

Evaluation and Learning after Major Railway Accidents

-Various perspectives of accident research theories in evaluation reports
and their implications for learning after accidents

Silje Storsveen

Norwegian university of science and technology

Master of Philosophy in Risk Psychology, Environment and Safety

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Norwegian university of science and technology

Faculty of Social Sciences and Technology Management

Department of psychology

Preface

This thesis link the topic of accident evaluation to organizational learning after major accidents in the Norwegian railway organization. Having worked with the thesis I have experienced how much the accident evaluation reports could be of value to learning processes after organizational accidents. The topic of the thesis has been very interesting and provided many challenges motivating me throughout the writing process.

I wish to thank my supervisor Professor Britt-Marie Drottz-Sjöberg (NTNU) for her critical view, inspiring discussions, and patience throughout the period. I would also like to thank the key management personnel in the National Norwegian Railway Administration (NNRA) for elucidating discussions and providing relevant material for the topic of the thesis.

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Silje Storsveen

Abstract

Accident causation has been differently approached and evaluated in the last decades. This thesis studies four large accidents in the Norwegian railway organization, i.e. the Tretten accident, the Nordstrand accident, the Åsta accident and the Alnabru/Sjursøya accident. Accident causation was investigated by systematically reviewing and comparing the respective accidents' evaluation reports to three dominant accident research theories: The Energy and Barrier theory, the Man-made Disaster theory and the Normal Accident theory. It is concluded that the development of the accident evaluation reports throughout a time period of 35 years initially developed from simple cause-effect relationships implemented mainly by local technical safety barriers to more recent strategies including an increasing number of indirect causes with following recommendations within non-technical areas, as communication processes and management strategies. The official accident reports evaluating the Tretten and the Nordstrand accidents focused on the immediate failures leading to the accidents. The two latter reports, evaluating the Åsta and Alnabru/Sjursøya accidents emphasized to a larger degree the indirect causes contributing to the accidents, as well as the decisive failures. From a theoretical point of view it is concluded that the stated causation with attached recommendations characterizing the Åsta and Alnabru/Sjursøya accidents provided a higher organizational learning potential than the stated causation of the Tretten and the Nordstrand accidents. This conclusion is mainly based upon the limited and narrow view of causation and recommendations in the available evaluation reports after the Tretten and Nordstrand accidents. After the Åsta and Alnabru/Sjursøya accidents, the respective Commission of inquiry presented a specific as well as general view, relating the causation, and recommendations, for the future to several levels in the organization. However, if indirect causation and following recommendations are too broad, difficulties might arise locating the failures and implementing corrections. From a theoretical perspective, indirect causation enhances organizational learning, but it may also lead to abstract and broader recommendations which are harder to implement in the system due to modern organization's continuous increase in complexity of components and interactions. It is concluded that to ensure enhanced organizational learning accident evaluation has to be more specifically adapted to organizational structures, i.e. adapted to both the formal and informal structures of an organization as well as focused on the practical consequences of the implementations.

CONTENTS

1 INTRODUCTION	1
1.1 Background	1
1.2 Aim and approach	2
1.3 Limitations.....	3
1.4 Structure	5
1.5 What is safety? From risk to safety	6
1.5.1 Risk, hazards and events.....	6
1.5.2 Safety and uncertainty	7
1.6 A historical review of the risk and safety management in the Norwegian railway organization ..	9
1.6.1The traditional railway	9
1.6.2The modern railway.....	11
2 THEORY	13
2.1 Investigating accidents	13
2.2 Causality.....	13
2.3 Accident theories.....	15
2.4 The energy and barrier theory	15
2.4.1 Preventive strategies.....	17
2.5 The Man-made Disaster theory	19
2.5.1 Information flow.....	19
2.5.2 Safety culture.....	20
2.6 The Normal Accident theory	21
2.6.1 Component failure accidents versus system accidents	22
2.6.2 High interactive complexity and tight coupling	22
2.7 What is organizational learning?	24
2.7.1 Organizational memory	26
2.7.2 Mental models and heuristics	28
2.7.3 Single and double loop learning	29
3 CASES	33
3.1 The Tretten accident (1975)	33
3.1.1 Direct cause	34
3.1.2 Recommendation.....	34
3.2 The Nordstrand accident (1993).....	34

3.2.1 Direct cause	35
3.2.2 Recommendations	35
3.3 The Åsta accident (2000).....	36
3.3.1 Direct cause	37
3.3.2 Indirect causes	37
3.3.3 Recommendations	39
3.4 The Alnabru/Sjursøya accident (2010).....	41
3.4.1 Direct cause	42
3.4.2 Indirect cause.....	42
3.4.3 Recommendations	44
4 DISCUSSION	47
4.1 The Energy and Barrier theory	47
4.2 The Man-made Disaster theory	49
4.2.1 Information processing	49
4.2.2 Safety culture.....	51
4.3 The Normal accident theory	54
4.4 Learning after accidents	57
4.4.1 Decisive causes, human errors and barriers.....	58
4.4.2 Indirect causes, shared mental models and organizational memory.....	61
4.5 Learning from failure	63
4.6 Implications for future research.....	64
4.7 Conclusion.....	65
5 REFERENCES	67

1. INTRODUCTION

1.1 Background

Organizational accidents (Reason, 1997) tend to have large negative effects, often affecting several levels in society, e.g. human life, the environment, material values and the organization itself. According to Slovic (1987) the societal effects after organizational accidents are analogous to a stone dropped in a pond. The ripples spread outward, encompassing first the directly affected victims (the ripples might stop here), then the responsible organization and, in the extreme case, reaching other organizations or industries. Reason (1997) defines organizational accidents as having multiple causes and as involving many people at different levels in an organization. In addition to the adverse outcomes these accidents tend to create, a great learning potential could also be identified, especially for the organization involved. After an accident, a committee (either internal or external) would normally carefully analyze the available evidence in order to backtrack and explain the course of events in terms of causal chains (Rasmussen & Svedung, 2000). According to Bennet (1978) several difficulties would be involved in this context, for instance, the determination of the scope of the phenomenon to investigate, the identification and documentation of the data required and the establishment of the focus for issuing recommendations based on the accident findings. Bennet (1978, para. 5) provided the following example to illuminate the accident investigation's many purposes:

“Accident investigation purposes I have observed are as varied as the number of people interested in a specific accident. The media personnel want to know immediately what “caused” the accident. Their quest for cause probably reflects the public’s curiosity, so one purpose is to satisfy this public curiosity. An injured employee wants to be made whole again or to recoup personal losses by an adequate claim. An attorney wants a basis for litigation and culpability. The regulatory representative wants to find out if the regulations are adequate or if someone should be prosecuted for their violation. An insurer wants to determine claim settlement or subrogation possibilities. A designer wants to learn if a design change is needed. Victims want a basis for recovering their losses. Many policemen want to get the accident form completed. A training man wants new material for his training course. An operator wants to understand his

liability, and wants to know if he will have to change his operations. The statistician wants statistics. The accident researcher wants accident data so he can better understand the phenomenon and control it. The investigator wants to satisfy one or more of these purposes”.

To guide the many interests and purposes in an accident investigation, several accident theories have been developed throughout the years. Accident theories support the accident investigations (Rausand & Utne, 2009), and they are useful to create mental images of the accident sequence, so that individuals, or a group of individuals, understand accidents similarly, and ask the “right” questions in an investigation process (Kjellén, 2000). However, when choosing what type of accident theory or what type of combination of theories to use the approach is defined. Accident theories could differ in philosophy and method¹ and influence therefore the accident evaluation (Kjellén, 2000). The choice of accident theory is important to our understanding of accident evaluation and what happens after the accident, or more specifically, what the organization *chooses* to learn from an accident.

1.2 Aim and approach

This thesis aims at contributing more insight to the understanding of accident evaluation across a time span of 35 years in the Norwegian Railway organization, and to elucidate links between accident evaluation and organizational learning.

The stated accident causation and recommendations of four large railway accidents, i.e. the Tretten accident (1975), the Nordstrand accident (1993), the Åsta accident (2000) and the Alnabru/Sjursøya accident (2010), are investigated using three dominant theoretical perspectives in accident research², i.e. the Energy and Barrier theory (Haddon, 1970; 1980), the Man-made Disaster theory (Turner, 1978; Turner & Pidgeon, 1997) and the Normal Accident theory (Perrow, 1984; 1999). To specify the aim of this thesis the following two research questions are posted for further investigation:

¹ According to Leveson (2004) and Hollnagel (2004) the majority of accident theories are based on three types of accident models. These have been summarized by Dekker (2006, p. 82) as the “sequence of events” model, the “epidemiological” model and the “systemic” model.

²The accident perspectives are referred to as theories in a rather broad sense. Based on Colman (2003, p. 760) a theory is defined as: “A proposition or set of propositions offered as a conjectured explanation for an observed phenomenon, state of affairs, or event”. The theories used in this thesis give such propositions of explanations to a phenomenon, i.e. they describe different frameworks in relation to accident causation.

- *How are the chosen accident theories reflected in the evaluation reports after four major railway accidents in the Norwegian railway organization spanning 35 years (1975-2010)?*
- *What consequences did the presentation of accident causation have for organizational learning after the accidents?*

The chain of events leading to the accidents together with the conclusions of the accident causation and the investigators' future recommendations are retrieved from the information presented in the accident evaluation reports. The accident evaluation reports used in this thesis are two internal evaluations describing the Tretten and the Nordstrand accidents (Uhellskommisjonen, 1975; Uhellskommisjonen, 1993), and two external investigation reports describing the Åsta and the Alnabru/Sjursøya accidents (NOU, 2000; AIBN, 2011). The research questions were investigated theoretically by systematically comparing and reviewing the causes and recommendations from each evaluation report and to the key points of the respective accident theories. A literature review was also conducted of the relevant organizational research field, accident research field, and a historical review of the Norwegian railway organization was made. Finally, elucidating discussions with key personnel in the railway organization were conducted.

The review of evaluated accident causation, combined with the discussion of organizational learning after accidents, may provide the Norwegian Railway organization with additional perspectives of accident management and the processes of organizational learning. Furthermore, this study aims at showing links between accident evaluations, organizational structures and learning processes in the organization. The results will hopefully offer some theoretical and practical value to all levels in the Norwegian Railway organization, and be of interest to similar organizations as well.

1.3 Limitations

The accident evaluation reports are studied from the perspectives of three major accident theories: the Energy and Barrier theory (Haddon, 1970; 1980), the Normal Accident theory (Perrow, 1984; 1999), and the Man-made Disaster theory (Turner, 1978; Turner & Pidgeon, 1997). These theories represent different philosophies of how to understand

accidents and the main goal of using these theoretical views was to bring forth perspectives that could illuminate different circumstances associated with organizational accidents and organizational learning. The theories are furthermore well-known within accident research and were chosen because of their likeliness to be reflected in the evaluation reports. The specific theories used in this thesis were published in the 1970s and 1980s, but have affected today's accident research as well as practice (Rosness, Guttormsen, Steiro, Tinmannsvik & Herrera, 2004; Rosness, Grøtan, Guttormsen, Herrera, Steiro, Størseth, Tinmannsvik & Wærø, 2010). Since the accidents presented in this thesis occurred in the time period from 1973 to 2010, it was also important to choose accident theories that could reflect the evaluation work in these periods. Table 1 illustrates the occurrence of the accidents and the publishing of the accident theories. When the Tretten accident occurred, the majority of the accident theories were not published, except for the Energy and Barrier theory. When the Nordstrand, the Åsta and the Alnabru/Sjursøya accidents occurred, all the accident research theories were published³.

Table 1. Overview of the time the chosen theories were published and the occurrence of the accidents*.

Accident	The Energy and Barrier theory Haddon:		The Normal accident theory Perrow:		The Man-made Disaster theory Turner: Turner & Pidgeon:	
	1970	1980	1984	1999	1978	1997
Tretten, 1975	+	-	-	-	-	-
Nordstrand, 1993	+	+	+	-	+	-
Åsta, 2000	+	+	+	+	+	+
Alnabru/ Sjursøya, 2010	+	+	+	+	+	+

*Note. (+) = the accident theory had been published when the accident occurred; (-) = the accident theory had not been published when the accident occurred.

³ The second edition of the Normal accident theory and the Man-made Disaster theory had not been published when the Nordstrand accident occurred. However, the key points of the theories are the same in the second as in the first edition.

The discussion of organizational learning processes in this study is mainly based on how the accident causation and the recommendations are presented in the evaluation reports. The discussion also involves how this information could be linked to processes of organizational learning. The author is certainly aware that other factors than the presented accident causation and the following recommendations could also influence organizational learning after accidents. While the accident evaluation reports normally include data collection and analysis closely related to the adverse events, also decisions, implementation, control/check, evaluation and acting are important to complete the loop of organizational learning (Kjellén 2000; Jacobsson, Sales & Mushtaq, 2010).

When discussing the evaluation reports after the Tretten and Nordstrand accidents the Norwegian Railway organization was still one organization, i.e. the Norwegian state-owned railway company (NSB). In 1996, NSB became divided into a railway infrastructure administrator, i.e. the Norwegian National Railway Administration (NNRA) and a public sector corporation for traffic operation, i.e. NSB BA (now NSB AS) (Gulowsen & Ryggvik, 2004). When discussing the evaluation reports after the Åsta and Alnabru/Sjursøya accidents the focus in this thesis was directed towards the NNRA organization. NNRA is more relevant than NSB AS to the research questions posted in this study because NNRA has the overall safety responsibility for the Norwegian railway transport (Svingheim, 2010; Jernbaneverket, 2011).

1.4 Structure

The study is structured as follows: in the remaining part of section one, a brief introduction of the risk and safety concepts will be presented to provide the reader some elementary background information of the use of these central terms in this study. A short presentation of the Norwegian railway organization is then given where NSB is presented as the “traditional” railway organization. The presentation of NSB represent the period of time when the earliest accidents, the Tretten (1975) and the Nordstrand (1993) accidents occurred. The NNRA is thereafter presented as the “modern” railway organization, representing the period of time when the more recent accidents, i.e. the Åsta (2000) and the Alnabru/Sjursøya (2010) accidents occurred.

In section two, the theoretical perspectives underlying the study’s approach are introduced. This section starts with introducing theory relevant for accident investigation. The three accident theories, i.e. the Energy and Barrier theory, the Man Made Disaster theory and

the Normal Accidents theory are presented thereafter, together with an overview of relevant literature from the organizational and accident research fields.

In section three, the relevant cases, i.e. the Tretten, the Nordstrand, the Åsta, and the Alnabru/Sjursøya accidents are summarized to the reader. The chain of events leading to each adverse outcome is briefly described together with the stated cause(s) and recommendation(s) from each evaluation report.

In section four, the two research questions are discussed based on a theoretical comparison of the material from the evaluation reports and the chosen relevant research literature. Implications for future research are thereafter presented. Finally, a conclusion is presented in section five.

1.5 What is safety? From risk to safety

An organization's low safety or high risk levels might slip into people's mind when considering why organizational accidents occur. But what is the relationship between safety and risk? Safety and risk are two tightly intertwined concepts, and a brief definition and an outline relative to this study's context is given below.

1.5.1 Risk, hazards and events

To determine how "safe" an organization is, or what kind of safety management is needed, the organization's risks or hazards are often charted out. In technical and organizational perspectives, risk is often presented in terms of calculated estimations defined as probable negative future events and its consequences (Wilston & Crouch, 1982). Breakwell (2007) describes "probability" as the estimated likelihood of some specific negative event, usually related to exposure to a hazard. In terms of "consequences", Breakwell refers to risk estimation including the extent of the detriment associated with the adverse event. This detriment is often presented as a numerical estimate of the harm, meaning that the severity or scale of the considered consequences is measured in numbers (Breakwell, 2007). Risk analysis is a central part of risk management (Breakwell, 2007), which focuses on identifying and assessing the main hazards presenting threats to the safety objectives of an organization. To analyze and estimate the potential organizational risk, *hazards* have to be identified. However, even though the term hazard is a central part of risk, it is not the same as risk.

According to Christensen, Andersen, Duijm and Harremoës (2003) mixing risks and hazards together is a common source of misunderstanding and poor communication. Kaplan and Garrick (1981, p.12) explained the difference as follows: “the principle difference is that a hazard does not include the probability of adverse outcomes, as it exists simply as a source”. Risk, on the other hand, entails the probability of that source being converted into a calculation of a negative outcome. Furthermore, the moment a hazard is realized, it is no longer a hazard, nor a risk, but an event. Hazards could, however, be eliminated, and then there would be no more risk, nor events. Or, the risk of that hazard potentially resulting in an adverse outcome could be reduced by taking preventive measures.

Conceiving hazard only as a source of threat could, on the other hand, be conceptually challenging. Hoenemser, Kates and Slovic (1983) point out that even though a realized hazard (meaning an event) may not be considered a hazard, it is still the consequences of the event we imagine when we identify and evaluate hazards. A hazard is defined by Breakwell (2007, p. 2) as “anything (animate or inanimate; natural or human product) that could lead to harm (to people or environment)”. To summarize, a hazard will be understood in this thesis as a property of the present, and it may be observable. Risk, on the other hand, will be understood as a property of the future, and is hence inherently unobservable.

An “event” could be synonymous with incidents, near-accidents and/or accidents. In the vocabulary of the ISO guide 73 (2009, p. 6), an event is widely defined as “the occurrence or change of a particular set of circumstances”. However, in this context, incidents and near-accidents are reserved for events without consequences in terms of human, environmental and/or material damage, whereas accidents denote events with adverse outcome. Adverse events and accidents will be used interchangeably in this thesis.

1.5.2 Safety and uncertainty

According to Reason (1997), safety is for most people equated with the freedom from risk. However, a synonymous use of safety and absence of risk is unrealistic in organizational contexts. Most organizations which manage risk use safety measures to reduce the risks, by preventing an event or reducing the probability of identified hazards or by reducing the expected effects if something should happen. To associate safety with zero risk, gives false assurances. Even though an organization is judged as safe, for instance, having had few accidents, it does not have zero risk.

Traditionally, safety has been defined as the antonym of risk (Möller, Hanson & Peterson, 2006). The antonym of risk could be understood as a low level of risk, e.g. the lower the risk, the higher the safety level (Möller et al. 2006). According to this view are safety levels in an organization dependent on the amount of hazards it faces; the lower the amount and severity of the hazards (therefore the potential risk), the higher the safety level, and vice versa. In most large and/or complex organizations it is, however, difficult to describe the exact number of hazards, or measure their severity. The notion of interdependencies and complex interactions between variables complicates an overview of the potential hazards (Perrow, 1999), and thereby also complicates the determination of how safe the organization actually is. Despite efforts of risk and safety management, accidents could still occur. The concept of uncertainty is inherent to this dilemma.

According to Aven (2008) and consulting the guidance on NUREG (2009) uncertainty can be divided into two aspects: aleatory and epistemic uncertainty. Aleatory uncertainty stems from the intrinsic randomness in a known population, for instance, the height of an arbitrary child in a specific school, while epistemic uncertainty relates to the lack of knowledge of a fundamental phenomenon. Epistemic uncertainty is relevant to contexts where an organization lacks necessary knowledge about hazards which might cause adverse outcomes. Epistemic uncertainty may, however, be reduced with acquisition of (the right) knowledge (Aven, 2008).

Another definition or understanding of safety, presented in the safety standards ISO/IEC Guide 51 (1999), and also used by the NNRA (Jernbaneverkets sikkerhetshåndbok, 2011a), is based on safety as freedom from unacceptable risk. This means that the organization itself decides what the most (identified) harmful hazards are, and what risk these hazards might pose. This definition has a close relation to the ALARP (As Low As Reasonable Practicable) principle (see Rausand & Utne, 2009), where the concept of safety refers to a state or situation where the statistical risk is deemed to be acceptable, or as low as reasonable practicable.

The challenge of defining safety as the freedom of unacceptable risk is the notion of risk acceptability. People differ in risk sensitivity, for instance, some people are upset and worried about virtually all hazards, while others are quite indifferent and tranquil (Sjöberg, 2000). The understanding of subjective risk is based on the research of risk perception. The field of risk perception originated in empirical studies of probability assessment, utility assessment, and decision making processes (Slovic, Fischhoff, & Lichtenstein, 1979). A major development in this area has been the discovery of a set of mental strategies, or

heuristics, that people employ in order to make sense of an information-charged and uncertain world. Although these heuristics are valid in some circumstances, in others they lead to large biases with implications for risk perception (Slovic et al., 1979; Slovic, 1987). Commonly there is a tendency to overestimate small risk and underestimate large risk (Slovic et al., 1979; Slovic, 1987).

To summarize, the notion of risk in this thesis is understood as the estimate of future negative events, while the concept of safety is understood as minimizing or managing the risks, either by reducing the probability or consequences of a future negative event. In an organizational context, safety management would relate to the prevention of unwanted events, for instance accidents.

This short account of risk and safety, while not doing justice to the width of theory and research on the topic, gives a provisional introduction to the reader in relation to the context of this thesis. The next section presents a brief historical review of the Norwegian Railway organization, starting with a short introduction of today's risk and safety management view in the NNRA, than leaping back to the "traditional" railway organization representing the time period where the Tretten (1975) and the Nordstrand (1993) accidents occurred. Finally, the "modern" railway organization, representing the time period where the Åsta (2000) and Alnabru/Sjursøya (2010) accidents occurred is presented.

1.6 A historical review of the risk and safety management in the Norwegian Railway organization

Railway transport reflects an ongoing interaction between infrastructure, materials, personnel and customers. It is today characterized as a complex socio-technical infrastructure system, where safe train transport is dependent on an efficient interaction between man, technology and organization, also known as the MTO perspective (Jernbaneverkets sikkerhetshåndbok, 2011b). The overall current goal of the NNRA is to achieve a general understanding, involving all groups in the organization, that safety is a dynamic element. One of NNRA's slogans is that safety is not something that exists, but has to be created every day (Jernbaneverkets sikkerhetshåndbok, 2011b). The NNRA is built on a traditional organization where safety has always been a top priority. Changes in society and within the organization have, however, presented challenges to the organization's safety perception and management throughout the years. The next section presents key steps and events relevant to the

development of safety thinking and management, from the “traditional” to the “modern” railway.

1.6.1 The traditional railway

The traditional railway organization refers to the time before the organizational division in 1996, when the railway organization was still one organization, namely NSB. Following the historical review of the Norwegian railway organization (Gulowsen & Ryggvik, 2004), the former safety system was decentralized and dependent on complex series of local decisions. It was important for the organization that everybody “talked the same language”, and understood the safety measures in similar ways. This situation required increased cooperation between the personnel groups, ensuring a general good overview of the train traffic and a strict compliance to the rules. Hazards were perceived as inherent to the technical system and the physical aspects of railway transport. Examples of hazards affecting the technical system could be, according to Gulowsen and Ryggvik (2004), large energy masses, long breaking distances, and lack of averting routes., communication challenges due to, for instance, operational aspects such as various operators being spread across the nation, were also perceived as a possible risk to the railway transport (Gulowsen & Ryggvik, 2004).

The basis for the quality of safety measures was a combination of a hierarchic organizational structure, a stable work force (it was common that people worked their whole life in the railways), a good overview of the railway technology, personnel with considerable experience in their work and a high focus on safety specific to the technical aspects of rail traffic. Central risk reducing measures were robust and fail safe technology⁴, detailed safety measures for traffic safety that emphasized the coordination under all possible conditions, training and discipline according to the safety regulations.

The traditional railway system was in addition (to a large degree) dependent upon human factors, and when accidents or unwanted events occurred the management had a tendency to blame the personnel who worked in the system (Ryggvik, 2004). Event-based analyses were a type of risk analysis traditionally used within the Norwegian railway to learn from previous events and to prevent future adverse events. Event-based analyses rely on the past and all “new” implementations and corrective procedures are based on experience. The

⁴ A fail safe system: If error appears in a system, other parts of a system are responding by shutting down to limit negative ripple effects (Rausand & Utne, 2009)

traditional railway system was adjusted to slow changes and the organization itself was centered around the maintenance of safety.

The safety office had the leading responsibility for safety in the traditional railway organization, including the development of safety measures and maintenance. The service of the safety office had a long tradition with tasks specifically directed towards practical and technical issues. In describing the first 100 years of the Norwegian railway organization, Johannesen (2007) states that there were no overall criteria for what an acceptable level of risk was, but rather that the term “safety duty” was used as a general term for all that was relevant to safety in the railway, e.g. mostly technically related hazards.

Hazards involving large energy masses, long breaking distance, lack of averting routes, were a central part of the technical aspects of railway transport. These types of hazards are as relevant in today’s railway organization as they were in the “traditional railway”. However, organizational alterations and influences from society have challenged the traditional perspectives. The next section will describe a development towards a “new “way of understanding safety.

1.6.2 The modern railway

To distinguish between the “traditional” and the “modern” railway, the alteration of technological systems and organizational structures during the 1980s up till today serve as an indicator. A description of relevant technological implementations and organizational events are briefly described below.

The centralized system, termed Centralized Traffic Control (CTC) was adopted by the Norwegian railway during the 1980s. Gulowsen and Ryggvik (2004) described the traditional railway system as an interwoven, but decentralized system resulting in local management from various points in the country. The introduction of the centralized system involved several changes, affecting the organization’s safety management. The implementation of the CTC resulted in management from a few central stations, instead of several local traffic stations in the country. This alteration of supervision resulted in a more centered overview of the train traffic. However, the safety management became more complex than before because the supervision of lines increased for the operator. In addition could the reparations of stations (that were no longer operated) take longer time, resulting in delays of the train transport which again could affect the safety level.

Internal controls were adopted by the Norwegian railway during the 1990s. According to these regulations the railway organization had to develop its own internal control system. This meant that the organization had the responsibility for determining its own safety goals and building the organization in a way so that these goals could be reached. The governmental authority, the Norwegian Railway Authority (NRA) was established to make sure that the organization followed up and achieved its own goals. With internal controls also followed a new concept of safety management, namely the combination of Safety, Health, and Environment (SHE). SHE management was adopted from the oil industry (Ryggvik, 2004). The concept of SHE introduced a different view of safety as compared to the traditional perceptions within the railway. While the safety office perceived safety as protective means to avoid accidents specific to the technical aspects of rail traffic, the SHE management strategy provided a more general view which combined the elements of safety, health and environment, expanding the concept of risk. This implied that the safety thinking and goals of the organization became more general than before, including additional aspects of the risk concept.

The organizational division in 1996 was a result of international regulations and a continuous development towards the market. The division separated the Norwegian state-owned railway company (NSB) into a railway infrastructure administrator, i.e. the Norwegian National Railway Administration (NNRA) and a public sector corporation for traffic operation, i.e. NSB BA (now NSB AS) (Gulowsen & Ryggvik, 2004). After years of organizational turbulence characterized by a diffusion of responsibility, especially regarding safety terms, the organizational structures become clearer. The NNRA received the main responsibility for the infrastructure, maintenance and management of safety, while the NSB AS received the main responsibility for the train operations. The main tasks of the NNRA are to plan, build and maintain railway infrastructure in Norway with the overall responsible for railway transport safety (Svingheim, 2010).

Even though “the division” should have ensured clearer structures and tasks for both the NNRA and the NSB AS, NNRA entered a transition phase that lasted for several years (Rosness, 2008). The organizational division resulted in an alteration of organizational structures, but there was also an alteration of personnel. The higher level management in the NNRA was supplied and replaced by people mainly from economic-administrative backgrounds. This created a gap between the upper management and the personnel working in the sharp end regarding the focus on safety perspectives. Rosness (2008) describes when problems occurred, for instance near-accidents or accidents; the upper management had a

tendency to focus on organizational challenges, while the personnel working in the sharp end would focus on technological challenges.

To summarize, the Norwegian railway has experienced major alterations since the 1980s, especially regarding organizational contexts. The “CTC”, “internal controls” and the “organizational division” brought, for instance, new perspectives to the railway organization management as well as to strategies in the risk and safety areas.

2. THEORY

2.1 Investigating accidents

There is an old saying that the stupid never learn, the intelligent learn from own mistakes and the wise learn from others' mistakes. The purpose of an organization's accident investigation and management is to prevent that the same, similar, and ideally all adverse events that could lead to accidents do not happen. How this process is carried out vary, however, from organization to organization.

The theory chapter starts with introducing the concept of "causality", and continues with a presentation of accident theories relevant to this study, i.e. the Energy and Barrier perspective (Haddon, 1970; 1980), the Man-made Disaster theory (Turner, 1978; Turner & Pidgeon, 1997), and the Normal accident theory (Perrow, 1984; 1999). Finally, the broad concept of organizational learning is introduced, focusing especially on theory and research based on learning from accidents.

2.2 Causality

Central to accident investigation is the concept of "accident causality". After an accident, a committee (either internal or external) would normally carefully analyze the available evidence in order to backtrack and explain the course of events in terms of causal chains (Rasmussen & Svedung, 2000). Causality has throughout history served a dual purpose for mankind. On the one hand it has been used for targeting credit and blame for past events. On the other hand understanding causality has enabled mankind to exert better control over future events. What a cause really means, and what effect it creates, has been abundantly discussed by scholars throughout history. In general the following type of definition is accepted: "to say that event X is the cause of event Y is to say that the occurrence of X is a necessity to the production of Y" (Leplat, 1997, p. 25). If the circumstances were to change, it could be that X no longer would be a necessary condition for the production of Y. The causes of an event are, further, theoretically infinite: any analysis considers only a subset of them (Leplat, 1997). The choice of this subset is one of the main issues in causal reasoning.

Historically, psychologists have taken advantage of experimental methods, and research laboratories when searching for cause and effect (Higbee, Millard & Folkman, 1982; Adair, Dushenko & Lindsay, 1985). By creating and controlling miniature realities, causal

factors can be identified with respect to how they affect people. However, when the situations are not experimentally manipulated, the search for causality and effect is harder, e.g. when there is no control group many variables interact and affect the outcome simultaneously. According to Kjellèn (2000) it is sensible to speak about causes of an accident if there is a logical relationship between the cause (specific events or conditions in the chain of events) and the effect before “perception of causes”. Mackie (1974) proposed that a perceived relationship between cause and effect is dependent on the characteristics of the events which trigger causal reasoning, and also that shifts in “causal field” (e.g. background) make alternative causes more or less salient. Mackie (1974) argues that intrusive events are perceived as more causal than events that generally occur, and something abnormal or wrong is seen as more causal than what is normal and right. For instance, a car accident was caused by the person veering to the left side of the road, not by the other person who drove straight ahead in the correct line. Factors playing a part of some presumed background have little or no causal relevance according to Mackie. He gave, for instance, the example of birth and death, and asked the question: does birth cause death? Although the former is necessary for the latter, it seems odd to consider birth being the cause of death. Even though birth leads to death (on a fundamental basis), it is not logical to assume this relationship as the decisive factor, although birth is a necessity, or in Mackie’s term, a condition.

Spurious correlation is a perceived relationship in which two events or variables have no direct causal connection. However, it may be wrongly inferred that they do, due to either coincidence or the presence of a third influencing factor (confounding variable). Thus, the perception of a relationship or confounding variable (for instance, as birth in the example above), a correlation does not imply causation (see Langdrige 2006; Hardman, 2009).

Einhorn and Hogarth (1986) suggest that people systemically use rules and strategies for assessing causes, both in science and everyday inference, and the assessment of causes can be seen as a result of a judgment process. This process can often lead to error. For example, the fundamental attribution error is a result of biases in judgment processes. The roots of attribution theory research can be traced back to the “lay” or “naive” psychology of Heider (1958), and related to the work of, for instance, Kelley (1967; 1973). A basic assumption of attribution theory is that people need to make sense of their world and that they spontaneously engage in attribution activities. When explaining someone’s behavior, we often underestimate the impact of the situation and overestimate the extent to which it reflects the individual’s traits and attitudes. For instance, we have a tendency to think it is the person’s fault that he or she did not pass the exam, instead of referring to the situational context. The discounting of

the situation is referred to as the fundamental attribution error. The fundamental attribution error usually occurs when we explain other people's behavior; whereas we explain our own behavior in terms of the situation (Myers, 2007). The accident investigator(s) having the responsibility for localizing the causes of an accident is also subjected to making errors based on imperfect judgment processes. The examples highlight the importance of logical or rational reasoning in the investigations of accidents' causes as well as the potential influence on this reasoning from the utilized overall perspective, i.e. accident theory.

2.3 Accident theories

To facilitate that the accident investigator(s) focus on the "right" elements when investigating accidents, specific accident theories have been developed. According to Kjellén (2000) accident theories are tools to create mental images of the accident sequence and asking the "right" questions. They are also useful tools in data collections, interpretation of the data, analyzing information, identifying and assessing remedial action and communication by providing a common frame of reference. Accident theories also contribute to establish stop rules for investigation. In other words, accident theories are helpful to an individual or a group of people to understand accidents, and also to understand them in similar ways. Accident theories are based on different philosophies and methods and can result in different weighting of causality (Kjellén, 2000). The Energy and Barrier theory (Haddon, 1970; 1980), the Man-Made Disaster theory (Turner, 1978; Turner & Pidgeon, 1997), and the Normal accident theory (Perrow, 1984; 1999) will be elaborated in the following section.

2.4 The Energy and Barrier theory

The Energy and Barrier theory was first introduced by Gibson (1961) and later modernized by Haddon (1970; 1980). It has acquired a dominant role in accident prevention (Rosness et al., 2010). The Energy and Barrier theory has a pragmatic approach to accident research. The theory has proven useful in identifying hazards, providing the basis of risk analysis, and generating accident models (Rosness, et al., 2010). Furthermore, the theory has been recognized as useful for detecting unsafe acts or conditions at the workplace, often characterized as the immediate failures leading to accidents (Dekker, 2006). The basis of the theory considers accidents as a result of linear sequential events leading to failure. One event causes another, and so on, until it leads to failure. The understanding of accidents as

sequential events was first adapted by Heinrich (1936) and termed the “Domino theory”. The descriptive name indicates that if one domino trips, so will the next one. The falling dominos symbolize a chain of events possible leading to an adverse outcome. Counter measures could easily be implemented by placing barriers between the dominoes (events) and to ensure that the particular sequence will not happen (again).

The Energy and Barrier theory view uncontrolled transfer of energy as the main element leading to accidents. Haddon (1970, p. 2230) describes “a major class of ecologic phenomena” which involves a transfer of energy in such ways and amounts, and at such rapid rates, that inanimate or animate structures would be damaged. Haddon (1970) exemplifies with the harmful interaction between people and properties of hurricanes, earthquakes, moving vehicles and ionizing radiation. The basic idea is that accidents happens when people or objects are affected by harmful energy in the absence of effective barriers between energy sources (hazards) and the former. Some authors include the notion of energy transfer explicitly in their definition of the term “accident”. For instance, Johnson (1980, p. 507), defines an accident as “an unwanted transfer of energy, because of lack of barriers and/or controls, producing injury to persons, property, or process (...)”.

2.4.1 Preventive strategies

Haddon (1970; 1980) has systemized ten strategies for accident prevention. The strategies are directed towards reducing the amount of energy, separating the potential victims from the energy sources by barriers, and to make vulnerable targets more resistant to damage from the energy flow (see Table 1). Haddon argued that the larger the amount of energy involved, the earlier the countermeasures have to intervene.

Table 2. Summary of Haddon’s (1970) ten preventive strategies of loss reduction.

Hazard (energy source)	Barrier	Vulnerable target
Strategies related to the hazard:	Strategies related to barriers between hazard and target:	Strategies related to the vulnerable target:
1. Prevent build-up of energy (thermal, kinetic, or electrical) 2. Modify the qualities of energy 3. Limit the amount of energy 4. Prevent uncontrolled release of energy 5. Modify rate or distribution of the released energy	6. Separate in time or space the source and the vulnerable target 7. Separate the energy source and the vulnerable target by physical barriers	8. Make the vulnerable target more resistant to damage from the energy flow 9. Limit the development of loss (injury or damage) 10. Stabilize, repair and rehabilitate the object of the damage

Barriers, described in strategy 6 and 7 are effective measures in accident prevention, and constitute the main principle behind safety in design (Kjellén, 2000). A barrier is, within the Energy and Barrier theory, understood as a means to separate the vulnerable target from a dangerous energy source (Haddon, 1970); either separated by time or physical barriers (see Table 1). Sklet (2006, p. 496) defines barriers as “physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents”. Barriers have also been labeled in different terms with similar meanings (barrier, defense, protection layer,

safety critical element, safety function, etc) and been used crosswise between industries, sectors, and countries (Sklet, 2006). Barriers have also been categorized in numerous ways by different authors and the performance of the barriers can be described in several ways. Reason (2000) for instance, explains that advanced technology systems have many types of defensive barriers. Some are engineered (alarms, physical barriers, automatic shut-downs, stops, etc), others rely on individuals' skills (control room operators, train drivers, pilots), and yet other barriers are related to procedures and administrative controls. Discussing safety critical functions within the Norwegian railway industry Vatn (2001) differentiates between primary, secondary, and tertiary safety critical functions (barriers). Primary safety critical functions are related to the technical system for the rolling material, the rail network, and the traffic control. Secondary safety critical functions are activities performed in order to maintain the primary safety critical functions. Tertiary safety critical functions are safety management systems, maintenance management systems, etc.

Even though barriers, especially physical barriers, are highly recognized as preventive measures, there are always weaknesses. In an ideal world each barrier would be intact, but in reality they are more like layers of Swiss cheese containing many holes (Reason, 1997). These "holes" are continually opening, shutting and shifting their location. Holes in one of the layers are not enough to cause a negative outcome. However, if the holes in each layer line up at the same time to form a trajectory, there are opportunities for accidents to occur (Reason, 2000). Imagine that the "holes" represent different types of barriers in an organization. If the engineered barriers fail, e.g. technical malfunctions, the operators (human barrier) could still prevent an accident. If, however, the operators are not available, or non-existing, the engineered and human barrier could form a trajectory and an accident might occur. As compared to the Domino model, which is a simple linear model, the Swiss cheese model is a complex linear model.

The prevention strategies of Haddon (1970) are only directed towards one type of potential hazards, namely the large and uncontrolled source of energy. Other factors that could contribute to accidents are not mentioned. The Energy and Barrier theory tells a relatively simple story of what causes an accident, focusing on the technical cause-effect relationships. Critique voiced against the theory involves, for instance, the linearity of the model, and the disregard of the system complexity (Dekker, 2006). The Energy and Barrier theory has been recognized as useful in the late chain of accident causality. This recognition could be described in relation to the "single fault principle" which is an important principle in the railway industry (Jernbaneverkets sikkerhetshåndbok, 2011b). The single fault principle

makes sure that single failures, for instance human error, will not lead to accidents. Barriers would function as buffers, preventing these failures leading to accidents. However, if a barrier is missing, malfunctioning, etc, there are no buffers to prevent that single failure leading to an accident. What happens before a barrier “gives in”, i.e. in the early chain of causality is not reflected upon within the Energy and Barrier theory.

2.5 The Man-made Disaster theory

The Man-made Disaster theory was one of the first contemporary accounts of organizational vulnerability (Turner, 1978; Turner & Pidgeon, 1997). The theory provided much of the conceptual understanding of organizational accidents as a result of poor management and administrative processes (Pidgeon & Leary, 2000). The Man-made Disaster theory views organizational accidents as caused by latent failures. These latent failures do not normally lead to accidents unless they are activated by other failures, for instance, unsafe acts or mistakes. In a systematic study of 84 accidents Turner (1987) came to the conclusion that one of the main failures leading to large accidents is a breakdown in the organization’s information flow.

2.5.1 Information flow

The Man-Made Disaster theory proposes that accidents develop through a long chain of events, leading back to root causes such as lack of information or misperception amongst the personnel. Turner (1978) charted out common weaknesses in the information flow which an organization should be aware of. Rosness et al., (2004, p. 40) summarize:

1. “Completely unknown prior information: Where the information which foretells disaster is completely unknown; it is clear that there is little that can be done, except searching for better procedures for information flow in the relevant arena. We are still unlikely to experience such situations today; there is always someone who (should) know something relevant.
2. Prior information noted but not fully appreciated: Where information is potentially available, but not fully appreciated. The situation indicates that the information may not have been understood completely because individuals have a false sense of security when faced with danger signals. Often this emerges from distractions or pressure of work, which can give the subject an impression of the information as irrelevant.

3. Prior information not correctly assembled: When information about danger signals is carried in minds of individual humans, others can't reach it. A key to prevent disaster is therefore to place information in places where everybody can reach it.
4. Information available to be known, but which could not be appreciated because of conflict with prevailed understanding: In cases of disaster, Turner saw that the relevant information was available, but when it was a conflict with prior information, rules or values, it was neglected and not taken into discussion".

Knowledge transfer is closely related to the organization's information flow and is defined by Argote and Ingram (2000, p. 151) as "the process through which one unit (e.g., group, department, or division) is affected by the experience of another". According to Kjellén (2000) information at various organizational levels could be interpreted differently partly because of the knowledge transfer and thereby perceived as contradicting, resulting in different assumptions. When accidents occur, Kjellén (2000) describes that operators and supervisors at the workplace have direct experiences with the adverse events. These events are then perceived as specific, concrete and rich in details. This type of information does not typically allow for generalization, and is not practical for anyone else than those who generated it. Management at higher levels of the organizational hierarchy asks, on the other hand, for coded summary data of the accident(s). This type of information represents the aggregated results of complex processes at the local level. Operators and first line supervisors are exposed to direct information about the accidents whereas higher level management receives filtered and interpreted information through the knowledge transfer. As a consequence different sets of conceptions develop regarding causes for effective prevention based on what organizational level one works at.

Turner (1978) proposes that the quality of an organization's information flow stems from the organizations *safety culture*. A typical accident can be traced back to beliefs and norms of an organization, which do not necessarily comply with existing regulations.

2.5.2 Safety culture

The notion of safety culture became widely known after large organizational accidents as for instance the Chernobyl disaster and the Piper Alpha explosion in the 1980s. Prior and parallel to these accidents, Turner had started to connect the points of culture in relation to risk and safety. Turner's (1987) work was critical in stating the relationship between cultural processes and organizational safety (Antonsen, 2009).

Turner (1987) refers to the chain of events leading to an accident or the time before an accident as the incubation period. The incubation period is characterized by wrong beliefs and misperception of danger signals. Incidents and/or near-accidents occur unnoticed or are being misunderstood by the personnel. An organization's ability to detect such danger signals is important to the notion of safety culture (Turner, 1978). To detect or neglect such signals depend on what Turner and Pidgeon (1997, p. 47) labels "rigidities of perception and beliefs". These perception and beliefs constitute the frame of reference through which the personnel relate to, for instance, information, activities, and the organization's surrounding. If, however, something falls outside these frames of reference a "collective blindness" (Turner & Pidgeon, 1997, p. 47) might occur. This collective blindness describes the attention directed towards certain hazards, which might not be the relevant ones. The cultural frames of reference include a set of shared perceptions about what is to be considered safe, and what is to be considered dangerous. The more locked these cultural assumptions are, the more reduced are the organization's ability to detect signals of dangers that fall outside. This is described as a "way of seeing" and a "way of not seeing" (Turner & Pidgeon, 1997, p. 49). If an organization's regulations or procedures are "out of date" with the personnel's perception of how they should be, situations could arise where the standards of the organization and the personnel beliefs are contradictory (Turner, 1987). This perspective offers an explanation as to how it is possible for organizational members to ignore signals of dangers that are obvious in hindsight.

The most common critique of theories focusing on latent conditions is their difficulty of handling latent failures in an appropriate way (Dekker, 2006). Everything could in theory be construed as possible latent failures after an accident. The hardest thing would not be to localize these failures, but to make meaningful predictions with them.

2.6 The Normal Accident theory

The Normal Accident theory (Perrow, 1984: 1999) highlights the limits of safety in complex systems, and has also inspired to further empirical research of safety systems⁵. The Normal Accident theory has close relations to the “system model” which draws attention to the incompatible organizational structures involved in a complex system (Dekker, 2006). Accidents are understood from the “systematic model” as emerging from interactions between the system’s components and processes, rather than failures within them. Accidents tend to arise from the normal workings of the system, and are a result of systematic by-products of people and organizations, trying to pursue success with imperfect knowledge and under pressure or other resource constraints, e.g. scarcity, competition, time limits.

Instead of focusing on the absence of barriers or a poor safety culture, Perrow claims (1999) that some systems have structural properties that make accidents virtually inevitable and these inevitable accidents are labeled “normal accidents”. To explain how “normal accidents” are separated from other accidents or incidents, Perrow (1999) separates *component failure accidents* and *system accidents*.

2.6.1 Component failure accidents versus system accidents

Component failure accidents are caused by a failure in one or more components (part, unit or subsystem) that are linked in an anticipated sequence (Perrow, 1999). Minor events are typically component failure accidents. These types of accidents can be identified (to a considerable extent) through standard risk analysis methods (Rosness et al., 2010). System accidents involve, on the other hand, unanticipated interaction of several latent and active failures in a complex system. Perrow claims that such accidents are difficult or impossible to anticipate because there are too many combinatory possibilities. Moreover, some systems have properties that make it difficult or impossible to predict how failures may interact. “Normal accidents” are then distinguished by the number of component failures involved, which makes the accidents unforeseeable. In addition to the components involved, Perrow also claims that some structural properties are conducive to “normal accidents” such as *high interactive complexity* and *tight coupling*.

⁵ For instance, the Normal Accidents theory’s counterpart, the research of High Reliability Organizations (Weick 1987)

2.6.2 High interactive complexity and tight coupling

High interactive complexity systems are difficult to control, not only because they consist of many components, but because the interactions among the components are *non-linear* leading to unexpected event sequences. *Linear* interactions lead, on the other hand, to predictable and comprehensible event sequences.

Tightly coupled systems are characterized by the absence of “natural” buffers. Changes in one component will lead to a rapid and strong change in related components. This implies that any disturbance propagates rapidly throughout the system, and there is little opportunity for containing disturbances through improvisation.

High interactive complexity and tight coupling are a two-dimensional, socio-technical system which builds an argument to why some systems are intractable, and would therefore lead to “normal accidents”. A system consisting of interactive complexity and tight coupling does, according to Perrow (1999) pose as an organizational dilemma. The argument is summarized by Rosness et al., (2004, p. 24) as follows:

1. “A system with high interactive complexity can only be effectively controlled by a decentralized organization. Highly interactive technologies generate many non-routine tasks. Such tasks are difficult to program or standardize. Therefore, the organization has to give lower level personnel considerable discretion and encourage direct interaction among lower level personnel.
2. A system with tight couplings can only be effectively controlled by a highly centralized organization. A quick and co-ordinated response is required if a disturbance propagates rapidly through the system. This requires centralization. The means to centralize may, e.g., include programming and drilling of emergency responses. Moreover, a conflict between two activities can quickly develop into a disaster, so activities have to be strictly coordinated to avoid conflicts.
3. It follows from this that an organizational dilemma arises if a system is characterized by *high interactive complexity* and *tight couplings*. Systems with high interactive complexity can only be effectively controlled by a decentralized organization, whereas tightly coupled systems can only be effectively controlled by a centralized system. Since an organization cannot be both centralized and decentralized at the same time, systems with high interactive complexity and tight couplings cannot be controlled, no matter how you organize. Your system will be prone to “Normal accidents”.

This argument is further summarized in Table 2.

Table 3. The organizational dilemma of interactive complexity and tight coupling*.

	Linear interaction(s)	Complex interaction(s)
Tight coupling (s)	Centralize to handle tight couplings.	Centralize to handle tight couplings and decentralize to handle unexpected interactions.
Loose coupling (s)	Centralize or decentralize. (Both will work.)	Decentralize to handle unexpected interactions.

*Note: Based on Perrow (1999) and adopted from Rosness et al. (2004).

An organization is prone to “normal accidents” if the system is both complex and tight coupled as presented in the upper right corner of Table 2. To manage such a system, an organization both needs a decentralized and a centralized system, which is impossible in Perrow’s opinion and “normal accidents” will therefore be inevitable. The Normal accident theory could, however, be difficult to “prove”. Organizational systems have a tendency to consist of complex structures and the ability to characterize and model the many interactions as a failure or as a success appear to be difficult (Dekker 2006).

Perrow (1984; 1999) presents a rather pessimistic view of the socio-technical system. There are, however, organizations that have proven able to sustain a failure free operation of complex systems, e.g. High Reliability Organizations (HRO). Organizational learning is a common and central feature within these organizations (Weick, 1987; Reason, 2000). Despite all the negative effects, organizational accidents create large potential for organizational learning. The second part of the theory section focuses on organizational learning, and how this could be enhanced after accidents.

2.7 What is organizational learning?

After an accident the main goal of organizational learning is to reduce the probability of the same adverse event, and also similar accidents, to occur again. However, the challenges for organization learning are many. For instance, to choose the right elements to focus on in the aftermath of an accident, to implement and adjust the experiences and knowledge received from an accident to fit every level in the organizations, and also, to preserve experiences from

the past to be utilized in the future. Before the many challenges of organizational learning will be discussed, an introduction of “organization” and “learning” is relevant.

After the meta-analysis by Levin and Klev (2002; Klev & Levin, 2009), organizations are today viewed as entities which can act collectively, and have the ability to share values and assumptions. An organization is furthermore described by the authors as a social interaction made by all the informal practices occurring on a work place. Formal descriptions, for instance rules and formal procedures, are only indications of how an organization is designed, but it is the concrete practice that makes the organization. The organization becomes realized due to how the members act and what the members do throughout their everyday activities. However, it is important to add to this description that the formal description makes a necessary framework for the organization relative to which the individuals can act, take decisions, etc. Without these formal frames there is no organization. An organization is therefore understood in this thesis as a social interaction made by all the formal and informal practices occurring at a work place.

Organizational learning is according to Levin and Klev (2002) a result of a relational system where changes in the organizational interactions, and not in the individual *per se*, constitutes the organizational alterations, and thus the organizational learning. They recognize, however, that individuals play a major part in enhancing organizational learning. By this they mean that the individuals, and not the organization, have to change their perceptions of a task, or perform tasks in different ways to contribute to organizational learning. However, learning at a solely individual basis will not automatically create modifications at organizational levels. For instance, gaining new experiences on an external course does not necessarily give any learning input to the respective organizations. The new ideas could seem far-fetched, diffuse etc, to others not participating in the external course.

The importance of tacit knowledge is emphasized in the field of collective learning and organizational learning (Nonaka & Takeuchi, 1995; Spender, 1996b). Polanyi (1966) classified human knowledge into two categories: explicit or implicit (tacit). Explicit knowledge refers to what is transmittable in formal systematic language, and what can be specified or communicated verbally, or in symbolic forms such as written documents, blueprints or computer programs. Tacit knowledge, on the other hand, has a personal quality, rooted in action, commitment, and involvement in a specific context. Based on Polanyi's (1966, p. 4) observation: “We know more than we can tell”, Polanyi argued that a large part of human knowledge is occupied by knowledge that cannot be articulated. This is particularly true in the case of operational skills or know-how acquired through practical experience

which is action oriented and has a personal quality that makes it difficult to formalize or communicate.

Since tacit knowledge cannot be specified in detail and is revealed through practice, it cannot be transmitted by prescription. Tacit knowledge can be transferred by example or observation, such as from master to apprentice. This restricts the range of diffusion to personal contacts. Unlike explicit knowledge which can be formulated, abstracted and transferred across time and space independently of the knowing subjects, the transfer of tacit knowledge requires close interaction and the buildup of shared understanding and trust. Nonaka and Takeuchi (1995) make a distinction between explicit and tacit types of knowledge and argue that the capacity to mobilize tacit knowledge and foster its interaction with explicit knowledge is vital for the creation of new knowledge and the learning and innovative capability of an organization.

Huber (1991) considers four constructs as integrally linked to organizational learning: knowledge acquisition, information disturbance, information interpretation and organizational memory. He highlights that organizational learning does not have to be conscious or intentional, as discussed in operant conditioning (Bower & Hilgard 1981), or in case studies of organizational learning (March & Olsen, 1979). Nor does it have to be effective. According to Huber (1991) entities can learn incorrectly, and they can correctly learn that which is incorrect. Huber (1991, p. 89) defines learning from a behavioral perspective as: “an entity learns if, through its processing of information the range of its potential behavior is changed”. According to Huber, this definition would stand whether the entity is describing a human, a group, an organization, an industry or a society. Huber (1991, p. 89) also defines *organizational* learning more specifically as: “an organization learns if any of its units acquires knowledge that is recognized as potentially useful to that organization”. A corollary assumption is that an organization learns even if just one part of the organization acquires learning (Huber, 1991).

Kjellén (2000), on the other hand, has a “broader” view of organizational learning. Instead of focusing on units separately, he refers to the “scattering of learning” throughout the organization and up the management chain. This scattering of learning is based on a continuum from local learning, e.g. change of routines at the place of the accident(s), to general levels of learning, e.g. change at national or corporate levels in the organization. Based on this geographical approach Kjellén (2000) presents five types of learning levels from level 1 to level 5. The lowest level of learning, Level 1, refers to learning as limited to a specific place in the organization, i.e. local levels of learning. Any correction and/or

alterations due to an accident occurs at the specific site were an accident occurred, but are not implemented in other parts of the organization. The more organizational units and higher management levels are affected by the accident, the higher learning levels are reached. Level 4 and 5 are the highest learning levels an organization can reach were changes and/or alterations are made in higher-order systems, such as higher level management system. At this point the learning processes would affect units all over the organization, and is according to Kjellén (2000) necessary after organizational accidents. Research has showed however that learning mechanisms obtained after accidents occurs mainly at local levels in the organization (Jacobsson et al. 2010).

2.7.1 Organizational memory

Organizational memory is an important element of organizational learning. By convention, memory is usually classified as short term and long term. Studies show that information or experiences fade rapidly in short term memory, while possibly extending for decades in long term memory (Squire, 1986). Kjellén (2000) differentiates between short term and long term memory also in organizational contexts. Short term memory is according to Kjellén (2000) salient at the lowest levels of learning, whilst long term memory is salient at the highest learning levels. Sitkin (1996) describes organizational memory as the knowledge an organization stores and uses based on the observation of successes and failures, both within the own, and other organizations. There is a common understanding that organizational memory becomes visible when individuals react to new demands by drawing on the organizational pool of prior responses to similar stimuli. This information is stored by individual recollections as well as through shared interpretations (Walsh & Ungson, 1991; Levin & Klev, 2002). Walsh and Ungson (1991) suggest that the most important attribute of organizational memory is the length of service in the organization. An organization needs a link to “old timers” to ensure adequate organizational memory acquisition and controlled retrieval processes. Walsh and Ungson (1991) also explain that memory only is of value when it can be retrieved easily for use in current projects. Some parts of the organizational memory information are more available for retrieval than others. Availability is according to Walsh and Ungson (1991) associated with routines, frequency, recent use and organizational proximity.

The process of retrieval is also described as active memory; what the organization pays attention to, how it chooses to act, and what it chooses to remember from its experience

(Sitkin, 1996). The retrieval of information from memory can vary along a continuum from an automatic to a controlled process (Kahneman, 1973). At automatic levels the previous practices and procedures have typically been shared and encoded in transformations, role structure, culture, and work place ecology. Retrieval of information at controlled levels is, on the other hand, based on conscious choices, typically responses to novel stimuli. Previous practices and procedures do not necessarily provide the best solution at these levels. Information based at controlled levels could be more difficult to elicit, especially in demanding and novel situations, than retrieval from automatic levels (Walsh & Ungson, 1991).

Organizational memory forms the basis for an organization's ability to acquire and make use of knowledge. However, it could both support and undermine the ability to give innovative solutions in present situations (Walsh & Ungson, 1991). This depends on how well the organization's past solutions and routines can be adapted to fit the problems of the present circumstances. Organizational memory can produce automatic responses, and these are especially problematic in situations where new suggestions are needed. The response to a new demand could end up as a routine decision response when a non-routine decision response was actually called for. Organizational memory could yield experiential wisdom but also produce superstitious learning (Argyris & Schön, 1978); competency traps, erroneous inferences (Levitt & March, 1988), or even become a source of rigidity (Leonard-Barton, 1995). Every alteration an organization experiences could be a challenge by using organizational memory. If an organization's response to change is uncritically being more consonant with the past than the present, problems will arise.

It is according to Kim (1993) necessary to differentiate between stored memory and active memory structures in organizations. Stored memory is all the information the organization has collected throughout a given time span, while active structures are the information the organization actually uses in its daily activities. One way to understand the functioning of the active structures is by introducing mental models and heuristics (Kim, 1993).

2.7.2 Mental models and heuristics

The theory of mental models was originally developed to explain the comprehension of discourse and deductive reasoning (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). The theory suggests that when individuals understand discourse, perceive the world, or image a state of affairs, they construct mental models of the relevant situation (Johnson-Laird, Legrenzi, Girotto, Sonino Legrenzi and Caverni, 1999). A mental model is according to Johnson-Laird et al. (1999) a representation of a possibility that has a structure and a content which captures what is common to the different ways a possibility might occur. The theory describes that reasoning is a semantic process rather than a formal one. According to Johnson-Laird et al. (1999), “reasoners” build mental models on the basis of their understanding of the premises and on any relevant knowledge. They can formulate a true conclusion on the basis of these models and furthermore validity by ensuring that there are no models of the premises in which the conclusion is false. Mental models enable people to predict the outcome of an action by running a mental simulation of reality. Kim (1993, p. 39) defines mental models in a more general way:

“Mental models represent a person’s view of the world, including explicit and implicit understandings. Mental models provide the context in which to view and interpret new material, and they determine how stored information is relevant to a given situation. (...). Mental models not only help us make sense of the world we see, they can also restrict our understanding to that which makes sense within the mental model”.

Even though mental models are always correct in regards to the “reasoners” understanding (Johnson-Laird et al., 1999), these types of models do not always have to be correct in relation to reality. According to Hardman (2007) the accuracy of one’s prediction is dependent upon the mental model’s accuracy to depict reality. Problems could occur if actions are based on mental models as if they *were* reality, and this could create difficulties since mental models have a powerful influence on what people do, because they also influence what people see (Senge, 1990a). Several studies have for instance found that asking people to imagine or explain a specific causal scenario increases the perceived probability of that scenario to occur (Carrol, 1978; Gregory, Cialidini & Carpenter, 1982; Koehler, 1991). The perceived probability may thus be reduced when people also consider alternative scenarios (Dougherty, Gettys & Thomas, 1997).

Heuristics (cognitive shortcuts) refer to experience-based techniques for problem solving, learning and discovery (Walsh & Ungson 1991). According to Tversky and

Kahneman (1974) people rely on a limited number of heuristic principles which reduce the complexity of a task and simplify judgmental operations. Representativeness, availability and adjustments relative an anchor are helpful heuristic “tools” in everyday life. When people have to judge the probability for whether object A belongs to class B, the representative heuristic is commonly used. For instance, a person’s line of work could be guessed based on the degree of similarity between the common feature of the tasks and a person’s trait and/or behavior.

However, these “tools” can also lead to cognitive biases (Tversky & Kahneman, 1974). Kjellén (2000) states that mental models and heuristics have flaws contributing to possible miscalculations relative the information used as a foundation for decision-making. People tend to terminate their search for information when they find a satisfying solution rather than to search for more information to find an optimal solution (Simon, 1956). People will terminate their search for additional information when they experience that the subjective costs (time, attention, etc) exceeds their benefits (Kjellén, 2000). It is necessary to be aware of these biases in investigation processes.

2.7.3 Single and double loop learning

The theory of single and double loop learning (Argyris & Schön, 1978) is a well-known and well-used learning theory after accidents. This is particularly so because it fits easily into modes of organizational change (Argyris & Schön, 1996), which is often demanded after large accidents.

According to Argyris (1977) organizational learning is a process of detecting and correcting errors. When the process enables the organization to carry on its present policies or achieve its objectives, the process may be called single loop learning. Argyris (1977) compares single loop learning with a thermostat that learns when it is too hot or too cold, and then turns the heat on or off. The thermostat is able to perform this task because it can receive information from the temperature of the room, and can therefore take corrective action. Single loop learning is the physical ability to produce an action at an operational level. It is linked to the step by step alteration where an organization tries out new methods and tactics, and attempts to get rapid feedback of their consequences in order to make continuous adjustments and adaptations. Double loop learning could also be compared to a thermostat in terms of the thermostat’s ability to question itself whether it should be set in a certain temperature (Argyris, 1977). When achieving double loop learning, the ability to detect errors as well as to

question underlying policies and goals are salient. Double loop learning is associated with radical change, possibly involving major alterations at strategic levels, and linked to replacement of management or revision of the system.

To further understand “the background” of single and double loop learning, the theories have to be described in relation to the organization’s “actions theories”. Argyris and Schön (1978) describe that organizations over time will develop collective action theories determined by a collective understanding of how the organization works, e.g. what norms and rules to apply, organizational values, areas of responsibility, and technological functions. These action theories are often interpreted as routines and incorporate responses to a demand or a need. As long as the goals turn out the same, and the actions performed produce anticipated results, discussions or conflicts are rare. Learning, in form of either single or double loop learning, is triggered when these action theories are interrupted by not producing the predicted results. Single loop learning occurs when learning is maintained within the organization’s action theories, e.g. the behavior is adjusted, but the shared norms, values etc, of the individuals are still the same. Double loop learning, on the other hand, occurs when questions are asked regarding the set structures of the organization’s action theories. Double loop learning challenges everyday assumptions and practice in organizations. Even though single loop learning is needed in learning processes, double loop learning is necessary after organizational accidents.

Another description of learning processes that relates to Argyris and Schön’s theory of single and double loop learning is Kim’s (1993) acquisition of “know-how” and “know-why”. Kim (1993, p. 2) defines learning as involving two meanings: “(1) the acquisition of skill or know-how, which implies the physical ability to produce some action, and (2) the acquisition of know-why, which implies the ability to articulate a conceptual understanding of any experience”. Learning as “know-how” represents learning at a procedural level where one learns the steps in order to complete a particular task. Learning as “know-why” is related to conceptual learning, and has to do with the thinking of why things are done in the first place, and could challenge the very nature or existence of prevailing conditions and conceptions. Both parts of the definition are important and they complete a learning circle by presenting how one learns, and the understanding of the learning itself (Kim, 1993).

Kjellén (2000) links the correction of direct and indirect causes after accidents to the single and double loop learning idea. Correction of direct cause(s), for instance deficient equipment or human error, commonly referred to as active failures (Reason, 2000), usually requires

simple responses, e.g. the reparation of equipment, or implementation of barriers. Single loop learning is effective for this type of corrections and the personnel learn the operative stages to perform a new task. However, the tasks performed and the behavior of the personnel is still located within the organization's action theories, for instance the organization's stated policies. Correction of the indirect cause(s) could, however, tap into the core weaknesses of an organization, for instance, the organization's management strategies, commonly referred to as latent conditions (Reason, 2000). This plunge into the organization's core might alter the organization's action theories, and as a result, double loop learning would be achieved. Indirect causes represent the mechanisms behind *why* the direct cause(s) occurred in the first place.

Despite the importance of double loop learning processes after accidents, research has shown that single loop learning is the dominant feature of organizational learning in general (Argyris, 1977), and after accidents (Kjellén, 2000; Jacobsson et al. 2010). Kjellén (2000) claims that organization's have a larger focus on direct causes because these are easier to correct, in contrast to indirect causes. Direct causes demand a superficial investigation, while the investigation of indirect causes might lead to an investigation and alterations in the central policies and strategies of an organization. This type of investigation takes more energy and time than investigating direct cause(s). Kjellén (2000) also points out that organizational accidents are rare events, and that it is unlikely that the management of an organization will encounter similar types of accidents again in the near future, and single loop learning will therefore be perceived as an easier process.

The correction of direct causes instead of indirect causes is described above as simpler, but the organization as a whole loses its opportunity to learn. The organization's management has, according to Kjellén (2000), the main responsibility for double loop learning to occur. He claims that the management has to encourage these processes in order to create an open and trustworthy atmosphere. This involves supporting participation of all involved parties in defining purpose and in making inquiry, minimizing unilateral control, creating win-win situations and allowing feelings to be expressed.

To prevent organizational accident(s), the goal and challenge is to combine safety thinking and learning in everyday (organizational) life. The next part will introduce the four railway accidents investigated in this thesis, i.e. the Tretten accident (1975), the Nordstrand accident (1993), the Åsta accident (2000) and the Alnabru/Sjursøya accident (2010). A description of the accidents will be presented together with a review of the respective accident's evaluation reports.

3. CASES

A short description of the sequence of events leading to the accidents (Tretten, Nordstrand, Åsta and Alnabru/Sjursøya) will be outlined in following section. Furthermore, a review of the evaluation reports (Uhellskommisjonen, 1975; Uhellskommisjonen, 1993; NOU, 2000; AIBN, 2011) focusing on the stated causes and recommendations are presented.

3.1 The Tretten accident (1975)

The 22nd of February, 1975, a northbound train and a southbound train were expected to have a crossing at Fåvang station. This particular day, however, the crossing point was moved to Tretten station because the southbound train was 35 minutes late. The driver of the northbound train tried to compensate this delay by increasing the speed of the train. But the effort was useless. It was in the middle of the winter holiday, and the attempted compensation was limited by the amount of people going on and off the train at the stations. By the entrance to the Tretten station, the distant signal showed green. This indicated that it was a clear entry to the Tretten station. The main signal, 800 m after the distant signal, showed two green and one yellow signal. This indicated that the train would not have a clear entry to *leave* Tretten station. The driver claimed, however, that he saw a green departing signal at the station. The northbound train therefore left the Tretten station and when the train had reached top speed the driver discovered a train approaching from the north. This was the southbound express train. Twenty-seven people died and 16 people were injured in the most deadly train accident in Norwegian history.

In relation to the scale of the accident, the accident report was relatively short, including 16 type-written pages and some technical appendices (Uhellskommisjonen, 1975). The report treated exclusively the question whether the train was driven against the stopping signal or not. The conclusion was unambiguous. No failures were apparent in the technical system, leaving only one option left, the accident was a result of human error, i.e. driving against the stopping signal. There was no discussion of indirect causes in the evaluation report.

3.1.1 Direct cause

- The Commission of inquiry has to establish that there were no technical failures in the interlocking plant and therefore it has to be concluded that train 351 passed the stopping signal leaving the Tretten station⁶.

3.1.2 Recommendation

- Accidents like this could presumably only be prevented by implementing Automatic Train Control system (ATC) if driving past stopping signals⁷.

3.2 The Nordstrand accident (1993)

The 3rd of October, 1993, a local train was positioned at Nordstrand station, while a freight train, on the same lines, was heading south towards Lodalen station. The freight train had to stop at Lodalen station due to failures in the brakes. The electrodynamic and the parking brakes were operating, but the pneumatic brakes were not. When the parking brakes were released at Rosenhold stop, the freight train started to roll uncontrollably towards Nordstrand station. The nature of the electrodynamic brakes is that they would not function if the train is set in the wrong direction (roll backwards). Since the pneumatic brakes were dysfunctional, there was no possibility for the driver to stop the runaway freight train, and it collided with the local train on the Nordstrand station. Five people died, and four people were seriously injured in the accident.

The accident report (Uhellsskommisjonen, 1993) treated to a large degree the technical aspects of the accident, and considered possible human error(s). Technical evidence showed that the brakes on the freight train were disconnected when the accident occurred. The freight train driver claimed he did not have any knowledge about these technical aspects, but he was still charged as responsible for the accident. Even though the Commission of inquiry still followed the traditional view of accidents, i.e. focusing on technical failures and who to

⁶ ”Uhellsskommisjonen må fastslå at det her ikke har vært noen feil i sikringsanlegget, og kan ikke forklare uhellet på noen annen måte enn at tog 351 er kjørt ut fra Tretten stasjon mot stoppsignal” (p. 16).

⁷ ”Ulykker som dette kan formodentlig bare avverges om det innføres automatisk tvangsbremsing ved kjøring forbi stoppsignal” (p. 16).

blame, the report presented a number of recommendations, including elements indirect to the decisive cause.

3.2.1 Direct cause

- The cause of the accident was due to a failure of noting that the stop cocks for the breaking cylinders were adjusted in the wrong position during check out of the locomotive⁸.

3.2.2 Recommendations

- The stop cocks for the pneumatic brakes and the elastic brakes should be marked in a responsible way with Norwegian texts⁹.
- The stop cocks for the pneumatic brakes should be sealed in an open position¹⁰.
- The working instruction should be upgraded and all drivers who operate freight trains will receive a better introduction in the pneumatic breaking system's principle of operation and the stop cock's significance¹¹.
- The regulations and procedures for material hire have to be determined¹².
- The rules for operator control in deliverance of the pneumatic brakes have to be enjoined. It has to be evaluated if there are special requirements for handling these brakes¹³.
- The follow-up and control of set routines in relation to check out and insertion of traction engine has to be enjoined¹⁴.

⁸ ”Årsaken til ulykken var at det under uttak av lokomotivet ikke ble registrert at stengekranene for bremsesynderne sto i feil stilling” (p. 12).

⁹ ”Stengekraner for trykkluftbrems og fjærkraftbrems funksjonsmerkes på en forsvarlig måte med norsk tekst” (p. 14).

¹⁰ ”Stengekran for trykkluftbrems plomberes i åpen stilling” (p. 14).

¹¹ ”Betjeningsforskriftene oppgraderes og alle lokomotivførere som skal kjøre lokomotivene, får en bedre innføring i luftbremsesystemes virkemåte og stengekranenes betydning” (p. 14).

¹² ”Regelverk og prosedyrer for innleie av materiell må fastlegges” (p. 14).

¹³ ”Regler for betjening av friggjøringsanordninger på fjærkraftbrems må innskjerpes. Det må vurderes om det er behov for spesielle bestemmelser for betjening av slike bremses” (p. 14).

¹⁴ ”Oppfølging og kontroll av at fastlagte rutiner i forbindelse med uttak og innsetting av trekkaggregater innskjerpes” (p. 14).

- Emergency numbers have to be established directly to the train leader over the mobile phone network¹⁵.
- The technical possibility to submit an acoustic warning system to the train leader if unintended movements on a distant controlled distance occur has to be evaluated¹⁶.
- The training of personnel working with new material has to be quality guaranteed¹⁷.
- The possibility to expedite the expansion of the train radio system has to be evaluated¹⁸.

3.3 The Åsta accident (2000)

The 4th of January 2000, the southbound train left Trondheim on its schedule for Hamar. When the train arrived at Røros station it was 21 minutes late. The delay was reduced to 7 minutes when the train arrived at Rena station. There were 75 persons on board including the driver and the conductor when the train left Rena at 13.07. Witnesses and the log taken from the Hamar rail traffic control centre indicate that the departing signal from Rena station was green.

The northbound train left Hamar on schedule. The train was scheduled to run to Rena and back to Hamar. It arrived at Rugstad on schedule at 13.06, stopped and picked up a passenger. According to the timetable the train was supposed to wait at Rugstad station from 13.06 to 13.10 for the southbound train to pass. However, the train left Rugstad at 13.07, and met the southbound train, coming towards it on the same tracks. The log from Hamar rail traffic control centre indicates that the departing signal from Rugstad station for a safe exit was not green. The trains collided at Åsta station between Rugstad and Rena at 13.12. Totally 19 people died in the collision and the fire that followed.

The following investigation (NOU, 2000) of the adverse event showed that it was *either* a signal failure or a human error that was the decisive cause of the accident. The Commission of inquiry could not be sure of what the departing signal had showed when the northbound train left Rugstad station. The evaluation report presented in addition numerous indirect causes; criticizing the organization's procedures, lack of barriers, inefficient rules and

¹⁵ "Det må opprettes egne nødnummer direkte til togleder over mobiltelefonnettet" (p. 14).

¹⁶ "Det må vurderes om det er teknisk mulig å legge inn akustisk varsling til togleder ved utilsiktet bevegelser på fjernstyrt strekning" (p. 14).

¹⁷ "Opplæring av personale på nytt materiell må kvalitetssikres" (p. 14).

¹⁸ "Det må vurderes om det er mulig å fortere utbyggingen av togradiosystemet" (p. 14).

a poor risk management (NOU, 2000). The commission weighted especially the latter category, the organization's risk and safety management.

3.3.1 Direct cause

- “Neither malfunction of the signaling system nor human error can be excluded as a possible cause to the accident¹⁹.”

3.3.2 Indirect causes

- The process in relation to the alteration of the departing procedure (...) never approved by the Norwegian Railway Authority (NRA), but was still practiced the day of the accident (...). In relation to the Åsta accident the indirect cause was not the process around the alteration, but the fact that the driver alone had the responsibility to control the departure signal of the passenger train²⁰.
- When the remote control system was established at the Røros line the conductors were removed and replaced with signals operated from the rail traffic control center at Hamar (...). If the conductors had been retained, the risk of a failure in the signal system developing into a critical situation would have been considerable reduced²¹
- If the cross-over plans still had been apparent in the schedule, and the driver had to contact the train leader if there was an alteration of the crossing, even if the departure signal was green, this would have been a barrier against possible signal failures or a wrong observation on the driver's part²².
- If the expansion of ATC had been implemented this would have been able to prevent the northbound train from passing the stopping signal at Rudstad²³.

¹⁹ ”Hverken signalfeil eller menneskelig feilhandling kan utelukkes som mulig årsak til ulykken.” (p. 244).

²⁰ ” (...) prosessen i forbindelse med den endrede avgangsproseduren (...) aldri godkjent av Tilsynet, men likevel ble den praktisert ulykkesdagen (...). I forhold til Åsta ulykken er det selsagt ikke selve prosessen rundt endringene som kan være indirekte årsak, men det faktum at lokomotivfører etter endring alene har ansvaret for å kontrollerer utkjørssignalet ved persontog fra avgang fra stasjon” (p. 245).

²¹ ”Da fjernstyringsanlegget var ferdig utbygd på Rørosbanen ble togekspeditørene fjernet og erstattet med signaler styrt fra togeledersentralen på Hamar (...). Hadde man beholdt togekspeditørerne ville risikoen for at en feil i signalanlegget fikk utvikle seg til en kritisk situasjon blitt betydelig redusert” (p. 245).

²² ”Dersom kryssningsplan fortsatt fremgikk i ruteboken, og lokomotivfører ved endret kryssing måtte kontakte togleder før avgang, selv om utkjørssignalet var grønt, ville dette være en barriere mot eventuelle signalfeil eller en feilobservasjon fra lokomotivførers side” (p. 246).

²³ ”Dersom ATC hadde vært utbygget ville dette kunnet stanse norgående tog dersom det passerte utkjørssignalet på Rudstad i stopp” (p. 246).

- The Røros railway is not electrified and the railway traffic is therefore diesel-powered. This implies that the rail traffic controller does not have the same possibility to stop the trains in contrast to an electrified line, where the electricity can be cut in case of an emergency situation²⁴.
- The consequence of not installing audible alarms at the rail traffic control center at Hamar was that the rail traffic controller was not warned about the two trains on collision course the 4th of January, 2000²⁵.
- The lack of audible alarms at the rail traffic center at Hamar should have ensured clear rules stipulating how often the rail traffic controller had to monitor each portion of line²⁶
- The expansion of train radios at the Røros line would have allowed Nybakken to make immediate contact with the trains when he observed the situation at the screens and hence prevented the collision²⁷.
- There were no regulations regarding the reporting, reception or storage of the mobile telephone numbers at the rail traffic control centre²⁸.
- There were insufficient regulations and routines regarding the change of shift²⁹.
- There was a lack of rules and routines regarding the information-exchange between the DROPS Nord and the rail traffic control center³⁰.
- Neither the former NSB nor the NNRA did any risk analysis in relation to the alterations and delays on the Røros line to be familiar with the consequences such alterations or delays would have for the safety level³¹.
- As the review (...) shows, there has been no systematic follow-up regarding the safety on the Røros line during the 1990s. This means that the influence of the serious and

²⁴ ”Rørosbanen er ikke elektrifisert og trafikkeres derfor med dieseldrevne tog. Dette innebærer at togleder ikke har samme mulighet til å stoppe toget som på en elektrifisert bane hvor strømmen kan tas dersom en nødsituasjon skulle oppstå” (p. 246-47).

²⁵ At det ikke var installert lydalarm på Hamar togledersentral hadde 4. januar 2000 den konsekvens at togleder (...) ikke ble varslet om at to tog var på kollisjonskurs (p.147).

²⁶ ”I mangel av lydalarm burde det ved Hamar togledersentral i hvert fall vært klare regler for hvor ofte togleder pliktet å holde øye med hver banestrekning” (p. 247).

²⁷ ”Dersom togradio hadde vært utbygget på Rørosbanen ville Nybakken kunne kontaktet de to togene umiddelbart etter at han så situasjonen på skjermene og således forhindre kollisjonen” (p. 248).

²⁸ ”Ingen regler for innmelding, mottak og oppbevaring av mobiltelefonnummer på togledersentralen” (p. 248).

²⁹ Manglende regler og rutiner i forbindelse med vaktskifte (p. 149).

³⁰ ”Manglende regler og rutiner for informasjonsutveksling mellom Drops Nord og togledersentralen” (p. 249).

³¹ ”I forbindelse med de endringer og utsettelse i planer som har vært gjort i tilknytning til Rørosbanen har det hverken i det tidligere NSB eller i Jernbaneverket vært gjennomført risikoanalyser for å gjøre seg kjent med hvilke konsekvenser en endring eller utsettelse ville få for sikkerhetsnivået” (p. 250).

partly familiar safety shortcomings at the Røros line had neither been analyzed nor followed up³².

3.3.3 Recommendations

- The Commission recommends that measures should be implemented to ensure that a proactive safety management is applied to the general railway operation³³.
- Furthermore, the Commission recommends that there should be a safety manager for railway operations with a direct line to the top management (...). The responsibility for the follow-up and implementations of safety measures must be in the line³⁴.
- The Commission recommends that the Norwegian National Railway Administration (...) should intensify their efforts to develop an adequate and efficient internal control system in all parts of their operation³⁵.
- In the Commission's opinion, competence requirements and training plans should be worked out to all personnel with safety responsibility³⁶.
- The Commission recommends that risk analysis should be used to assess the risk connected with railway operations³⁷.
- In the view of the Commission, measures should be implemented to boost the personnel's motivation to report and give feedback on undesirable incidents in all parts of the organization³⁸.
- The Commission recommends that reports regarding unwanted incidents should be compared and systematized to investigate if failures are being repeated, and if they are safety-critical³⁹.

³² "Som gjennomgangen (...) viser, har ikke vært en systematisk oppfølging av sikkerheten på Rørosbanen i løpet av 1990-tallet. Dette innebar at den påvirkning på sikkerheten, alvorlige og til dels kjente sikkerhetsmangler på Rørosbanen hadde, hverken ble analysert eller fulgt opp" (p. 251).

³³ "Kommissjonen anbefaler at det i den samlede jernbaneverksamheten iverksettes tiltak for å sikre en proaktiv sikkerhetsstyring" (p. 285).

³⁴ "Det anbefales videre at aktørene innenfor jernbaneverksamheten har en sikkerhetssjef med direkte linje til toppledelsen (...). Ansvaret for oppfølging og gjennomføring av sikkerhetstiltak må ligge i linjen" (p. 285).

³⁵ "Det er Kommissjonens anbefaling at Jernbaneverket (...) bør intensivere innsatsen med å utvikle fullverdige og fungerende internkontrollsystem i alle deler av sin virksomhet" (p. 285).

³⁶ "Kommissjonen mener at det bør utarbeides kompetansekrav til, og opplæringsplaner for, alle ansatte med sikkerhetsansvar" (p. 285).

³⁷ "Kommissjonen anbefaler at risikoanalyser blir benyttet til å kartlegge risikoen i jernbaneverksamheten (...)" (p. 285).

³⁸ "Kommissjonen mener det bør iverksettes tiltak som vil gi større motivasjon for rapportering og tilbakemelding om uønskede hendelser i alle deler av organisasjonen" (p. 285).

³⁹ "Kommissjonen anbefaler at meldinger om uønskede hendelser sammenstilles og systematiseres for å avdekke om feil gjentar seg og om de eventuelt er sikkerhetskritiske" (p. 285).

- The Commission holds the opinion that analyses of reported incidents should be made more available in the organization to visualize relationships and circumstances important for safety⁴⁰.
- The Commission recommends that clear rules and routines should be prepared for the internal accident committees by actors within the railway operation⁴¹.
- Furthermore, the Commission recommends that the possibility for equipping all lines with reliable log systems should be investigated⁴².
- The Commission holds the opinion that a complete reengineering of the interlocking system NSB- 87 should be carried out before the system is put back into normal operations and before ATC is installed⁴³.
- It is also the opinion of the Commission that a technical review of the interlocking system NSI- 63 should be carried out, and that this evaluation should be followed up by an external party⁴⁴.
- The Commission recommends the installation of ATC at the Røros line and at other remotely controlled lines where ATC is not installed⁴⁵.
- The Commission recommends that the NNRA (...) reviews all the documentation relevant to technical systems and ensures that it is complete⁴⁶.
- The Commission holds the opinion that rolling stocks should be reviewed and assessed to be renewed so the material meets the current requirements⁴⁷.
- The Commission recommends that audible alarms for safety-critical failures (should) be installed at all rail traffic control centers as soon as possible⁴⁸.

⁴⁰ ”Kommissjonen er av den oppfatning at analyser av rapporterte hendelser bør gjøres mer tilgjengelige i organisasjonen for å synliggjøre sammenhenger og forhold av betydning for sikkerheten” (p. 285).

⁴¹ Kommissjonen anbefaler at aktørene innenfor jernbanevirksomheten utarbeider klare regler og rutine for de interne uhells- og ulykkeskommissjonene (p. 285).

⁴² Videre anbefaler Kommissjonen at muligheten for å utstyre alle banestrekninger med pålitelige loggsystemer utredes (p. 285).

⁴³ ”Kommissjonen er av den oppfatning at en fullstendig reengineering av sikringsanlegg NSB-87 må gjennomføres før anlegget settes i normal drift igjen, og før ATC installeres” (p. 285).

⁴⁴ ”Kommissjonen mener videre at det bør foretas en teknisk gjennomgang av sikringsanlegg NSI-63, og at en slik gjennomgang bør ha ekstern oppfølging” (p. 286).

⁴⁵ ”Kommissjonen anbefaler at ATC bygges ut på Rørosbanen og andre fjernstyrte banestrekninger hvor ATC ikke er installert” (p. 286).

⁴⁶ ”Kommissjonen anbefaler at Jernbaneverket (...) går igjennom dokumentasjonen vedrørende alle tekniske systemer, og at det påses at dokumentasjonen er fullstendig” (p. 286).

⁴⁷ ”Det er kommissjonens syn at eldre materiell bør gjennomgås og vurderes oppgradert slik at materiellet tilfredstiller gjeldende krav” (p. 286).

⁴⁸ ”Kommissjonen anbefaler at lydalarm ved sikkerhetskritiske feil installeres på alle togledersentraler så snart som mulig” (p. 286).

- The Commission holds that the NNRA ought to perform a review and evaluation of the organization and the conditions at all the rail traffic control centers both at an overall and a local level⁴⁹.
- Furthermore, the Commission recommends that the internal rules for maintenance and upgrading are altered so that they adhere to the constitution⁵⁰.
- The Commission believes it is important to introduce procedure and rules for the use of mobile telephones until train radios or other reliable communication equipment has been installed⁵¹.

3.4 The Alnabru/Sjursøya accident (2010)

The 24th of March, 2010, a set of empty wagons started to roll uncontrollably from Alnabru freight yard in the direction towards Sjursøya. The mechanical brake of the freight car set was released by mistake without having a connecting shunting engine. The wagons rolled out of Alnabru marshaling yard and onto the freight-train track towards Loenga. At Loenga station, the runaway wagons passed through and rolled into Oslo Port's track system heading for Sjursøya. Some of the rearmost wagons derailed at Sørenga, while the rest crashed into the terminal building in the Oslo Port's container terminal. When the derailment occurred the speed was estimated to 125 km/h. The front section of the freight car set (seven freight cars, 194 tons, 207 m) continued through a buffer stop at the end of the track, across a parking area, through the access gate to the container terminal and into the gate building. Freight cars 2 and 3 went over the edge of the quayside, across a tug boat and ended in the harbor basin, while the rest of the wagons stopped at the quayside. Three people died and four were seriously injured. There was extensive damage to buildings, infrastructure, motor vehicles and wagons.

The accident evaluation report (AIBN, 2011) stated unclear communication between collaborating units (the local traffic controller and the shunter) as the decisive cause of the accident. Indirect causes were also investigated in the aftermath of the accident focusing mainly on procedures, barriers, risk management, human error and safety culture.

⁴⁹ Kommisjonen mener at Jernbaneverket bør foreta en gjennomgang og vurdering av organiseringen og forholdene ved alle togledersentralene både på et overordnet og et lokalt nivå (p. 286).

⁵⁰ Videre anbefaler Kommisjonen at interne regler for vedlikehold og oppgradering endres slik at de blir i overensstemmelse med grunnloven (..) (p. 286).

⁵¹ "Kommisjonen mener det er viktig at det innføres prosedyrer og regler for bruk av mobiltelefonen inntil togradio eller annet sikkert kommunikasjonsutstyr er installert" (p. 286).

3.4.1 Direct cause

- “The active failure consisted of a misunderstanding between the local traffic controller and the shunter concerning which shunting route to set, which caused the freight car set to start rolling from the A track at Alnabru” (p.117)⁵².

3.4.2 Indirect causes

- “A practice had developed at Alnabru shunting yard whereby the A tracks were extensively used for temporary storage between loading operations. The freight car set in question was parked in an A track every night” (p. 118).
- “The provision that an additional brake should be used when parking in an A track for more than four hours was ‘dormant’ and unknown to CargoNet AS’s shunting personnel. The freight car set had therefore been secured using the A track’s mechanical brake only” (p. 118).
- “When the shunter added an additional car to the freight car set, the local traffic controller was sure that the freight car set was to be shunted for loading. The shunter did not intend to move the freight car set and had disconnected the shunting engine” (p. 118).
- “The local traffic controller did not make sure that the shunting engine had control of the freight car set before releasing the mechanical brake” (p. 118).
- “The procedure for releasing the mechanical brake was ‘dormant’ and unknown to the local traffic controllers. The local traffic controller may have been affected by the ergonomic conditions in the Central Control Tower, responsibility for training a trainee and the absence of the assistant local traffic controller” (p. 118).
- “The rolling freight car set was not observed in time to stop it by means of the lowering brake or divert it to buffer track T1/T2 through tracks G2/G3” (p. 118).
- “There were no run-off points for tracks G4/G5. Hence, the freight car set was able to leave Alnabru via the freight track towards Loenga” (p. 118).
- “No arrangements were in place to divert, derail or stop the freight cars in a controlled manner once the freight car set had left Alnabru” (p. 118).

⁵² The direct and indirect causation as well as future recommendations are copied from the English report (AIBN, 2011).

- “The empty freight cars had a very low center of gravity and hence particular good running properties. They passed through track 10 and the derailer at Loenga without derailing” (p. 118).
- “No procedures had been established for the use of standard phrases or rearback-
hearback in communication between local traffic controllers shunting personnel at Alnabru with a view to preventing or detecting any misunderstandings” (p. 119).
- “Neither the NNRA (...) had defined what constituted safety-critical information, and had not emphasized the establishment of a common reference framework to ensure unambiguous and efficient communication between shunting personnel and the local traffic controllers” (p. 119).
- “The use of A tracks for parking freight car sets was a result of an increase in traffic/
shortage of space, and the fact that it simplified shunting operations” (p. 119).
- “The practice of using A tracks for parking freight car sets had not been the subject of a formal decision-making process, including safety analysis, in the NNRA (...)” (p. 119).
- “The operating personnel knew that there was a situation without run-off points on tracks G4 and G5, and they had adapted their work practice accordingly. The matter had not been formally considered as a safety problem by the NNRA” (p. 119).
- “Nobody in CargoNet AS or the NNRA had identified the risk of freight cars starting to roll uncontrollable from an A track towards the G tracks leaving Alnabru” (p. 119).
- “The investigation has disclosed a lack of trust in and social acceptance of the reporting and nonconformity systems of (...) the NNRA” (p. 119).
- “Verbal communication had been the central form of communication of (...) the (...) NNRA. As far as possible, problems have been resolved informally on the spot, at the expense of documentation and traceability” (p. 119).
- “Two examples of ‘dormant’ provisions show that there were weaknesses in how governing documents were prepared, and in the way in which they are currently maintained and distributed in the NNRA’s own organization and in CargoNet AS” (p. 119).
- “Governing documents do not adequately distinguish between barriers and information of a more general nature” (p. 119).
- “Alnabru was not covered by the NNRA’s system for risk identification because minor changes had taken place over time and not been significant enough for the need

for an analysis to be apparent, and because the section analyses did not encompass the activities at Alnabru” (p. 119).

- “The available risk analysis for Alnabru from both the NNRA and CargoNet AS are inadequately with respect to work processes and barriers, and they rely excessively on previous events (incidents statistics)” (p. 120).
- “Structurally, the NNRA had not taken into account the complexity of the operations and ownership structure in the Alnabru area” (p. 120).
- “The communication of risk in (...) the NNRA may have been influenced by differences between the skills and technical terminology of operating personnel, management and support functions” (p. 120).
- “The NNRA had not adequately followed up its responsibility as infrastructure manager and Principal Enterprise pursuant to the Working Environment Act. Alnabru lacked an overall safety function and no overall risk assessment had been carried out since 2001” (p. 120).
- “As a consequence of structural changes and a growth in the freight traffic by rail, combined with an inadequate remodeling/development of the facilities to accommodate these developments, Alnabru was being used in a way that had not originally been intended” (p. 120).
- “A focus on efficiency and productivity in a worn-out, outdated yard and terminal, and an insufficient focus on updating safe work practices had reduced the safety margins” (p. 120).
- “Remodeling/ developing Alnabru had not happened as a result of both political prioritizations and NNRA’s own priorities of freight traffic” (p. 120).
- “As a consequence of under-reporting and the fact that few minor incidents are no guarantee that there is little risk of a major accident, the figures on which the NRA based its supervision do not provide a complete risk picture” (p. 120).
- “The NRA had not requested any overall risk picture for Alnabru, as it was before the notified changes, from the NNRA” (p. 120).

3.4.3 Recommendations

- “The barriers established to prevent rail cars without brakes from breaking loose and rolling away from Alnabru has been inadequate. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration to analyse the operational situation at Alnabru and to establish necessary barriers so that runaway rail cars cannot roll out of the station” (p. 125).
- “Alnabru was not covered by the NNRA’s system for risk identification because minor changes had taken place over time and not been significant enough for the need for an analysis to be apparent, and because the section analyses did not encompass the activities at Alnabru. The risk analyses available for Alnabru from (...) the NNRA (...) are also inadequate with respect to work processes and barriers. They are excessively based on establishing risk figures for top events (top-to-bottom approach) and previous incidents. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration (...) to review and improve their systems for risk assessments and analyses” (p. 125).
- “Alnabru lacked an overall safety management that could identify the risk that followed from the many changes that had taken place over time. There was no safety function that could address and deal with safety-related information from both the NNRA and the railway undertakings at the overall level. The safety work was divided between many different line and support functions, and forums, internally and between the various organisations. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration (...) to review and improve the way safety work is organised, in order to ensure the overall safety of freight terminals and shunting yards” (p. 125).
- “The investigation has uncovered a lack of trust in and social acceptance of the reporting and nonconformity system in the NNRA (...). In the case of (...) the NNRA (...), the main problem concerns the ability to communicate information between the various levels that are involved in identifying, assessing and reducing risk. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration (...) to improve their safety management, with a particular emphasis on collecting and processing information in order to improve the safety culture” (p. 125).

- “The immediate cause of the accident was a misunderstanding between the local traffic controller and the shunter. Neither the NNRA (...) had defined what should constitute safety-critical information, and they had not emphasised the establishment of a common reference framework to ensure unambiguous and efficient communication. No procedures had been established for the use of standard phrases and readback-hearback. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration and the railway undertakings to review communication in connection with shunting operations, define safety-critical information, and establish barriers to prevent/detect misunderstandings” (p. 126).
- “Two provisions that could potentially have prevented loss of control of the freight car set were not in use or known to the operating personnel at Alnabru. This shows that there were weaknesses in how governing documents were prepared, and in the way in which they are currently maintained and distributed in the NNRA’s own organization (...). Governing documents do not adequately distinguish between barriers and information of a more general nature. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration (...) to update and distribute governing documents and ensure that they are understood” (p. 126).
- “There are no barriers in the tracks towards Loenga or Oslo S that can divert, derail or stop runaway rolling stock in a controlled manner so as to prevent loss of human life and serious personal injuries. It is not possible for the traffic controller to release any main train routes instantly. The Accident Investigation Board Norway recommends that the Norwegian Railway Authority order the Norwegian National Rail Administration to consider whether it is necessary to establish barriers in order to protect the freight train track from Alnabru to Loenga, Hovedbanen and Oslo S station” (p. 126).

4. DISCUSSION

How the accident causation and recommendations are evaluated and presented in the accident evaluation reports is important for how the respective organization “understands” the accidents. The “understanding” of an accident is furthermore elementary and important for how the organization can learn from the experience. This section starts by discussing how the respective accident theories, i.e. the Energy and Barrier, the Man-made Disaster and the Normal Accident theories are reflected in the accident evaluation reports, especially in relation to the causes and recommendations presented in the evaluation reports. The weaknesses of the theories are also discussed and theoretical contributions are suggested for further improvements.

In the second part of the section, the evaluated accident causation and the attached recommendations are discussed in relation to the notion of organizational learning. It is noted that the shift from internal to external accident investigations made a large difference to how the accident evaluation reports were written and how the causes and recommendations were presented. How the accident evaluation reports’ content differed and how this might have affected the organizational learning process after the accidents are the main issues of this part of the discussion. Finally, implications for future research are suggested, before a conclusion is presented.

4.1 The Energy and Barrier theory

The Energy and Barrier theory claims that accidents could be prevented by focusing on dangerous energy and means by which such energy can be separated from vulnerable targets (Haddon, 1970; 1980). All the accidents described in this study involved a transfer of energy, or put differently, without energy the accidents could not have occurred. When trains derail, collide, and so forth, there is a substantial amount of energy present. The larger the amount of energy, e.g. the higher the velocity, the heavier trains, and so forth, the more harmful the potential outcome will be. This is, however, an overall description where ordinary events not necessarily are separated from adverse events. If a train passes a red or a green signal the amount of energy would be the same. The Energy and Barrier theory focuses on how to avoid accidents due to the release of energy. Organizational accidents have a far more

complex causation pattern, and thus, claiming that energy and barriers are the sole causes contributing to accidents would be erroneous.

Nevertheless, large amounts of energy are present and inevitable when going by train and to prevent this energy leading to accidents the Energy and Barrier theory presents the concept of barriers. Barriers were described in all the evaluation reports, and failures of barriers were stated either as indirect causes or considered in the recommendations. This was not surprising since the barrier perspective is a fundamental risk reducing measure in safety contexts (Kjellén, 2000), and also a fundamental risk reducing measure in the Norwegian railway management strategies (Jernbaneverkets sikkerhetshåndbok, 2011a; b).

The only recommendation given after the Tretten accident was a technical barrier, i.e. to introduce the ATC system. The purpose of the recommendation was to decrease the motion or prevent trains from passing stopping signals (Uhellskommissjonen, 1975). The recommendations presented after the Nordstrand accident were, on the other hand, more related to procedural barriers, for instance, to implement emergency mobile phone numbers to enhance the communication between the drivers and the rail traffic controller (Uhellskommissjonen, 1993). The Commission investigating the Åsta accident described a lack of, or poor technical, procedural and human barriers contributing to the accident. After the Alnabru/ Sjursøya accident, the lack of efficient technical barriers at Alnabru freight terminal was emphasized together with failures in procedural and human barriers (AIBN, 2011).

The review of what type of barriers that failed, as presented above, gives an overview of what went wrong in the proximate time-frame before the accidents occurred. Focusing on barriers offers a starting point for an investigation and contributes to localizing the immediate causation after organizational accidents. A substantial flaw of the Energy and Barrier theory is that it does not provide any suggestion of what latent conditions contributed to the accidents. The risk analyses performed at Alnabru terminal in advance of the Alnabru/Sjursøya accident became, for instance, strongly criticized by the NRA and the Commission of inquiry. The risk analyses performed had only dealt with specific changes, and had not considered how the small changes throughout a longer time-period had developed and affected the general risk level at the Alnabru terminal (AIBN, 2011). This description could be compared to the Swiss cheese model (Reason, 1997), where active failures, become more and more gradual, ending up as latent conditions (described in section 2.4.1).

Reason's (1997) "Swiss cheese model" provides an important contribution to the Energy and Barrier theory, showing that barriers could fail and form a trajectory were

opportunities for accidents occur. This development can start a long time before the accident actually happens. The “Swiss cheese model” illustrates furthermore that both active failures and latent conditions (pending failures) are difficult to grasp, especially when they occur and develop across a longer time span. In theory, failures can be divided into active failures and latent condition (Reason, 1997). However, it might be more complex in practice. In the evaluation report after the Alnabru/Sjursøya accident it seemed problematic to separate the types of failures. The risk analysis performed at the terminal had only dealt with specific changes, while other small changes had developed throughout a longer time-period affecting the general risk level at the terminal. Interacting components occurring in a longer time period would increase the difficulty to separate between the different types of failures. However, focusing on what barriers that failed might guide the localization of failures. Vatn’s (2001) classification of primary barriers (see section 2.4.1) could, for instance, be related to active failures, while his secondary and tertiary barriers are related to latent conditions. This is, however, a topic that requires more discussion than the scope of this thesis can offer.

To summarize, understanding organizational accidents purely in terms of dangerous energy and poor barriers would be insufficient, although those aspects play important roles in safety management and are clearly represented in the evaluation reports. Failures leading to organizational accidents are more complex and also influenced by elements that may not be easy to see or touch, as for instance, informational and human processes.

4.2 The Man-made Disaster theory

The Man-made Disaster theory (Turner, 1987) understands accidents as a result of a breakdown in the organization’s information flow. This information flow is weakened because of differing elementary beliefs in the organization, which do not necessarily comply with existing regulations. According to Turner (1987) the quality of the information flow stems from the organization’s safety culture.

4.2.1 Information processing

The evaluation reports after the Åsta and Alnabru/Sjursøya accidents describe weaknesses in the organization’s information processing. Some examples are given below.

After the Åsta accident, weaknesses in the organization’s information processes were described in the evaluation report. These weaknesses originated in the absence of an ATC

system on the Røros line. An existing ATC system would probably have stopped the northbound train within the station area of Rudstad, and should have ordered the southbound train to stop before it entered the station area. According to NOU (2000) the traffic safety manager warned about distantly controlled sections without ATC at two top management meetings in NSB where the managing director was present in 1995. In 1996, the traffic safety manager issued a memo where he repeated his concerns. Once again, in 1997, he repeated his concerns in an additional memo. When the Commission of inquiry (NOU, 2000) asked the Director of NSB about his knowledge regarding the safety manager's concerns, the Director could not remember he had received any memo from the traffic safety manager. He was confident that the consequences of a non-installation had been assessed, and proclaimed that there had been no disagreement in the organization about the reordering of priorities. The Director described that nobody had expressed that the priorities could not be changed, and that the management rather wanted to speed up the process of installing ATC. According to the Director, there was a clear and general judgment that the organization had a safe and good system.

Another example of poor information processes within the organization described after the Åsta accident was the alterations of the departing procedures on the Røros line (NOU 2000:30). The control of the departing signal was previously the responsibility of both the driver and the conductor. In 1997, the procedure was changed. The driver exclusively received the responsibility of controlling the departing signal. By changing responsibility, the overall safety level would, according to the management, increase. However, the Commission of inquiry stated that if the procedure had not been changed a possible wrong observation from the driver could have been corrected by the conductor (NOU, 2000). An excerpt from the evaluation report (NOU 2000, p. 245) describes that the changed procedure was known to, and practiced by the NNRA, but not approved by the authority: "The alteration of the departing procedure (...) was never approved by the National Railway Authority (NRA), but was still practiced the day of the accident (...)"

An example from the Alnabru/Sjursøya evaluation report (AIBN 2011, p. 119) also reveals that the acknowledged risk in hindsight was actually known in the organization before the accident occurred: "The operative personnel knew that there was a situation without run-off points on tracks G4 and G5, and they had adapted their work practice accordingly. This matter had not been formally considered a safety problem by the NNRA)".

The examples above illustrate that the information was available in the organization, but for various reasons not shared with the dominant decision makers, and therefore not acted upon. In the first example, the safety critical information was available within the organization, but not taken into account by the management. The second example shows that the correction from the authority (NRA) regarding used practices were not appreciated in the NNRA organization, and therefore not acted upon. The last example from the evaluation of the Alnabru/Sjursøya accident describes that the information about danger signals was carried in the minds of certain individuals, while others could not reach it. These examples fit into Turner's (1987) view of accidents as caused by a breakdown in the organization's information flow. When investigating accidents Turner (1987) saw that safety critical information was always available in the organization, but not appreciated due to a non accordance with the prevailing understanding of the dominant decision makers.

The overall challenge regarding information flow or information transfer is according to Kjellén (2000) different conceptualizations of safety critical information. Even though there are different perceptions of safety critical information in large organizations with several units and divisions, the goal is to create some common grounds of understanding. Turner's views of safety culture might be helpful to reach this goal of common understanding.

4.2.2 Safety culture

An organization's ability to detect dangers is an important element in Turner's (1987) notion of safety culture. Turner claims that the personnel create frames of reference of what they view as important. These frames of reference include a set of shared perceptions about what is considered to be safe, and what is considered to be dangerous. These frames of "seeing" and "not seeing" would in addition be more ambiguous if the regulations and procedures are out of date with the personnel's perception of how it should be. The majority of the recommendations described in the evaluation report after the Nordstrand accident was related to upgrading the organization's rules, procedures and working conditions (Uhellskommissjonen, 1993/11). For instance, the breaking system of the trains should be marked with Norwegian instead of Dutch labels, the personnel should get better training in how to manage the breaking systems and the rules or procedures for hire of materials should be determined together with the personnel (Uhellskommissjonen, 1993/11). If the personnel's frames of reference, e.g. their beliefs, had been discussed in relation to the organization's regulations and procedures, a discrepancy might have been discovered. Based on knowledge

about this discrepancy the accident could have been prevented by changing the regulations and procedures or by providing a better training regime for the personnel. It could not, for instance, have been the first time someone had difficulty reading and understanding the Dutch labels on the brakes.

Organizational safety becomes jeopardized given different and contradicting beliefs in an organization (Turner, 1987). In relation to this statement the railway organization's safety culture was denoted by the safety manager in NSB after the Nordstrand accident as "blurry", and affected by large re-organizations. The safety manager pointed out that the organization struggles with poor leadership and management, system-weaknesses and technological systems based on considerable regulations. The safety manager further claimed that the safety management was not fully integrated in the HES philosophy, and that the management had mainly local solutions to general problems. He summarized the culture as static and bound by regulations. The recommendations from the safety manager were to create better attitudes and to increase the knowledge and understanding of safety thinking in the railway organization (NSB Konsernstab, 1993).

This statement exemplifies an existing static culture bound by regulation, while the safety management presses for a more flexible culture integrated in the HES safety philosophy. In similar terms Gulowsen and Ryggvik (2004) described a development towards new safety philosophies involving conflicting views mainly represented by the "traditional" versus the "modern" perception of how railway traffic should be performed during the 1980s and 1990s. These reflections are also found in the evaluation report after the Åsta accident. The NNRA faced major critique after the Åsta accident regarding their "wrong" focus of risk and safety management (NOU, 2000:30). Safety was acknowledged by the Commission of inquiry as one of the core values in the NNRA, but the Commission still asked specifically for improvements regarding proactive risk and safety management. A recommendation from the evaluation report illustrates this: "the Commission recommends that measures should be implemented to ensure that proactive safety management is applied to all railway operations" (NOU, 2000:30, p. 285). The recommendation demanded an increase of risk-based analysis to ensure an overall proactive safety management. Risk and safety management has traditionally been perceived as a specific approach, an area primarily for safety managers in the Norwegian railway (Gulowsen & Ryggvik, 2004). However, as history reveals, the perceptions of hazards have developed from technical hazards, for instance the elements of train kinetic, to also include more general elements combining the aspects of health,

environment and safety (HES). In other words, it has been recognized that other aspects than the technical elements affect safety.

The evaluation report after the Alnabru/Sjursøya accident explicitly described “poor safety culture” as one of the factors leading to the accident (AIBN, 2011). The decisive failure was a misunderstanding between the shunter and the local traffic manager. What underlaid the misunderstanding was a variation of communication phrases which made it difficult to interpret the messages, but also sub-cultural differences between the two groups of shunters and local traffic managers (AIBN, 2011). When interviewed by the Commission of inquiry, the shunting personnel and the local traffic controllers showed an inadequate understanding of each other’s tasks and the pressure they experienced at work. Furthermore, formal reporting was described as little integrated in the operational activities resulting in a poor reporting culture. The review of the interviews suggested that formal reporting was not socially acceptable, and was seen in context with allocating blame (AIBN, 2011).

Previous to the Alnabru/Sjursøya accident, Det Norske Veritas (DNV) was hired to assist in the work of reinforcing and improving the safety culture for NNRA. One of the conclusions from DNV was that the organization had to develop a better understanding of safety, not only as a static, but also as a dynamic element, and to improve the cooperation between the different divisions and units in the organization (DNV, 2010). The communication and interaction problems charted out after the Alnabru/Sjursøya accident implied that the co-operation challenges DNV had pointed out earlier were salient, at least in parts of the organization.

“Poor” safety culture has taken over as the most common diagnosis for organizational accidents during the last years, but it is questioned how it can explain organizational accidents in a reliable way. Rosness (2000) explains that most organizations treat poor safety culture as an individual commitment to safety objectives. However, individual commitment does not necessarily create organizational commitment to safety, and is not enough to prevent the occurrence of organizational accidents. Esso experienced, for instance, a major explosion at its Longford gas plant in 1998, in spite of the organization’s expressed dedication to safety and its excellent LTI rates⁵³. The public investigation of the Longford explosion revealed a

⁵³ The LTI rate is defined as the number of lost-time injuries per one million hours of work. A lost-time injury is an injury due to an accident at work, where the injured person does not return to work on the next shift (Kjellén, 2000).

broad range of serious safety problems (Hopkins, 2000). Such findings are difficult to reconcile with a claim that the organization has succeeded in promoting an overall commitment to safety. A more plausible interpretation is, according to Rosness (2000), that the company achieved good performance with regard to those aspects of safety that were intensively followed up throughout all management levels. The key factors were thus not attitudes and values *per se*, but rather management attention, feedback and sanctions. These factors favored efforts preventing minor accidents, but were not operative with regard to safety problems that did not affect the LTI-record.

How safety culture is interpreted is therefore important to consider when investigating accidents and when determining accident causation. Safety culture should not only pinpoint the individuals' "poor attitudes", because an organization consists of more than merely the individuals. An organization is understood as a social interaction made by all the formal and informal practices occurring at a work place. The organization's safety culture should also describe the processes and patterns of interaction within the organization. Additionally, it would be sensible to link cultural diversity (Weick, 1987) to Turner's notion of safety culture. Different levels in an organization work differently, demanding adopted safety cultures. That is, some levels are more action-oriented, characterized by more rapid and co-ordinate response to critical situations, for instance train drivers, while safety at other levels would be best served with a culture where people can take time to avoid risky situations, for instance when planning a new railway infrastructure. It is furthermore important that the organization encourages bridging efforts between different sub-cultures.

4.3 The Normal Accident theory

Perrow (1984, 1999) placed railway activity in the upper left corner in his categorization of "proneness" to "normal accidents" (see previous Table 2), defining railway activity as a tightly coupled and linear system. By this he concluded that railway accidents could not be defined as normal accidents, since normal accidents need a tightly coupled system together with the interaction of complex components. The notion of tightly coupled and complex systems will nevertheless be used and discussed in relation to the accidents presented in this thesis.

Tight couplings: Perrow (1984) described railway transport as a tightly coupled system. Since trains are confined to rails, trains have, for instance, no way to divert from the rails when in

motion, except when derailing, and then often with a harmful outcome. This tightly coupled system came especially into focus after the Nordstrand and the Alnabru/Sjursøya accidents. Runaway freight trains were involved in both these accidents. The freight trains started to roll uncontrollably, and the railway safety system was not flexible enough to stop the trains in a safe way. The system did not have efficient barriers, as for instance shunting points (Uhellskommissjonen, 1993; AIBN, 2011), which made the system appear even tighter coupled.

The railway system is characterized by tight couplings in regular train operations as well, but barriers like shunting points and effective communication tools could, for instance, “loosen” the couplings and make room for deviations. Direct emergency mobile phone numbers between different units would have for instance prevented or reduced the consequences of accidents like the Tretten or/and the Åsta accidents. With a direct emergency number the driver or the control tower would have been able to contact other train(s) and warned them about the approaching train. Being able to perform different preventive measures the tight coupling would have been “loosened”.

Complexity: Even though Perrow claimed that railway activity was determined by linear components (not complex), the evaluation reports after the Nordstrand, Åsta and Alnabru/Sjursøya accidents describe components within the system as more complex, or interacting in a more complex manner, than expected (Uhellskommissjonen, 1993; NOU, 2000; AIBN, 2011). Some of the recommendations after the Nordstrand accident were directed towards the complexity of handling technical elements, and the stressful and chaotic working conditions for the driver (Uhellskommissjonen, 1993). The drivers received, for instance, poor information and training in the breaking system principles of operation, and instructions on vital parts in the technical system were marked in a foreign language. These factors might have increased the degree of complexity for the driver.

After the Åsta accident, the Commission of inquiry could not decide whether the decisive cause was a technical one or human error. The Commission could not conclude that the driver passed a stopping signal because the electromagnetic elements in the signal-system did not always react instantaneously. It was found by the Commission that green light could occasionally occur for a second or two when the signal should have been red (NOU, 2000), and this technical malfunctioning might have caused the driver to pass the stopping signal in good faith.

The investigation after the Alnabru/Sjursøya accident showed no indications of failures or unexpected couplings in the technical systems. However, the local traffic controller's working conditions were described by the Commission of inquiry as "demanding" (AIBN, 2011). There were two centers operating to manage the traffic: a control center and a center to release the mechanical brakes in relation to the freight trains. Ideally, there is a local traffic controller and an assistant local traffic controller to handle each system. In the Alnabru/Sjursøya accident all the traffic control systems were operated by the local traffic controller alone. The systems had different design and were located at different places in the control room. This together with handling various communication tools at the same time could have contributed to reducing the local traffic controller's overview of what happened, and would have increased the complexity of handling the systems.

While Perrow treats complexity as a stable property of a socio-technical system, this complexity might, however, be more dynamic than he suggests. Whether the context or the environment described in relation to the accidents were always "stressful and chaotic" is difficult to say, but the perception of context and environment was probably more complex for those involved in the accidents above, than on any ordinary day. Weick (1990) argues that the Normal Accident theory should be extended from a static, structural theory to a dynamic theory. Several failures can combine, making the system increasingly difficult to control, hence contributing to an accident. This sounds reasonable when we know that organizations consist of dynamic structures (Klev & Levin, 2002). Beck (1992) suggests that we live in a "risk society", where risks are a product of the internationalization process of the world. Risk is according to Beck (1992) defined as a global phenomenon, without geographical boundaries. Examples of such risks could be the production technology contributing to natural disasters and pollution or the information technology contributing to more vulnerable administration systems. The risk in today's society is not an effect of too little information, but is according to Beck (1992) a product of all the knowledge that exists. Using a similar logic, all large organizations are characterized by an increased use of technology, information channels, and new communication systems. Therefore, the railway organization and system could also be more complex than first assumed, placing the organization in the upper right corner of Perrow's quadrant (see Table 2).

All the accident theories were to a certain degree reflected in the accident evaluation reports. The only report that deviated from this finding was the accident evaluation report after the Tretten accident in 1975. The point of views of the Energy and Barrier theory was, however,

well represented in this report. None of the accident theories investigated in this thesis explained both the direct and indirect causes to the accidents. However, modern accident theories seek to explain both direct and indirect causes and hence try to complete the “learning circle” of single and double loop learning. But an ideal accident theory should also take into account what an organization actually is and how it can learn from the adverse event. An accident theory should not only describe different perspectives and points of view relevant to the specific levels in an organization. A theory’s framework for “understanding” the accident should also give guidance of how to apply the knowledge differently within the organization. When we know that people interpret safety critical information differently (Kjellén, 2000), and organizational accidents have different implications for the personnel, it would only be sensible to pay attention to their understanding and rather emphasize the bridging and knowledge transfer between the different cultures in an organization. An organization should have a common goal, but the understanding of safety critical information would be different as long as people have different tasks. The implementation of the results derived from an accident evaluation theory is also an important aspect of organizational learning and is worth a broader discussion than this thesis can offer.

The review of the accident evaluation reports show furthermore a “trend” describing human error and failures in barriers as the main contributors to organizational accidents, especially after the Tretten and partly after the Nordstrand accidents, while poor informational and complex socio-technical processes increasingly color the evaluation reports after the Åsta and Sjursøya/Alnabru accidents. There are most likely many reasons for this “trend”. For instant, the accident committees received different influences from the available accident research theories and methods, i.e. what type of accident theory was published in the time period when the accident occurred (see Table 1). Other contributing and possible explanations could for instance be the major alterations of organizational structures which occurred in the 1980s-1990s that ensured an external investigation organ and the resulting composition of the evaluation committees and the published results. Furthermore, explanations could be sought in the effect of the accidents themselves, e.g. the accidents had different causes and different effects. But, whatever constitutes an optimal explanation, the more relevant question related to this thesis is what these events can contribute regarding the potential of organizational learning. How an accident was evaluated by a committee may have large implications for how the organization “understood” the accident, and what it can learn from the experience

4.4 Learning from accidents

Both Gulowsen and Ryggvik (2004), and key management personnel in the NNRA (Anonymous, personal communication, November 10, 2010⁵⁴) highlight the Åsta accident in 2000, as being the most influential accident in terms of providing the highest organizational learning potential throughout the railway history. As the management person described: “The Åsta accident acted as a paradigm shift in the NNRA. It changed how we perceived and handled safety elements”. The accident resulted in 19 fatalities and affected several levels in the organization (Gulowsen & Ryggvik, 2004). In addition to these adverse outcomes it was also the first time in the Norwegian railway history that an external organ was set to investigate a major accident with a following public evaluation report. This created substantial attention from the media and from the society in general which could not be compared to the reporting of the Tretten or the Nordstrand accidents (Gulowsen & Ryggvik, 2004). In the time period of the Tretten and Nordstrand accidents the organization investigated accidents themselves, and the accident evaluation reports were internal.

The Alnabru/Sjursøya accident was also investigated by an external organ, and this accident, as well as the Åsta accident, created major attention from media and the society in general. However, the investigating process of the Åsta and the Alnabru/Sjursøya accidents were different in one important way, that is, the investigation after the Åsta accident resulted in, for the first time in railway history, a massive *external* critique of how the organization managed some of its core tasks, namely safety⁵⁵.

The shift from internal to external accident investigations made a large difference to how the accident evaluation reports were written and how the causes and recommendations were presented and reviewed. The next section will discuss the evaluation results of the different accidents reports in relation to the notion of learning from accidents.

⁵⁴ One of the discussions with a management person and such person are made anonymous.

⁵⁵ *Internal* critique towards the organization’s safety management has been given in the past; see Gulowsen and Ryggvik (2004).

4.4.1 Decisive causes, human errors and barriers

The evaluation reports describing Tretten and Nordstrand accidents present relatively few causes and recommendations compared to the two latter evaluation reports describing the Åsta and Alnabru/Sjursøya accidents. The reports after the Tretten and Nordstrand accidents describe only the decisive cause (human error) which led to the accidents. The accident causation from both the Tretten and the Nordstrand reports gives important and useful information of what went wrong right before the accident occurred. However, a focus on the decisive failures as means to an accident, as the Energy and Barrier theory reflects, *limits* the organization's learning potential and hence future accident prevention. When the Tretten accident occurred, the only published accident theory out of the three theories discussed in relation to the accidents, was the Energy and Barrier theory (see Table 1). This time specification is important for understanding the framework of how the accident evaluation reports were structured and what type of causation was emphasized. Having this time frame in mind, the discussion will carry on relating the accident causation presented in the Tretten and Nordstrand reports to organizational learning.

The approach taken by the evaluation committees of correction the decisive failures is related to Kim's (1993) notion of learning as a "know-how". To "know-how" implies a physical ability to produce some action, and as a result of this learning process a specific behavior is altered. For instance, after the Nordstrand accident, the decisive failure was that the stop cocks for the cylinders in the breaking system were adjusted in the wrong direction. One of the following recommendations issued that the stop cocks should be sealed in an open position. By focusing on the decisive causes the specific behavior is only altered to complete a particular task, as in specific routines or when "the job has to be done". When the decisive failures are corrected, as sealing the stop cocks in an open position, so is the specific chain of events leading to the accident. However, the chance of that particular chain of event to occur again is minimal (Hale, 1997). By focusing on one specific chain of event, the organization loses its opportunity to achieve a broader perspective of the accident scenario, and therefore avoids a higher learning process. There are a number of factors leading to accidents, and by focusing on one specific scenario, similar and/or other types of accidents scenarios might still occur in the future.

A focus on the decisive failures would correct a specific behavior, which most likely would lead to a behavior alteration within stated policy. This type of learning processes is referred to by Argyris and Schön (1987) as single loop learning. Single loop learning implies that individual action theories, for instance routines, are interrupted in some way, and the

behavior is adjusted in relation to these interruptions. The behavior has been altered, but it is still within the *organization's* action theories, for instance, the organization's shared norms and values. Single loop learning could also be compared to "individual commitment to safety". Individual commitment to safety was discussed in relation to safety culture (see section 4.2.2) and is often rewarded with management attention, feedback, and sanctions (Rosness, 2000). Individual tasks are central, for instance to reduce personal injury. A specific type of behavior would be altered, obtaining single loop learning. The general commitment to safety or the organizations' action theories would on the other hand still be the same.

Human error is often observed as the decisive factor leading to an accident. This is according to Kjellén (2000) a common feature since the personnel is often the last controllers in a technical system. However, if the focus is directed towards human error as the main (and only!) cause, as stated in the Tretten and Nordstrand accident evaluation reports, this would have negative implications for organizational learning. Even though the focus of responsibility might induce higher motivation among the personnel to better examine their activities (Pidgeon & O'Leary, 2000), a localization of scapegoats whenever an error has occurred leads to avoidance of blame rather than constructive critique and honesty, resulting in a state of poor or incomplete information and communication (Hale, 1997; Pidgeon & O'Leary, 2000). This approach limits the reporting of incidents and near-accidents and the openness and possibility of sharing experience, which is important for organizational learning (Johnsen, Okstad, & Skramstad, 2010; Baram, 1997; McDonald, 1997).

The implementation of barriers is furthermore important and elementary in safety work, but barriers are somewhat theoretically contradicting to the notion of learning. Let us illustrate with an example from the accident evaluation reports. After the Tretten and Åsta accidents, a technical barrier system, ATC, was implemented to prevent trains from passing stopping signals and possibly collide with other trains (Uhellskommissjonen, 1975; NOU, 2000). It was described in the evaluation report after the Åsta accident that it is not uncommon for the drivers to pass the stopping signals. The implementation of barriers, in this case ATC, allows for human error, but the barrier's role is that these failures shall not lead to accidents. In general are ATC and barriers obstacles to prevent unwanted behavior from leading to harmful outcomes. But do barriers prevent unwanted behavior from occurring in the first place? For instance, most drivers would not pass a stopping signal on purpose, but it still happens (NOU, 2000). This behavior could of course have many causes. The driver could be unfocused, have changed habit, something unexpected occurs, and so forth. However, the ATC system gives a reassurance that nothing fatal occurs if you should drive pass the

stopping signal. Too much faith in barriers is referred to, by some researchers, as “dangerous” learning (Haugen, 2011). According to Haugen (2011) this faith would contribute to a difficulty of imagining that organizational accidents could happen and thereby a difficulty of preventing them. The point here is that the implementation of barriers is not a learning tool in itself; it only prevents unwanted behavior from occurring. The implementation process is therefore very important, that is, to inform the personnel why barriers are present and why they are implemented in the first place together with training in case barriers fail.

4.4.2 Indirect causes, shared mental models, and organizational memory

The evaluation reports after both the Åsta and Alnabru/Sjursøya accidents present numerous indirect causes as well as direct causes. Indirect causes are causal factors and determinants further back in the chain of events than the decisive failure leading to accidents. Examples of indirect causes could be failures in procedures and poor decisions in the management chain. Instead of narrowing down an accident scenario, the pursuit of indirect causes opens it up (Hale, 1997). Since indirect causes describe more general phenomena, for instance training procedures, it would be easier to localize similar failures in other parts of the organization than were an accident occurred. If indirect causes are recognized after accidents, an organization would, according to Kjellén (2000), be able to receive long term memory of experience. This would ensure that the organization remembers its failures and the chances for those failures to occur again would be reduced.

The correction of indirect causes is related to Kim’s (1993) aspect of learning as a “know-why”. The meaning of know-why is explicitly stated in the term, i.e. it concerns *why* things are done in the first place and aims at challenging the nature or existence of prevailing conditions and conceptions. Knowledge determined by experience and/or practice is referred to Argyris and Schön (1978) as implicit knowledge. If this knowledge is altered, behavior could be changed outside stated policy, hence obtaining double loop learning (Argyris & Schön, 1978). Double loop learning includes that the organization’s action theories, for instance the shared norms and values are challenged and altered. The individual behavior has not only changed, but also the way of thinking. Indirect causes open up for double loop learning because this type of causes challenge the nature of the prevailing conditions and the correction of indirect failures can alter subconscious behavior, turning routine-like behavior into new behavior patterns (Argyris & Schön, 1978). But how does, for instance, the

challenge of different safety cultures, stated as indirect causes after the Åsta and Alnabru/Sjursøya accidents open up for organizational learning?

From Turner's (1987) point of view, the search for shared mental models is important to answer this question. A diversity of safety perceptions are based upon the organization's safety culture which assumes the existence of different mental models in the organization (Turner, 1987). To create common safety perceptions, shared mental models are a necessity. Shared mental models are described as a part of organizational memory which is *active*, or more specifically, what an organization pays attention to, how it chooses to act, and what it chooses to remember from its experience (Kim, 1993). Different perceptions or different safety cultures, stated as indirect causes after the Åsta and Alnabru/Sjursøya accident need efficient communication and bridging activities between the subcultures to develop a shared view of safety. To create common visions in areas as important as risk and safety would be elementary for organizational learning. In organizations like the NNRA there are different ways of handling risk and safety elements depending on work level and tasks. As a result, different units handle risk and safety elements in accordance with their specific roles and tasks. The overall goal, for instance, the overall safety goal, has to be accepted and mean the same to all levels in the organization. By creating shared mental models, the chances for double loop learning increases.

However, a challenge related to the correction of indirect causes, for instance poor safety culture, is the difficulty of measuring improvements concerning organizational learning. A recommendation after the Alnabru/Sjursøya accident was to perform a "working environment analysis" (AIBN, 2011). A sensible question to ask is how to measure organizational learning. Would a survey measuring attitudes be a plausible tool to say something about organizational learning? In other words, does attitude influence behavior?

During the 1970, research on behavior and belief revealed that what people say, think and feel have little to do with how they act (Wicker, 1971). For instance, self-described racial attitudes predict little of the variation in behavior when people face an actual interracial situation. However, research has also shown that our attitudes influence our behavior in some circumstances: if other influences are minimal, if the attitude specifically relates to the behavior, and if the attitude is potent because something brings it to mind (Fishbein & Ajzen, 1975). Overall, behaviors are in specific situations influenced by many situational factors, which often overrule the impact of attitudes (Hale & Glendon, 1987). Besides being aware of these issues when measuring attitudes, a more elementary concern relates to what organizational learning really is. Organizational learning is not only based on individual

learning, but rather a result of relational systems where changes in the interaction and not in the individuals *per se* constitute the organizational alterations, and thus the organizational learning. From this point of view, measuring safety culture in relation to organizational learning should not only be based on surveys investigating individuals, but also include measures of the alteration of relational interactions within the organization. For instance, organizational learning could be depicted as an alteration of procedures and regulations or as alterations of the interaction between different units.

4.5 Learning from failure

Logically speaking should learning from past mistakes be the “easy” part, whilst identifying new risks that have not occurred yet be the harder part. Having worked with the accident evaluation reports from the investigated accidents, it is noteworthy that some important causes and recommendations have been repeated from accident to accident. Even though the evaluation report after the Tretten accident issued only one recommendation, i.e. to implement an ATC system (Uhellskommissjonen, 1975), it took eight years until the ATC system was implemented on the Tretten line (Bjerke & Holom, 2004), and a substantially longer time to implement ATC in other parts of the organization. This negligence was unfortunately one of the factors that made the Åsta accident possible (NOU, 2000). One of the recommendations issued after the Åsta accident was again to implement ATC at an overall basis in the organization (NOU, 2000:30). There are, however, still several lines today without ATC (Network Statement, 2011). If the organization had learned from its previous mistakes, and followed its own recommendation, the Åsta accident most likely would have been prevented. In addition to search for new elements affecting the organizational safety by for instance risk-based analyses, it is evident that the organization should take advantage of its past experiences and utilize the potential of organizational memory which plays a central part in organizational learning (Walsh & Ungson, 1991; Sitkin, 1996; Kjellén, 2000).

A perhaps even larger challenge than the repetition of technical barriers is the iterative descriptions of some indirect causes, for instance poor informational processes or the different safety perceptions and beliefs in the organization. These failures would be harder to correct than the poor technical barriers because they involve complex and dynamic interactions and relationships. Even though indirect causes and recommendations are theoretical more related to organizational learning, they might still pose as a challenge to organizational learning. Take for instance poor informational processes. Large organizations, including the NNRA are

characterized by an increased use of technology, information channels, new communication systems and personnel working at different units. Because of the expanded possibilities to communicate, it would also be harder to locate and correct poor informational processes. Challenges would for instance be to establish an overview and pinpoint where the communication processes failed and to facilitate better interactions between the affected parts.

To summarize, the evaluation reports after the Tretten and Nordstrand accidents presented only the immediate causes to the accidents, blaming the human controller. However, for organization learning to occur, accident causation need to be both specific and general, applying to several levels in the organization. Accident causation has to go further back the management chain, rather than focusing on blame and target the human controller in charge. The accident causation after the Åsta and Alnabru/Sjursøya accident were, on the other hand, both specific and general, applying to several levels in the organization. This type of accident causation provides theoretically a higher learning potential to the organization. However, stating “causation” after organizational accidents and recommending future improvements need in the author’s opinion a closer link to what an organization consist of and how an organization function. The Man-made Disaster and the Normal accident theory propose poor intergroup and socio-technical processes contributing to organizational accidents, but how are these processes interlinked with the organizational processes? When we know that organizations consist of relational systems where changes in the interaction, and not in the individual *per se*, constitute the organizational alterations, these processes are also necessary to be aware of in relation to accident causation, organizational learning and prevention of future accidents. The Commission of inquiry has the responsibility of presenting the most accurate “picture” of accident causation, and guiding what recommendations the organization should implement. For this purpose it is essential that the accident research and the organization research field are tightly interlinked when investigating accidents.

4.6 Implications for future research

The discussion in this thesis has illuminated some suggestions for future research. The accident theories' views reflected in the accident evaluation reports were here divided to a large degree between direct and indirect causation. It is evident that a modern accident theory should focus on both direct and indirect causation to get a comprehensive view of the accident scenario as well as to ensure single and double loop learning (Kjellén, 2000). However, organizational learning processes rely on what type of corrections and alteration that actually occur after an accident. Therefore would the link between causes and recommendations in accident evaluation reports be interesting to investigate further together with the study of follow-up actions. Do causes and recommendations correspond in the first place? How does the inclusion of increasingly more indirect causes affect the relationship between "causes" and "recommendations"? For instance, the immediate cause was the only cause stated in the evaluation report after the Nordstrand accident (Uhellskommissjonen, 1993). However, several recommendations related *indirectly* to the presented cause. What does this mean with respect to the understanding of the accident and what are the consequences for implementation of safety measures? Furthermore, what consequences do different degree of correspondence between causes and recommendations have for organizational learning?

Accident evaluation, focusing on both direct and indirect causation with following recommendations is commonly used as a foundation to achieve organizational learning after accidents. However, the discussion in this thesis suggests that the link between accident evaluation and organizational learning processes might benefit from more investigation. Clarifying the link between organizational processes within the SHE safety paradigm and accident evaluation theories and models might for instance have large consequences for the validity of accident causation as well as the implementation of recommendations and thus safety standard.

4.7 Conclusion

The aim of this thesis was to look at how the chosen accident theories were reflected in the accident evaluation reports after major railway accidents in Norway across a time span of 35 years, and what consequences the presentation of the accident evaluations had for organizational learning.

This thesis concludes that the development of accident evaluation reports through a time period of 35 years shows a early simple cause-effect relationships implemented mainly

in local technical safety barriers to later strategies including an increasing number of indirect causes with following recommendations within also non-technical areas, such as communication processes and management strategies.

The events and failures leading to the accidents have been described as simple and robust to large and complex. It seems like the Commissions of inquiries over time have increasingly emphasized that organizational accidents originate in more than practical, local solutions and physical barriers. Since organizational accidents usually have a complex causation pattern, broader perspectives in accident causation and recommendations, as the evaluation reports after the Åsta and Alnabru/Sjursøya describes, are necessary.

Even though it is salient that an accident evaluation should include indirect causation and recommendations to enhance organizational learning, there is a point where this might have the opposite effect. If indirect causation and following recommendations are too broad, difficulties might arise localizing and finding failures and implementing corrections. The problematic issue of defining a line between direct and indirect causes is salient to this matter. Direct causation often leads to practical and relatively easy implementation of changes in the system. Indirect causation may on the other hand lead to more abstract and broader recommendations which are harder to implement and follow up with respect to effects in the system due to modern organization's continuous increase in complexity of components and interactions. To ensure organizational learning it is concluded that accident evaluation has to be specifically adapted to organizational structures, i.e. the formal and informal structures of an organization and focus on the practical consequences of the implementations.

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