health-care there appears to be a high level of professionalism and self-regulation. Individual self-reliance and decision-making are common, while the use of pre-established procedures in task performance seems to occur predominantly during learning phases. This emphasis on self-regulation, however, decreases the accessibility of knowledge about best practices, leading to more problems related to a lack of knowledge and experience than in the steel industry.

Proposition 5
The organisational structure of hospitals is generally characterised by way of a variety of independent specialist departments united under one roof for expediency. Departments are both financially and organisationally independent of each other while coexisting in a dependent relationship within the hospital. This is expected to lead to a larger number of problems related to communication between departments than in the steel industry.

Proposition 6
The previously described organisational structure of hospitals is also likely to lead to problems related to conflicting priorities, since each department makes decisions according to its own goals, without being able to fully consider the effects this might have on other related departments.

The following propositions are formulated about differences in the occurrence and importance of organisational failure factors between the four medical settings.

Proposition 7
The most important difference between the A&E department and the anaesthesia department involved in this study is the level of experience of the medical staff involved. Since A&E is mainly run by junior doctors, while the anaesthesia department is run by experienced anaesthetists, a larger number of knowledge and experience problems are to be expected in the A&E department.

Proposition 8

The ICU involved in this study differs from both the A&E department and the anaesthesia department in its strong functional relation between medical staff and nursing staff. Although the medical strategy for a patient is determined by medical staff, the actual care (e.g. administering drugs) is mainly provided by nursing staff. As a result of this strong functional relationship a larger number of (internal) communication problems is expected in the ICU than in the previously described departments.

Proposition 9

The institution for the care of the mentally handicapped is unique since it primarily focuses on care for the resident as opposed to trying to cure, which is the primary focus of hospital departments. Since little treatment is provided and residents live in the institution for the rest of their lives, the actual risks are spread over a much larger period of time. Therefore, a decreasing level of alertness is likely to result, which will be expressed in a higher contribution of cultural factors in this setting.

These propositions will also be evaluated, together with the previously stated propositions, in chapter 5.

4 Case studies in the medical domain

As outlined in chapter 2, the move to the medical domain was made primarily for methodological purposes. To broaden the applicability of the taxonomy of the organisational causes of safety related incidents developed in the steel industry, an apparently different domain was needed. For reasons discussed earlier, the medical domain complied with this criterion. In this chapter, the four case studies carried out in the medical domain are described. For each case study, a description of the department investigated, the specific set up of the case study and the results, followed by a discussion will be given. Based on the data collected in these four case studies, a classification tool for the medical domain will be developed. The insight gained into the organisational strengths and weaknesses of the medical domain will also be discussed in this section. The classification tool developed for the medical domain will be presented first. The development of this tool is discussed in section 4.6.1 of this chapter.

4.1 A classification tool for the medical domain

Based on the incident data collected in the four case studies in the medical domain, the Eindhoven Classification Model is changed into the classification tool shown in figure 4.1. The main difference between the tool for the steel industry and the Eindhoven Classification Model is the distinction between internal and external failure factors. A new main category has been added for patient related factors. For the human behaviour categories some modifications have been made to facilitate use in the medical domain. In paragraph 4.6.1 the changes made will be explained in detail. The definitions of the organisational categories are presented first (Van Vuuren *et al.*, 1997).

External:	any failures at an organisational level beyond the control and responsibility of the investigated organisation.
Transfer of Knowledge:	refers to failures resulting from inadequate measures taken to ensure that situational or domain specific knowledge or information is transferred to all new or inexperienced staff.
Protocols:	failures related to the quality and availability of the protocols within the department (too complicated, inaccurate, unrealistic, absent, poorly presented).
Management priorities:	refers to failures resulting from management decisions in which safety is relegated to an inferior position when faced with conflicting demands or objectives.
Culture:	refers to failures related to collective beliefs and attendant modes of behaviour regarding risks and the importance of safety within the investigated organisation.

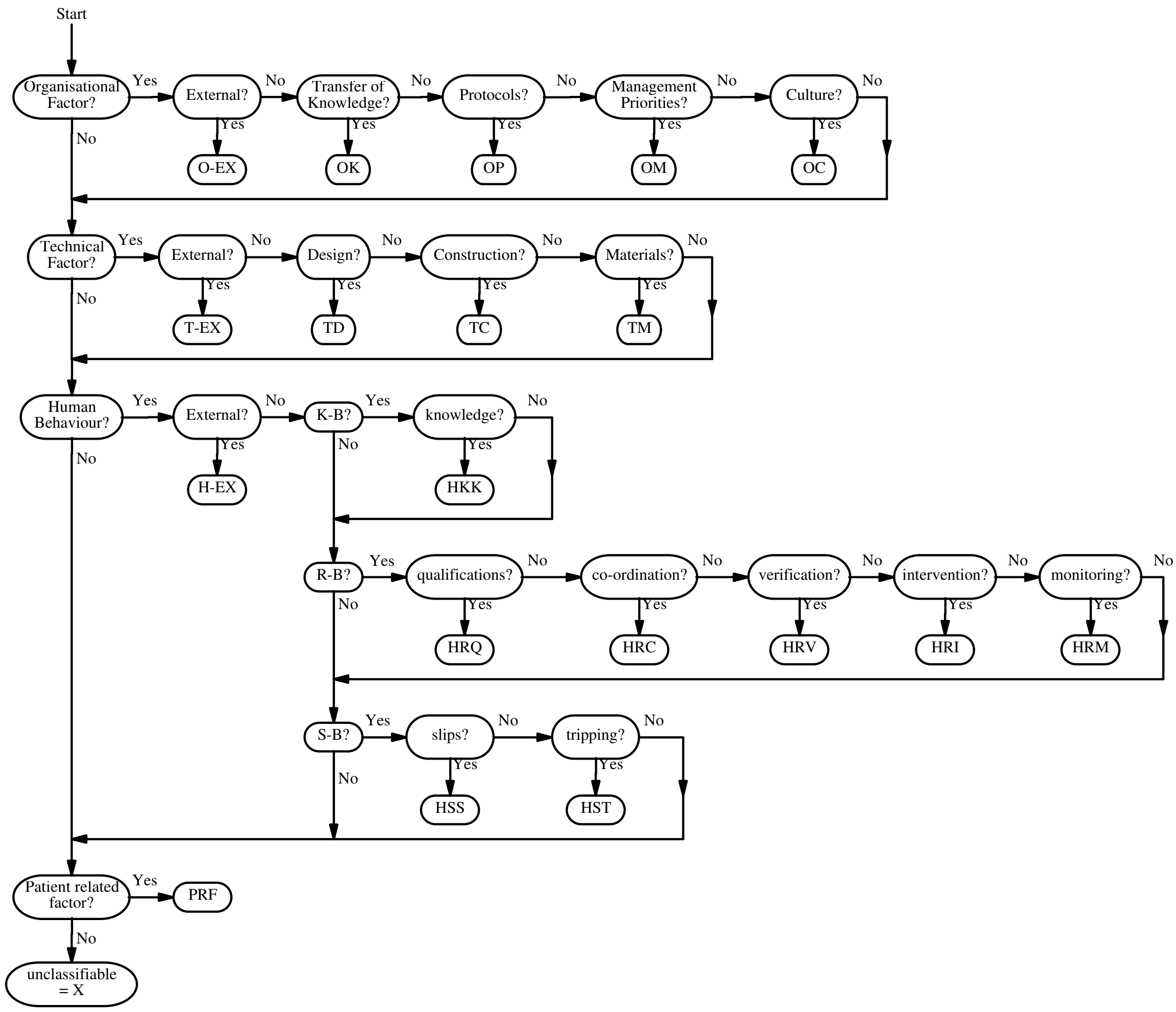


Figure 4.1: The classification tool for the medical domain.

4.2 Case 3: Accident & Emergency

The first case study in the medical domain was carried out over a three month period in the accident & emergency (A&E) department of a large British teaching hospital. The case study was initiated and supported by the School of Education of the University of Manchester as a follow up project to a PhD study (Shea, 1996) that had recently been carried out in two British Accident and Emergency departments. One part of this PhD study involved collecting and analysing incident data to identify problematic work processes in the two A&E departments.

4.2.1 Characterisation of the A&E department

The British A&E department is a relatively new and dynamic area of health care. It was created with the National Health Service in 1947 and was called 'Casualty'. The Casualty department was developed to treat those patients who could not afford a General Practitioner and those who fell through the cracks of the new system.

Essentially it was to be both a treatment and referral service for patients, providing primary care for all. The General Practitioner service was intended to appropriate this function leaving the casualty department to focus on critically ill or injured patients. This situation has yet to be attained. Instead, the importance of the A&E service has increased in relation to a rise in demand for primary critical and minor, non critical accident and emergency treatment (Shea, 1996).

An A&E department serves as a link between the outside world and the hospital and is responsible for providing medical care in case of emergencies. Patients visiting an A&E department may have life-threatening illnesses or injuries necessitating immediate treatment and subsequent admission to hospital, as well as minor illnesses or injuries requiring treatment and rapid discharge. The A&E service is available twenty-four hours a day, seven days a week, and is performed by A&E medical and nursing staff in specially equipped departments.
The A&E department that participated in this case study was located in a large teaching hospital in the centre of one of the larger cities in Northwest England. During the case study, the medical staff of the department consisted of 2 A&E consultants, 2 specialist registrars, 1 training fellow and 7 Senior House Officers (SHOs). The non-medical staff consisted of approximately 35 nurses and 5 emergency department assistants. Senior staff (consultants and registrars) mainly work week days from 9 a.m. to 5 p.m. Based on a shift system, junior staff have to cover the 24 hour, seven days a week schedule. SHOs are on a six month rotation and move on to a different department each 6 months. Annually, approximately 60,000 patients visit the A&E department.

The patients who visit the A&E department all go through the same basic process. Exceptions are only made for emergency cases, which arrive predominantly by ambulance. In general, a patient's visit starts at reception where a patient card (casualty card) is made. Within a few minutes the patient is seen by a 'triage nurse', who records primary observations including a brief patient history and a brief investigation of the patient's complaint on the patient card. Finally, the patient's priority for treatment is assigned by the triage nurse and the card is placed according to the nurse's assessment in the "to be seen box". The A&E doctors simply take the first card from this box, which means that patients are seen in order of priority. The actual assessment by the doctor can result in direct treatment, which is often carried out by a nurse following the doctor's instructions. Treatment may include admitting the patient to a hospital department or immediate discharge.

4.2.2 Background and set up of the case study

Similar to the case studies in the steel industry, the purpose of this case study was to collect and analyse empirical incident data, in order to gain insight into organisational root causes. The department involved in this case study was, in its own way, familiar with incident reporting and analysis. The A&E department had been involved in the PhD study by Shea (1996), which included incident reporting and analysis, using

PRISMA. As a result, the department was familiar with PRISMA and considered the case study as an extra stimulant in the process of improving the quality of patient care. Since no incident reporting and analysis system was implemented in the department or being implemented at that time, the case study was not part of an ongoing project and should be considered as an independent project.

Given this background, a 'straightforward' data collection approach, using PRISMA, could be followed, without any adjustments or compromises related to department objectives. As a result, no work group or safety co-ordinator was involved or had to be trained in this case study and employee involvement was limited to providing information about the incidents they had been involved in. The following steps were carried out:

1. Introduction and familiarisation.
2. Data collection and analysis, using PRISMA.
3. Feedback to management of the departments involved.

Moving from industry to the medical domain did not only mean moving to a new domain but also moving to a domain unfamiliar for most researchers with a non-medical background. Consequently, at the start of this case study an extensive introduction and familiarisation with the department's activities occurred. The entire first month of the three month period was used for this purpose. There are several reasons to take this phase seriously. Perhaps the most obvious reason is to gain insight into the kind of jobs, the daily activities and working conditions of the staff in this department. Without this knowledge, performing in-depth interviews is an impossible job. Job related knowledge is essential to ask the right questions but also, and perhaps more importantly, to be taken seriously by the medical staff. A second critical reason for an introductory period is to gain insight into the organisational aspects of the departments. This includes aspects related to the formal organisational structure, the prevailing culture(s) and the goals and priorities of the department. The third reason is practical and is simply to become acquainted with staff in the department and to explain the purposes of the study. When dealing with incidents, uncertainty about the way data is used and for what purpose, may directly result in a lack of co-operation. In the medical domain particularly, where litigation following mishaps during treatment is getting more common every day, the introductory phase should be used to reduce distrust and to create a positive atmosphere for the case study to take place.

The PRISMA steps are discussed in detail in chapter 2. It is important to note that each final causal tree resulted from two meetings with the person(s) involved in the incident. During the first meeting the critical incident interview was conducted, after which a draft version of the causal tree was built by the researcher. During the second meeting, the final representation of the incident in a causal tree and the classification of the root causes was discussed and agreed on. This set up was chosen because a work group did not exist to discuss the incidents collected.

The final step of the case study was to provide feedback to the department. This feedback included both a brief evaluation of the current system related to incident reporting and analysis and the insights that were gained into the organisational strengths and weaknesses of the departments. The results will be discussed in detail in the next section.

4.2.3 Results

The case study in the Accident and Emergency department resulted in 19 incident descriptions of recent incidents, containing 93 root causes, giving an average of 4.9 root causes per incident. When the root causes are distributed over the main categories of the classification tool for the medical domain, this results in the distribution shown in table 4.1.

	Organisational	*Technical*	*Human*	*Pat. related*	*Unclassifiable*	*Total*
Root causes	42	3	38	6	4	93
Percentage	45%	3%	41%	7%	4%	100%

Table 4.1: Distribution of root causes over main categories.

Table 4.1 shows that 45% of the root causes are classified as organisational, which means that for this set of incidents, organisational failure is the main contributor to incident causation in this A&E department. The remaining 55% of the root causes are divided over technical root causes (3%), human root causes (41%), patient related failure factors (7%) and unclassifiable root causes (4%). Figure 4.2 shows the distribution of the root causes over the categories of the classification tool for the medical domain.

Organisational failure factors
Figure 4.2 shows the distribution of the 42 organisational root causes for the A&E department. Contrary to the case studies in the steel industry, this distribution contains a category for external organisational root causes. This category is intended for those root causes that are classified as an organisational failure factor and are beyond the control and responsibility of the investigated department. Because the external factors are beyond the control of the investigated department, it is difficult to assess their real causes. It is of little use to hypothesise in great detail about the origins and accompanying corrective actions of root causes in other departments. For this reason, only the three main categories of organisational, technical and human have an external category. A high score on external failure factors in the A&E department is not very surprising. The department is highly dependent on specialist services provided by other departments (i.e. radiology and biochemistry) and on available beds on wards when patients have to be admitted. However, the majority of the external factors relate to the priorities of hospital management. The consequences of these priorities influence day

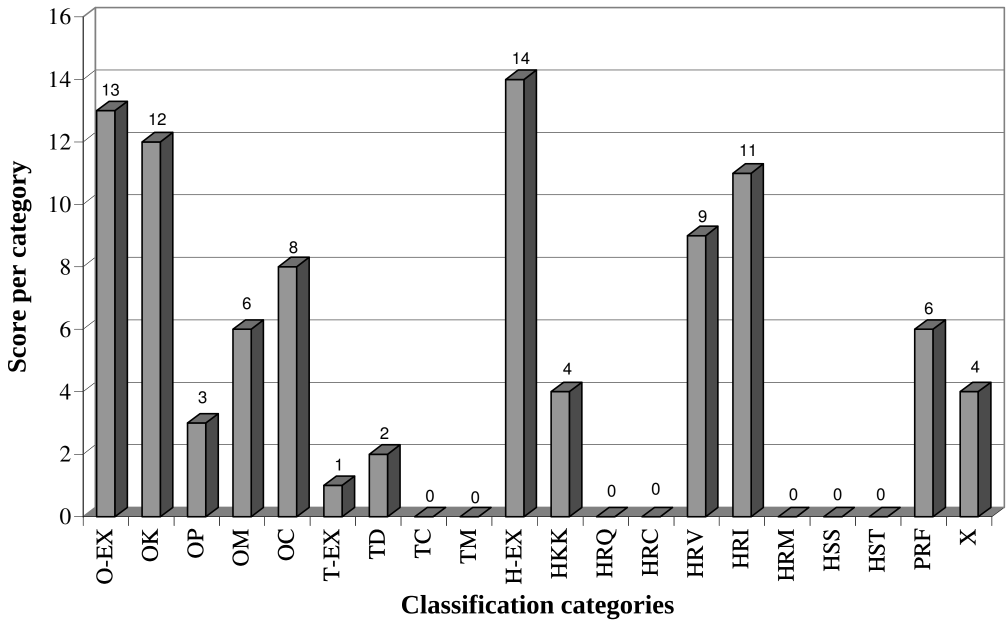


Figure 4.2: Distribution of root causes in the A & E department (n = 93).

to day practice in the A&E department, revolving mainly around staffing problems (not enough senior staff) and bed problems (lack of beds for A&E patients due to the continuous closing of beds on the wards). Although these external factors are beyond the control of the investigated department, their reporting is important to enable informal discussion between departments and to stimulate other departments to assess their own performance and its impact.

The majority of the internal organisational problems related to a lack of knowledge and experience. New SHOs in particular have problems with reading x-rays, making the correct diagnosis or prescribing the correct drug. For most SHOs involved in this case study, it was their first job as an SHO and therefore their first real independent practical experience. There are several causes for this knowledge problem. One possible cause is the national training system of SHOs. SHOs work on a six month rotation, which means that they change departments every six months. For the department this means that every six months they get a new group of inexperienced doctors. By the time the doctors have gained the experience to function confidently in the department they leave and the department must start again. Another problem is time related. SHOs have to start immediately and training has to take place on the job. There is no spare time available to spend on training before they begin working. Training sessions are weekly but are short due to the high workload in the department.

They are not always accessible to everyone working on the 24 hour shift system. Together with the fact that senior staff is only available during the daytime, it is almost impossible for SHOs to deal with their knowledge problem successfully and experience is often gained by learning from mistakes.
It is unlikely that the rotation system will change in the near future. It is also unlikely that in the near future there will be more time available to train the SHOs. Many of the knowledge and experience problems can be solved by having senior staff in the department 24 hours a day, ensuring that there is always someone available to ask for advice.

Inside the department cultural pressure to refrain from contacting senior doctors (particularly during night shifts) was noted. In many cases SHOs were afraid that consulting a senior colleague would be interpreted as incompetence. Another cultural factor influencing performance is that during daily practice x-rays are often taken by protocol only and used accordingly, resulting in incorrect diagnoses.

Problems with management priorities originated mainly outside the A&E department and included priorities of hospital management. However, inside the department it was decided that senior staff works 9 to 5 and week days only, leaving inexperienced doctors to deal with the weekends and night hours. The problems resulting from this choice have been discussed above.

In only three cases protocols were missing or did not fit the situation at hand. Providing best practice protocols would be helpful especially in coping with the knowledge and experience problems. However, time is needed to get acquainted with these best practices and time is lacking.

Technical, human, patient related and unclassifiable failure factors
The low number of technical root causes is not surprising. The majority of the work involves making the correct diagnosis and performing interventions, so that a patient can be referred to the proper department for further treatment, or discharged. Technical equipment is rarely used in the A&E department and existing equipment is very reliable.

Most human root causes are related to checking and work planning. Because of the long waiting times in the department (a five hour waiting time is not exceptional), SHOs feel pressed to process patients as quickly as possible. This sometimes leads to forgetting certain steps, which actually need to be taken (e.g. forgetting to look at all x-rays taken, or forgetting or omitting to do certain tests). An incorrect diagnosis is the most common consequence of these errors.

The patient related or unclassifiable factors mainly deal with the physical or mental state of the patient (e.g. patient being very drunk or violent). Although they are beyond the control of the doctors, they can seriously influence the diagnosis. Patients' poor communication skills can also make the diagnosis phase very difficult.

4.2.4 Discussion

This first case study in the medical domain clearly showed the importance and feasibility of modelling organisational failure factors in the medical domain. In the A&E department organisational failure factors appeared to be the main contributor to incident causation and several structural problem areas were clearly expressed in the distribution of the organisational failure categories.

First, the A&E was mainly run by inexperienced junior doctors. Experienced staff only worked nine to five on week days. The consequences were clearly summarised by the high number of knowledge and experience problems in the contemporary A&E department. Secondly, the level of teamwork that was required to perform a task in the A&E department should be considered. Doctors of other departments were often needed to admit a patient to the hospital or to help with the diagnosis and treatment. This led to a variety of communication and priority problems and problems related to cultural differences. Priorities of hospital management, such as closing beds to cut expenses, also influenced the work of the A&E doctors directly. This was clearly visualised by the high score on external organisational failure factors.

Feedback to management of the department showed that they could clearly recognise the problems detected in the department, giving an indication about the face validity of the data. In particular problems related to knowledge and experience were known, though incident data as provided by this study was lacking to show the impact of these problems on incident causation.

The description of the A&E department might have given the impression that A&E departments are dangerous places to go to. The reverse is true. Although there are weaknesses that are open for improvement, the system has several built-in recovery mechanisms to prevent these weaknesses from developing into actual negative consequences for the patient. The critical incident interviews revealed the following three recovery mechanisms:

- *Team work*. Within the A&E department, consulting other A&E doctors while on the job, particularly in doubtful cases, is highly encouraged. Since everyone meets in the duty room to write the casualty cards, it is easy to discuss patients, look at x-rays together or decide what drug to prescribe. Many mistakes are prevented or corrected this way.
- *The casualty card review.* As stated earlier, SHOs often make incorrect diagnoses, prescribe the wrong drug or suggest an incorrect or sub-optimal treatment. Most of these mistakes are detected the next morning when the casualty cards are reviewed by one of the consultants. In the vast majority of cases it is then still possible to correct the mistake without serious consequences for the patient.
- *The daily review clinic.* A&E, like many other departments, holds a review clinic in which follow-up is given to certain types of problems by one of the consultants, although this is beyond the primary aim of the department. SHOs can use this review clinic as a safety net in doubtful cases. Particularly at night SHOs can, if

immediate treatment is not necessary, refer doubtful cases to the review clinic the next morning. This way treatment is delayed for a few hours but the patient is given the best possible care.

Particularly in organisations where improvements are hard to accomplish (because of financial restrictions, departmental differences, etc.), promoting recovery mechanisms can be an effective alternative.

4.3 Case 4: Anaesthesia

The second case study in the medical domain was also carried out over a three month period in a second large British teaching hospital. This case study was also initiated and supported by the School of Education of the University of Manchester, however, not as a follow up of a previous study. The anaesthesia department was included to achieve a maximum variety in two case studies in British teaching hospitals.

4.3.1 Characterisation of the Anaesthesia department

From an organisational point of view, the most visible difference between the A&E department and the Anaesthesia department is that the Anaesthesia department is outside the 'flow of patients' within a hospital. It is a department that provides anaesthetic services to other departments (within the flow of patients), such as the operating theatre, the intensive care unit, the A&E department and the wards. The expertise of the anaesthetist is therefore required in several departments across the hospital and several anaesthetists also work in different hospitals.

The anaesthesia department that participated in this case study was located in the same city as the A&E department, in a second large teaching hospital. A total of 20 anaesthetists work in the department. Contrary to the A&E department, the majority of the anaesthetists were senior anaesthetists (consultant or registrar) or training fellows, who had already decided to become anaesthetists. SHOs who work for the anaesthesia department are at the end of their 3 years of training, while the SHOs in the A&E department are mainly at the beginning of their 3 years of training. Anaesthetic services are for the most part provided during the day-time and are planned in advance. However, in case of (unplanned) emergencies, there are always a number of anaesthetists on call.
The anaesthetist is often recognised as 'the bloke who knocks you out' or 'the gas man' (Heining *et al.*, 1996). In fact, the job is much more complex and involves assessment of risk, pre-operative preparation, keeping the patient alive during surgery, minimising the side-effects of anaesthetic drugs and ensuring that there is no memory of intra-operative events. The remainder of this paragraph will give a simplified and general overview of the anaesthetic process.

The assessment of risk and the pre-operative preparation begins on the ward, where the patient is visited by the anaesthetist. The primary aim of the pre-operative visit is to ensure that the patient is presented for theatre in an optimal state, so that the risks of anaesthesia and surgery are reduced to a minimum. Additionally, it offers an opportunity to discuss options with the patient, to plan the anaesthetic and to prescribe premedication if appropriate. In the anaesthetic room next to the operating theatre the patient is 'put to sleep' by the anaesthetist, assisted by an anaesthetic assistant. Putting a patient to sleep is only one of three main aspects of anaesthesia. A so called balanced anaesthesia is a combination of *sleep* to be unaware of what is going on, *analgesia* in order not to feel pain and *muscle relaxation* in order to keep the body motionless during surgery. During surgery, the patient is connected to the anaesthetic machine which provides oxygen and anaesthetic agents to the patient. The anaesthetist will further monitor the vital signs of the patient to make sure the patient stays alive. After surgery the anaesthetic is reversed in the operating theatre and the patient is disconnected from the anaesthetic machine. Full recovery from the anaesthetic takes place in the recovery room after which the patient returns to the ward.

4.3.2 Background and set up of the case study

The anaesthesia department was, in its own way, familiar with incident reporting and analysis and had an incident reporting system up and running. Similar to the A&E department, the case study was considered an extra stimulant in the process of improving the quality of patient care. The case study was not part of an ongoing project and should be considered as an independent project.

Given this background, a 'straightforward' data collection approach, using PRISMA, could also be followed in the anaesthesia department, without any adjustments or compromises related to department objectives. Again no work group was involved or had to be trained. Therefore, employee involvement in this case study was also restricted to providing information about incidents that happened recently. The following steps were carried out:

1. Introduction and familiarisation.
2. Data collection and analysis, using PRISMA.
3. Feedback to management of the departments involved.

The importance of a proper introduction and familiarisation period has already been discussed in section 4.2.2. This is also true for the case study in the anaesthesia department. The final PRISMA analysis of each incident in this case study is based on two meetings with the person(s) involved. During the first meeting the critical incident interview was conducted, after which a draft version of the causal tree was built by the researcher. During the second meeting, the final representation of the incident in a causal tree and the classification of the root causes were discussed and agreed on. This format was chosen because in the anaesthesia department there was no work group to discuss the incidents collected.

The final step in the case study was to provide feedback to both departments. This feedback included both a brief evaluation of the current system related to incident reporting and analysis and the insights that were gained into the organisational strengths and weaknesses of the departments. The results are discussed in detail in the next section.

4.3.3 Results

The case study in the anaesthesia department resulted in 15 incident descriptions of recent incidents, containing 78 root causes, giving an average of 5.2 root causes per incident. When the root causes are distributed over the main categories of the classification tool for the medical domain, the distribution shown in table 4.2 results.

	Organisational	*Technical*	*Human*	*Pat. related*	*Unclassifiable*	*Total*
Root causes	21	20	31	5	1	78
Percentage	27%	26%	40%	6%	1%	100%

Table 4.2: Distribution of root causes over main categories.

Table 4.2 shows that 27% of the root causes are classified as organisational. The remaining 73% of the root causes are divided over technical root causes (26%), human root causes (40%), patient related root causes (6%) and unclassifiable root causes (1%). Figure 4.3 shows the distribution of the root causes over the categories of the classification tool for the medical domain.

Organisational failure factors
Only a limited number of organisational failure factors are detected, which are equally distributed over four of the five organisational categories. No root causes are found that can be classified as management priorities. Management priorities do exist, however, on an external level. Efforts to reduce costs inside departments that make use of the services provided by the anaesthesia department result in a number of equipment problems (e.g. availability and quality of equipment). However, this is beyond the direct control of the anaesthesia department.

The majority of the internal organisational problems deal with the quality and availability of protocols. There appears to be a reluctance to use protocols by the anaesthetists. Contrary to the SHOs in the A&E department, the anaesthetists consider themselves to be specialists, who do not need written protocols to dictate what to do. However, the incidents show that at least a written best practice could have prevented a number of the incidents. The quality and availability of protocols also need to be reviewed on a regular basis. Protocols about the division of work between the

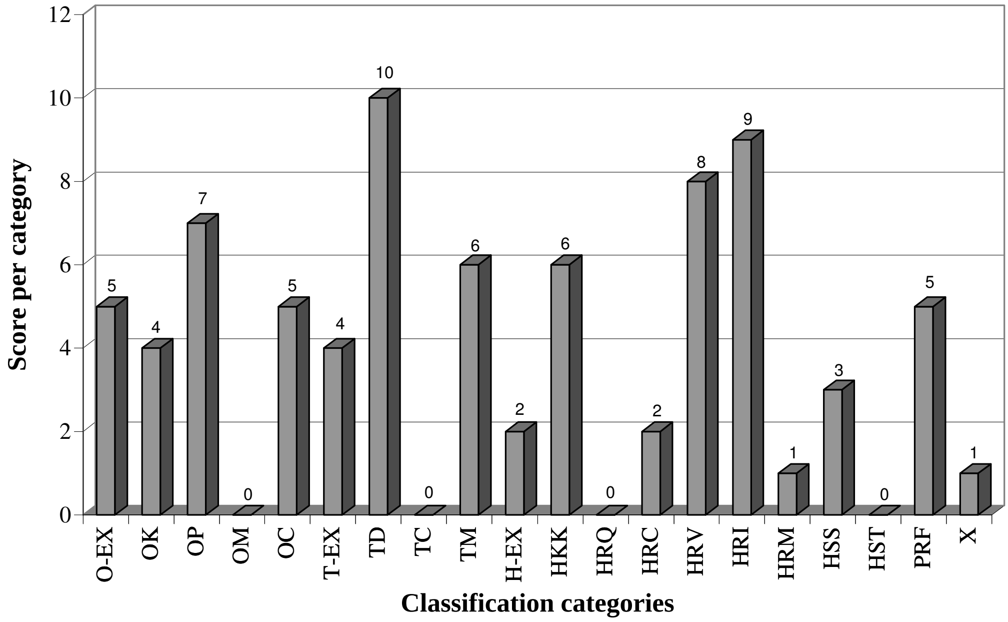


Figure 4.3: Distribution of root causes in the anaesthesia department (n = 78).

anaesthetist and anaesthetic assistant appear to be unclear and protocols about which drugs to keep in stock and how to store them are missing.

Cultural problems are mainly related to following safety procedures. One anaesthetist once said "when everything goes right, anaesthesia is boring". This lack of 'excitement' can easily lead to situations in which safety procedures are taken less seriously. When nothing ever happens, it is hard to stay fully alert and easy to reduce vigilance. Incident reporting systems can be helpful in showing that incidents do occur on a regular basis yet fortunately without negative outcomes.

A total of 4 root causes are classified as being related to a lack of transfer of knowledge. Only one of these root causes is related to a lack of experience similar to the incidents in the A&E department case study. The remaining root causes involve failing communication about new equipment features.

Technical, human, patient related and unclassifiable failure factors

The majority of the technical problems are design related. On different levels the design of equipment can lead directly to problems (e.g. a superfluous power switch on a switch board next to the light switches) or influence the behaviour of the person using the equipment (e.g. all the new and extra graphical displays and alarms on the new anaesthetic machines).

The two most predominant human errors are forgetting to check the system before using it (e.g. leading to problems in ventilating a patient) and slips and lapses in the planning of work (e.g. forgetting to use an airway to protect the tube against biting). At this stage, forgetting to check the system is considered to be a human error, since evidence to suggest otherwise is lacking. However, more data is likely to show the cultural nature of this error, which is important to recognise before formulating corrective actions.

The patient related factors are all related to the physical characteristics of a patient. A good example is the case of an obese woman, whose size made it impossible to verify if both lungs were ventilated. The size of the woman made it impossible to hear or see the functioning of the lungs.

4.3.4 Discussion

This second case study in the medical domain confirms the importance and feasibility of modelling organisational failure factors in the medical domain. In the anaesthesia department organisational failure factors are also a main contributor to incident causation. More data is needed however, to draw conclusions about structural organisational problems for the anaesthesia department. To determine whether or not a certain type of failure should be considered as human or as a cultural factor requires more data. Although the same amount of time was spent in the anaesthesia department and in the A&E department, this case study resulted in fewer incidents. The anaesthetists were clearly less willing to report incidents than the doctors in the A&E department. According to the nursing staff, only a small portion of the incidents that happened were reported by the anaesthetists. A possible explanation might be that the highly experienced anaesthetists are less accustomed to discussing incidents than for example the less experienced A&E doctors. Fortunately, sufficient insight was provided to model organisational failure factors. Feedback to department management showed that they could clearly recognise the problems detected, giving an indication about the face validity of the data. Again, the types of organisational problems were known, however, data was lacking to show the impact of these problems. More importantly for the modelling process, no other organisational failure types could be identified that are missing in the data set.

4.4 Case 5: An Intensive Care Unit

The third case study case was carried out in an intensive care unit (ICU) of a large hospital in the Netherlands. In many hospitals the ICU is considered the department where many new developments, such as developments related to patient safety and quality of patient care, are first tested. Once the new developments have 'survived' the complex and demanding environment of the ICU, the developments may be adopted by other departments in the hospital.

4.4.1 Characterisation of the Intensive Care Unit

Intensive care units in general are complex patient management environments. The clinical skills of the care-providers are supplemented by sophisticated monitoring devices, life support systems and multiple drug administrations. Together with the critical condition of the patients visiting the ICU, this results in a high-risk environment, where minor changes in the condition of the patient or minor mishaps during treatment can lead to serious consequences for the patient.

The intensive care unit that participated in this case study consists of four rooms with four beds each and four single bed rooms, called "boxes", for isolated treatment. In this way 20 patients can be treated, which by Dutch standards is considered a large ICU. About 55% of its patients have to recover from cardiac or open-heart surgery and stay in the ICU for about two to three days before returning to a ward. The remaining patients visit the ICU for various reasons, including trauma and treatment of critical illnesses. The ICU specialises in adult care. Paediatric intensive care is provided by another nearby hospital.

The ICU is managed by two senior doctors, an intensive care specialist and an anaesthetist. The staff employed by the ICU can be subdivided into three groups: medical staff, nursing staff and support staff. The medical staff of the ICU consist of two intensive care specialists, 3 anaesthetists and a varying number of training fellows. The medical staff did not participate in this case study and will therefore not be discussed in detail. It is important to note that the medical staff are responsible for determining the medical strategy to be followed for the patients in the ICU. The ICU is also regularly visited by doctors from other departments who are or have been involved in the treatment of the patients now visiting the ICU.

The nursing staff are the largest and most predominant presence in the ICU. They are managed by a senior nurse manager and two assistant nurse managers. For every shift, a shift leader (normally the most experienced nurse) is assigned. Twenty-four hours a day and seven days a week specialised ICU nursing staff are available to take care of patients, to monitor and carry out the medical strategy determined by the medical staff (administering drugs, fluids, etc.). Every hour of the day, at least two nurses are present in every room and three nurses are assigned to the boxes for isolated treatment. In a corner of each room, a work area consisting of a desk, shelves, PC and central monitoring equipment is used for nursing staff to make notes, prepare drugs and monitor the vital signs of all four patients in the room. Similar facilities are present for monitoring the patients on the boxes, however, these are located in the central nursing station of the ICU, outside the boxes.
The support staff consist of a technician to maintain and test the technical equipment (to be) used on the ICU, two secretaries and a group of non-medical staff who clean nursing equipment, manage laundry and perform a variety of non-patient related jobs for the nursing staff.

4.4.2 Background and set up of the case study

Given the complexity of the system and its accompanying risks, implementing systems to monitor and improve patient safety and quality of care has become the target of most intensive care units. In this ICU, at a nursing level, five separate work groups are investigating different aspects of the ICU, including:

- incident reporting and analysis to detect problem areas in the contemporary ICU;
- process modelling, to detect shortcomings and risks in current day to day practice;
- implementing quality circles, to monitor the quality of care provided;
- a variety of activities to support professional development; and
- reviewing new and relevant literature, to support and maintain the professional knowledge of the nursing staff.

These activities are primarily carried out by nursing staff but are supported by medical staff. As a result of the leading role of nursing staff in incident reporting and analysis, the incidents used for this case study are reported by nursing staff only.

Advice was provided by the Eindhoven Safety Management Group about how to structure the incident reporting and analysis system according to the PRISMA approach. In return, incident data could be used for the study described in this thesis. The set up of the case study is therefore similar to the case study performed at the coke production plant. The following activities are included:

1. Guiding and supervising the process of developing and implementing a system for reporting and analysing incidents according to PRISMA on the ICU.
2. Collecting empirical incident data following the PRISMA techniques.
3. Feedback to management of the ICU about its organisational strengths and weaknesses and possibilities for improvement.

In this case study, members of the work group were also asked to participate in the analysis process, in order to become familiar with the PRISMA techniques. Work group meetings were organised regularly to evaluate progress and to discuss the incidents that were collected to date. The final representation of each incident in a causal tree and the final classifications of its root causes were decided on during these work group meetings. To achieve a maximum of variety, recurring incidents have been excluded from the data collection phase.

4.4.3 Results

The case study in the Intensive Care Unit resulted in 21 incident descriptions of recent incidents, containing 99 root causes, giving an average of 4.7 root causes per incident. When the root causes are distributed over the main categories of the classification tool for the medical domain, the distribution shown in table 4.3 results.

	Organisational	*Technical*	*Human*	*Pat. related*	*Unclassifiable*	*Total*
Root causes	30	8	45	4	12	99
Percentage	30%	8%	46%	4%	12%	100%

Table 4.3: Distribution of root causes over main categories.

Table 4.3 shows that 30% of the root causes are classified as organisational. The remaining 70% of the root causes are divided over technical root causes (8%), human root causes (46%), patient related root causes (4%) and unclassifiable root causes (12%). Figure 4.4 shows the distribution of the root causes over the categories of the classification tool for the medical domain.

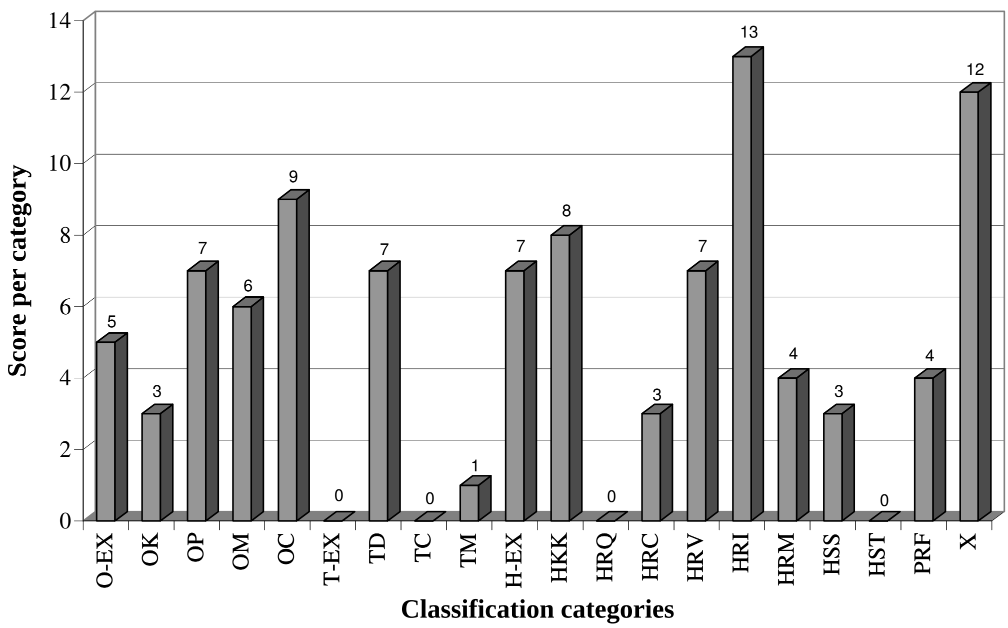


Figure 4.4: Distribution of root causes on the ICU (n = 99).

Organisational failure factors
Of the 30 organisational categories, five originated outside the department. All of these root causes involved organisational decisions made in the operating theatres, which indirectly influenced work and safety in the intensive care unit. One root cause refers to a missing (or generally not followed) protocol about where to leave packed cells (i.e. blood) when transferring a patient from the operating theatre to the ICU. The other

four cases refer to cost reduction decisions made in the operating theatres that do not consider possible adverse side-effects in the ICU.

The highest number of internal organisational root causes is found at the cultural level. The majority of the organisational root causes classified according to this category have to do with not checking if drains are still properly connected while the patient is in the ICU. For example, during an open-heart surgery, drains are placed in the chest area to draw off blood and other fluids from the patient. This is done in the operating theatre. Once the patient arrives in the ICU, nursing staff must check that all drains are still properly connected and should continue checking regularly while the patient is in the ICU. In order to be sure drains are properly connected, this must be checked manually. When a patient arrives in the ICU this is done properly, however, manual checking degrades quickly to visual checking to save time, to not checking at all. It is often simply assumed to be correct. The incidents, however, suggest otherwise, as patients tend to move around in their bed or try to disconnect drains deliberately or unconsciously.

The availability of protocols also appears to be a main contributor to incident causation in the ICU. For two specific situations protocols were regularly found to be missing, leading to a number of similar incidents or unwanted situations. The first situation is again related to the drains discussed earlier. To prevent drains from disconnecting, tape can be wrapped around the connections. However, it was unclear whether this should be done in the operating theatre or in the ICU. Due to this uncertainty, no one felt responsible and tape was not used. The second situation where protocols were missing refers to the handover of patients arriving from the operating theatre. Frequently, too many packed cells of blood are ordered in the operating theatre. They are then sent along with the patient to the ICU. However, protocols to dictate where to put the packed cells and who is responsible for them are missing in the ICU. This resulted in several occasions where packed cells were not noticed until they were spoiled and had to be thrown away.

A total of six root causes are classified as management priorities. Four of these root causes are related to staffing levels. At all times, at least two nurses are present in each room. However, more patients may occasionally require attention at the same time than the number of nurses present in the room. It is a management decision to weigh the costs of adding a nurse to each room against the resulting reduction in risks for the patients. Incident data can and should be used to make this decision wisely. The remaining root causes in this category refer to missing equipment.

Only three root causes are related to problems due to poor transfer of knowledge during the introduction of employees in the ICU. No recurring problems were found in this category.

Technical, human, patient related and unclassifiable failure factors
The technical factors are, apart from one material problem, all design related. An ICU is a high-tech environment and patients are all connected to various sophisticated machines to monitor the patient's condition, including life support systems and pumps to administer drugs or fluids. Unfortunately, the equipment does not always appear to be ergonomically designed. For example, it is difficult to visually check if drains are properly connected, pump readings are often difficult to see given their position behind the bed and the lighting of the room and the lay-out of the department makes it difficult to monitor the patients who are treated in the boxes from the central nursing station.

At a human level most errors are related to incorrect planning and execution of known activities. Most of these errors are due to haste or routine. This is true for both the internal and external human errors. The external human errors are either made in the operating theatres or by external personnel (e.g. from the radiology department) in the ICU. On an internal human level, three peaks can be detected. The first peak is found for HKK (knowledge). For this situation, a higher number in this category refers to problems with correctly estimating risks associated with a certain situation. The (unconscious) behaviour of patients in the ICU is often highly unpredictable, leading to decisions that may ultimately be incorrect (e.g. leaving the room at the wrong moment). The second peak is found on HRV (verification). Not checking the connections of drains correctly has already been discussed and is considered a cultural problem given its generally accepted nature. This category refers to verification errors that are made only occasionally and include incidents such as forgetting to double-check the type of drug before administering it and forgetting to check a particular reading on one of the monitoring devices. The highest number of human error root causes is related to errors made during the delivery of care itself (HRI). Most of the errors made in this category (e.g. forgetting to make notes, forgetting to re-connect a drain) are due to haste or a high workload.

The patient related factors in this study can be characterised as 'violations' by the patient. For example, in one incident the patient deliberately removed the oximeter (device to measure the percentage saturation of haemoglobin with oxygen) to get attention from the nursing staff.

The unclassifiable failure factors vary strongly in nature. Several are related to drains that are accidentally disconnected by the patient while waking up. Others are due to 'unfortunate planning' of the nursing staff (e.g. a nurse just leaving the room to get some medication when a patient 'decides' to disconnect a tube).

4.4.4 Discussion

Only the nursing staff participated in this case study. As a result, only incidents related to day to day nursing practice in the ICU are reported while some incidents include the 'interface' between the medical staff and the nursing staff. Although medical staff did not participate in this case study, a useful set of incidents has been reported and analysed, showing the usability of the tool for nursing incidents. Only a sub-set of the reported incidents are analysed given the high similarity in the reported incidents.

Conclusions based on the results discussed earlier should, as in all the other case studies discussed in this thesis, be drawn carefully given the limited number of incidents collected. Incident data is primarily collected to gain insight into the organisational failure factors involved and only in the second place to gain insight into the strengths and weaknesses of the department investigated. To draw solid conclusions, more incidents need to be collected.

Worth noting is also the high total of unclassifiable root causes for this case study. In this case, these root causes are all related to a certain level of bad luck. A high total in this category should always be taken seriously, since it might also indicate a missing category in the classification tool.

4.5 Case 6: Care of the mentally handicapped

For the final case study in the medical domain, a domain was chosen that until now remained beyond the focus of safety or quality of patient care related research: the care of the mentally handicapped. To date, research on safety or quality of care in the medical domain has primarily focused on hospital departments that are publicly perceived as high-risk departments, such as surgery, anaesthesia, intensive care, radio therapy. Although perhaps less obvious, the care of the mentally handicapped is an important discipline in the medical domain and has its share of risks that deserve attention in safety or quality of patient care related research.

4.5.1 Characterisation of the institution

The case study was carried out in an institution for the care of the mentally handicapped. With 725 'residents', this institution is large by Dutch standards. In the care of the mentally handicapped the term resident is preferred to patient. Given the severity of the handicap of the residents, recovery to a point following discharge from the institution is not to be expected and therefore most residents will live in the institution for their entire life. The main location of the institution accommodates approximately 600 of the 725 residents. The remaining residents live in sheltered accommodation outside the institution, with minimal supervision. The main location is freely accessible and includes facilities such as a playing ground, shops and ample possibilities for walking and cycling. The sheltered accommodations are located in the city centre close to the institution.

The mission of this institution is to provide care and support to the residents. This results in the highest possible quality of life for the residents. This means for example that if possible, residents are expected to make their own decisions and the facilities are designed to resemble a normal living environment. Given their handicap, most residents are dependent on a high level of care and support provided by the institution.

To provide the best possible care to the residents, close to 1100 people are employed by the institution, of which a large amount work on a part time basis (resulting in an average of about 750 full time equivalents). Figure 4.5 (Versluis, 1997) shows the organisational structure of the institution. Aside from senior management, a finance department and a department for personnel and human resources, the institution is subdivided into three main groups. The majority of the employees (81%) work in the care services. The residents living in the main location are subdivided into six housing groups, depending on their accommodation needs. A housing group consists of 10 to 12 housing blocks, with 6 to 12 residents living in each block. The care and support of the residents of these blocks occurs 24 hours a day and is provided by qualified personnel. On average, 2 to 3 employees are present in each block, however if necessary, more personnel is available for assistance. Pastoral services are also available

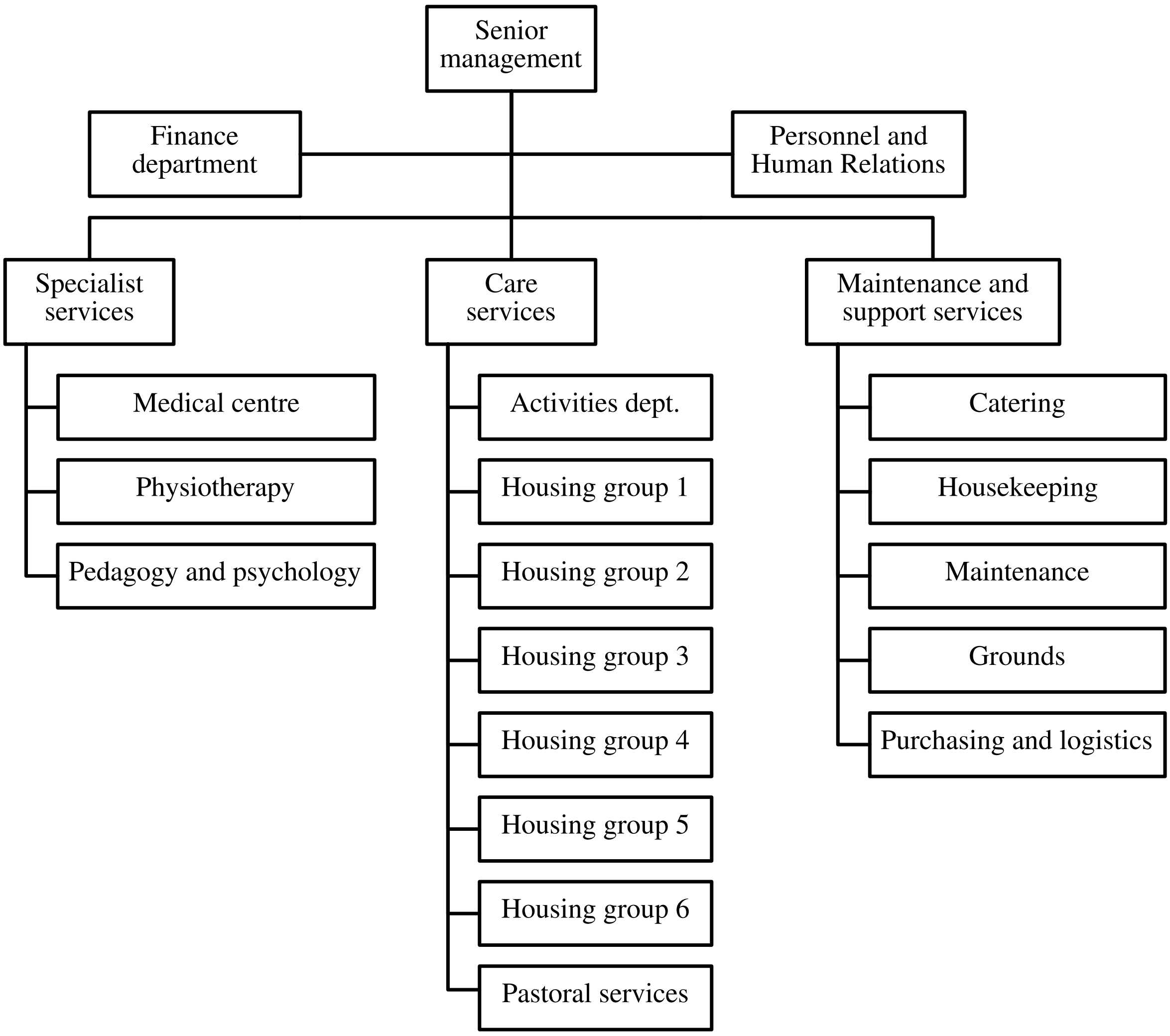


Figure 4.5: Organisational structure of the institute for the care of the mentally handicapped.

to the residents and a large number of activities are organised on a daily basis. These activities involve both work related activities (e.g. painting and assembly jobs) and creative and recreational activities (e.g. swimming, horse riding, arts and crafts). Participation depends on the individual capabilities and needs of the residents.
When required, specialist treatment is provided by the specialist services. The specialist services (4% of the total number of employees) include a medical centre, a department for physiotherapy and a department for pedagogy and psychology. Additional medical assistance is provided by specialists from outside the institution (e.g. psychiatrists).

The remaining activities are carried out by maintenance and support services. If possible, residents are invited to help as part of their daily activities. Housekeeping jobs, such as collecting dirty laundry, are considered suitable to be carried out by the residents. Involvement in housekeeping jobs also depends on the individual capabilities and needs of each resident.

4.5.2 Background and set up of the case study

The case study in the institution for the care of the mentally handicapped was started because the institution had been involved in nine serious incidents over the past five years. These incidents resulted in the death of eight of their residents and one near miss where the resident involved could barely be saved from drowning in the swimming pool at the institution. The direct causes of death varied between three cases of asphyxiation, three traffic accidents outside the main location of the institution and two drownings while taking a bath.

Most departments or institutions in the medical domain have established committees whose job it is to collect and analyse incident reports, in order to improve the quality of care provided to the residents. In this institution a so called FOBO-committee (FOBO = Faults, Accidents and Near Accidents) exists. This committee, consisting of five members of different disciplines inside the institution, is responsible for the analysis of reported incidents and to provide management with information about structural problems. The incidents are reported through an incident reporting system. In case of an incident, an incident reporting form can be used by staff involved to give a brief description (1 or 2 lines) of the incident. This form is sent to the committee for further analysis. On a monthly basis the new reports are discussed by the committee and recommendations are suggested to management. There is no feedback about the conclusions of the committee to the person(s) who reported the incident. The 'analysis' of each individual incident report by the committee normally takes only a few minutes and mainly consists of classifying the symptoms of the incidents in one of the following ten pre-defined symptom-based categories:

- aggressive resident;
- malfunctioning of bed rails;
- found medication;
- poisonous substances;
- complaints related to catered food;
- forgotten to administer medication;
- incorrect medication order;
- incorrect administration of medication;
- unrecognised risks;
- traffic accidents.

An additional investigation into a reported incident is rarely performed, which means that the real root causes behind these symptoms are rarely discovered. Annually, approximately 400 incidents are reported, of which over 50% are related to medication.

After a very serious incident, such as those that triggered this case study, a temporary work group is formed by management to thoroughly investigate the incident. This work group normally consists of members of management, the FOBO-committee, medical staff and one or more representatives of the housing group involved. The investigation normally involves additional interviews with the persons involved in the incidents. Based on the transcripts of the interviews, conclusions are drawn about the causes of an incident. After each incident described in this case study a work group was formed to investigate the incident. However, without a structured method to perform these investigations and to analyse and interpret the collected information, the institute had not been able to gain insight into the causes leading to the incidents or to find recurring problems. A re-analysis of the nine incidents based on PRISMA was requested by the institution to resolve the lack of insight and to demonstrate the added value of the method. It was not the intention of management to take additional actions based on the new insights. All cases had already been closed.

To gain insight into the causes of the nine incidents, the following basic PRISMA-steps were carried out:

1. a thorough analysis of the transcripts of the interviews that were conducted by the institution after each incident, followed by additional critical incident interviews with the staff involved;
2. transferring the collected information into causal trees and classifying the root causes using the medical version of the Eindhoven Classification Model;
3. analysis and interpretation of the data and provision of feedback of the results to the management of the institution.

These three steps were carried out over a period of three weeks. Contrary to case studies discussed earlier, the final causal tree was based on the critical incident interview only. For the institution this case study was mainly intended to show the added value of PRISMA, therefore it was not possible to organise a second meeting with the persons involved to discuss the final causal tree and the classifications of the root causes. Feedback was provided to management only.

The case study was included due to its main focus on the care process, instead of medical treatment, and the special kind of 'patients' that are involved in this discipline in the medical domain. Both factors may lead to additional insights into organisational failure in the medical domain and how to manage it.

4.5.3 Results

The case study resulted in nine incident descriptions, containing 71 root causes, giving an average of 7.9 root causes per incident. When the root causes are distributed over the main categories of the classification tool for the medical domain, the distribution shown in table 4.4 results.

	Organisational	*Technical*	*Human*	*Pat. related*	*Unclassifiable*	*Total*
Root causes	29	3	24	11	4	71
Percentage	41%	4%	34%	15%	6%	100%

Table 4.4: Distribution of root causes over main categories.

Table 4.4 shows that 41% of the root causes are classified as organisational, which means that for this medical setting as well, organisational failure is the main contributor to incident causation. The remaining 59% of the root causes are divided over technical root causes (4%), human root causes (34%), patient related root causes (15%) and unclassifiable root causes (6%).

Figure 4.6 shows the distribution of the root causes over the categories of the classification tool. Although the interpretation of a distribution as shown in figure 4.6 is based preferably on a larger number of classified root causes, an indication of possible problem areas can be derived from this figure.

Organisational failure factors
A total of 29 root causes (41%) are classified as organisational and two of the four peaks are also found at an organisational level. The high total of OC (culture) refers to a kind of group behaviour of personnel that is contrary to the rules of the institution, however, accepted by the group. The incidents show several cases where residents are left unsupervised in situations where supervision is of utmost importance (e.g. epileptic residents taking a bath). Although it is known that direct supervision is a prerequisite, residents are regularly left alone for a short period of time (2 to 3 minutes). Overestimating the safety of the work environment is a common problem in safe organisations. When few real incidents happen, alertness of employees is likely to decrease, resulting in a changing attitude towards safety regulations.

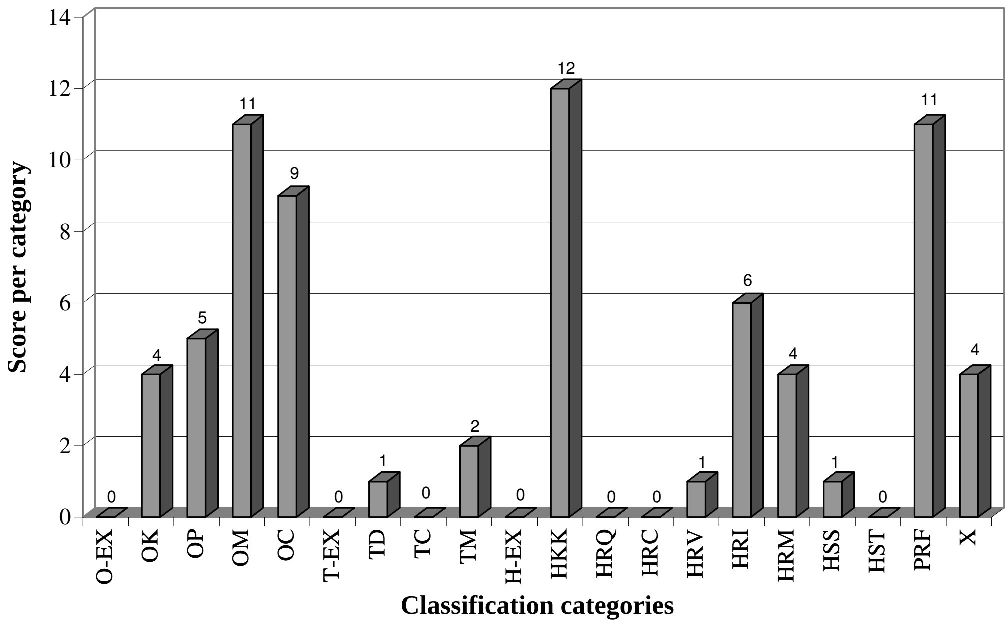


Figure 4.6: Distribution of root causes of the institution for the mentally handicapped (n = 71).

The high total of OM (management priorities) is related to the mission of the institution. The institution's aim to achieve the highest possible quality of life of the residents directly results in additional risks to the residents. Integrating residents in society (e.g. sheltered accommodation), the large number of activities that are organised for the residents and the open character of the main location are some of the means used to increase the quality of life of the residents. However, the level of risks that results from this policy needs to be in accordance with the staffing levels. The incidents investigated show that this harmony between the level of risks and the staffing levels is not always taken into account by management.

Failures related to protocols all refer to missing protocols for situations where protocols are needed. For example, the drowning of an epileptic resident while taking a bath, highlighted the lack of a protocol about what rules should be followed.

Only a limited number of root causes referring to a lack of skills and knowledge are highlighted by the incidents. In all cases, inexperienced (junior) staff were involved.

Technical, human, patient related and unclassifiable failure factors

Only three root causes (4%) are classified as technical. This is not surprising given the kind of institution and the type of care that is provided to the residents. Contrary to hospital departments as discussed in the previous three case studies, the focus of this institution is mainly on the care process instead of on the delivery of medical treatment. Therefore, technical equipment is not often used. Equipment that is used is robust and designed and tested for use in this kind of institution.

A total of 24 root causes are classified as human failure, of which the majority are classified as HKK (knowledge). This refers to the inability of an individual to apply existing knowledge to manage a novel situation. Failures at this level are not surprising in combination with the previously described organisational problems. When risks are increased without taking compensatory measures at a management level, the problem is left for those who are directly involved in the care of the residents. To manage the increased risks, known risks are evaluated for their likelihood of occurrence. Available resources and 'attention' are allocated to those situations that are perceived most risky. Unfortunately these estimations are not always correct.

The last peak is formed by PRF (patient related factors) with 11 classified root causes. Given the kind of 'patients' in this situation, a high total in this category is not surprising and is probably difficult to manage by management. The handicaps of the residents automatically result in extra risks. Although these patient related factors can be more or less considered as a given and recognised factor in this sector of the medical domain, this does not imply that they are not worth noticing. As described earlier, the absence of incidents can result in the alertness of employees decreasing. Unfortunately, the same is also true for recognised problems.

4.5.4 Discussion

The case study in the institution for the care of the mentally handicapped also shows the added value of the classification tool for the medical domain. Although different from the medical settings and the types of incidents discussed earlier, similar root causes are found in this setting which can easily be classified using the classification tool. This clearly indicates the general applicability of the classification tool in the highly diverse medical domain.

The added value of the PRISMA-analysis for the institution can be summarised under the following four headings:

1. An in-depth incident analysis;
2. Classification at a root cause level;
3. Participation of staff in the incident-analysis process;
4. A link between root causes and preferred countermeasures.

Most problematic in the current method of incident analysis in the institution is its superficial nature. Without an in-depth analysis of reported incidents, only the directly visible symptoms are detected. These symptoms rarely provide any information about the real problems preceding these symptoms. Corrective actions based on symptoms are therefore likely to result in the recurrence of the same or similar symptoms, since the preceding problems have not been solved. PRISMA on the other hand only focuses on root causes, irrespective of the symptoms of the incident. In this case study, this resulted in a total of 71 classified root causes, which do provide useful starting points for improvement. This clearly shows the added value of PRISMA, based on its in-depth incident analysis through critical incident interviews, causal tree analysis and classification at a root cause level.

PRISMA also increases the active participation of staff in the incident analysis process. The in-depth analysis of the incidents is not based on the written incident report only, which is true for the current method of analysing incidents by the FOBO-committee. Additional critical incident interviews are conducted with the staff involved, followed by a causal tree analysis. In both steps, staff members are actively involved. This directly covers most of the criticism of the current system. Due to its lack of feedback and a lack of additional investigations into reported incidents, the current system is seen as a black box. This has a serious negative influence on the motivation of staff to report incidents and prevents the system from being used as a learning system. Consequently, the goals of the FOBO-committee are only partly known, it is unclear what should be reported as an incident and reporting incidents has only a low priority for most staff members. PRISMA on the other hand, provides feedback by including the staff involved in an incident in the analysis process and by doing so, provides insight into the incident causation process.

PRISMA also provides a link between classified root causes and preferred corrective actions. The classification/action matrix has been developed to do this. However, generating suggestions for improvements, based on the classification/action matrix, was beyond the scope of this case study. It is premature to draw conclusions based on only nine incidents. It is also not sensible since the incidents occurred over a period of five years and are therefore not necessarily representative of the current situation.

4.6 Lessons from the medical domain

In the last section of this chapter the classification tool developed for the medical domain is justified. The organisational strengths and weaknesses of the medical domain are summarised and some concluding remarks are made about incident reporting and analysis in the medical domain.

4.6.1 A classification tool for the medical domain

In section 3.4.1, criteria for the selection and definition of the organisational categories for the classification tool for the steel industry are discussed. The same criteria are applied to the classification tool for the medical domain. The classification tool developed for the medical domain differs from the initial Eindhoven Classification Model on the following points:

- the position of the organisational categories in relation to technical and human failure;
- additional categories for organisational failure factors;
- the distinction between internal and external failure factors;
- changes to the technical and human categories to facilitate use in the medical domain;
- an additional category for patient related factors.

The position of the organisational categories in relation to the technical and human categories remain the same for tool for the steel industry. The change in order from the original model is made for the same reasons as discussed in section 3.4.1. The four (internal) organisational classification categories are also similar to those presented for the steel industry. Differences only exist in the labelling of the categories. Two minor changes have been made to facilitate use in the medical domain. The category 'working procedures' is now called 'protocols'. The term protocols is preferred to procedures, since in the medical field the term protocol is regularly used and readily understood. The category 'safety culture' is changed to 'culture', because incident reporting and analysis in the medical domain is often used under the heading of evaluating the quality of patient care. The term safety culture is therefore confusing and too narrow.

New to the classification tool for the medical domain is the distinction between internal and external failure factors (Van Vuuren *et al*., 1997). The importance of making this distinction became apparent particularly during the case study in the A&E department, since this department is highly dependent on specialist services provided by other departments. The significance of making this distinction originates from the typical organisational structure in the medical domain. In a hospital setting, a variety of specialist departments are united under one roof for expediency. The departments are both financially and organisationally independent of each other, while coexisting in a dependent relationship within the hospital. Because of this dependent relationship, the safety performance of a department may be negatively influenced by the performance of another department. Since the different departments in a hospital are organisationally independent of each other, the external factors are beyond the direct control of the department that is being adversely influenced by them. It is the obligation of each department or service to manage its own internal affairs. Not only are external factors beyond the control of the department, it is also very difficult to assess the real causes behind these external factors. It is of little use to hypothesise in great detail about the origins and accompanying corrective actions in other departments. For this reason, the three main categories of organisational, technical and human have an external category, to be used when a root cause originates outside the department investigated. Sub-categories on an external level are left outside the classification tool.

While showing the need for distinguishing between internal and external factors, the incident data of the A&E department also showed the need for the category 'transfer of knowledge'. As discussed earlier, a large number of incidents in the A&E department are caused by insufficient transfer of knowledge to junior doctors in the department. The incident data of the anaesthesia department highlights the consequences of poor or missing protocols. Both the case study in the Intensive Care Unit and the institution for the care of the mentally handicapped highlight the consequences of cultural factors and show the need for adding this category to the model. The latter also clearly shows the consequences of management priorities on day to day practice.

For the technical and human categories, some minor changes have been made to facilitate use in the medical domain. The original technical category of 'engineering' is re-labelled as 'design' to improve its understanding and breadth of application in the medical domain. The term engineering does not include medically specific problems such as the poor design of drugs (i.e. having serious side-effects). The new category still refers to failures resulting from the poor functional design of items and now may include not only equipment or hardware but also items such as medications, dressings, labels and forms.
The differences in characteristic task elements found between the industrial setting and the medical domain support the revisions made to the human categories of the model, to improve its implementation and comprehension. At the knowledge based level the two categories of 'status' and 'goals' are reduced to one, 'knowledge'. A distinction between the two original categories is difficult to make accurately and renders the second category (goals) difficult to use. Similar alterations are made in the rule-based categories. The two original categories 'licence' and 'permit' are combined in a category called 'qualifications', to improve the model's applicability. This category more accurately represents the circumstances in the medical domain. The categories 'checks', 'planning' and 'equip/info' of the initial model have been changed to 'verification', 'intervention' and 'monitoring', which more correctly represents the tasks that are carried out before, during and after the medical invention. The skill-based categories are re-labelled as 'slips' and 'tripping' to improve their understanding, however, represent the same types of human failures as in the original model.

The penultimate category of the classification tools is now called 'Patient Related Factors' (Van Vuuren *et al.*, 1997). This category is intended to capture the failures that arise due to uncontrollable and unpredictable patient factors. The need for this category is shown in every medical setting. The biggest contribution of this category is found in the case study in the institution for the care of the mentally handicapped. This, however, is not surprising.

4.6.2 Organisational strengths and weaknesses of the medical domain

Looking back over the case studies in the medical domain, some preliminary conclusions can be drawn about the organisational strengths and weaknesses of this domain. Again, organisational failure appears to be a very significant contributor to incident causation, which should not be underestimated when improvements are to be made. For the individual case studies, 45% (A&E), 27% (anaesthesia), 30% (ICU) and 41% (mentally handicapped) of the root causes are classified as organisational. A more detailed look at the organisational scores can allow us to draw the following additional conclusions:

- When a department is dependent on services provided by other specialist departments it should be aware of and safeguard itself against the possible adverse influences of these departments on day to day practice. These influence are clearly shown in the A&E department, while no external factors are found in the institution for the care of the mentally handicapped. This is not surprising, since the institution is self-sufficient.
- The higher the level of experience of staff involved, the lower the contribution of knowledge and experience problems. This is clearly shown in the A&E department that is mainly run by inexperienced doctors. A low total is also found in the highly specialised Intensive Care Unit. The importance for departments to invest in training and selection of new personnel is clearly shown in the incident data.
- A high number of management priorities is found in the institution for the care of the mentally handicapped. In chapter 3 it was concluded that the low number of management priority problems in the steel production plant was the result of assigning a maximum of authority to the teams. This way, fewer decisions were made by those who were not fully aware of the consequences of the decisions on the shop floor. The opposite is true for this institution. Although management is often not fully aware of the risks and consequences of certain decisions on the shop floor, they still decide on how the shop floor should organise their work. Authority should be delegated where possible and assigned to those who are aware of the risks and consequences of decisions made.
- The incident data clearly shows a relation between the level of routine of the tasks performed and the contribution of cultural failure factors. The lowest totals are found in the A&E department (19%) and the anaesthesia department (24%). The highest in the ICU (30%) and the institution for the mentally handicapped (31%). Given the diversity of medical problems the A&E doctors are confronted with and the time they spend in the A&E department routine is not likely to turn into serious cultural problems. More routine actions are found in the anaesthesia department. The high contribution of cultural factors in the ICU and the institution for the mentally handicapped is related to the dominant involvement of nursing staff in the incidents in both settings. In the ICU, only the nursing staff participated in the case study. The institution for the care of the mentally handicapped is predominantly run by nursing staff. Tasks of nursing staff in general involve a high level of routine.

Nursing staff seem to be more willing to co-operate in systems to improve patient safety and quality of patient care than medical staff. There are several likely explanations for this phenomenon, which can be summarised under the headings 'cultural differences' and 'focus of attention'. The cultural differences between medical and nursing staff relate to the level at which it is common or accepted to discuss occupational mishaps. For nursing staff it is common practice to discuss incidents that happen during daily practice. For medical staff, however, this is less common. Two possible explanations are to maintain the hierarchical and professional position and fear of possible litigation. As a result of this cultural difference, in one case study no incidents detected or caused by medical staff were reported. Nursing staff may be aware of 'medical' incidents but are not likely to report them, essentially because of their lower hierarchical position inside the organisation. According to nursing staff it is not up to them to report these incidents. In most cases the best possible option for the nursing staff is to bring the incident to the attention of the doctor involved, hoping this will lead to the incident being reported by the doctor.
When quality of patient care is considered in particular, an interesting difference between medical and nursing staff exists in their focus of attention. Medical staff in general are primarily focused on the effect of the treatment provided. Did the treatment provided to the patient solve the patient's medical problem? Is the patient cured? If yes, the care provided has been successful. If not, treatment has not been successful and additional treatment has to be provided. Nursing staff generally have a broader perspective and also include the perception (the satisfaction) of the patient about his or her stay in the department. Medical staff are often not interested in systems that have this broad perspective and include subjects that are considered far less significant by medical staff than by the nursing staff.

When considering the configurations by Mintzberg (1983) discussed in chapter 2, it can be concluded that for medical staff standardisation of worker skills is the dominant mechanism of co-ordination. Nursing staff on the other hand strongly rely on the standardisation of work processes. Consequently, no single configuration can be used to explain both professions. For the medical staff, the best characterisation would be Mintzberg's professional organisation, given its focus on skill and knowledge as the predominant co-ordination mechanism and its focus on the operating core as the key area. For the nursing staff, the best characterisation would be the machine organisation, although it should be noted that the nursing staff are becoming more and more involved in defining its own working procedures and also strive rapidly towards professionalisation.

5 Reflection on the case study results

The second step on the theoretical path develops the taxonomy of the organisational root causes of safety related incidents. This is discussed in the first section of this chapter. The classification tools developed for the two domains are compared and evaluated and the remaining goals of this study are discussed. This includes the tools for detecting and describing organisational failure factors and the guidelines for managing organisational failure. This chapter concludes by outlining the position of organisational failure in relation to technical and human failure and providing a more precise definition of organisational failure based on the empirical incident data collected in this study.

5.1 From a theoretical framework to a taxonomy

In section 2.2.5 the theoretical framework was presented. The framework is the result of the first step on the theoretical path towards the development of a taxonomy of the organisational causes of safety related incidents. In this theoretical framework, a first subdivision of organisational root causes was made based on a review of literature on organisational change and development. This first subdivision resulted in three main categories of organisational failure: structure, strategy and goals, and culture. A first indication of a further subdivision was also presented, based on the literature review. Based on the empirical data collected in the six case studies, this section discusses the second step on the theoretical path.

As discussed in section 2.4.3, the second step of the theoretical path is made following an analytic generalisation strategy (Yin, 1994), similar to the strategy followed for the development of the domain specific classification tools. The main difference between the two development processes is that for the development of the taxonomy the case study results of the two domains are considered at the same time, contrary to the focus on only one domain for the development of each classification tool. The incidents are considered individually, since this process is only stopped when all incident data has been evaluated.

Based on the theoretical framework presented in chapter 2 and the empirical data presented in chapters 3 and 4, the taxonomy of the organisational causes of safety related incidents is developed. For this, the same iterative process of explanation building (Yin, 1994) is used as for the development of the classification tools and described in section 2.4.3. The theoretical framework presented in chapter 2 is used as the initial taxonomy and is compared with each individual incident of this study. Based on these comparisons, the taxonomy is revised where necessary. According to the theoretical framework, organisational failure can be divided into three main problems areas, structure, strategy and goals, and culture. Table 5.1 shows the taxonomy of the organisational causes of safety related incidents that resulted from the process of explanation building. This taxonomy shows how the three main categories are operationalised and where possible further subdivided. The taxonomy contains nine subcategories that can be used to categorise organisational failure factors.

Main categories	*Subcategories*	*Definitions*
Structure	Task demands	Refers to failures related to the wrong fit between the capabilities of the worker and the demands of the job.
	Responsibilities	Refers to failures related to the absence or inaccurate allocation of responsibilities among departments, groups and persons.
	Skills and knowledge	Refers to failures resulting from inadequate measures taken to ensure that situational or domain specific skills and knowledge are transferred to all new or inexperienced staff.
	Working procedures	Refers to failures related to the quality and availability of the working procedures within the department (too complicated, inaccurate, unrealistic, absent, poorly presented).
	Supervision	Refers to failures related to the absence of supervision on work with increased risks.
Strategy and goals	Management priorities	Refers to failures resulting from management decisions in which safety is relegated to an inferior position when faced with conflicting demands or objectives.
Culture	Norms and rules for dealing with risks	Refers to failures resulting from the absence of explicit or tacit norms and rules for dealing with risks.
	Safety attitudes	Refers to failures related to the collective beliefs about risks and the importance of safety, together with the motivation to act on those beliefs.
	Reflexivity on safety practice	Refers to failures related to an inadequate learning of the organisation from its own safety experiences.

Table 5.1: The taxonomy of organisational causes of safety related incidents.

When the taxonomy is compared with the organisational categories of the domain specific tools, two main differences are detected.

The first difference is an extension of the number of categories related to the structure of an organisation. In the classification tools only two categories related to structure (OP and OK) are included. The second difference is a further subdivision of the category 'culture' (OC in the classification tools). No extension or subdivision is found necessary for the main category of strategy and goals. The subcategory management priorities seems to capture this category satisfactorily.

The extension of the number of categories related to the structure of an organisation is based on the two main aspects of structure, decomposition and co-ordination, discussed in chapter 2. Decomposition refers to the process of subdividing tasks and responsibilities among departments, groups and persons. Once tasks and responsibilities are subdivided, co-ordination is needed to integrate the differentiated subtasks so as to achieve successful completion of the whole task. So far, decomposition has been left out of the classification tools. The incident data collected in the Dutch steel industry did show problems related to the demands of tasks to be performed and responsibilities, however, not enough to justify additional categories in the classification tool, given the criteria used. For the classification tools, categories are defined at a high level of abstraction to maximise the usability of the tools (i.e. a minimum number of categories), whereas in the case of the taxonomy, categories are defined at low level of abstraction, leading to more and more precisely defined categories.

The remaining three structure categories all refer to co-ordination and are based on the co-ordinating mechanisms presented by Mintzberg (1983; 1989). The empirical data clearly shows the importance of skills and knowledge, and working procedures as co-ordinating mechanisms. The empirical data in the steel industry also showed the need for direct supervision, though again not enough to justify an additional category for the classification tool. Supervision appears to be necessary in situations with increased risk, where skills and knowledge and working procedures alone are not sufficient to co-ordinate the job in such a way that safe performance is guaranteed. The remaining three co-ordinating mechanisms mentioned by Mintzberg (i.e. mutual adjustment, standardisation of outputs and standardisation of norms) are not included in the taxonomy. Mutual adjustment is a co-ordinating mechanism at a human level and is therefore beyond the scope of this study. Medical staff tend to evaluate their own performance in terms of 'desired output'. However, task performance is primarily co-ordinated by means of standardisation of skills and knowledge, and standardisation of working procedures. Standardisation of norms is captured by another subcategory in this taxonomy (i.e. norms and rules for dealing with risks).

Culture as one comprehensive category in the classification tools is subdivided in three distinct categories for the taxonomy of organisational failure. This subdivision is based on the characterisation of a 'good' culture by Pidgeon (1991), which can be evaluated on three different aspects of culture: norms and rules for dealing with hazards, attitudes towards safety and reflexivity on safety practice. This much more precisely differentiates between different aspects of culture and also provides more direction for corrective actions to be taken. All three categories can be detected in the empirical data collected. The majority of the root causes, however, refer to the attitudes of employees towards safety, which justifies its place in the classification tools.

5.2 Domains compared

In chapters 3 and 4 the two domains are discussed separately. In this section the two domains are compared on both the tools that are developed and their organisational strengths and weaknesses. The propositions that have been formulated prior to starting the case studies are also evaluated.

5.2.1 Management tools

In chapter 1 it is stated that tools need to be developed for detecting, describing and classifying organisational root causes of safety related incidents. During this study it became clear that the critical incident interviews and the causal tree technique used in PRISMA cope with the first two requests satisfactorily. To detect organisational failure factors, in-depth information in incident causation is needed. There are basically two techniques that qualify for providing this in-depth information: critical incident interviews and an extensive questionnaire to be used to report incidents. There two reasons not to use an extensive questionnaire to detect organisational failure factors. First, practical experience with implementing systems for reporting and analysing incidents has shown repeatedly that to increase the acceptance of a reporting system, the threshold to report incidents must be made as low as possible. Three known ways for management to promote the acceptance of a reporting system by employees are: anonymity, forgiveness (or a no blame policy) and feedback (Lucas, 1992; Van der Schaaf, 1992). However, both the pilot studies (Van Vuuren, 1993; Van Vuuren & Van der Schaaf, 1995) and the case studies clearly showed that also the incident report should be as simple and limited as possible. Since in practice most of the incident reports have to be filled in after working hours, one is generally not willing to spend much time on them. The direct benefits of reporting incidents are often unclear, thus reporting incidents is low on the priority list of most employees. Employees are also often biased towards a certain type of failure. It is difficult to overcome this bias in a questionnaire. By using critical incident interviews, all of these problems can be overcome. A brief and simple incident reporting form can be used, since in-depth information is collected during interviews. In this case, the report is only used to trigger a further investigation. The investigator performing the critical incident interviews can be trained to overcome biases and to ensure that all possible failure factors are taken into consideration during the interview.

The causal tree technique appears to be a powerful method to describe or present organisational failure factors and to show how they are both chronologically and logically related to other failure factors involved in the incident. By displaying the contributing failure factors in a causal tree, valuable insight is provided into incident causation. Only when this process is understood, can improvements be made effectively. Given the power of the causal tree technique, this study shows no direct need to develop new tools or techniques for describing or presenting organisational failure factors.

This thesis has primarily focused on the development of domain specific classification tools, which incorporate the classification of organisational failure factors satisfactorily. The two organisational categories of the Eindhoven Classification Model proved to be insufficient for this purpose. Two classification tools have been developed and have been discussed in the previous chapters. This section briefly discusses the differences between the two classification tools, which support the decision to develop two domain specific classification tools instead of one generally applicable classification tool.

A number of minor (didactic) changes exist to facilitate acceptance and use in a particular domain. These changes to facilitate acceptance and use mainly involve the labelling of the classification categories (e.g. working procedures versus protocols) and have been discussed extensively in both chapters 3 and 4. This section briefly summarises the more structural differences, which justify the need for two domain specific classification tools. Two major structural differences exist between the two classification tools, of which the first also relates to organisational failure factors. First, in the medical domain a distinction needs to be made between internal versus external failure factors given its characteristic organisational structure, a distinction shown unnecessary for the contemporary Dutch steel industry. Second, a separate category to classify patient related factors must be included for the medical domain. Patient involvement is unique for the medical domain and, as indicated by the incident data, should not be underestimated when investigating incident causation in the medical domain. It should be noted, that a similar category is also likely to be necessary in domains where 'customer involvement' (e.g. public transportation) might result in safety related risks. These domains, however, have not been included in this study.

Based on the tools and insights provided by this study, although not mentioned specifically as a goal of this study, the classification/action matrix mentioned in chapter 2 can and should be modified. Detecting and classifying root causes is one step in incident prevention, making the link between these classifications and effective corrective actions is another. The initial classification/action matrix has been modified for the organisational categories of the classification tools. The initial matrix only suggested a corrective action for organisational problems related to procedures (OP). The modified matrix discusses possible corrective actions for all organisational

categories. Since developing strategies for improvement was not included in both the goals and set up to this study, the matrix is based on the practical experience gained during this study only. Additional research to test the effectiveness of the actions suggested in the modified classification/action matrix is necessary.
Although differences exist in the labelling of the organisational classification categories, one classification/action matrix can be developed. The corrective actions proposed in the matrix are similar for the two domains, irrespective of the labelling used to facilitate acceptance and use in a particular domain. Table 5.2 presents the modified version of the organisational part of the classification/action matrix.

	Interdepartmental communication	*Training and coaching*	*Procedures / protocols*	*Bottom-up communication*	*Maximise reflexivity*
O-EX	X				
OK		X			
OP			X		
OM				X	
OC					X

Table 5.2: The modified version of the organisational part of the classification/action matrix.

The classification/action matrix connects each organisational classification category to its 'best fitting' corrective action type. The term 'corrective action type' is chosen to indicate that at this level a set of corrective actions make up the type of corrective action. The final choice regarding which corrective action to take must be based on the possibilities and limitations (e.g. financial limitations) of the organisation or department involved. Different actions than the ones suggested in the matrix are also possible, however, are likely to be less efficient. This classification/action matrix is only intended to guide this choice in the right direction, since ineffective or inefficient actions are easily taken. To give an example, the next paragraph about external organisational problems discusses both the suggested corrective action and another possible but less efficient option.

To solve external organisational problems (O-EX), communication between the departments involved is needed. It is not unlikely that the department causing the problem is unaware of (the size of) its negative influence on safety in another department. When the department causing the problems is not notified about this, improvements are not to be expected. Internally, one can build defences against negative external influences, however, it is much more efficient to solve a problem at its source. For this, communication between departments which coexist in a dependent relationship is needed.

Problems related to a lack of domain specific knowledge and experience (OK) require corrective actions related to training and coaching. Training prior to starting a job in a new working environment or at the very beginning and coaching while gaining knowledge and experience on the job. Both have to be taken seriously to prevent failures due to unfamiliarity with the domain specific characteristics, rules and dangers.

Problems related to working procedures or protocols (OP) require corrective actions aimed at completing or improving these procedures or protocols for efficient and safe task performance. Procedures or protocols should be reviewed regularly to check whether or not they still fit the tasks to be performed.
It should be noted that problems related to procedures are not always solved by changing the procedures. The developments in the task or domain involved should also be taken into account. For medical staff for example, there is a tendency to proceduralise skills, while for nursing staff a tendency to professionalise procedures has been noticed (i.e. transferring the task to the domain of competence). The suggested corrective action in table 5.2 is based on the assumption that improvement can be and therefore should be made at the level of procedures. Training or motivating employees to work safely is also frequently encountered in practice as a popular corrective action as opposed to completing or improving inadequate procedures. This option, however, should only be considered when procedures or protocols would be too extensive or complex to use.

Before discussing the final two categories of the classification/action matrix, it should be noted that the corrective actions presented for these categories are only preliminary suggestions based on the incident data collected. Pinpointing the true causes behind problems related to management priorities and culture is far more difficult than for the categories discussed above, because they are often caused by even higher level management decisions or influences. These causes or influences are beyond the scope of the incident investigations presented in this study.

In the classification/action matrix presented in chapter 2, no corrective action is suggested for problems related to management priorities (OM). Van der Schaaf (1992) states that "OM failure relates to the local managers themselves and therefore requires moving to higher levels of management to solve this (e.g. by improving management policies), than is feasible for the line-managers who are supposed to be supported by this matrix". This is only partly true. As discussed in section 5.2.3, managers are not always fully aware of the practical consequences of their actions on safety on the shop floor. Feedback from the shop floor can prevent this lack of practical knowledge by management from developing into incidents. The suggested bottom-up communication in table 5.2 should be used by management to evaluate its decisions. Bottom-up communication should not be considered the sole solution to this type of problem. It would be far too simple to consider that it is possible to capture this type of problem in one corrective action type. Part of the problem can indeed only be solved by higher levels of management. The case study in the steel production plant shows that assigning a maximum of authority to teams leads to a low score on management priorities. However, deciding to do so is often beyond the control of line-management. At a top-management level it is very important to formulate a clear policy related to safety. This policy or mission should be recognised throughout the organisation and should be used to evaluate the performance of every employee, including managers, of the organisation.

Finally, a corrective action type for problems related to the culture of an organisation (OC) is presented. Similar to the discussion about a corrective action type for problems related to management priorities, it is not possible to capture this type of problem in one corrective action type. Cultural changes take time, are difficult to accomplish and require more than just one corrective action. However, the incident data clearly shows decreased risk awareness and vigilance as main contributors to adverse group behaviours, leading to incidents. Therefore, an organisation should reflect on its safety experiences and try to learn as much as possible from them. The correct level of risk awareness and vigilance can be maintained by reporting and analysing the often abundantly available near misses. Based on these analyses, feedback to the organisation can be provided to show the dangers of day to day practice. This way, a continuous circle of learning from its own safety experiences and measuring the safety performance of the organisation results.

5.2.2 Organisational strengths and weaknesses

The incident data collected in the six case studies has provided insight into the organisational strengths and weaknesses of the settings investigated, which are now used to compare the two domains. In the medical domain, knowledge appears to be more important as a co-ordinating mechanism than in the Dutch steel industry, which is primarily reliant on standardisation of work processes. In particular in the A&E department this need for knowledge is clearly demonstrated. The importance of skills and knowledge as a primary co-ordinating mechanism can be related to the high level of uncertainty of the tasks to be performed in the medical domain. Galbraith (1973) states that "the greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution, in order to achieve a given level of performance". If tasks are well understood prior to performing them, much of the activity can be pre-planned or formalised in written procedures. This is exactly what happens in the Dutch steel industry, where the majority of tasks involve little or no task uncertainty and can be pre-planned in great detail. This explains the emphasis on standardisation of work processes in the steel industry.

On both management priorities and safety culture the two domains have similar scores. In both domains management decisions are taken in which safety is relegated to an inferior position, primarily because of financial objectives. In the Dutch steel industry safety appears to be subordinated by management in situations where following the safety procedures will negatively influence production. In the medical domain, patient safety is negatively influenced by management decisions to reduce staffing levels (in particular experienced staff). Root causes classified as safety culture are in both domains mainly related to a type of time saving behaviour, in which the risks of this behaviour are greatly underestimated and the skills and knowledge available are greatly overestimated.

Two important differences in applying risk management have been highlighted by the case studies in the two domains. The first difference deals with the organisational level from which initiatives for risk management originate. In the steel industry, most initiatives originate from a management level and tend to have their effect on the whole organisation. In the medical domain, the reverse is more common. Initiatives normally arise at a shop floor level and are often restricted to (a part of) the nursing or medical staff only. These local initiatives are often not fully supported by management. The expertise and resources needed to perform the initiatives effectively are often not available at a local level. Therefore, in most cases these initiatives lead to sub-optimal results and missed opportunities for improvement. As a result of the small-scale and local character of the studies in the medical domain and its larger diversity, it was decided to include four relatively small (parts of) departments of the medical domain in this study as opposed to only two large plants in the steel industry.

Second, during the first case study in the medical domain it became clear that the medical domain differs from the steel industry in its focus for improvement. The medical domain appears to be highly 'end-product' focused, meaning that assessment of quality of care and learning is primarily based on the final outcome of treatment given to a patient. Attention is paid to the final result but hardly to the process preceding this result. Some studies have tried to include causal factors (Webb *et al.*, 1993; Beckmann *et al.*, 1996), though still focusing heavily on reporting and classifying symptoms of medical incidents. The opposite situation is found in industry, where the focus of assessment and learning is primarily on the process. When looking at adverse outcomes in medicine, only the tip of the iceberg is discovered. This not only results in a very limited set of incidents, but also in incidents that have already happened. As Reason (1991) comments this is "too little and too late". A process focus not only provides more information for improvement, it also provides information in time to make recovery possible. Using a product focus, only mistakes made at the sharp end become visible (e.g. a misdiagnosis by a junior doctor). However, contributing factors at the beginning of incident evolution (e.g. staffing levels, training and supervision, cultural factors, etc.) may remain hidden.

5.2.3 Propositions: true or false?

At the end of both chapter 2 and chapter 3 propositions were formulated about the occurrence of organisational failure factors in the different settings and about differences between the two domains. Both types of propositions were based on known characteristics of both domains and the individual settings to be investigated.

In this section these propositions are evaluated based on the empirical data collected in the case studies. By doing this, the propositions also provide theoretical knowledge about organisational failure, although the propositions were initially only intended to select the domains of this study and the settings to be investigated within these domains.
The propositions are evaluated in the same order as they were presented in this thesis. First the propositions about the case studies in the Dutch steel industry (1, 2 and 3), followed by the propositions about differences between the two domains (4, 5, and 6). Finally, the propositions about the case studies in the medical domain (7, 8 and 9) are discussed.
Since propositions and not hypotheses or predictions are evaluated here, no statistical testing is included. The propositions were only used to state trends in organisational failure that were expected prior to starting the case studies.

Proposition 1
In proposition 1 it was stated that a lower contribution of cultural factors was expected in the steel production plant, since employees are more exposed to dangers and therefore more aware of the risks involved in day to day practice. The empirical data shows that in the coke production plant 33% of the organisational root causes are attributed to culture, versus 27% in the steel production plant. The contribution is smaller, however, not significantly smaller given the limited number of incidents and root causes involved. It appears that the level of risks one is exposed to is not the problem, it is the blindness that results from being exposed to risks regularly. Even in the more dangerous steel production plant risks become common and because serious incidents are (fortunately) lacking, it is hard to stay fully alert and easy to reduce vigilance. It is therefore not the level of risks one is exposed to that determines the cultural contribution to incident causation, it is more likely to be the organisation's effort to maintain the correct level of alertness and vigilance that makes the difference. Both settings investigated in the Dutch steel industry did not differ significantly on this aspect, which is likely to explain the similarity in scores on the contribution of culture. An incident reporting and analysis system can be used to maintain the correct level of alertness by showing and discussing the large number of near misses that happen on a day to day basis. Both settings investigated were in the process of developing and implementing such a system.

Proposition 2
Proposition 2 stated that an increased need for co-ordination between teams was expected in the steel production plant, since a maximum of authority is assigned to the teams, reducing the level of management involvement and control over the teams. As discussed in section 3.5.1, only the incident data in the steel production plant indicates a possible need for a category aimed at co-ordinating problems between teams, departments or even suppliers and contractors. However, since only 6 root causes would have been classified according to this category, it was decided not to add this category to the classification tool for the steel industry. Additional research is needed to test the influence of decentralising authority on organisational failure.

Proposition 3

In this proposition it was stated that less impact from management priorities was expected in the steel production plant because of the level of authority that is assigned to the teams. A lower score on management priorities is found in the steel production plant. In the coke production plant 21% of the organisational root causes is attributed to management priorities, against only 12% in the steel production plant. Management decisions are often based on a limited knowledge about the consequences of certain decisions on safety on the shop floor and are often influenced by conflicting objectives at a management level. By reducing the level of management involvement in day to day practice on the shop floor, the number of decisions based on a limited knowledge about risks on the shop floor and conflicting management objectives can be reduced. Assigning a maximum of authority to the teams proves to be a good method to achieve this reduction in management involvement.

Proposition 4

Proposition 4 stated that more problems related to knowledge and experience were expected in the medical domain than in the steel industry, because of the medical domain's strong emphasis on individual self-reliance and decision-making. As discussed in the previous section, greater task uncertainty exists in the medical domain, resulting in a greater amount of information to be processed during task performance and fewer pre-planned tasks. Consequently, knowledge and experience related failures are to be expected and are also clearly shown by the empirical incident data. In the steel industry the emphasis is on standardisation of work processes, reducing the level of individual self-reliance and decision-making. The level of task uncertainty proves to be a good indicator of the impact of knowledge and experience problems to be expected in a certain setting or domain.

Proposition 5

Similar to proposition 2, communication problems are expected between hospital departments because of the autonomous manner in which the departments are organised. Again, communication in itself is not found to be a significant problem. However, the fact that departments are both financially and organisationally independent from each other, while coexisting in a dependent relationship within the hospital did result in a considerable number of interdepartmental problems. However, given the diversity of these problems and the difficulty in detecting the true nature of their causes, only the distinction between internal and external root causes has been made for the medical domain. Therefore, the independent way in which departments are organised within a hospital does lead to a considerable amount of interdepartmental problems, however, it is too simple to relate this only to communication. Differences in cultures, priorities (see proposition 6), protocols, etc. also exist. Research projects including more than one department are needed to gain insight into the true nature of the (organisational) causes of interdepartmental problems.

A question that results from the outcome of this proposition is why such a considerable amount of interdepartmental problems exist in the medical domain, while only a limited number of problems are recorded in the steel production plant? This difference is likely to be explained by the level to which the departments, or teams in the steel production plant, are independent of each other. In the medical domain departments are both financially and organisationally independent of each other. In the steel production plant, teams are only partly organisationally independent of each other. Therefore, the higher the independence of departments or teams, the greater the number of problems between these departments or teams to be expected.

Proposition 6

Proposition 6 expected a high number of problems related to differences in priorities between the different hospital departments in the medical domain. The discussion about the previous proposition has already highlighted this problem. Differences in priorities between departments do exist in the medical domain, resulting in a considerable amount of interdepartmental problems. In particular decisions with a financial background (e.g. staffing levels, number of beds on a ward) are often taken without fully considering the consequences for other departments. The reason for a different total in this category in the steel industry has been discussed earlier.

Proposition 7

In proposition 7 it was stated that a higher number of knowledge and experience problems was expected in the A&E department than in the anaesthesia department, given the type of medical staff that is employed by both departments. The totals in the category 'OK' show that this proposition is indeed correct. The A&E department is mainly run by inexperienced doctors, while the opposite is found in the anaesthesia department. Again the level of task uncertainty is responsible for this difference. Both the lack of knowledge and experience of the A&E doctors and the enormous variety of unpredictable and unplanned medical problems they are facing on a day to day basis, results in great task uncertainty in the A&E department. The anaesthesia department on the other hand is staffed with experienced doctors and tasks are well-planned and known in advance. Problems related to knowledge and experience are therefore less common in the anaesthesia department than in the A&E department.

Proposition 8

Proposition 8 expected a greater number of internal communication problems between the medical staff and the nursing staff in the ICU than in the A&E and the anaesthesia department. This was based on the strong functional relationship between the medical staff and the nursing staff in the ICU. This proposition could not be tested properly since the medical staff did not participate in this case study. The incident data collected from the nursing staff does not provide enough information to draw conclusions about this proposition.

Proposition 9

In proposition 9 it was stated that a high number of failures related to culture in the institution for the care of the mentally handicapped was expected, because of its focus on long term care in which risks are spread out over a long period of time. It is expected that this leads to a decrease in level of staff alertness. The incident data collected in the institution does give a high score on culture (31% of the organisational root causes). As discussed for proposition 1, most risks in this institution are common risks, which are encountered daily. When systems are missing to repeatedly expose the dangers of day to day practice it is easy to reduce vigilance. In section 4.5.2 it was stated that the level of routine seems to influence the impact of cultural factors. The majority of the tasks performed in this institution involve routine tasks.

5.3 Guidelines for managing organisational failure

In the course of the previous chapters, several guidelines for managing organisational failure have been given. This section therefore does not reveal many new insights but can be considered a concise summary. Based on the study presented in this thesis, two main conclusions can be drawn about organisational failure, which shape the guidelines presented in this section. These conclusions are:

- The traditional focus on technical and human failure as presented in both the incident description and the literature review in chapter 1 is inappropriate and ineffective when trying to prevent incidents. This study repeatedly showed the considerable impact and importance of organisational failure factors on incident causation, although a strong bias towards technical and human failure was detected in all settings investigated. This bias shows that the traditional focus on technical and human failure still exists.
- Organisational failure factors are more latent and, when contributing to an incident, are always followed by a number of technical and human failures before resulting in an incident (see section 5.4.1). Consequently, organisational failure factors are far less visible than the technical and human failure factors, which may explain part of the traditional focus on technical and human failure discussed earlier.

Based on these conclusions the following two main guidelines for managing organisational failure are presented in order to manage incident reporting and analysis effectively:

- The organisational side of incident causation needs to be emphasised within an organisation, to take away the traditional bias towards technical and human failure. For this, proper feedback about incident causation is needed. This feedback should be based on incident investigation and analysis of real incidents in the organisation involved. Only when one is aware of all contributory factors to incident causation, can improvements be achieved effectively. A complete, non-biased, understanding of the true nature of incident causation will result in a change in attitude towards technical and human failure on every level in the organisation and hopefully to a more precise initial analysis of the incident by the one reporting it, leading to better (less descriptive) incident reports.

- Only an in-depth investigation into an incident will provide insight into organisational failure factors. In particular for organisations where large numbers of incidents are reported, this may result in a conflicting situation. Every incident can provide useful insights for improvement, however, only limited capacity is available to analyse the incoming incidents. Unfortunately, this often results in a superficial analysis of all incidents based on the reported information. Because time is lacking, no additional interviews are conducted. However, it would be much more effective if the available time were to be spent on investigating only a small representative subset of the incidents thoroughly, than a large set or all incidents superficially. For this, selection rules related to for example the severity of the incident have to be formulated. The reason for the emphasis on a small representative subset of incidents is simple. It is much better to have only a bit of useful information about the true nature of incident causation, than a large amount of useless information about the symptoms of incident causation. Unfortunately, it often appears the quantity of data collected seems more important than its quality.

These two main guidelines are again only the tip of the iceberg, since both include many other guidelines to be followed. To increase awareness about the organisational contribution to incident causation, information has to be provided to the organisation to support this claim. Therefore, not only a thorough in-depth analysis of incidents is required but also proper feedback about the true causes of incident causation. This feedback should not only include the scores on the different types of failures but also the correct corrective actions that are supported by these scores. This study clearly showed the difficulty of recognising organisational failure factors. Acknowledging and acting upon organisational failure will be even more difficult.

5.4 Improved insight into organisational failure

The study described in this thesis has resulted in improved insight into organisational failure. Better insight is gained into the position of organisational failure in relation to technical and human failure, based on this improved insight.

More importantly, the concept of organisational failure can be defined more precisely than the working definition presented in chapter 1.

5.4.1 Position of organisational failure in relation to technical and human failure

In section 1.3.1, a simple model of incident causation developed by Van der Schaaf (1992) was presented to explain some of the concepts used in this study. In this section this model is presented again (see figure 5.1), however, with organisational failure placed in a different position.

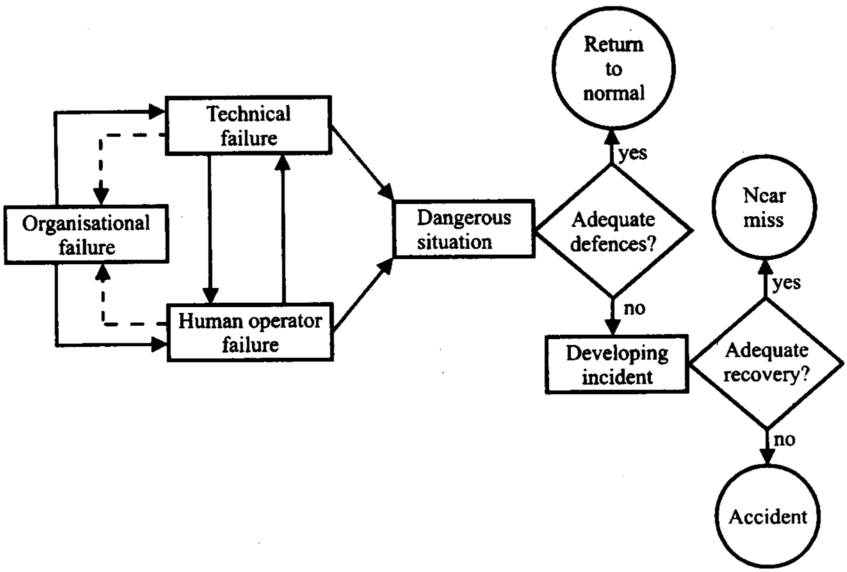


Figure 5.1: Organisational failure in relation to technical and human failure.

The incident data collected in this study clearly shows that organisational failure is always followed by technical and human failure in the process of incident development. Organisational failure never leads to a dangerous situation directly. A dangerous situation is caused by technical and/or human failures, which are either root causes in themselves or triggered by organisational root causes. The dashed lines are drawn only to show that the human and technical failures of an incident can lead to (corrective) organisational decisions, which in the end may be incorrect and become the starting point of other incident causation processes. This to show the dynamic and complicated nature of incident causation.

5.4.2 Towards an improved definition of organisational failure

Finally, it is time to take the final step in this study towards formulating a definition of organisational failure. In section 1.5.2 the following working definition of organisational failure was presented to 'guide' the reader through the study presented in this thesis:

Organisational failure refers to those non-technical latent failures by those at the blunt end of incident causation, which after a considerable time may trigger one or multiple active failures by those at the sharp end of incident causation.

This working definition is based on the distinction between active and latent failure, the blunt and sharp end of incident causation and the consequences of different types of failures, both in time and in number. Based on the empirical incident data collected in this study, a more precise but not yet final definition of organisational failure can be given. The incident data has provided the following insights into organisational failure, which form the basis of the changes made to the initial working definition:

- Based on a literature review in chapter 2, organisational failure is subdivided into three main categories. These three main categories incorporate failures related to the structure, the strategy and goals and the culture of the organisation. This subdivision is supported by the empirical incident data collected in the case studies and is included as the basis for the final taxonomy presented in this chapter. Based on this taxonomy, organisational failure can be defined more precisely than in the working definition. In the working definition, organisational failure refers to non-technical latent failures. A subdivision in failures related to the structure, strategy and goals and culture of an organisation provides better insight into the true nature of these non-technical latent failures.
- The previous section highlighted the indirect relation between organisational failure and dangerous situations. The incident data collected in this study shows that organisational failure is always succeeded by one or multiple technical and/or human failures before resulting in a dangerous situation. The time lag between the initial organisational failure and the resulting dangerous situation varies from a few hours or days (e.g. management decisions in situations where following the safety procedures will negatively influence production) to weeks, months or years (e.g. a poor training and coaching policy).

Given the initial working definition and based on the new insights discussed in this section, this results in the following more precise definition of organisational failure:

Organisational failure refers to failures related to the structure, strategy and goals and culture of an organisation, which indirectly cause one or multiple dangerous situations by triggering one or multiple technical and/or human failures.

This definition more precisely states the nature of organisational failure, highlights the indirect relation with dangerous situations and weakens the emphasis on a time lag between the actual organisational failure and its consequences.

6 Conclusions and discussion

Chapter 5 reflected on the incident data collected in the case studies and discussed the final taxonomy, the tools developed and the insights into organisational failure generated from the incident data. The final chapter of this thesis reflects on the study itself. In the first section the contributions of this study to the field of incident investigation and risk management are discussed, followed by a discussion of the choices made during this study and its exploratory set up. The final section of this chapter looks ahead and discusses suggestions for further research.

6.1 Contributions of this study

In chapter 5 the final taxonomy of the organisational root causes of safety related incidents was presented and justified. A comparison of the classification tools developed and the strengths and weaknesses of the domains investigated was given. Finally, the insight gained into organisational failure was discussed with reference to the position of organisational failure in relation to technical and human failure and a final definition of organisational failure. The contribution of these outcomes to the field of incident investigation and risk management in general are the focus of this section. First, the improved insight into organisational failure and the taxonomy and classification tools that have resulted are discussed. The second part examines the contribution of improved insight into the strengths and weaknesses of the domains investigated.

6.1.1 Improved insight into organisational failure

This thesis started with a description of a plane crash and the investigation that followed, which purported to show the classical focus of accident investigation on human failure (blaming the pilots for shutting down the wrong engine), while a closer look revealed numerous failures that cannot be attributed to the pilots involved in the crash. Some of these problems can be attributed to the technology used in the plane (e.g. the small cursors which had replaced the big white needles or the location of the vibration gauge) or to unknown or unpredictable factors (e.g. flutter that stresses the fan blades at altitude). However, even without these human, technical and unknown or unpredictable failure factors, several factors remain which also seem to have had a strong influence on the plane crash. In chapter 1, these factors were suspected to be organisational, without defining organisational failure properly. Defining organisational failure was one of the aims of this study.

At the end of this study and at the end of this thesis, insight has been gained into organisational failure. A definition of organisational failure has been provided by this study and both a taxonomy and classification tools have been developed to categorise and classify different types of organisational failure. Guidelines have also been provided to manage organisational failure successfully. To show the added value of this knowledge to incident investigation, the plane crash described in chapter 1 is re-evaluated. Based on this re-evaluation of the East Midlands plane crash several conclusions can be drawn.

First, in this incident organisational failure factors are found at the beginning of incident causation. Initially, the incident investigators only focused on the highly visible contributing factors at the end of incident causation, which resulted only in detecting the snapped fan blade that caused the engine failure and in blaming the pilots for shutting down the wrong engine. Only much later, after an in-depth investigation into the real causes of the plane crash, were organisational failure factors detected at the beginning of incident causation. This corresponds to both the conclusion from the discussion about the position of organisational failure in relation to technical and human failure and the guideline that states that organisational failure factors are only detected through an in-depth analysis of an incident. The organisational failures, which are discussed in the remainder of this section, are removed in both time and space from the sharp end of incident causation and are responsible for triggering the majority of the technical and human failures involved.

Second, the in-depth analysis reveals a number of organisational failures that can be attributed to the airline itself. These are called the internal organisational failures, since they are within the airline's responsibilities. Several organisational failures are detected which are related to management priorities (OM according to the classification tools). Safety is relegated to an inferior position by management when faced with conflicting, in this case, financial objectives. Training sessions for pilots were kept as brief as possible to limit the loss of expensive pilot time. Experience cannot be gained in the safe environment of a simulator, since a simulator was not available. Instead, pilots had to acquire their hands-on training on regular scheduled flights. Failures related to transfer of knowledge (OK) were also found in the incident description. These failures refer to the new features of the new plane which were unknown to the pilots. In the old planes, vibration gauges were known to be highly unreliable and pilots were even allowed to and accustomed to flying with them disconnected. In this new plane the vibration gauge is highly reliable but no one was ever told. Therefore, it is unlikely that even if the pilots had noticed the high reading of the vibration gauge it would have triggered a corrective action.

Finally, some external organisational failure factors are detected (O-EX). This immediately highlights an interesting difference with the steel industry, where external factors did not influence incident causation and were therefore not included in the classification tool. In this incident, however, the importance of including external failure factors in aviation is clearly shown. The first external organisational failure is related to the design of the new engine. Testing the new engine at altitude was not included in the development process, since only a small upgrade of the engine seemed necessary fro the new Boeing. This way, development costs on the new engine were limited to a bare minimum, however, the influence of flutter on the fan blades was left unexplored. Perhaps most interesting is the influence of the Civil Aviation Authority (CAA) in this plane crash. Recommendations based on previous similar incidents were rejected by the CAA, because the CAA not only had to protect the interests of the travelling public but also the interest of commercial aviation. Since the two interests are often conflicting, management priorities at the CAA determine the relevance and importance of each claim. Unfortunately, in most cases these decisions are shown to be taken in favour of commercial aviation. Looking back, some of the recommendations (e.g. installing external cameras) could easily have prevented this incident from happening.

It can be concluded that in this incident, both the guidelines and the classification tools show their value and usability in incident investigation. It also shows that the medical domain is not the only domain where external factors influence incident causation. In commercial aviation external factors seem to have a considerable influence on incident causation as well. The decision to include external failure factors in a classification tool must therefore be taken separately for each domain, based on collected incident data. Internally, similar root causes are found in commercial aviation as well as in the Dutch steel industry and in the medical domain.

6.1.2 Improved insight into strengths and weaknesses of the domains investigated

The case studies have generated more general knowledge, as well as providing insight into the strengths and weaknesses of the individual settings or the domains involved. Of course, for the plants or departments involved it is important to know about their strengths and weaknesses and about possibilities for improvement. In most cases this strongly influenced their decision to participate in this study. For this study, however, it is more important to look at the general conclusions that can be drawn from the insights generated.

First, based on the case studies and the classification tools developed, it can be concluded that though at first sight the two domains appear to be very different, numerous similarities exist when taking a broader perspective. When focusing in great detail on the technical environment, the products or services delivered and the individual tasks performed, only differences between the two domains appear. Numerous similarities do exist when, with a broader perspective, the type of human behaviour involved and the way the processes are organised are considered. In particular, at an organisational level, the same root causes are detected in both domains. The case studies in the medical domain gave reason to develop a new category for classifying patient related factors. They also showed the importance of distinguishing between root causes originating from within and those originating from outside the department investigated. Therefore, transferring risk management tools from one domain to the other seems possible, however, domain specific differences should be identified and acknowledged to prevent sub-optimal results. In the case of organisational failure, the need for adding a category for external factors needs to be considered for each domain individually. The case studies in the steel industry do not show the need for this external category, while both the medical domain and the (single) incident description from commercial aviation do.

Second, Mintzberg's configurations and in particular their accompanying primary co-ordinating mechanisms, as presented in chapter 2, seem to be useful in predicting certain types of organisational failure. It should be noted however, that only two of the six configurations defined by Mintzberg and three of the co-ordinating mechanisms were encountered in this study. In chapter 3, the plants investigated in the Dutch steel industry were categorised as a 'machine organisation'. According to Mintzberg, a machine organisation is characterised by standardisation of work processes as a primary co-ordinating mechanism and incorporates the technostructure as the key part of the organisation. Both case studies in the steel industry also showed the influence of different levels of direct management involvement or direct management supervision on organisational failure. Direct supervision is the primary co-ordinating mechanism of Mintzberg's 'entrepreneurial organisation'. This configuration does not fit the plants in the steel industry, given the emphasis of this configuration on the strategic apex as the key part of the organisation. Still, clear differences in direct supervision are detected in the steel industry, which seem to result in differences in contributing organisational failure factors.

In the medical domain it was difficult to satisfactorily categorise an entire department according to one configuration. As described in chapter 4, a medical department is generally best categorised as a 'professional organisation'. A professional organisation is characterised by standardisation of skills as the main co-ordinating mechanism and the operating core is considered to be the key part of the organisation. It is necessary, however, to make a clear distinction between medical staff and nursing staff. Although working in and for the same department, the two groups are organised separately, in their own way. The qualification 'professional organisation' is well suited to the way medical staff are organised. To determine the best suitable configuration for the nursing staff is less clear. For the nursing staff, the traditional emphasis on standardisation of work processes is gradually changing to an emphasis on standardisation of skills, since the work of the nursing staff is becoming increasingly professional. Consequently, using Mintzberg's configurations, the way nursing staff are organised is also gradually changing from a machine bureaucracy to a professional organisation.

Based on the incident data collected in the case studies, the following predictions are made about the co-ordinating mechanisms belonging to Mintzberg's configurations and organisational failure factors that are likely to accompany them:

- The machine organisation's emphasis on standardisation of work processes is likely to result in a high number of failures related to working procedures or protocols (OP). The case studies in both the steel industry and the medical cases, which are highly dominated by nursing staff, both show a high number of causes in this category, since systems to evaluate and update the protocols or procedures used are regularly found missing.
- The professional organisation's emphasis on standardisation of skills is likely to result in a high number of failures related to transfer of knowledge (OK). The case studies in professional organisations clearly showed that the need for proper transfer of knowledge is easily underestimated and therefore neglected.
- The entrepreneurial organisation's emphasis on direct supervision is likely to result in a high number of failures related to management priorities (OM), if the organisation is becoming too large or too complicated for this co-ordinating mechanism to be used. The case studies in the steel industry clearly show the benefits of assigning a maximum of authority to teams instead of to ill-informed managers.

Since it was beyond the focus of this study to test these predictions, further research is needed to do so. The last section of this chapter discusses some suggestions for further research.

6.2 Research design of the study

The study presented in this thesis is characterised as a qualitative exploratory research design. In chapter 1 the choice of design for this study is explained. This section highlights and discusses the consequences of this choice on the quality of this study in terms of the validity and reliability of the incident data collected, the validity and reliability of the classification tools and the taxonomy developed and the possibility to generalise the taxonomy developed in this study and the guidelines about how to manage organisational failure.

6.2.1 The incident data

There are several dangers in the way empirical incident data was collected in this study, which can negatively influence the quality of the data collected. First of all, this study involved a post-hoc analysis of real incidents. This means that the people involved in the incident have to recall what has happened. This is likely to result in some gaps in the incident description, since contributing factors are easily forgotten over time, or in a lack of detail in the incident description, since details seem to quickly fade away. Second, recollecting the process of incident causation is susceptible to subjectivity, both in reporting and in recalling causes. People only remember what they want to remember or are biased towards a certain failure type. Third, no strict protocol can be followed to collect the incident data, since every incident requires a slightly different approach. Some people involved are highly biased towards a certain failure type and need to be questioned about other failure types that may also have contributed. Some incidents are highly sensitive or politically loaded, so that no one really wants to discuss them. The amount of information to start with also differs from incident to incident. Finally, mistakes are easily made when classifying the root causes, if the incident data collected are interpreted incorrectly. These dangers have to be dealt with to ensure both the validity of the data and the reliability of the data collection process.

The need for valid incident data for this study meant that only incidents that had actually occurred were included and that a correct and complete representation of the process of incident causation had to be established. To ensure the validity of the incident data, multiple sources of information were used and the incident data was reviewed by either a work group or a key person within the organisation investigated. The information sources used for each incident included the initial (verbal or written) incident report, if possible and useful, an observation of the incident location and finally critical incident interviews with those involved in the incident. By including multiple sources of information, the best possible and least subjective incident description was established. The incident data collected was reviewed by key members of the organisation investigated to obtain an 'objective' opinion about the suggested incident causation process and to evaluate the likelihood of the incident occurring as described. It is not uncommon that a study like this one is misused by employees on the shop floor to trigger certain changes within the organisation investigated, for which previous and other attempts to trigger these changes have not been successful. In this study, fictive incidents have also been reported for this purpose and fictive causes were added to the incident description of a real incident. In several occasions, the review process resulted in additional critical incident interviews with those involved in the incident.

In the previous chapters the likelihood of a selection bias has already been discussed. Incidents have been selected by variety of root causes by the researcher and a tendency to report only those incidents that are likely to lead to changes within the organisation has been noticed by some of the employees involved in this study. In particular the latter selection process was taken seriously during the data collection phase, in order to prevent it from influencing the face validity of the incident data. During the case studies, employees have been strongly encouraged not to screen incidents and to report every known incident. As a result of the latent nature of organisational failure, it is 'fortunately' also difficult to determine which organisational root causes have contributed to an incident without a proper incident investigation. Therefore, it is unlikely that certain organisational failure types have been excluded completely from the incident data, due to possible screening of incidents at a symptom level by employees.

The face validity of the final results of each case study was checked in three different ways. First, the outcomes of each case study were compared with the propositions stated prior to starting the case studies. Second and even more importantly, the results were presented to management of the plant or department investigated to check if they could recognise the structural problems which were discovered from the case study. Finally, experts in the field (see appendix 2 for list of experts) were asked if the final results corresponded with their opinion about structural problems related to safety in the domains investigated. The experts represent both industry and the medical domain and were both involved in theory development and implementing systems to improve an organisation's safety performance. None of the checks resulted in questions about the validity of the results of this study.

A reliable data collection process for this study means that the process can be repeated (by someone else) with the same results. This includes both the representation of each incident in a causal tree and the classification of the root causes involved. The best and only way to check this is to have someone else repeat the whole incident investigation again, though causal trees can also be checked for logic. For practical reasons, such as the amount of time employees are allowed to be 'disturbed' for this study, a second investigation was not included in this study. Again, both the logic and correctness of the causal trees and the classifications of the root causes was checked by either the work group or a key person within the organisation. It should be noted that it is unlikely that two different persons investigating the same incident will come up with exactly the same causal tree. The level of detail of the steps made in the tree is likely to differ. This is not problematic as long as in the end the same depth of analysis is reached and the same set of root causes is detected. Important for this study is a reliable classification of the root causes involved. Apart from the checks by a work group or a key person, a database of classified root causes was developed and used to monitor the distribution of the root causes over the classification categories. This way, the results of a previous month could be used as a reference for the results of the current month. Serious changes in the distribution of the root causes should trigger an investigation into the causes of this change. The change may be the result of corrective actions, however, they may also indicate a change in the depth of the analyses performed or the way root causes are classified.

6.2.2 The classification tools and the taxonomy

Valid incident data and a reliable data collection process still do not guarantee a reliable development process of valid classification tools and a valid taxonomy of organisational failure. Although for the development of both the classification tools and the taxonomy a clear protocol was followed, the process is still susceptible to the subjectivity of the researcher involved. In particular the final subdivision of organisation failure into discrete categories is susceptible to subjectivity. To reduce the influence of subjectivity on the development process and therefore on the results of this process, several 'defences' were built in for both the classification tools and the taxonomy of organisational failure.

The Eindhoven Classification Model was used as the initial model for the development of the domain specific classification tools. The further development of the tools itself is solely based on empirical incident data collected in this study. To reduce subjectivity of the researcher, the development of the classification tools was carried out in close co-operation with the domain involved (i.e. the plants or departments). The tools developed have also been presented to experts in the field during the 2nd European Workshop on Incident Reporting and Analysis (see appendix 2), organised by the Eindhoven Safety Management Group, to check if the categories of the tools correspond with the main problem areas known to them in the domains investigated.

To reduce subjectivity in the development process of the taxonomy of the organisational causes of safety related incidents, this development process strongly relied on existing theory on organisational change and development. Developing a theoretical framework based on this theory has been the first step in the development of the taxonomy. Because of this solid theoretical base, the influence of subjectivity on the second and final step of the development process has been reduced to a minimum. Again, the validity was checked by experts in the field during the 2nd European Workshop on Incident Reporting and Analysis.

6.2.3 Generalisation of the results

The final point to discuss in this section, is the general applicability of the taxonomy of organisational failure and the guidelines about how to manage organisational failure. Both the taxonomy and the guidelines were developed based on case studies in two domains only. Still, the taxonomy is presented as a general, not domain specific, taxonomy and the guidelines about how to manage organisational failure are presented in the same way.

A common complaint about case studies is that it is difficult to generalise from one case to another. For this, one tries to select a 'representative' case or set of cases. Yet no set of cases is likely to deal satisfactorily with this complaint. According to Yin (1994), one should not try to generalise to other case studies but one should try to generalise case study findings to theory, analogous to the way a scientist generalises from experimental results to theory. When generalising to theory, selecting representative cases becomes irrelevant, since the theory to be developed is the focus of attention not the cases or the domain involved. Consequently, variety between cases has been the main criterion by which the case studies have been selected instead of selecting representative cases.

The guidelines about how to manage organisational failure are based on both the experiences in the pilot studies (Van Vuuren, 1993; Van Vuuren & Van der Schaaf, 1995) and the case studies presented in this thesis. This study and the pilot studies cover three different domains (i.e. the steel industry, the chemical process industry and the medical domain) and the value of the guidelines is also shown in the incident in commercial aviation presented in chapter 1 and re-evaluated in this chapter. This variety of domains provides a good indication of the general applicability of the guidelines.

6.3 Suggestions for further research

The final section of this chapter looks ahead and discusses suggestions for further research. In this study, a step is made towards a better understanding of organisational failure. Building blocks for theory development about organisational failure are provided. However, further research is needed to take up these (exploratory) building blocks and move on to a full understanding of organisational failure. This final section discusses the research designs that are necessary to continue the development of theory about organisational failure. Given the results of this study, it is concluded that additional exploratory research is not likely to provide new insights. Different research designs are needed in order to be able to explain and test the impact of organisational failure factors on incident causation. Based on these research designs, suggestions for further research are discussed.

6.3.1 Research designs

In order to explain and justify the exploratory nature of the study presented in this thesis, the following four types of research were presented and discussed at the end of chapter 1:

- exploration;
- description;
- explanation;
- testing.

These four types of research fall into a logical order. The first type of research is needed when a completely new field is to be explored and research is necessary to discover which attributes (variables) of the phenomenon investigated are important for further research. Description aims at the frequency of occurrence of the variables. In exploratory research, causal relations between variables are the area of interest. Finally, hypotheses about the causal relations are tested.

The study presented in this thesis focuses on exploring organisational failure and also describes its occurrence in several settings of two completely different domains. Further research should focus on the last two types of research, based on the outcomes of this study. Given the similarities in outcomes of the two different domains investigated in this study, it is not likely that additional exploratory research will provide new insights. The research questions presented in the next section will therefore all focus on explanation or on a combination of both explanation and testing. When focusing on explaining and testing, the following differences with the exploratory study presented in this thesis have to be taken into account.

In the first place, for the selection of case studies in this study, variety between cases has been the main criterion. This fully corresponds with the exploratory nature of this study. However, when explanation and testing are the main focus of concern, other selection rules for selecting case studies have to be followed. Besides theoretical replication logic based on variety between cases, a literal replication logic should be followed as well. Literal replication is needed to check the reliability of the results of a study (e.g. this study) in other similar settings. This way, a solid base is created for further research that focuses on explaining and testing causal effects of organisational failure on incident causation. For literal replication logic, differences between case studies have to be limited and known or controlled, in order to be able to explain similarities or differences in the occurrence of organisational failure factors.

Second, in chapter 2 it was shown that a case study design was the most suitable design for this exploratory study. This was based on considering the following three conditions:

- the type of research question posed;
- the extent of control an investigator has over actual behavioural events;
- the degree of focus on contemporary as opposed to historical events.

For explaining and testing organisational failure, as it was for exploring organisational failure, the focus is also on contemporary events. Differences exist in the type of research question posed and the extent of control an investigator has over the circumstances in which studies are carried out. In table 2.3 it is shown that a case study design is best when faced with a 'how' or 'why' question, posed about a contemporary set of events over which the investigator has little or no control. Besides a focus on how and why, a focus on 'who', 'what' and 'where' can also be included, when for example the occurrence of organisational failure types is related to organisational characteristics. Control over behavioural events is also possible, depending on the research question posed. For example, when testing relations between organisational characteristics and the occurrence of certain types of organisational failure, only those organisations can be selected that comply to strict criteria (e.g. the type of organisational structure, or the primary co-ordinating mechanism). It might also be possible to create the required organisational characteristics by changing the organisation investigated. Therefore, surveys and field experiments have to be considered as possible research designs as well.

Finally, future research should include longitudinal studies to monitor the impact of corrective actions or organisational changes on organisational failure. The case studies presented in this thesis only take a 'snapshot' of a current situation, without considering changes within the settings investigated.

6.3.2 Research questions

As stated earlier, this study is only a first step towards a full understanding of organisational failure and further research is needed to build on the exploratory building blocks provided by this study. Several new research questions emerged from this study, which are worth investigating in the process of gaining more insight into the true nature of organisational failure. These research questions cover three different topics, which are strongly related to each other and fit the type of research designs suggested in the previous section. The three topics, which are discussed in the same order, are related to:

- characteristics of organisations versus organisational failure types;
- effective and efficient corrective actions to manage organisational failure;
- possibilities for timely recovery of organisational failure.

The study presented in this thesis focuses on identifying and categorising organisational failure factors, in order to shed some light on this still relatively unknown phenomenon. The study also indicates some possible relations between characteristics of organisations and the presence and impact of certain organisational failure types, although this was beyond the scope of this study. Exploration is an indispensable first step in gaining insight into organisational failure. However, it is only useful when in further research these insights are related to characteristics of organisations. Based on these relations, it is possible to predict the likelihood of organisational failure types to occur. This way, preventive actions can be taken to stop incidents from developing, instead of waiting for them to happen. Three research questions about characteristics of organisations and the occurrence of organisational failure types emerged from this study.

1. Is it possible to predict organisational failure types based on the configurations of organisations and their accompanying co-ordinating mechanisms as presented by organisational theory (e.g. Mintzberg)?
2. What is the effect of prescribing work in best practices or protocols on organisational failure in different task situations?
3. What is the impact of decentralising authority on the contribution of management priorities on incident causation?

The second topic focuses on corrective actions. Once it is known which organisational failure factors have contributed to incident causation within an organisation, corrective actions can be taken to prevent recurrence. Further research is needed to find out which corrective actions to take and to test the effectiveness of these actions. The suggested classification/action matrix is based on practical experience gained during this study only, since implementing and testing the actions suggested was beyond the scope of this study. This results in the next topic for further research.

4. Implement and test the effectiveness and efficiency of corrective actions, which aim at preventing the recurrence of known organisational failure types.

It should be noted that for this purpose different rules for the selection of incidents should be followed. In this study incidents were selected for variety in root causes, without considering the frequency of occurrence of the different types of incidents. If implementing and testing the effectiveness and efficiency of corrective action is the aim of a study, the relative importance of the individual failure factors becomes the focus of study. This means that a representative set of incidents needs to be collected and that larger numbers of incident are needed to obtain a reliable profile. The incidents also need to be collected over a longer period of time in order to be able to monitor the impact of the corrective actions.

Finally, similar to human failure, organisational failure can never be prevented completely. Since humans will always make mistakes, consequences at an organisational level are inevitable as well. Taking corrective actions is one way to manage organisational failure, however, this only takes place after organisational failures have already contributed to the development of one or more incidents. It might also be possible to improve the ability of the organisation to detect organisational failure before it results in incidents. Timely recovery from organisational failure can serve as additional preventive action to stop organisational failure from developing into incidents. There are two sides to recovery, which should both be considered in further research into recovery. The first side is related to timely recovery from organisational failure. Incidents can be prevented effectively if organisational failures are detected and acted upon before they trigger many human or technical failures. As a result of the latent nature of organisational failure, this requires a timely and critical evaluation of organisational decisions or changes on their possible negative consequences.
The second side is related to organisational recovery factors to prevent incidents in general. Insights provided by both the normal accident theory (Perrow, 1984) and theory on high reliability organisations (e.g. Roberts, 1989; La Porte & Consolini, 1991; Sagan, 1993) can be useful in this perspective. Perrow classifies organisations according to their *interactions*, which my be linear or complex and their *coupling,* which may be either loose or tight. Based on this classification he considers whether authority should be either centralised or decentralised in order to reduce the risk of accidents. Based on this classification Perrow concludes that a conflicting situation exists for tightly coupled, complex organisations, since tight coupling requires authority to be centralised, while complex interactions require decentralised authority. According to Perrow, this paradox inevitably leads to accidents, which can therefore be considered 'normal'. The High Reliability Theory objects to this pessimistic conclusion of Perrow for tightly coupled, complex organisations and claims that, given the right organisational conditions, it is possible for such organisations to operate in a reliable and safe manner. High reliability organisations were found to be able to shift from a

strict rank to a decentralised high-tempo structure during critical periods, in order to deal with critical situations successfully.
This results in the last two research questions:

5. Which factors positively or negatively influence the timely detection of and recovery from organisational failure?
6. Which organisational recovery factors can be built into an organisation to prevent failures in general from developing into full blown incidents?

Based on these research questions, the next step towards a better understanding of organisational failure can be made.

References

Aken, J.E. van (1994). *Strategievorming en organisatiestructurering: Organisatiekunde vanuit een ontwerpperspectief*. Deventer: Kluwer.

Beckmann, U., West, L.F., Groombridge, G.J., Baldwin, I., Hart, G.K., Clayton, D.G., Webb, R.K, & Runciman, W.B. (1996). The Australian Incident Monitoring Study in Intensive Care: AIMS-ICU. The development and evaluation of an incident reporting system in Intensive Care. *Anaesthesia and Intensive Care, 24*(3), 314-319.

Bij, J.D. van der, Schaaf, T.W. van der, & Bagchus, P.M. (1996). *Organisatie-diagnose via de Kwaliteitsincidenten Methode.* Report EUT/BDK/79, Eindhoven University of Technology, Faculty of Technology Management.

Botter, C.H. (1988). *Industrie en organisatie: Een overzicht en uitzicht.* Deventer: Kluwer.

Broadbent, D.E. (1989). *Advisory Committee on the Safety of Nuclear Installations: Study Group on Human Factors, first report on training and related matters*. London: Health and Safety Commission.

Cox, S., & Cox, T. (1991). The structure of employee attitudes to safety: a European example. *Work and Stress, 5*(2), 93-106.

Deal, T.E., & Kennedy, A.A. (1982). *Corporate cultures: The rites and rituals of corporate life.* Reading: Addison-Wesley.

Flanagan, J.C. (1954). The Critical Incident Technique. *Psychological Bulletin, 51*, 327-358.

Galbraith, J.R. (1973). *Designing complex organisations*. Reading, Massachusetts: Addison-Wesley.

Glendon, A.I., & McKenna, E.F. (1995). *Human Safety and Risk Management*. London: Chapman & Hall.

Hale, A.R. & Glendon, A.I. (1987). *Individual Behaviour in the Control of Danger*. Amsterdam: Elsevier.

Heining, M.P.D., Bogod, D.G., & Aitkenhead, A.R. (1996). *Essential Anaesthesia for medical students*. London: Arnold.

Hoeksema, L., & Vliert, E. van de (1989). Driedimensionaal kijken naar organisatieproblemen. *M&O, Tijdschrift voor organisatiekunde en sociaal beleid, 43*(3), 181-191.

Hoewijk, R. van (1988). De betekenis van de organisatiecultuur: Een literatuuroverzicht. *M&O, Tijdschrift voor organisatiekunde en sociaal beleid, 42*(1), 4-46.

Hofstede, G. (1980). *Culture's consequences: International differences in work-related values*. London: Sage.

Hofstede, G. (1991). *Allemaal andersdenkenden: Omgaan met cultuurverschillen*. Amsterdam: Contact.

Hudson, P.T.W., Wagenaar, W.A., Reason, J.T., Groeneweg, J., Meeren, R.W. van der, & Visser, J.P. (1991). Enhancing safety in drilling: Implementing TRIPOD in a desert drilling operation. *SPE paper 23248, First International Conference on Health, Safety and Environment*, The Hague, The Netherlands, 10-14 November 1991.

International Loss Control Institute (1978). *International Oil and Petro Chemical Safety Rating*. Loganville, GA: ILCI.

Johnson, W.G. (1980). *MORT safety assurance system*. New York: Dekker.

Kirwan, B. (1994). *A Guide to Practical Human Reliability Assessment*. London: Taylor & Francis.

Kletz, T. (1974). *HAZOP and HAZAN - Notes on the Identification and Assessment of Hazards.* Rugby: Institute of Chemical Engineers.

Kumamoto, H., & Henley, E.J. (1996). *Probabilistic risk assessment and management for engineers and scientists* (2nd ed.). Piscataway: IEEE Press.

La Porte, T.R., & Consolini, P.M. (1991). Working in practice but not in theory: theoretical challenges of 'high reliability organisations'. *Journal of Public Administration Research and Theory, 1*(1), 19-47.

Leeuw, A.C.J. de (1982). *Organisaties: management, analyse, ontwerp en verandering: een systeemvisie*. Assen: Van Gorcum.

Lucas, D.A. (1991). Organisational aspects of near miss reporting. In T.W. van der Schaaf, D.A. Lucas & A.R. Hale (eds.), *Near Miss Reporting as a safety tool* (pp. 127-136). Oxford: Butterworth Heinemann.

Lucas, D.A. (1992). Understanding the human factor in disasters. *Inter-disciplinary Science Reviews, 17*, 185-190.

Mintzberg, H. (1983). *Structure in fives: Designing effective organisations.* Englewood Cliffs, New Jersey: Prentice-Hall.

Mintzberg, H. (1989). *Mintzberg on Management: Inside Our Strange World of Management.* New York: The Free Press.

Mintzberg, H., & Quinn, J.B. (1991). *The strategy process: Concepts, contexts, cases* (2nd ed.). Englewood Cliffs, New Jersey: Prentice-Hall.

Mulder, A.M. (1994). *Technische rapportering EGKS-project SAFER.* Hoogovens Staal, IJmuiden.

Nieuwenhuys, W. (1993). *Concern in beweging: vijfenzeventig jaar Hoogovens.* Wormer: Inmerc; IJmuiden: Hoogovens Groep.

Norman, D.A. (1981). Categorization of action slips. *Psychological review, 88*(1), 1-15.

Perrow, C. (1984). *Normal accidents: living with high-risk technology.* New York: Basic Books.

Peters, T.J., & Waterman, R.H., Jr. (1982). *In search of excellence: Lessons from America's Best-Run Companies.* New York: Harper & Row.

Pidgeon, N.F. (1991). Safety culture and risk management in organizations. *Journal of cross-cultural psychology, 22*(1), 129-140.

Porras, J.I. (1987). *Stream analysis: A powerful way to diagnose and manage organizational change.* Wokingham: Addison-Wesley.

Rasmussen, J. (1986). *Information processing and human-machine interaction: An approach to cognitive engineering.* Amsterdam: Elsevier Science Publishing Company.

Reason, J.T., & Mycielska, K. (1982). *Absent-Minded? The psychology of Mental Lapses and Everyday Errors.* Englewood Cliffs, NJ: Prentice Hall.

Reason, J.T. (1987) Generic Error-Modelling System (GEMS): A Cognitive Framework for Locating Common Human Error Forms. In J. Rasmussen, K. Duncan & J. Leplat (eds.), New *Technology and Human Error.* New York: Wiley.

Reason, J.T. (1990). *Human Error.* Cambridge: Cambridge University Press.

Reason, J.T. (1991). Too little and too late: a commentary on accident and incident reporting systems. In T.W. van der Schaaf, D.A. Lucas & A.R. Hale (eds.), *Near Miss Reporting as a safety tool* (pp. 9-26). Oxford: Butterworth Heinemann.

Roberts, K.H. (1989). New challenges in organizational research: high reliability organisations. *Industrial Crisis Quarterly, 3*(2), 111-125.

Sagan, S.D. (1993). *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons.* Princeton, NJ: Princeton University Press.

Schaaf, T.W. van der (1991). A framework for designing near miss management systems. In T.W. van der Schaaf, D.A. Lucas & A.R. Hale (eds.), *Near Miss Reporting as a safety tool* (pp. 27-34). Oxford: Butterworth Heinemann.

Schaaf, T.W. van der (1992). *Near miss reporting in the chemical process industry.* PhD thesis, Eindhoven University of Technology.

Schaaf, T.W. (1996). PRISMA: A Risk Management Tool Based on Incident Analysis. *Proceedings of the International Conference and Workshop on Process Safety Management and Inherently Safer Processes* (pp. 242-251). October 8-11, 1996, Orlando, Florida.

Schein, E.H. (1985). *Organizational culture and leadership*. San Fransisco: Jossey-Bass.

Segers, J.H.G. (1987). *Methoden voor de sociale wetenschappen: inleiding tot de structuur van het onderzoeksproces en tot de methoden van dataverzameling.* Assen: Van Gorcum.

Shea, C.E. (1996). *The organisation of work in a complex and dynamic environment: the Accident & Emergency department*. PhD thesis, University of Manchester.

Stamatis, D.H. (1995). *Failure mode and effect analysis: FMEA from theory to execution.* Milwaukee: ASQC Quality Press.

Strauss, A.L. & Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory, Procedures and Techniques.* London: Sage.

Swanborn, P.G. (1987). *Methoden van sociaal-wetenschappelijk onderzoek: inleiding in de ontwerpstrategieën*. Meppel: Boon.

Turner, B.A., Pidgeon, N.F., Blockley, D.I., & Toft, B. (1989). Safety culture: Its importance in future risk management. *Position paper for the Second World Bank Workshop on Safety Control and Risk Management*. November 6-9, Karlstad, Sweden.

Turner, B.A. (1992). The sociology of safety. In D.I. Blockley (ed.), *Engineering Safety* (pp. 186-201). London: McGraw-Hill.

Versluis, R. (1997). *PRISMA als kwaliteitsinstrument voor de intramurale verstandelijk gehandicaptenzorg.* Internal report, Safety Management Group, Eindhoven University of Technology.

Vincent, C., Ennis, M., & Audley, R.J. (1993). *Medical Accidents*. New York: Oxford University Press.

Vuuren, W. van (1993). *SAFER: Near Miss rapportage bij Hoogovens IJmuiden.* MSc thesis, Eindhoven University of Technology.

Vuuren, W. van, & Schaaf, T.W. van der (1995). Modelling organisational factors of human reliability in complex man-machine systems. *Proceedings of the 6th IFAC Symposium on Analysis, Design and Evaluation of Man-Machine Systems* (pp. 323-328). June 27-29, 1995, M.I.T., Cambridge, MA USA.

Vuuren, W. van , Shea, C.E., & Schaaf, T.W. van der (1997). *The development of an incident analysis tool for the medical field.* Report EUT/BDK/85, Eindhoven University of Technology, Faculty of Technology Management.

Wagenaar, W.A. (1983). Human error (in Dutch). Inaugural lecture. Leiden University.

Wagenaar, W.A., Hudson, P.T.W., & Reason, J.T. (1990). Cognitive failures and accidents. *Applied Cognitive Psychology, 4*, 273-294.

Wagenaar, W.A., Groeneweg, J., Hudson, P.T.W, & Reason, J.T. (1994). Promoting safety in the oil industry: The Ergonomics Society Lecture. Presented at the Ergonomics Society Annual Conference, Edinburgh, 13-16 April, 1993. *Ergonomics*, 37(12), 1999-2013.

Webb, R.K., Currie, M., Morgan, C.A., Williamson, J.A., Mackay, P., Russell, W.J., & Runciman, W.B. (1993). The Australian Incident Monitoring Study: An Analysis of 2000 Incident Reports. *Anaesthesia and Intensive Care, 21*(5), 520-528.

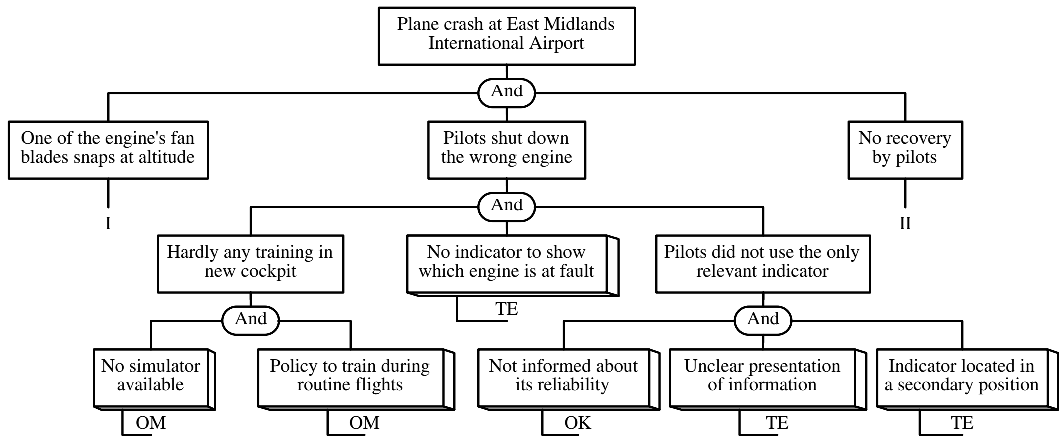
Yin, R.K. (1994). *Case study research: Design and methods* (2^{nd} ed.). Thousand Oaks, California: Sage Publications.

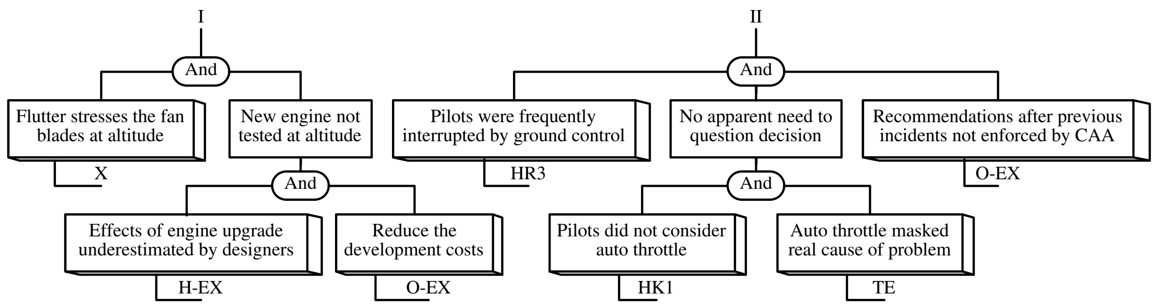
Zwaan, A.H. van der (1990). *Organisatie-onderzoek. Leerboek voor de praktijk: het ontwerp van onderzoek in organisaties.* Assen: Van Gorcum.

Appendices

1 Causal tree of the East Midlands plane crash

It should be noted that this causal tree is based on the case description given in section 1.1 only. More in-depth information about the incident is likely to result in a more accurate representation of the incident.





2 Participants 2nd European Workshop on Incident Reporting and Analysis

Participants of the 2nd European Workshop on Incident Reporting and Analysis, Eindhoven, May 28-30, 1997:

The Netherlands	Drs. Ruud de Graaf	Academic Medical Centre, Cardiopulmonary Surgery Department, Amsterdam
	Prof.dr. Andrew Hale	Delft University of Technology, Safety Science Group, Faculty of Technology and Society
	Ir. Floor Koornneef	Delft University of Technology, Safety Science Group, Faculty of Technology and Society
	Dr. Tjerk van der Schaaf	Eindhoven University of Technology, Safety Management Group
	Dr. Christine Shea	Eindhoven University of Technology, Safety Management Group
	Ir. Wim van Vuuren	Eindhoven University of Technology, Safety Management Group
UK	Dr. Sally Taylor-Adams	University College London, Clinical Risk Unit, Department of Psychology
	Jane Carthey, MA	Great Ormond St. Hospital for Children, Cardiothoracic Unit, London
	Dr. David Embrey	Human Reliability Associates, Wigan
	Dr. Deborah Lucas	Health Directorate, HSE, Bootle
	Dr. Mike Rejman	DERA, Centre for Human Sciences, Farnborough
US	Dr. James B. Battles	University of Texas, Office of Medical Education, Dallas
	Dr. Sue Bogner	Institute for the study of Medical Errors, Bethesda
	Prof. Harold S. Kaplan, MD	University of Texas, South-western Medical Centre, Department of Pathology Dallas
Israel	Prof. Yoel Donchin, MD	Hadassah-Hebrew University Medical Centres, Jerusalem
Sweden	Prof.dr. Ola Svenson	Stockholm University, Risk Analysis and Decision Research Unit, Department of Psychology

Summary

Analysing accidents and near-misses (further referred to as 'incidents') is not new. For years, creating and maintaining a safe working environment has been considered one of the main topics in many organisations' day-to-day practice. For this purpose, recent incidents within the organisation were analysed. "People can learn from their own mistakes" is the motto behind this type of incident analysis. However, despite all efforts, many organisations seem to have problems in reducing the number of incidents. This raises the question: are incidents analysed in such a way that lessons can actually be learned?

When, with this question in mind, literature on safety science and risk management is reviewed, it appears that:

1. root causes of incidents are usually subdivided into three main categories: technical, human and organisational failure;
2. research into the causes of incidents has predominantly focused on technical and human failure;
3. the majority of the root causes of incidents (often 80 to 100%) are attributed to technical and human failure.

This leads to the conclusion that, although organisational failure as a concept is not unknown, research into the nature of organisational failure and its influence on incident causation is still lacking. As a result, a clear definition of organisational failure is still missing. What should qualify as technical or human failure is clear. Technical failure refers to problems such as machine breakdowns, material defects and design errors in machines or installations. Human failure refers to interpretation errors, slips and lapses or deviations from known procedures by those directly involved in the incident. For decades, researchers particularly in the field of psychology tried, successfully, to model and predict human failure. The nature of organisational failure remains unclear. This study showed that organisational failure refers to the negative influences of the structure, goals and culture of an organisation on safety. This includes for example problems related to the division of tasks, transfer of knowledge and experience, management priorities and the prevailing safety culture.

The emphasis on technical and human failure was shown repeatedly in the analysis of large and well known accidents. Classic examples are plane and train accidents, where in most cases the pilot/engine-driver was blamed directly for not following a known procedure. The public verdict in the case of the sleeping assistant bosun of the Herald of Free Enterprise is another classic example of an overemphasis on human failure. Technical failures, such as failing engines and failing technical safeguards, normally surface quickly when cleaning up the pieces. Organisational failure was, until now, rarely detected as a contributing factor. Does this mean that organisational failure factors did not contribute at all, or that one has not been able (or willing) to detect them? This question was a factor in starting this study.

The literature on safety science and risk management does provide a very important indication about the nature of organisational failure by stating that organisational failure is *latent* in nature. This means that the consequences of organisational failure may lie dormant within the system for a long while, only to become evident under the right circumstances. Organisational failure does not lead to incidents directly but creates inviting circumstances for technical and human failures to be made. Organisational failure therefore becomes apparent by means of technical and/or human failure. Both the time lag between the organisational failure and its consequences, and the indirect way in which organisational failure becomes apparent make organisational failure factors far less visible than technical and human failure factors. An in-depth analysis is needed to look past the technical and human failures and to arrive at the level of organisational failure. This immediately provides a plausible explanation for the inferior position of organisational failure in safety science and risk management literature.

Given the lack of knowledge about organisational failure, the following goals were formulated for this study:

1. to gain insight into the nature of organisational failure and its influence on incident causation;
2. to translate this insight into a practical tool for classifying and interpreting organisational root causes of incidents, in order to be able to suggest effective and efficient corrective actions to prevent recurrence;
3. to formulate guidelines about how to analyse incidents in such a way that organisational failure factors are also detected.

As a result of the lack of models and theories about organisational failure in safety science and risk management literature, an exploratory set up was followed for this study. After reviewing literature on organisational change and development for useful theoretical insights, the study primarily focused on gaining insight into organisational failure by analysing empirical incident data. To gain insight into the root causes of incidents, a large number of interviews were conducted with employees who had been involved in an incident. For this purpose six case studies were carried out in six different organisations. Based on these interviews insight was gained into the technical, human and most importantly, the organisational root causes preceding the incidents involved. During the case studies, attention was also paid to the current way of incident analysis within the organisations involved. Where needed organisations were advised about how to develop and implement effective and efficient systems for incident analysis.

To maximise the scope of this study into the organisational factors of safety related incidents, two apparently different domains, the Dutch steel industry and the medical domain, participated. Variety in settings within the two domains has also been the main criterion in selecting the individual case studies. Two case studies were carried out in the Dutch steel industry, in two different plants. In the medical domain a total of four case studies were carried out, as a result of the small-scale settings involved (i.e. departments or only part of a department contrary to whole plants in the steel industry) and the larger diversity of disciplines in the medical domain.

The first case study in the steel industry was carried out in a coke production plant. Coke is a solid substance that is left after gases have been extracted from coal in an oven and is primarily used as fuel for blast furnaces. At the same time, the gases that are extracted from the coal are purified to regain valuable and useful substances and to keep air emissions below levels permitted by law. The coke production plant involved can be characterised by a classical hierarchical organisational structure in which the different disciplines, production, maintenance and process control, are strictly separated.

The second case study was carried out in a steel production plant. The goal of this plant is to transform pig-iron from the blast furnaces into different qualities of steel. The quality of steel is mainly determined by the percentage of carbon present in the steel. To remove carbon from pig-iron, oxygen is blown into a bath of pig-iron, which results in burning most of the carbon and other unwanted elements. Carefully selected scrap iron and other supplements are added to acquire the correct quality of steel. The steel is poured into a mould and then cut in approximately 20 meters long bars, which are used elsewhere. The steel production plant participated in the study because of its organisational structure, which differs greatly from the organisational structure of the coke production plant. The organisational structure of the steel production plant is based on socio-technical design principles. This means that steel is produced by small multi-disciplinary and autonomous teams, with a maximum of authority to organise the work assigned to them. Production, maintenance and process control are integrated in the autonomous teams.

The study in the medical sector focused on three hospital departments, of which two are in England, and an institution for the care of the mentally handicapped. The two case studies in England were carried out in an Accident and Emergency (A&E) department and an Anaesthesia department. The A&E department can be characterised by its highly fluctuating and unpredictable flow of patients and the wide variety of medical problems of these patients. The assessment of a patient by an A&E doctor results in either direct treatment in the A&E department followed by discharge or admitting the patient to a hospital department. The A&E department is mainly run by inexperienced doctors.

Contrary to the A&E department, the Anaesthesia department can be characterised by its well-planned and often highly technical working conditions. It is run mainly by experienced anaesthetists. Although anaesthetists provide anaesthetic services to a wide variety of hospital departments, they are mostly working in the operating theatres or in Intensive Care Units. This case study focused on incidents during the anaesthetic services provided to the operating theatres only.

After two case studies that predominantly focused on medical care, the case studies in the Netherlands focused mainly on nursing practice. These two case studies were carried out in an Intensive Care Unit (ICU) and in an institution for the care of the mentally handicapped. Nurses play an important role in the day-to-day practice of the ICU. Although medical staff is responsible for the medical strategy to be followed, actual care (e.g. administering drugs and fluids) is provided mainly by nursing staff. This functional relation requires flawless communication between medical and nursing staff and a high level of skills and knowledge among nursing staff. The nursing staff are, contrary to the medical staff, present on the ICU twenty-four hours a day and therefore an indispensable link in the process of monitoring patients and detecting complications.

The last case study was carried out in an institute for the care of the mentally handicapped. An institute like this differs on at least three aspects from a regular hospital department. The institute deals with (1) mentally handicapped patients (called 'residents'), who (2) stay in the institute for the rest of their life. Therefore, (3) the care provided is not focused on curing residents but primarily on maintaining and improving residents' quality of life. As a result, the risks involved are spread out over a relatively long period of time and nursing staff must maintain a high level of vigilance and alertness at all times.

The cases studies in the steel industry resulted in 78 incident descriptions, containing 498 classified root causes. Of these 498 root causes, 184 (= 36,9%) were organisational. The case studies in the medical domain resulted in 64 incident descriptions, containing a total of 341 classified root causes. Of these 341 root causes, 122 (= 35,8%) were organisational. These results clearly show the impact of organisational failure on incident causation, contrary to the low impact that is traditionally claimed. Organisational failure also created inviting circumstances for technical and human failure. Therefore, technical and human failure can only be prevented effectively when the preceding organisational factors are also taken into consideration. This requires in-depth analysis of incidents that looks beyond the obvious and highly visible technical and human factors to reach the level where organisational factors become evident. Based on the organisational root causes detected during the case studies, this study has resulted in:

1. a definition of organisational failure, based on the available literature about organisational failure and the organisational root causes that were found in the incident analyses;

2. a taxonomy of the organisational causes of safety related incidents;
3. domain specific tools for classifying and interpreting organisational root causes;
4. guidelines for managing organisational failure, which in particular emphasise the importance of in-depth incident analysis.

The results of this study are a first and important step towards a full understanding of organisational failure. Not only is insight provided into the nature of organisational failure, tools and guidelines are also developed to effectively manage organisational failure. Based on the results and the experiences gained during this study, this thesis concludes with several suggestions for further research. Additional research is needed to build on the exploratory and descriptive insight into organisational failure that resulted from this study, to move on to an explanatory level. Explanatory insight into organisational failure is needed to be able to predict organisational problems. It is useful to learn from mistakes, however, it is even better to prevent mistakes from happening.

Samenvatting (Summary in Dutch)

Het analyseren van ongevallen en bijna-ongevallen (verder incidenten genoemd) is niet nieuw. Al jaar en dag staat veiligheid hoog in het vaandel bij vele organisaties en wordt er veel aan gedaan de veiligheid waar mogelijk te verbeteren. Hiervoor wordt met name gekeken naar incidenten die onlangs binnen de eigen organisatie hebben plaats gevonden. “Van gemaakte fouten kun je leren” is het terechte motto achter de analyse van incidenten. Ondanks alle inspanningen lukt het vele organisaties echter niet het aantal incidenten naar het gewenste niveau terug te brengen. Een logische vraag is daarom: worden incidenten wel zodanig geanalyseerd dat er ook daadwerkelijk iets van kan worden geleerd?

Wanneer met deze vraag in het achterhoofd naar de veiligheidskundige en risicomanagement literatuur wordt gekeken, valt het volgende op:

1. voor de onderverdeling van basisoorzaken van incidenten worden gewoonlijk drie categorieën gehanteerd, te weten: technisch, menselijk en organisatorisch falen;
2. onderzoek naar de basisoorzaken van incidenten heeft zich tot nu toe hoofdzakelijk op technisch en menselijk falen gericht;
3. het merendeel van de basisoorzaken van incidenten (vaak 80 tot 100%) wordt toegeschreven aan technisch en menselijk falen.

Kortom, alhoewel organisatorisch falen als begrip zeker niet onbekend is, is onderzoek naar de aard van organisatorisch falen en de invloed van organisatorisch falen op het ontstaan van incidenten vrijwel achterwege gebleven. Een duidelijke definitie of afbakening van organisatorisch falen ontbreekt dan ook nog steeds. In geval van technisch en menselijk falen is het duidelijk wat dit zoal omvat. Technisch falen omvat storingen aan machines, materiaaldefecten en ontwerp-fouten in machines of installaties. In geval van menselijk falen gaat het om interpretatiefouten, vergissingen of het niet opvolgen van bekende regels door personen die direct bij het incident betrokken zijn. Met name binnen de psychologie wordt al jaren, en met succes, getracht menselijk falen zo goed mogelijk te modelleren en te voorspellen. Wat organisatorisch falen precies omvat wordt niet duidelijk uit de aanwezige literatuur. Dit onderzoek heeft laten zien dat organisatorisch falen de negatieve invloeden van de structuur, doelen en cultuur van de organisatie zelf op de veiligheid betreft. Dit omvat o.a. onjuistheden in de taakverdeling, de opleidings- en trainingsprogramma’s, de prioriteiten van het management en de heersende veiligheidscultuur.

De nadruk op technisch en menselijk falen blijkt ondermeer keer op keer bij de analyse van grote en spraakmakende ongevallen. Klassieke voorbeelden zijn vlieg- en treinrampen waar meestal direct de piloot/machinist als schuldige wordt aangewezen wegens het niet opvolgen van een bekende procedure. De publieke veroordeling van de slapende bootsman op de Herald of Free Enterprise valt zeker ook in die categorie. Technische mankementen, zoals falende motoren en ontoereikende technische beveiligingen, komen vaak ook snel aan het licht bij het opruimen van de brokstukken. Organisatorische aspecten worden tot nu toe slechts zelden als bijdragende factor genoemd. Maar betekent dit dat ze ook daadwerkelijk geen bijdrage hebben geleverd, of heeft men ze simpelweg niet kunnen (of willen) ontdekken? Dit onderzoek is gestart om onder andere op deze vraag een antwoord te geven.

De veiligheidskundige en risicomanagement literatuur levert in ieder geval één zeer belangrijke aanwijzing over organisatorisch falen en wel dat organisatorisch falen *latent* van aard is. Dat houdt in dat de gevolgen van organisatorisch falen niet onmiddellijk, maar slechts na verloop van tijd en alleen onder de juiste omstandigheden tot uiting komen. Organisatorisch falen leidt tevens niet rechtstreeks tot incidenten, maar creëert uitnodigende omstandigheden voor technisch en menselijk falen en treedt dan ook in die hoedanigheid naar buiten. Zowel de vertraagde consequenties, als de indirecte gevolgen maken dat organisatorisch falen veel moeilijker zichtbaar is dan het vaak letterlijk voor de hand liggende technisch en menselijk falen. Het vereist een diepgaande analyse om verder te kijken dan technisch en menselijk falen en door te dringen tot de organisatorische basisoorzaken. Dat is dan ook meteen een zeer aannemelijke verklaring voor de ondergeschikte positie van organisatorisch falen in de veiligheidskundige en risicomanagement literatuur.

Met het voorgaande als uitgangspunt is voor dit onderzoek het volgende ten doel gesteld:

1. het verkrijgen van inzicht in de aard van organisatorisch falen en de invloed ervan op het ontstaan van veiligheidsincidenten;
2. het vertalen van dit inzicht in praktische ‘tools’ voor het classificeren en interpreteren van organisatorische basisoorzaken van incidenten, zodat effectieve en efficiënte maatregelen ter voorkoming van organisatorisch falen kunnen worden genomen;
3. het opstellen van richtlijnen voor het analyseren van incidenten, zodat organisatorisch falen de aandacht krijgt die het verdient.

Het gebrek aan theorieën en modellen over organisatorisch falen in de veiligheidskundige en risicomanagement literatuur heeft geleid tot een sterk exploratieve onderzoeksopzet. Na eerst gezocht te hebben naar bruikbare theorieën en modellen buiten de veiligheidskundige en risicomanagement literatuur, heeft het onderzoek zich met name gericht op het verkrijgen van inzicht in organisatorisch falen door middel van het analyseren van werkelijk gebeurde incidenten. Om inzicht te krijgen in de basisoorzaken van deze incidenten zijn, tijdens zes case studies, een groot aantal interviews gehouden met medewerkers die bij incidenten betrokken zijn geweest. Op basis van deze interviews is inzicht verkregen in het technisch, menselijk en met name organisatorisch falen voorafgaande aan de betrokken incidenten. Tijdens de case studies is tevens aandacht besteed aan de huidige manier waarop incidenten worden geanalyseerd binnen de betrokken bedrijven en het opzetten van systemen voor het effectief en efficiënt rapporteren en analyseren van incidenten.

Om een zo breed en compleet mogelijk beeld te krijgen van organisatorisch falen en de manier waarop organisatorisch falen wordt benaderd, is het onderzoek uitgevoerd in twee totaal verschillende domeinen en wel in de staalindustrie en de medische wereld. Ook bij de keuze van de cases binnen de twee domeinen is diversiteit het belangrijkste criterium geweest. In de staalindustrie zijn twee case studies uitgevoerd binnen twee verschillende bedrijven. In de medische sector zijn in totaal vier case studies uitgevoerd, gezien het kleinschaligere karakter van de case studies (afdelingen of slechts delen van afdelingen in plaats van hele bedrijven) en de grotere diversiteit aan disciplines in deze sector.

De eerste case studie in de staalindustrie heeft plaats gevonden in een kooksfabriek. In een kooksfabriek wordt in grote ovens uit kolen kooks geproduceerd, wat als brandstof dient voor hoogovens. Daarnaast worden de gassen die bij het produceren van kooks vrijkomen gereinigd om luchtverontreiniging tot een minimum te beperken en om waardevolle bestanddelen terug te winnen. De betrokken kooksfabriek wordt gekenmerkt door een klassieke hiërarchische organisatie met een strikte scheiding tussen produktiebeheer, technisch beheer en procesbeheer, de disciplines waarbinnen de medewerkers werkzaam zijn.

De tweede case studie in de staalindustrie is uitgevoerd in een oxystaalfabriek. Het ruw ijzer afkomstig van de hoogovens wordt in de oxystaalfabriek omgezet in de gewenste kwaliteit staal. Ongewenste bestanddelen worden uit het vloeibare ruw ijzer gebrand door er zuurstof met een lans in te blazen. Tevens worden er toeslagstoffen aan het ruw ijzer toegevoegd om de gewenste samenstelling van het staal te bereiken. Het staal verlaat in lange plakken de oxystaalfabriek, om elders verder te worden verwerkt. De oxystaalfabriek is met name betrokken bij het onderzoek vanwege zijn organisatiestructuur, die sterk afwijkt van de organisatiestructuur van de kooksfabriek. De organisatiestructuur van de oxystaalfabriek is gebaseerd op sociotechnische ontwerp-principes, wat inhoudt dat staal wordt geproduceerd in multidisciplinaire teams, waaraan een maximum aan bevoegdheden is toegewezen om het eigen werk te regelen. Produktiebeheer, technisch beheer en procesbeheer zijn hierbij geïntegreerd in de afzonderlijke teams.

Het onderzoek in de medische sector heeft zich gericht op drie ziekenhuisafdelingen, waarvan twee in Engeland, en een instelling voor verstandelijk gehandicapten. De twee case studies in Engeland hebben plaats gevonden in een Accident & Emergency (A&E) afdeling en een anesthesie afdeling. Een A&E afdeling is enigszins te vergelijken met een Eerste Hulp afdeling in een Nederlands ziekenhuis en wordt gekenmerkt door een grote en onvoorspelbare toestroom van patiënten, met een grote diversiteit aan medische problemen. Na een eerste onderzoek worden de patiënten of op de afdeling geholpen, of doorverwezen naar een andere afdeling binnen het ziekenhuis. Het werk op de A&E afdeling wordt met name uitgevoerd door (onervaren) artsen in opleiding.

In tegenstelling tot de A&E afdeling, wordt de anesthesie afdeling gekarakteriseerd door een strakke planning van de werkzaamheden en de hoge mate van ervaring van de betrokken anesthesisten. De anesthesisten verlenen hun diensten aan een grote variëteit aan afdelingen binnen het ziekenhuis, maar zijn met name te vinden in operatiekamers en op intensive care units. Deze case study heeft zich alleen gericht op incidenten tijdens de werkzaamheden op de operatiekamers.

Na twee case studies sterk gericht op medisch handelen, hebben de twee case studies in Nederland zich met name gericht op verpleegkundig handelen. De twee case studies hebben plaats gevonden binnen een intensive care unit (IC) en een instituut voor verstandelijk gehandicapten. Verpleegkundigen spelen een zeer belangrijke rol in de dagelijkse gang van zaken op een IC. Alhoewel de medische staf verantwoordelijk is voor de te volgen medische strategie, wordt het merendeel van de handelingen (het toedienen van medicijnen, vloeistoffen, etc.) uitgevoerd door de verpleegkundige staf. Dat stelt hoge eisen aan de communicatie tussen de medische en verpleegkundige staf en de kennis en vaardigheden van de verpleegkundigen. De verpleegkundige staf is, in tegenstelling tot de betrokken medische staf, fulltime aanwezig op de IC en vormt daardoor een onmisbare schakel in het observeren van de patiënten en het detecteren van problemen.

De laatste case studie is uitgevoerd in een instituut voor verstandelijk gehandicapten. Een instituut voor verstandelijk gehandicapten verschilt op tenminste drie punten van welke ziekenhuisafdeling dan ook. Het gaat (1) om verstandelijk gehandicapten, die (2) voor de rest van hun leven in het instituut verblijven. Het gaat hier dan (3) ook om verzorging en niet om het verhelpen van een medisch probleem. De genoemde verschillen leiden met name tot een spreiding van de risico's over de lange verblijfsduur van de verstandelijk gehandicapten in de instelling, waardoor veel wordt vereist van de waakzaamheid en alertheid van de betrokken verpleegkundigen.

De case studies in de staalindustrie hebben geleid tot 78 incidentbeschrijvingen, met in totaal 498 geclassificeerde basisoorzaken. Van deze 498 basisoorzaken zijn er 184 (= 36,9%) organisatorisch. De case studies in de medische wereld resulteerden in 64 incidentbeschrijvingen, met in totaal 341 geclassificeerde basisoorzaken. Van deze 341 basisoorzaken zijn er 122 (= 35,8%) organisatorisch. Deze resultaten laten duidelijk zien dat organisatorisch falen wel degelijk een belangrijke bijdrage levert aan het ontstaan van incidenten, in tegenstelling tot wat traditioneel wordt beweerd. Daarnaast creëert organisatorisch falen uitnodigde omstandigheden voor het optreden van menselijk en technisch falen. Menselijk en technisch falen kan daarom alleen effectief worden bestreden als ook voldoende aandacht wordt besteed aan het voorkomen van organisatorisch falen. Het vereist echter een diepgaande analyse om verder te kijken dan het vaak voor de hand liggende menselijk en technisch falen en door te dringen tot de organisatorische basisoorzaken. Op basis van de gevonden organisatorische basisoorzaken heeft dit onderzoek verder geresulteerd in:

1. een definitie van organisatorisch falen, gebaseerd op de beschikbare literatuur over organisatorisch falen en de organisatorische basisoorzaken van de geanalyseerde incidenten;
2. een taxonomie van de organisatorische basisoorzaken van veiligheidsincidenten;
3. domeinspecifieke tools voor het classificeren en interpreteren van organisatorische basisoorzaken;
4. richtlijnen voor het omgaan met organisatorisch falen, waarbij met name de nadruk wordt gelegd op het belang van een diepgaande analyse van incidenten.

De resultaten van dit onderzoek vormen een eerste en belangrijke stap in de richting van een volledig begrip van organisatorisch falen. Niet alleen is inzicht verkregen in de aard en invloed van organisatorisch falen, ook zijn tools en richtlijnen ontwikkeld voor het effectief omgaan met organisatorisch falen. Op basis van deze resultaten en de opgedane ervaringen tijdens dit onderzoek wordt het proefschrift afgesloten met een aantal suggesties voor verder onderzoek. Vervolgonderzoek is zeker nodig om het nu verkregen exploratieve en beschrijvende inzicht in organisatorisch falen verder te ontwikkelen naar een verklarend niveau. Dit verklarend niveau is nodig om organisatorisch falen te kunnen voorspellen, zodat eventuele organisatorische problemen vroegtijdig kunnen worden onderkend. Leren van fouten is mooi, maar voorkomen is nog steeds beter dan genezen.

Curriculum Vitae

Wim van Vuuren was born on October 2, 1969, in Almkerk, The Netherlands. In 1988 he received his VWO diploma from the Oude Hoven college in Gorinchem, after which he studied industrial engineering and management science at the Eindhoven University of Technology. He graduated from the master's program in December 1993. His master's thesis was awarded the NIVE (Dutch Association for Management) annual award in 1994 for the best master's thesis in industrial engineering and management science. After graduating he worked for three months at ARCO Chemie Nederland, Ltd. on developing and implementing a reporting and analysis system for safety related incidents. In February 1994 he started his PhD work at the Eindhoven University of Technology as a member of the Safety Management Group in the faculty of Technology Management. The PhD study focused on gaining insight into the organisational root causes of safety related incidents and developing tools for managing organisational failure effectively. The study was carried out in two plants in the Dutch steel industry and four different medical settings, situated in both The Netherlands and in the UK.

STELLINGEN

Behorende bij het proefschrift

Organisational failure:

An exploratory study in the steel industry and the medical domain

van

Wim van Vuuren

17 maart 1998

1. De meeste managers hebben de neiging in geval van incidenten eerst naar menselijke en technische faaloorzaken te zoeken, alvorens organisatorisch falen als oorzaak te overwegen.
(Hoofdstuk 1 van dit proefschrift)

2. In werksituaties waar fouten, gezien hun mogelijke consequenties, het minst wenselijk zijn, worden onervaren medewerkers het snelst zelfstandig de praktijk ingestuurd.
(Hoofdstuk 4 van dit proefschrift)

3. Binnen de meeste ziekenhuizen is de mate waarin afdelingen onderling afhankelijk zijn niet in balans met het regelvermogen om elkaars performance te beïnvloeden.
(Hoofdstuk 4 van dit proefschrift)

4. Wanneer initiatieven met betrekking tot veiligheidsbeheersing vooral bottom-up plaatsvinden, wijst dit op een op dit terrein nog onvolwassen organisatie.
(Hoofdstuk 5 van dit proefschrift)

5. Het bewust negeren van de meerderheid van gerapporteerde incidenten werkt bevorderend op de kwaliteit van verbetermaatregelen.
(Hoofdstuk 5 van dit proefschrift)

6. Zolang FONA-commissies in ziekenhuizen onverenigbare doelen blijven nastreven, namelijk het leren van incidenten en het nemen van maatregelen gericht op personen, zullen ze nooit naar behoren van de grond komen.

7. Slechte managers worden gekenmerkt door het nemen van beslissingen die hun ondergeschikten ook hadden kunnen nemen.
(naar P.K. Jagersma, 400 management wijsheden)

8. Het getuigt van weinig gezond verstand om bij de Amerikaanse juryrechtspraak te vertrouwen op het gezonde verstand van de gemiddelde Amerikaanse burger.

9. Het invoeren van rekeningrijden rond de randstad gedurende de ochtendspits levert alleen een positieve bijdrage aan het financieringstekort, niet aan het verkeersprobleem.

10. Het enige echt vrijwillige aan vrijwilligerswerk is de beslissing om eraan te beginnen.

11. De beslissing van de ANWB om Malta als enig Europees land niet in 'Het beste boek voor de weg' op te nemen, is terecht.