Helene Cecilie Blakstad

Revising Rules and Reviving Knowledge

Adapting hierarchical and risk-based approaches to safety rule modifications in the Norwegian railway system

Doctoral thesis
for the degree of doktor ingeniør

Trondheim, February 2006

Norwegian University of
Science and Technology
Faculty of Industrial Economics and Technology Management
Department of Industrial Economics and Technology
Management

NTNU
Innovation and Creativity

NTNU
Norwegian University of Science and Technology

Doctoral thesis
for the degree of doktor ingeniør

Faculty of Industrial Economics and Technology Management
Department of Industrial Economics and Technology Management

ISBN 82-471-7934-2 (printed ver.)
ISBN 82-471-7933-4 (electronic ver.)
ISSN 1503-8181

Doctoral Theses at NTNU, 2006:90

Printed by Tapir Uttrykk

Revising Rules and Reviving Knowledge

Adapting hierarchical and risk-based approaches to safety rule modifications in the Norwegian railway system

Helene Cecilie Blakstad

Norwegian University of Science and Technology
Faculty of Social Sciences and Technology Management
Department of Industrial Economics and Technology Management

Doctoral thesis
Trondheim, February 2006

Helene Cecilie Blakstad
Department of Industrial Economics and Technology Management
Faculty of Social Sciences and Technology Management
Norwegian University of Science and Technology
N7491 Trondheim
Helene.Blakstad@iot.ntnu.no

Thesis supervisors:
Professor Jan Hovden,
Department of Industrial Economics and Technology Management.
Norwegian University of Science and Technology
Senior Scientist Ragnar Rosness,
SINTEF Technology and Society

Evaluation committee:
Professor Andrew Hale, Delft University of Technology, Netherlands
Professor Kurt Petersen, LTH, Lund University, Sweden
Associate Professor Monica Rolfsen, Norwegian University of Science and Technology, Norway

Keywords:
Safety rule modification, Goal-oriented rules, Prescriptive rules, Risk-based, risk informed, Knowledge, Organizational learning

NTNU Doctoral Thesis 2006
ISBN 82-471-7934-2 (printed version)
ISBN 82-471-7933-4 (electronic version)

Preface

Safety rules are an inherent part of safety work, much effort is invested in them and few deny that they have a function. However, there is still little theoretical knowledge about how to keep them updated. The motivation for this work has been to improve this situation, in particular regarding increased use of hierarchical and risk-based approaches to rule development. Knowledge of the rules' context in this transformation is given special attention.

The study has been carried out from September 2001 to January 2006 at the Department of Industrial Economics and Technology Management, Faculty of Social Science and Technology Management, Norwegian University of Science and Technology.

My supervisors have been Professor Jan Hovden at the Department of Industrial Economics and Technology Management and Senior Scientist Ragnar Rosness at SINTEF Technology and Society. I want to thank them both for their important contributions to the work and for support in difficult times. They have different theoretical backgrounds, experiences and personalities and therefore they have given different contributions to the work. Thus they have complemented each other in a very constructive way. We have had fruitful discussions and I have always felt that their advice and criticism have been given with the best intentions. However, I have not always managed to solve the challenges of these.

I also want to thank all the contributors in the Norwegian railway system. Without their help and positive attitude towards my work this study would have been impossible. These contributors did not necessarily share a common opinion. However, they all had one common feature; they wanted to contribute to the safe development of the Norwegian railway system. The study is based on their rich descriptions from the system. To transfer this rich material into a compact study has been a challenging task. It has required a simplification of the stories. During this work I have been concerned they were not given full justice. I hope the study will give something back to their preventive safety work.

Other PhD students and colleagues both in my department and at SINTEF, Technology and Society, have been both friends and colleagues and I have benefited from the many discussions and good times we had. In particular I want to thank the other members of my study group Grethe Osborg Ose, Snorre Sklet, Ketil Hunnes, Eirik Albrechtsen, Ranveig Tinnmansvik and Kjell Corneliussen.

I have been fortunate to be a guest of the Danish Transport Research Institute and the Safety Science Group of Delft University of Technology, Faculty of Technology, Policy and Management. Thank you for your contributions!

Thanks also to The Research Council of Norway that financed the work.

Finally, my warmest thanks go to my husband Bjørnar, along with my family and close friends for encouragement and support.

Trondheim, February 2006

Helene Cecilie Blakstad

Abstract

The study is about safety rule revision with hierarchical and risk-based approaches in the Norwegian railway system. The two approaches represent a change in the rule modification tradition of this system. The overall research question is:

> *How did the Norwegian railway system respond to new requirements for safety rule modifications?*

The study gives special attention to the influence of modification processes upon railway knowledge.

There are three objectives for the study. One objective is to provide descriptions of modification processes that can contribute to increased understanding of these. This includes revealing how problems and roles are framed and to contribute to the building of repertoires of how such processes can be run (Schön, 1991). Another objective is to compare the descriptions with theory. A third objective is to discuss implications of the study.

For these purposes four rule modification processes of the Norwegian railway system have been studied. The study has applied an explorative and qualitative approach. The main sources for information have been interviews with participants of the modification processes and documents developed by the projects. The study was performed in the last phase of the processes. Accordingly, the study looks at the modification processes from the perspective of the participants of the studied processes as experienced in their last period of their work.

The main conclusion of the study is that the four modification processes abandoned the intentions of hierarchical and risk-based approaches. First, they did not develop outcome-oriented rules on the background of risk analyses. Second, they did not derive prescriptive rules from outcome oriented rules. Third, they did not choose rule solutions where the hierarchy of rule solutions was linked to the positions of rule-imposers in the organizational hierarchy such as had been suggested.

The main reason was that the new approaches did not take existing railway knowledge, that had been found to be important for safe performance, sufficiently into account. Instead, the modification work of all cases turned into processes that are given the name “reverse invention” in the study. Here existing railway knowledge and prescriptive rules were used as a fundament for the work. Accordingly, existing knowledge was brought forth.

The risk analyses supplemented railway knowledge. The four cases integrated the risk analyses in the modification processes in four different ways (See Figures 7.1, 7.2, 7.3, 7.4 in Chapter 7). This gave the analyses different functions in the rule development. The evolving work was evaluated with railway knowledge as a reference and brought in accordance with this knowledge.

The cases favored solutions that took advantage of different perspectives upon rationality and knowledge. However, existing railway knowledge, including existing prescriptive rules, appeared remarkably persistent compared to the expectations for the work. Furthermore, the modification processes contained mechanisms that validated this knowledge.

The new approaches and the processes of reverse invention raised questions that initiated inquiries into railway knowledge. These inquiries revived this knowledge. It remained uncertain whether the potential of inquires for organizational learning resulted in actual new knowledge.

However, the rationalistic ideals of new approaches stimulated a reduction of the revived railway knowledge into more rationalistic theoretical forms, i.e. relational and contextual elements were removed. Theory argues that the latter knowledge is important for the ability to decode theoretical knowledge for future use and to judge its relevance (Stein, 1995; Baumard, 1999; Nonaka & Takeuchi, 1995). The benefit of revived knowledge might therefore be lost in the future. The study outlines some solutions for counteracting such a negative development.

At the end of the study the implications of this conclusion are discussed. Also, links to theory and needs for further research are elaborated upon.

Content

List of figures and tables

Figures

Tables

PART I: FRAMEWORK AND STUDY DESIGN

Part I is an introduction to the study. It starts with a brief introduction to the problem area, the field of the research, the methodological approach and the core research questions. These topics are then elaborated upon in the following chapters. Chapter 2 presents the Norwegian Railway system, its historical development and the two projects included in the study. The emphasis is upon issues of relevance for the research questions. Chapter 3 provides the framework and the theoretical basis for the study. Here theoretical concepts and problems are elaborated. The last chapter of this part, Chapter 4 provides a presentation of the applied research method, the study material and a discussion of the research quality.

1 Introduction

The study is about safety rule revision with hierarchical and risk-based approaches in the Norwegian railway system. Special attention is given to the influence of modification processes upon railway knowledge.

The overall purpose of the study is to contribute positively to accident prevention through increased knowledge of safety rule revision. The study has three objectives. One objective is to provide descriptions of modification processes that can contribute to increased understanding of these. This includes revealing how problems and roles are framed and to contribute to the building of repertoires of how such processes can be run (Schön, 1991). Another objective is to compare the descriptions with theory. A third objective is to discuss implications of the study.

1.1 Framework of the study

The theme of the study needs an introduction. Its main elements are introduced below. These will be further elaborated in Chapter 3.

1.1.1 Safety rules and knowledge

Safety rules are important elements of safety work and are based upon two assumptions. First, it is possible to do something to prevent accidents. Second, rules can contribute to this purpose (Kirwan et al. 2002).

Hale et al. (2003) argue that every technology and activity has safety rules that are usually formulated explicitly, taught to those operating in the system and imposed on them. The safety rules also determine liability after accidents. The primary purpose of the rules is to make the system manageable by revealing how it can be made to work most effectively and who is responsible for doing what (Hale, 1990). Hence, rules direct attention, influence decisions and activities and provide demands and limitations. Rules can also serve other purposes such as power (Weber, 2000), creation of scapegoats (Hale, 1990; Hovden, 1998b) and communication of knowledge (Baumard, 1999).

To be useful for safety work, safety rules must fit the actual situation they are applied to (Reason et al. 1998). The rapidly changing conditions of society make this a serious concern, which is discussed in safety literature (Bourrier, 1998; Rasmussen, 1997; Rasmussen & Svedung, 2000; Reason, 1997). Hale et al. (2003) point to the fact that there is surprisingly little literature about how to manage safety rules effectively, how to decide what rules are needed, how to prepare and formulate them and how to promulgate them and ensure that they stay appropriate Also, there are still few clear ideas of how best to avoid the main pitfalls in producing workable safety rules. The purpose of the study

implies that the focus here will be on the work to ensure that rules stay appropriate. This includes to change or remove existing rules or to develop additional rules.

Rules constitute an important record of the organization's learning about its operational dangers (Reason, 1997; Reason et al. 1998). Traditionally safety rules have been developed in accordance with the lessons learned from past accidents, i.e. their evolution has been based on practical experiences (Kjellén, 2000; Rasmussen, 1997). Hence, there is a close relationship between safety rules and knowledge of activities and related risks in a regulated area. The rules have been directed at control of known risks and can be seen as a result of the knowledge at the time of the rule making. In Baumard's terminology they represent explicit collective knowledge (Baumard, 1999).

Hale (1990) also argues that the greatest value of safety rules lies in the process of actually finding out and writing down the rules. This is a value the rules can retain by being treated as a living repository of all lessons learned in the life of the system. Accordingly, safety rules are not only a result of a learning process, they can be seen as a part of them. However, there is also a general concern that it is not wise to transfer all lessons learned into rules (Hale, 1990; Rasmussen, 1997; Reason, 1997).

The discussion of the relationship between safety rules and knowledge illustrates that traditionally rule development has been developed in accordance with rule-developers' current understanding of the actual situation. Hence, the logic of appropriateness has played an important role. This logic is associated with rule- and identity based decision-making where actions are matched to situations by means of rules organized into identities (March, 1994).

1.1.2 From practical experiences to the risk-based approach

The evolution based on practical experiences is now subject to discussion. Rasmussen (1997) and Rasmussen & Svedung (2000) find that in the past the empirical approach to risk management has been very effective for prevention of small and medium scale accidents. However, they argue that it is necessary to reconsider this in the present fast pace of change in the conditions of risk management. During periods of fast change, they find it necessary to choose a risk management strategy based on a predictive hazard and risk analysis. They suggest taking advantage of the more analytical management strategy developed by industries positing a potential for large scale accidents. Reason (1997) supports the critics of the reactive approach. He argues that if organizations continue to rely principally on outcome measures, they have to experience accidents before they know where they are. His outline to a workable alternative is the regular assessments that are common to both quality and safety. Risk assessment is also an inherent element in the internal control principles that are increasingly used for risk management (Flagstad, 1995; Hovden, 1998a). Here the organizations are required to identify and control their own risks.

The main purpose of risk analyses is to provide decision support (Aven, 2003; Rausand & Øien, 2004). In Perrow's terminology, this move towards increased use of risk analyses represents a strengthening of the tradition of absolute rationality (Perrow, 1999). According to him, this is a form of rationality wherein calculations can be made about risks and benefits, clearly showing which activities we should prefer. The risk assessment professionals are generally technologists and statisticians such as engineers, scientists and social scientists. Accordingly, the experts come from theoretical, academic fields. This means that risk analyses serve as support for choices between preferences, i.e. choice based decision-making as described by March (1994). He links the term "rationality" to this form of decision making.

Rasmussen (1997) argues that there is a parallel evolution of the paradigms within decision- and management research and changes in paradigms within branches of safety research. Description of human behavior typically starts by identification of rational behavior by normative models. Then actual behavior is described in terms of some kind of deviation, i.e. error with reference to the normative behavior. There is now a wide spread acceptance of limitations in human cognition (See for instance Kahneman et al. 1982; Simon, 1966). March (1994) sums up that rational choice theories have adapted to the observations of decision-making in the real world and gradually introduced the idea that rationality is limited or bounded. The core notion of limited rationality is that individuals are intentionally rational. Although decision-makers try to be rational they are constrained by limited cognitive capabilities and incomplete information. Thus their actions may be less than completely rational in spite of their best intentions and efforts. According to Rasmussen this brings with it a further trend. This is a trend towards modeling actual behavior in terms of behavior shaping constraints of the environment and the adaptive mechanisms of human actors in the environment.

The increased emphasis upon risk assessment, both in theory and in the internal control principles, implies an incitement for increased emphasis upon more academic oriented risk analyses as decision support in rule modification processes. The analyses are supposed to provide information that serve as basis for the definition of rules. In this study this approach will be labeled the "risk-based approach".

1.1.3 From operative prescriptive rules to the hierarchical approach

Hale (1990) describes safety rules as usually specifying the means by which safe working should be achieved in the form of prescriptions about what to do or specified standards. Very often they also specify who is responsible for doing what. With reference to March (1994) one can say that they are directed at forming appropriate decisions and actions at the execution level, i.e. rule- and identity based decision-making at the lower levels of the organizational hierarchies.

There is a now a trend to move away from detailed prescriptive rule solutions towards rule solutions directed at decision-making and management (See for instance: Becker, 2002; Hale et al. 1997; Hovden, 2002; Maidment, 2002;). One of the main arguments

behind this development is that such rules are seen to be more flexible and hence more suitable for changing conditions (See for instance Becker, 2002; Maidment, 2002; Rasmussen, 1997; Rasmussen & Svedung, 2000; Reason et al. 1998).

This development and the increased use of the internal control principles can be seen to represent a trend towards more hierarchical strategies to the development of rule systems. This consists of different hierarchical elements that in the study will go under the heading "the hierarchical approach".

Hopkins & Hale (2002) relate these rule solutions to three levels of intervention in risk control. The safety case/safety management regime specifies the rules for the safety management block and/or requires that block to demonstrate how it structures and runs the direct control activities. The internal control principles are examples of this level of intervention. The rules directed at decision-making might have a goal-oriented form that tries to specify the safety output instead of the rules to achieve it. The rules to achieve it or the technical prescriptions specify the rules for the direct risk control function.

With reference to hierarchical task analyses, Hale (1990) argue that the central levels of the systems should formulate the rules that represent objectives illustrating what must not happen and what has to be achieved. When necessary, the central level should also formulate rules for methods to increase thinking before decisions are taken and the explanatory supplements to the rules. The detailed rules must be worked out more locally because they become more context specific. Building upon this, Hale & Swuste (1998) propose a thesis that rules should be seen as a progressive limitation of freedom of choice, limiting first goals, then how decisions are arrived at and finally limiting the actions themselves.

According to Hovden (1998a) internal control means a shift to meta-regulation by society and delegation of direct rule-based control by the industry itself. Each enterprise is free to adjust it to own needs, routines organization and culture. There is supposed to be a logical chain of inferences between authorities, companies and parties where the distribution of responsibilities are one important element (Flagstad, 1995). Hovden finds that emphasis upon internal control places more obligations on top management of organizations.

This deductive thinking is also an inherent element in the striving for harmonization within the European Union (EU) (European Commission, 2004b).

This implies a hierarchy of rule solutions where the traditional prescriptive rules describing what to do become subordinated higher order rules with focus upon management and objectives. An increased emphasis upon goals in rule solutions implies a strengthened position of rationalistic choice based decision making. Furthermore, such changes in the content of rules imply a change in the required competency of the rule-imposer and the rule-follower. The rule-imposer must know what the desired goals are and the rule-follower must know how to achieve these.

In addition, this can be seen to imply a hierarchy of rule imposers and rule followers where the work of rule development should start at the central higher hierarchical levels of the organizational system, i.e. the direction of invention is top-down from the higher to the lower levels. The hierarchy of rule solutions can be associated with the positions of rule-imposer and rule-follower in the organizational hierarchy.

This can also be seen to imply that prescriptive rules should be derived from higher order goal-oriented rules, i.e. that a deductive strategy should be applied for rule development. Inherent in this strategy is a need for some kind of risk assessment to decide the means to fulfill higher order rules. Therefore this deductive strategy is also influenced by the rationality of risk assessments.

Put together, this reveals that the hierarchical approach to rule development can refer to four aspects. The first is the order of the development of the different hierarchical rule solutions, i.e. a deductive or inductive process. This will be elaborated in Subsection 3.3.3. The second is the hierarchy of rule solutions. This will be elaborated in Subsection 3.3.1. The third is the placing of the rule-imposers in the organizational hierarchy. The fourth is the placing of the rule-follower in the organizational hierarchy. The two latter aspects will be elaborated in Subsection 3.3.2.

However, as will also be elaborated in these sections the picture is not so simple and orderly. The need to adapt rule solutions to the actual situation and characteristics of the rule-followers is also widely recognized in theory (Hale, 1990; Hale & Swuste, 1998; Hopkins & Hale, 2002; Rasmussen & Svedung, 2000; Reason, 1997). Hovden (1998a) argues that internal control means both “top-down” and “bottom-up” approaches with involvement and responsibility of top line management combined with participation and participation and industrial democracy. Hale & Swuste (1998) find the key question to be how to decide who is best placed in what types of situation to impose what level of limitation. In addition, the introduction of meta-regulation and delegation of responsibilities can also lead to a development where risk assessment is used to prove the legitimacy of rules developed for local purposes. Furthermore, it differs what the central higher level consists of. Due to ongoing internationalization, this level might be international or national bodies or simply the highest level of an organization.

1.1.4 Issues of concern and limitations

This introduction reveals that it is of general interest to study responses to the incitements to use hierarchical and risk analytical approaches to safety rule modifications. The study will concentrate upon these two aspects of rule modification. As revealed above, these two approaches are not alternative approaches. Instead, the risk based approach can be seen as an important element in the hierarchical approach.

The introduction also demonstrates that safety rule modification might have a value in itself regarding organizational learning and knowledge development. Therefore, the study

will give special attention to the impact that the two approaches have upon knowledge about regulated activities and related risk.

Perspectives upon knowledge and decision-making are closely related (March, 1994). The increased emphasis upon "rationality" in decision-making that hierarchical and risk analytical approaches represent makes it necessary to give some attention to decision-making when discussing knowledge.

The study focuses upon rule modification with the two presented approaches. This implies that it will not go deeply into the choice of detail level of rules nor their different roles as, for instance, official requirements or internal codes of practice. It will also not go deeply into discussions of rules as a solution compared to other means to enhance safety nor other purposes that modification process and resulting rules can serve. Furthermore, it will not pay much attention to discussions of internal control and safety management. In spite of special attention towards knowledge, the ambition is not to develop knowledge theories.

The limited theoretical knowledge of safety rule modification calls for an empirical approach containing both descriptive and analytical elements. Therefore, the study will analyze real modification processes to achieve insight into scientific and practical dilemmas of the application of these two approaches.

1.2 The Railway framework

The Norwegian railway system[1] and European railways are now undergoing severe changes. The Treaty on European Union includes the broad aim of creating trans-European networks and promoting interoperability, in particular through technical harmonization (DG Energy and Transport, 2000). Three specific objectives are set for the railways. These are improvement of interoperability, creation of a single market for railway equipment and restructuring to develop competition and new markets in train operations. Further, the 1996 EU White Paper urges the member states to separate railway infrastructure management and transport operations into distinct business units, and to introduce market forces within domestic passenger transport (European Commission, 1996).

A report for the Directorate-General (DG) for Energy and Transport argues that the development of European railways into a more dynamic industry increases the importance of safety regulations as a means to ensure safety (DG Energy and Transport, 2000). The report relates this to more innovation, more operators including new entrants and a wider range of suppliers. However, it also comments that safety regulations have only been in the background of these developments. The investigations in the report reveals that in all Member states most existing rules and standards are still those created under the previous nationalized industry regime. Further, it is generally recognized that

[1] Definition of "Railway system", see the introduction to Chapter 2, page 15.

however strong the commitment to reform, substantial change in railway rules and standards cannot be made quickly.

The challenges of the ongoing changes in railway systems are now given attention both in Norway and within EU. The Research Council of Norway has an ongoing 5-year research program focusing upon Risk and Safety in the Transport sector, including the railways (The RISIT program). Here the question of deregulation is thoroughly discussed. The program considers deregulation to be "a multi-level process initiated by political or regulatory action to open up competition" (Rosness et al. 2004b).

As a part of this program, Rosness et al. (2004b) provide two conclusions of particular interest for the study. One is that deregulation usually leads to a need for more regulations, i.e. an increased public effort in order to regulate the market conditions and commercial aspects as well as safety. Another is that the need for an effective regulatory authority during and after a deregulation process is emphasized. In another paper for the program, Savage (2003) describes that in the United States, deregulation had made it necessary to replace previous implicit rules with explicit safety regulations. There have been contacts between this study and participants in the research program.

Within the EU, the challenge of the changes is followed up by the Railway Safety Directive (Directive 2004/49/EC). Here it is noted that it is necessary to establish a common regulatory framework for railway safety. To provide a basis for the development and implementation of the Directive, the European Commission has financed a project under the Fifth Framework Programme given the name SAMRAIL. The objective of the project is to develop a comprehensive and consistent safety management program for European railways (European Commission, 2004c). The project is run in parallel with this study.

One of the work packages of this project focuses on safety regulations and rules of the railways (European Commission, 2004b). Here current practice in four countries is studied and compared to a preset framework. My study supplements the SAMRAIL study in several aspects. First, it is an in-depth study that goes into a limited part of the framework; the modification process. Second, my study limits itself to give special attention to adaptation of the hierarchical and risk-based approaches. Third, special attention is given to the influence of these approaches upon knowledge. Fourth, the main purpose is not normative. There have also been contacts with the working group of this work package.

The work package, focusing upon safety rule management, reveals that there is a lack of systematized knowledge of how to manage safety rules properly (European Commission, 2004b). However, the studies also reveal that a large knowledge-base is available in the railway organizations. Unfortunately there are no formal processes in place to retain this organizational knowledge. In addition, the privatization processes of formerly nationalized railway companies have contributed with a fragmentation and distribution of knowledge throughout the railway systems. Accordingly it is of special interest to

increase the understanding of safety rule modifications in railways and their influence upon knowledge of rail activities and related risk.

The Railway Safety Directive also identifies risk assessment as one of the main elements in a common safety management system framework for the EU railways (Directive 2004/49/EC). Risk assessment is defined as an overall process of risk analysis and risk evaluation (European Commission, 2003a). In order to accelerate the introduction of innovative systems within EU, the European standards EN 50126 (CENELEC, 1999), EN 50128 (CENELEC, 1997) and EN 50129 (CENELEC, 2003) introduce systematic hazard identification and risk reduction as the main tool. This is done as a supplement to the former tradition to use proven technology (Schäbe, 2002).

The report for DG Energy and Transport illustrates that this is consistent with a long time trend towards a more analytical approach to the safety work in the European Railways (DG Energy and Transport, 2000). However, the report also illustrates that the use of risk assessment varied widely across Member states of EU. Further the case studies of rule management in different European countries, made by SAMRAIL, reveals that in general there is a lack of systematic risk identification and analysis at a formal level (European Commission, 2004c). Attempts to apply risk analyses in rule development have also been made (Becker, 2002; Harms-Ringdahl & Kecklund, 2004; Harms-Ringdahl, 2004; Maidment, 2002;). In the suggested framework for safety rule management of SAMRAIL, risk assessment is included (European Commission, 2004b). Hence it is of interest for railways to elaborate the adaptation of a risk-based approach to rule modifications.

The railways are subjected to a hierarchy of rules, procedures, regulations and work instructions (European Commission, 2004c). Maidment (2002) has compared the rule development of the railways in different countries. He found that in some countries the national railway systems have taken the initiative to reconsider the traditional prescriptive standards and rules; in other cases the railway safety regulators have been the prime movers for change. With different emphasis, all were working towards fewer prescriptions, more room for innovation, more proactivity, simpler rules and more flexible standards. Attempts are also made to develop higher order rules in the railways (Becker, 2002; Maidment, 2002). This development is encouraged by the Railway Safety Directive (Directive 2004/49/EC). Due to limited knowledge of rule modification, there is limited knowledge about how to perform such changes in rule principles.

The Norwegian railway system that consists of a number of subsystems reflects the situation within EU. The system is under a process of severe change. The main changes are related to the transformation of the former bureaucratic monopolistic state organization to a pluralistic, partly privatized and competitive system of organizations (Gulowsen & Ryggvik, 2004).

Over years the Norwegian railway system has developed knowledge about the functions and interactions of the railway system, i.e. railway knowledge[2] (Gulowsen & Ryggvik, 2004). The system has had a practical oriented and often experience-based prescriptive

[2] The expression “Railway knowledge” is elaborated in Chapter 3, page 74

rule tradition mainly directed at lower operative levels of the system (Ryggvik, 2004). The rules have been gradually developed on the basis of growing railway knowledge, especially after experiences with severe accidents. They have also been changed as a result of changes in the technology. This tradition is now changing. To a great extent the Inspectorate have introduced the goal-oriented form in their rule development, for instance in their new regulation for education (Samferdselsdepartementet, 2002). Furthermore, it has emphasized a safety management strategy built upon the internal control principle (Ryggvik, 2004). The Ministry of Transport and Communication has specified that the safety management system must apply risk analyses (Samferdselsdepartementet, 2001a).

The Norwegian railway system has run two rule modification projects of relevance for the purpose of the study. One project modified rules related to traffic operation and another rules related to maintenance of the infrastructure. These rules have traffic safety as one important element. This is particularly evident in the rules for traffic operation. The modification projects were instructed to introduce a risk-based approach to the rule modifications. They were requested to reduce the amount of prescriptive rules by developing higher order rules and to relate these to the new organizational system, i.e. a hierarchical approach to rule development. The rules of both projects have had a role in the system's knowledge management, especially the rules of traffic operation.

1.3 Research questions

The study uses these two rule modification projects of the Norwegian railway system as cases. The overall research question is:

> *How did the Norwegian railway system respond to new requirements for safety rule modifications?*

In accordance with the limitations of the study, the research will focus upon the adaptation of hierarchical and risk-based approaches in the rule modification processes of the projects. This raises two sub questions:

1) *How was a hierarchical approach to rule modification adapted?*

2) *How was a risk-based approach to rule modification adapted?*

The study intends to give special attention to the impact from the modification processes upon knowledge of the regulated activities and related risks, hereafter called railway knowledge. Related to both sub questions above, a third research question becomes:

3) *How did new requirements influence railway knowledge?*

These research questions will be elaborated upon in the theory chapter (Chapter 3). Here problems related to the new approaches will be discussed.

Further, these research questions are rather prescriptive. The overall purpose of this study is to increase the understanding of modification processes. It is therefore interesting to go behind the descriptive answers to these questions and try to explain the results, i.e. to ask "why?".

As safety rule modification is a practical challenge, it is interesting to follow up the conclusions with reflections upon practical implications. This is done together with the conclusions in Chapter 9.

1.4 Study approach

The scientific tradition that is chosen as a basis for research depends on the problem area and the research questions (Latour, 1987). The research strategy depends on the type of research question, the control an investigator has over actual behavioral events and the focus on contemporary as opposed to historical phenomena (Yin, 1994).

The purpose of the study is to contribute to new insights into the rule modification process. This is a practical goal related to ongoing development in railway system. The wish is to study contemporary and real rule modification processes as close to their natural environments as possible. Hence, it is neither possible nor desirable to exert any kind of control over behavioral events or to set up an experimental situation. Further it is difficult to develop standardized instruments for the work.

The limited scientific knowledge about the subject also calls for an explorative and qualitative approach (Hellevik, 1991). An explorative investigation is flexible and gives an opportunity to capture and interpret new information when it is achieved. A case study design is chosen in combination with a grounded theory approach and related methods. A theoretical framework that illustrates the main subjects and indicates work hypotheses is studied with a flexible and open mind. Special attention is given to problems revealed in theory. The hope is that this will make the study relevant for both nonacademic and academic audiences. The theoretical framework and problems are presented and discussed in Chapter 3.

The core elements in the study are interviews of participants of the modification work of the two projects and documents developed by the projects. Accordingly the study looks at the modification processes from the perspective of the participants of these processes as experienced in their last phase of their work. This means that the study does not include systematic studies of rule-followers' opinions of the rules. Their opinions are only included when they are included in the modification processes. Furthermore, their efficiency to prevent accidents is not evaluated.

The development of the work of the study has been an iterative process. The work has developed from an ever-interlocking attention to theory and data collection and analyses.

As the work of the projects was not fully finished when much of the data collection was done, the research might have influenced their processes.

From the beginning of the study I posited prior knowledge of the Norwegian railway system as a former employee in their health services. My background is elaborated in Appendix B.

1.5 Structure of the study

The structure of the study is as follows:

To introduce the studied projects and their context, an introduction to the Norwegian railway system, its rule tradition and the projects are given in Chapter 2.

Chapter 3 introduces the theory applied in the study. Central concepts are clarified and the theoretical framework for the study is discussed.

In Chapter 4 the methodological approach and the study design are presented. The procedures for data collection and analyses and a discussion of the quality of the study are also included.

Chapter 5 presents the near context of the study cases, i.e. traditions of rule modification that the cases build upon and known plans for future modifications, characteristics of rule-imposers and rule-followers and the rules' context

Chapter 6 presents findings and discussions of the adaptation of the hierarchical approach and discusses these.

Chapter 7 presents findings and discussions of the adaptation of the risk-based approach and discusses these.

In Chapter 8 the influence from the adaptation of the new approaches upon railway knowledge are discussed.

Chapter 9 draws the main conclusions of the research and pull out the implications of these. Links to theory and needs for further research are also discussed.

2 The Norwegian railway system and the cases of the study

The two projects to be studied here are not isolated phenomena. The Norwegian railway system has a long history and the safety rule development of the system has been an integrated part of this. Therefore, it is necessary to present the history and organizing of the system, its rule tradition and current development and the links between rules and railway knowledge. In addition, it is necessary to present the two projects that were chosen for the study.

The introduction draws on historical documents, official documents, policy documents and steering documents of the railway system itself, information from the research and my own knowledge.

Based on the definition of the Railway Safety Directive, in this study the "railway system" means the totality of subsystems for structural and operational areas as defined in Directives 96/48/EC and 2001/16/EC as well as the management and operations of the system as a whole (Directive 2004/49/EC, Article 3).

2.1 History and organizing of the Norwegian railway system

For the purpose of the study it is convenient to divide the development of the Norwegian railway system into two parts. The fist concerns the development of the organization into a rather stable bureaucratic organization. The second concerns the background for ongoing changes in the organizing of the system and its safety management.

2.1.1 The development towards a stable bureaucratic organization

As one of the last countries in Europe to do so, Norway got its first railway in 1854. The further development of Norwegian railway policy evolved as a result of private and governmental, local and centralized interests and investments. This resulted in a differentiated railway system that operated under changing geographical conditions regarding nature, technical solutions and traffic density. Because of the late start up of the Norwegian railways, it was possible to take advantage of technical development and experiences of other countries. This included safety rules that were adapted to local conditions. (Berg, 2004)

Gradually the government took more control of the development. At the end of the 1920s this ended with a centralized and political governed state railway system. All the different local railways were brought together under one governmental organization, the Norwegian State Railway (hereafter called NSB). (Berg, 2004)

NSB developed a bureaucratic organization. The management style had a militaristic feature (Ryggvik, 2004). The routines were considered so good that there was almost no

need for commands, every man was supposed to know his position and his duties (NSB BA, 1998).

From the beginning, a considerable part of the railway work was to accomplish safety procedures. The work functions were described in detail in the form of rules. But the safety aspects were not only related to the rules, they were also incorporated into the culture. Many of the work force performing safety critical activities were working alone. Their superiors seldom interfered in their work. Hence the work contained a great deal of autonomy. Further, the work was governed by the formal procedures. When the rules did not provide sufficient instructions, the workers had to make the decisions by themselves. (Ryggvik, 2004)

NSB alone controlled the traffic safety of the organization. A special "Safety Office" was responsible for the development of safety rules, control of compliance and accident investigations related to traffic safety, e.g. collisions or to prevent trains from derailing. The employee safety work in respect of the Working Environment Act was kept separate from this work (Ryggvik, 2004).

2.1.2 Incitements for changes

The new liberalistic trends in politics with increased emphasis upon so called "New public management" have changed the conditions of the former NSB. Whether the Norwegian railways should be governed by socioeconomic or commercial principles, has been an issue for discussion and conflict (NSB BA, 1998). In 1996 the Norwegian Parliament decided to reorganize the traditional NSB. The part of NSB that was responsible for infrastructure management was transferred to the newly established Norwegian National Railway Administration (Rail Administration). Some of the former activities of the latter are now privatized, outsourced or run by subcontractors.

The traffic operational part of the former NSB with its inherent service activities was transferred to a new company for traffic operation called NSB BA and later NSB AS (hereafter called NSB BA or NSB AS depending on historical timing). The requirement of the new company was to operate with profit based on market orientation and competitive power (NSB BA, 1998). This company is later divided into separate and partly state owned companies. The Norwegian railway infrastructure is now open for other train operating companies (NSB AS and the newcomers as group are hereafter called traffic operators). In addition the Norwegian railway system is under pressure of competition from other transport domains, e.g. private cars, buses, aviation.

Due to the changes of the system and criticism of leaving the system to control its own performance, the Ministry of Transport and Communication established a new authority, the Norwegian Railway Inspectorate (Inspectorate), in 1996. In the beginning the division of the responsibilities between the Inspectorate and the Rail Administration was unclear. The new Inspectorate was sparsely staffed and many of the recruited personnel had background from the oil industry (Ryggvik, 2004). The staff has grown and more people

with backgrounds from the railway system have now been recruited. With the establishment of the official body of an inspectorate, the safety work of the system became more open for insight by external parties. In addition, in 2002 the mandate of the Accident Investigation Board for aviation run by the Ministry of Transport and Communication became extended to include investigations of railway accidents.

The organizing of these safety control functions under the ministry with administrative responsibility for promoting the business of the railway sector is criticized. This issue has been discussed by a Commission of the Norwegian government on means for reducing vulnerabilities. The Commission proposes that as a rule, any safety control function should be allocated to a ministry other than the one with administrative responsibility for promoting the business or sector in question (Justis- og politidepartementet, 2000a).

There is also a general trend of the Norwegian authorities that within given frameworks, the responsibility for the governing of the activities is gradually transferred to the actors themselves. However, the Ministry of Transport and Communication has neither earlier nor lately, been directly engaged much in the safety of the railways (Justis- og politidepartementet, 2000b).

The increased emphasis upon commercial principles of the Norwegian railway system increased the attention to competition between involved actors and cost-effectiveness. The interviewees provided examples where knowledge was considered a competitive advantage. They also provided examples where concerns for cost-effectiveness had caused pressures to shorten the duration of railway educations and trainee periods. Furthermore, a number of discussions of staff reductions were reported. For instance, the number of engine drivers in the trains was reduced from two to one. The timeframes was reduced for many tasks.

Regarding the technological development, the Norwegian railway system started out with simple technological principles. To ensure predictable and safe traffic performance, the railway system developed complicated human based information networks. The limitations of human performance and the costs related to this system have caused a gradual introduction of automatic solutions. Introduction of new automatic solutions was often followed by staff reductions. This is particularly evident with the gradual introduction of the Centralized Traffic Control (CTC). (Gulowsen & Ryggvik, 2004)

In the last century the Norwegian railway system has experienced major accidents with more than five victims in 1921, 1950 and 1975 (Gulowsen & Ryggvik, 2004). In 2000 two serious accidents happened again. One was the Åsta accident where two trains collided on a single track line (Justis- og politidepartementet 2000b). The accident report concluded that one of the trains most probably drove through a red light (Justis- og politidepartementet 2000b). The actual line had Centralized train control (CTC) but as the line was not electrified it could not be stopped by turning off the power. Nineteen people were killed. The other was the Lillestrøm accident, where defective brakes made a train transporting compressed explosive gas collide into a parked train. The gas leaked and set fire. Nobody was killed but an explosion was close to happening (Justis- og

politidepartementet, 2001). This could have destroyed the whole center of the city Lillestrøm.

The discussions following the accidents and in particular the work of the accident commission, had consequences for the safety philosophy of the system (Gulowsen & Ryggvik, 2004). For the first time, railway accidents became investigated by an external commission. The same commission investigated both the Åsta and Lillestrøm events. In its accident report, the commission gives credit to the safety work of the railway system (Justis- og politidepartementet. 2000b). It finds that the Norwegian railway system has made serious efforts regarding the safety work. However, the commission criticizes the safety work for being too event based and reactive. The commission recommends implementing measures to ensure that proactive safety management is applied to all railway operations. Further it recommends that the Rail Administration and the NSB BA should intensify their efforts to develop higher quality and efficient internal control systems in all their activities.

2.2 Safety rule tradition and current development

As already indicated, the Norwegian railway system has developed a rule tradition. Below, this tradition and the influence from the incitements for changes will be discussed.

2.2.1 Safety rule tradition

The safety rule tradition that serves as a fundament for the rule modifications of the study, builds upon the traffic safety tradition of the old NSB. The rules were gradually developed for internal use in the relatively stable NSB organization. Interviewees of the study revealed that practical considerations played an important role in the rule development. Therefore many of the rules were developed for safe traffic performance under normal conditions and for maintaining undisturbed and safe traffic performance under exceptional conditions, i.e. the rules combined concerns for traffic safety and other purposes. Rules that required strict adherence and rules of a more advisory nature were included in the rule system.

The rules were considered as a collection of several generations' experiences with railway activities (Gulowsen & Ryggvik (2004). However, common knowledge was not always expressed in the rules because it was taken for granted[3]. Hence, there were holes in the rule system.

The interviewees of the study described that the rule-developers of the former NSB usually were a few centrally placed, very experienced and respected people with good knowledge about the actual activities. The most common educational background was either internal railway educations or railway relevant external technical educations. When

[3] Information from Safety director Skovdahl of the Rail Administration, 2/19/2003

employed the latter had to follow introduction courses to the railway system. These introduction courses included extensive and varied trainee programs. Accordingly, the rule-developers posited extensive railway knowledge and networks of people. Usually, the networks included rule-followers.

The rule-developers performed the rule modifications according to their own knowledge, beliefs and norms. Very often they were in dialog with their personal network within the organization and trade unions. However, the latter were not involved in a systematic way. Furthermore, the interviewees revealed that the stable situation of the organization, the recruitment pattern and stability of the employees and a tradition of overlapping when they were leaving, made it possible to transfer knowledge from one modification process to another.

The main rule modifications were based upon knowledge transferred from other countries, analyses of dangers related to changes in technology and after experiences with dangerous events or accidents within the system itself (Berg, 2004; Gulowsen & Ryggvik, 2004). However, as long as the traffic across national borders was rather limited, the organization had the possibility to make relatively free decisions related to technical solutions and rules.

Gulowsen & Ryggvik (2004) explain that the attitude to rule modification was that the existing rules were carefully developed. Therefore it was necessary to be hesitant before changing them. When in doubt, the practice was to keep the old rule. One interviewee illustrated the tradition like this:

> *"…if changes in the rules shall happen, first someone has to die. Yes, it was like that before. It is a little better now."*

Accordingly, there were seldom dramatic changes of rules. New rules were mainly made when technology was changing or when accident investigations revealed that rules could have prevented events from happening. (Ryggvik, 2004).

The main target group of the rules, i.e. the rule-followers, was actors at the operative level. This means that they were posited at the lower levels of the organizational hierarchy. According to Ryggvik (2004) most of the work force of the railways was stable and recruited from families that were already involved in the railway system. They had good knowledge about each other and the organization. The educational system for the railway professions was rather comprehensive. The function of the rules in the educational system is further elaborated in Section 2.3.

Lack of compliance with the rules could lead to sanctions, for example reprimands or demotion. However, Ryggvik (2004) describes how the trade unions of the railway system used to counteract sanctions by addressing the responsibility of the management.

2.2.2 Current development and challenges

Lately the rule tradition of the Railway system has been increasingly challenged. In particular, the increased emphasis upon internal control principles and the development within EU has represented a challenge for the tradition. Furthermore, the organizational changes have changed the conditions for transfer of knowledge about accomplishing rule modification processes.

2.2.2.1 Internal control: Emphasis upon hierarchies and risk assessments

With the Regulations relating to Systematic Health, Environmental and Safety Activities in Enterprises (Internal Control Regulations) the principle of internal control was introduced to the railway system for the first time in 1992 (Arbeids- og inkluderingsdepartementet, 1996). However, Ryggvik (2004) explains how attempts to implement internal control principles to traffic safety created conflicts and were not successful. According to him the main reason was that the Safety office of NSB associated internal control with the work for the employees' safety. The office considered the traffic safety of the railways to be another discipline where internal control was irrelevant. Furthermore, the attempts to implement internal control was combined with attempts to weaken the dominance of railway professionals in the existing railway culture. The staff at the Safety office also felt that traffic safety as such was under pressure.

Ryggvik (2004) reveals that the newly established Inspectorate chose to emphasize the safety tradition of the oil industry instead of the existing safety tradition of the Railway system, as for instance Sweden did. This tradition has applied the principles of internal control. However, in accordance with the tradition of Traffic safety, the democratic elements with its bottom-up approach did not become as evident here as in the regulation of Internal control for Health, Safety and Environment. Accordingly, the deductive top-down elements are dominating.

As already mentioned in Chapter 1, the principles of internal control require some kind of risk assessment. According to Rausand & Øien, (2004) the Railway Inspectorate were also influenced by the development in England. In 1994 the British Health and Safety Executive (HSE) implemented a solution closely related to the internal control principle; the so-called "Safety Case" regime (Rausand & Øien, 2004). This requires the companies to demonstrate to the authorities that safety is effectively managed. Here quantitative risk analyses are required.

In the Safety regulation ("Sikkerhetsforskriften") of 1999 and the later Requirement regulation ("Kravforskriften") of 2001, the Inspectorate specified the requirement to perform risk analyses (Samferdselsdepartementet, 1999/2001). Here it is required that those engaged in railway activities have to perform the necessary analyses to identify conditions that can cause loss of life or serious personal injury and to follow up on the results of analyses. However, the kind of analyses is not specified like it is in the

mentioned Safety case regime of the British HSE. The actors are also required to ensure that single errors cannot lead to such accidents and to establish criteria for acceptable risk.

The Inspectorate has intended to use goal-oriented rule solutions as the underlying principle for regulations[4]. As revealed in Chapter 1, it has also started to apply the goal-oriented form in their regulations. However, the prescriptive form is also still used throughout the system.

In total these changes direct attention towards decision making, safety management and use of risk analyses. Hence the rule system has become more differentiated into a rule hierarchy. The safety responsibilities at the management level of the railway system are emphasized instead of the former tradition, where the responsibilities were placed with the operative staff at lower levels in the organizational hierarchy. Furthermore, the ongoing division of the system has created a situation where the former safety rules are distributed in accordance with new roles and responsibilities. This implies that the rule-imposers and the rule-followers are more distributed in the organizational hierarchy than before.

The distribution of responsibilities and rules at different hierarchical levels of the system give the rules different levels of formality. The rules at the level of the authorities, i.e. the Ministry and the Inspectorate, have the form of laws and regulations. These can be supplemented with guidelines and standards in the form of supplementary texts or separate publications. The regulations are related to the laws and concretize their requirements at a more detailed level. The Rail Administration issues rules that regulate operators' access to rail infrastructure. These rules can have contents serving other purposes than the safety, for instance economic considerations. When found necessary or useful, the Rail Administration, the traffic operators and other companies that operate within the Railway system, develop their internal safety rules for internal activities. These rules can have different forms that vary from clear requirements that have to be followed without deviation, to informal guidelines and advice for the work. Also at these lower levels of the railway system's hierarchy, the safety related rules are often combined with rules serving other purposes.

Many interviewees underlined that the establishment of the Inspectorate and the division of responsibilities have increased the emphasis on formal juridical aspects of rules. The recent accidents have also illustrated that juridical aspects of responsibility are of great interest for the media. On the other hand, many of the interviewees argued that efforts had been made to change the former tradition to sanction lack of compliance with rules. More attention is now given to communication about possible reasons behind lack of compliance and opportunities for organizational learning. This includes learning about the quality and efficiency of existing rules.

Ryggvik (2004) provides some reflections upon the influence from the oil industry. He claims that the authorities related to the oil industry, the scientists educated by grants from that industry, safety experts of the large enterprises and particularly all the

[4] Information from Director Johnsen of the Norwegian Railway Inspectorate, 3/5/2003.

consultants with background from the oil industry have a hegemonic role in Norwegian safety work. These actors were influenced by the conditions of this industry with a short history and new and rapidly evolving technology. Their safety thinking was oriented towards system thinking and risk analyses. The tradition of the oil industry has also influenced the Railway system, and in particular the Inspectorate. Furthermore, in the work of the accident commissions, the traditional safety philosophy anchored in the old railway system and its culture were blamed for the accidents. According to Ryggvik (2004), this laid the way open in the railway system for the prevailing practices of the oil industry. However, he finds that these practices gave little attention to the technology of the railway system and its old tradition where safety has been a central element.

The influence of the oil sector is also discussed in a-state-of-the-art review of current knowledge of risk and safety in the transport sector (The Research Council of Norway, 2003). Here the transport sector is advised not to apply the prevailing practices of the oil industry without further considerations. They consider the greatest danger of the practices to be the power this gives to a small group of experts who implicitly have the power to decide a kind of objective risk. Instead the review recommends bringing the actual decision-makers more firmly into the picture. Further it argues that assessments of what is adequate from a safety perspective are of a political nature. Hence, these should not be decided through a mechanical use of risk acceptance criteria, where the analyst may not see the full scope of the choices that are made.

Many of the interviewees of the study spontaneously provided reflections upon this. They illustrated that the early attempts to introduce internal control, new types of rules and the risk analytic approach did not develop without hurt feelings among the railway staff. This was based on interpretation of limited respect for their safety competency and the former safety work. Further some interviewees argued that the transfer of practices from the oil industry had not taken the special features of the railway activities sufficiently into consideration. In particular they emphasized the features of the rail technology with requirements to coordination and communication between different involved actors.

2.2.2.2 Influence from the development within EU

An additional challenge to the rule development of the Norwegian Railway system is the international rule development. Through the agreement of European Economic Area (EEA) Norway has to conform to EU decrees and directives. Hence, the opportunity of the system to freely choose rule solutions will be gradually restricted.

Of particular importance is the Railway Safety Directive (Directive 2004/49/EC). It contains many of the same basic principles as the Norwegian oil industry. Point 13 states that in carrying out their duties and fulfilling their responsibilities, infrastructure managers and railway undertakings should implement a safety management system. The guidelines for the safety management system proposed by the SAMRAIL-project introduced in Section 1.2 suggests that the structure follows the Plan-Do-Check-Act (PDCA) cycle, which is the recommended approach by the International Organization for

Standardization (ISO) for specifying management systems (European Commission, 2004d). This is compliant with the Safety Management System requirements given in Annex III of the Railway Safety Directive. Management of Rules and Standards is one element in the proposed system.

Further, in point 10 the Directive recommends that national rules should gradually be replaced by rules based on common standards, i.e. Technical Specifications of Interoperability (TSI) (Directive 2004/49/EC). These are directed at the Trans-European Conventional Rail System and in particular associated with traffic across borders (Weill-Fassina et al., 2003). The introduction of new specific national rules, which are not based on such common standards, should be kept to a minimum. This implies higher levels of a top-down approach to future rule development. Except for instances where the development of these TSIs directly influence the studied modification processes, the development of these are outside the scope of the study.

The European Standard EN 50126 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) has already influenced the Inspectorate (Rausand & Øien, 2004). This standard does not require a full quantitative risk analysis but suggests different types of accept criteria. This gives the opportunity to also apply qualitative approaches.

In addition, some of the activities of the railway system are regulated by regulations that indirectly relate to railway activities, for instance regulations directed at activities involving electricity.

According to interviewees, the Norwegian Railway system is also expected to become more involved in trans-national traffic, particularly between Norway and Sweden and between Sweden and Denmark. Therefore Scandinavian railway systems are cooperating with the purpose to harmonize infrastructure, rule systems and terminology. Further, foreign traffic operators are already operating in the Norwegian infrastructure. Some maintenance activities are conducted abroad.

2.2.2.3 Knowledge of accomplishing modification processes

Regarding the knowledge of how to accomplish rule modifications, the interviewees explained that the ongoing changes of the Railway system have reduced the chances for overlap in rule modification processes. Accordingly, the traditional experience transfer between modification processes is weakened. Further, ongoing changes at both the national and international level have created expectations of future need for rule modifications. Therefore, methods for rule modification have been discussed.

In addition, the ongoing changes have endangered knowledge about context and the intended function of rules, and some are already lost. This has led to a concern about the value and conservation of such knowledge. Some efforts are already being made to

prevent more losses of knowledge. As an example, one Safety Officer of NSB AS has interviewed retired employees. He reported the results of the interviews as:

> *"I was glad I did those interviews, I got lots of input about previous events and against which the rules were established as a barrier."*

The recent practice for modifications of the two projects and plans for the future are presented in Chapter 5.

2.3 Links between rules and railway knowledge

Gulowsen & Ryggvik (2004) explain that the rule tradition was closely related to the management of the safety knowledge of the railway system. Safety and related rules were fundamental for the teaching of rail employees. The traditional teaching approach was to train the students to memorize the rules. The students were taught that even if they didn't immediately understand the meaning of a rule, they should still assume there was a reason for it.

The educational programs contained long periods of varied practice where the work force contributed, i.e. a trainee system. The interviewees of the study provided vivid descriptions of how rules and functions of the systems were illustrated and discussed during the practice periods. Stories of accidents and unwanted events were kept alive. The students learned about the practical application of the rules. Further they learned about other functions of the railway system than their own (Ryggvik 2004). This illustrates that the educational programs contained strong elements of rich and comprehensive practical knowledge and socialization. These elements were strengthened by the discussed recruitment pattern to the system. Further, a career in the system was heavily based on a combination of professional skills and length of service. According to Ryggvik (2004), the former railway personnel knew almost everything about trains, railways and railway traffic. This extensive competency made it possible for the actors to quickly discover any kinds of failures.

The interviewees who are involved in the education of railway professionals, argued that the theoretical education has also gradually come to put more emphasis upon a deeper understanding of the rules. This included the history behind them, their context and their intended function. The rules and this knowledge are used to explain the functions of the system and the role of the rules in safe traffic performance. Increased attention is now given to the role of the rules in the system's safety barriers[5]. However, the duration of practice periods is reduced. More personnel without any former links to the railway system are recruited directly into different positions in the system, for instance at the management level. Hence, the ongoing changes of the Railway system have also changed the conditions for traditional experience transfer and socialization.

[5] Information from Østningen, the Administrative Manager of the Railway school, 10/14/2003

The interviewees also revealed that during recent years, the future of the educational programs of the Norwegian railway system and the Railway school has been heavily discussed. The discussions are not yet fully concluded. Parts of the education system are under pressure for more efficiency in terms of duration and in particular the practical part.

Many interviewees spontaneously expressed a concern that changes in the educational system, policies for personnel recruitment and promotion and the introduction of new actors to the railway system might have a negative effect upon the competency of the railway personnel. This might undermine their knowledge of the function and competency of each other, their understanding of the complex interactions of the different activities and the context and intended functions of the safety rules.

2.4 Cases of the study

The two projects chosen for this study were selected because they were feasible for the research questions.

2.4.1 The Traffic-rule project

The project for modification of Traffic-rules is named TRJ 2003 (Traffic-rules for Railways 2003). This project represents one process of rule modification and will therefore be treated as one case, labeled the "Traffic-rule case". The formal organization of the case is presented in Subsection 4.2.1 and illustrated in Figure 4.1, page 82. The organizing of the work and characteristics of the rule-imposer are elaborated in Section 5.2.

There were several reasons for the project. These were closely related to the development of the Norwegian railway system presented above. In particular: the change from a practical experience-based safety policy to an analytical one, the changes in responsibilities because of the division of the system, changes in technology and international development.

The rules to be modified in the project were the experience-based prescriptive and very detailed rules for traffic operation. These were not pure safety rules; they had more the form of procedures for the part of the traffic performance that were not automatic[6]. Hence, they combined concerns for safety and a stable and effective traffic performance. The rules have had a function similar to formal regulations. During the project the responsibility for the rules was transferred from the Rail Administration to the Inspectorate. The rules were directed at the actors at the lowest level of the system's hierarchy, i.e. the operative staff. The main groups were those directly involved in traffic management and train control and train driving. The rule-followers were engaged by

[6] Information from Safety director Skovdahl of the Rail Administration, 6/24/2003

different organizations involved in traffic operation, i.e. the traffic operators and the Rail Administration.

Supplementary rules and advisory texts were provided as separate issues. However, there were no textbooks to explain the context and the intended function of the rules. Such knowledge was transferred orally through lessons and practice via the educational system of the core rule-followers. Therefore the rules also had a function as textbooks. They introduced the different functions of the railway system to the students. As revealed, the rule-followers were supposed to know the rules almost by heart and strict compliance was demanded.

In the initial discussions and preparation of the project, the Rail Administration played the major role, but also the Inspectorate participated. The project was formally established as a Rail Administration project 1/1/2000 and administered by the department for Traffic Safety. The plan was to implement the rules in 2003. The modification process became delayed and 4/1/2004 the preliminary rules of the project were transferred to the Inspectorate for further development and approval. This study follows the development of the rules during the project period, i.e. until the transferal to the Inspectorate.

In the beginning, the project did not receive any clear mandate or formal documents for its management[7]. The intention was to clarify these in parallel with the project. Success criteria for the project were developed.

One of the initial objectives for the project was to *"…maintain and develop the established safety level in a positive direction. The safety level shall be based upon risk analyses and be evaluated in a social economics perspective."*[8] In the mandate for the project dated 4/15/ 2002 it was specified that the rules should be based upon analyses of the safety conditions[9]. No risk analytic method was decided upon in advance.

Later versions of the success criteria contained the sentence *"The rules shall be made goal-oriented where found appropriate."*[10] This implied that higher order rules and a more hierarchical rule system were introduced. This was in accordance with the Inspectorate's policy and its hierarchical position in the railway system. User-friendliness and simplicity of the rules were also emphasized; the case should *"…concentrate around the most important conditions and not specify unnecessary details but instead describe the directives for the employees in unexpected situations."*[11]

Basic knowledge and information such as arguments for the rules and considerations should be kept aside from the rules but be accessible and organized in the same system as

[7] Audition report about the project from the Norwegian Railway Inspectorate: Statens jernbanetilsyn. 2000. Report no 3-00
[8] Project log 12
[9] Project log 695
[10] Project log 690
[11] Project log 690

the rules[12]. The main participants of the work reported that they were encouraged to "*think new*".

2.4.2 The Maintenance-rule project

The modification project for the Maintenance-rules for the railway infrastructure was one sub-project of an Overarching Maintenance project. This project was run by the Technical department in the Rail Administration. The rule modification project will hereafter be called the "Maintenance-rule project" and the overarching project the "Overarching Maintenance project"

The main reason for the Overarching Maintenance project was the increased focus upon cost-effectiveness[13]. Its purpose was to develop and improve the management of the infrastructure maintenance. In addition to the development of the Maintenance-rules, this Overarching project paid attention to the development of a steering document for maintenance, tools for decision support, a strategy for development of competence, optimization of preventive maintenance and definition of what kind of data is important to register for analytical purposes[14]. Therefore, this project also contains other sub-projects than the Maintenance-rule project.

The formal organization of the Overarching Maintenance project is presented in Subsection 4.2.1 and illustrated in Figure 4.2, page 86. The Maintenance-rule project had an informal organizational structure and did not provide formal descriptions of this.

The Maintenance-rules are organized according to the four main systems of the infrastructure. One system is the Superstructure that consists of equipment on the surface of the ground such as rails, sleepers and points. Another is the Substructure that consists of structures and equipment under the ground such as the foundation of the ties and bridges. A third is the Power-supply that consists of equipment that transfers electricity to the system such as electrical cables, transformers and switches. This system consists of three subsystems. A fourth is the Signalling and interlocking that consists of equipment for the different signals directing the traffic, for example different types of signals and information signs.

The study follows three modification processes within the Maintenance-rule project. In accordance with the subsystems that the rules of these cases regulate, the cases are labeled the Signal case, the Power-supply case and the Superstructure case. The selection of cases is presented in Section 4.2.1. The organizing of the work and characteristics of rule-imposers are elaborated in Section 5.2.

The rules to be modified in this project were also consistent with the experience-based and prescriptive rule tradition. To some extent their form and focus differed between the

[12] Project log 690
[13] Home page of the Overarching Maintenance project
[14] Home page of the Overarching Maintenance project

cases. For instance some rules had a form of work instructions or detailed check lists, a few had a form of detailed triggering requirements. Generally, concerns for safety and for maintenance performance have been integrated. However, according to interviewees there had been a tradition to judge rules for accessibility and rules for safety differently and to build in more safety margins in the safety related rules.

Again the rules were directed at actors at the lower operative level of the organizational hierarchy but here the core rule-followers were the line managers, who were the staff leading this operative work. However, many of the prescriptions in the rules were also directed at the staff performing the practical maintenance work and their group leaders. These rule-followers were all employed by one organization, the Rail Administration. Due to the ongoing privatization process, sub contractors have been increasingly involved in activities. The different subject areas have developed different traditions for management and use of the Maintenance-rules.

The old rules of the Maintenance-rule cases had included explanatory texts. These had later been removed from the rules and gathered in separate textbooks. Here the context and the intended functions of the rules were explained. [15]

The Overarching Maintenance project was established on 10/1/2001. The Maintenance-rule project was established shortly after. The Overarching Maintenance project is still not complete. The Maintenance-rule project implemented the modified rules on 1/1/2004. The study follows the project until the development of the rules was finished.

The reasons for establishing the Maintenance-rule project were both related to the general development of the Norwegian railway system and the purpose of the Overarching Maintenance project. The intention was to move from rule-based to risk-based management of the maintenance activities, i.e. to introduce a risk-based approach and to make sure that the activities and limitation that the rules imposed were really necessary[16]. The rules had to be concise, that is to say that they only consist of requirements/accept criteria[17]. One reason for this requirement was a wish to reduce differences in the standards of the infrastructure because of different traditions in the regions. Furthermore, the rules had to be differentiated according to the function and importance of the components[18]. The level of safety relevance of the rules should also be taken into consideration.

On this background, the project intended to apply risk assessment and to increase the use of higher order rules, i.e. triggering requirements as the participants of the work labeled them. These rules should contain defined standards for the technical equipment that the maintenance activities were supposed to maintain and descriptions of required actions if the standards were weaker than defined. By reducing work instructions, requirements to

[15] Information from Nordgård, the leader of the Maintenance-rule project
[16] Information from Svee, the leader of the Overarching Maintenance project and Nordgård, the leader of the Maintenance-rule project.
[17] Homepage of the Overarching Maintenance project.
[18] Homepage of the Overarching Maintenance project.

maintenance intervals and checklists to a minimum, and to give them a status as attachments, the rules were supposed to be less voluminous. This reveals that a hierarchy of rules was introduced. The plan was to relate the higher order rules in the form of triggering requirements to higher levels of the organizational structure and to give them and safety related rules higher level of formalization regarding procedures for changes and deviance.

When found adequate and optimal there should also be room for professional judgments in the maintenance activities[19]. Further, due to differences in the rule traditions of the different subject areas, there was a wish to develop a more uniform and consistent rule system for maintenance[20]. User-friendliness was emphasized here too[21]. Also in this project the main participants of the work reported that they were encouraged to "*think new*".

2.5 Delimitations of the cases

To sum up, this introduction to the Norwegian railway system, its rule tradition and the two projects illustrates that the four chosen cases offer possibilities to study the accomplishment of rule modification regarding the research questions of the study.

However, there are also inherent limitations in the cases. First, this study has a time limit. Within this limit it is only possible to follow the cases until the rules are written within the frames of the projects. Accordingly, this study will not follow up the further development of the Traffic-rules by the Inspectorate. Further it will not follow up the approval, the implementation and the effects of the modified rules. Second, the rules of the projects include elements of other issues than safety. Therefore they do not offer the opportunity to study modification of pure safety rules. However, this is also typical for safety rules in railways elsewhere (European Commission. 2004b).

[19] Homepage of the Overarching Maintenance project
[20] Homepage of the Overarching Maintenance project
[21] Homepage of the Overarching Maintenance project

3 Theoretical basis for the study

3.1 Revisiting the framework of the study

The theme of this thesis is safety rule modifications in the context of the Norwegian railway system. Safety rule modification implies that safety rules already exist and a rule tradition serves as an outlet for the work. Chapter 2 has introduced the rule tradition of the Norwegian railway system. Chapter 1 has revealed that there is not much theory describing how to perform safety rule modifications. However, Hale et al. (2003) discuss the content of such processes. They provide this description:

> *"…the modification process in which the activity, process or technology may change, in which lessons from experience may suggest that rules for previously unregulated situations are necessary, or that rules can or should be removed or relaxed, or simply changed for better rules" (Hale et al., 2003, p 4).*

The modification processes of this study are according to this description. The rules of the Norwegian railway system have been dominated by prescriptive rules directed at personnel at lower levels of the organizational hierarchy. The intention of a hierarchical approach where different rule solutions are adapted to rule-imposers and the rule-follower at different levels of the system's organizational hierarchy, implies to change existing rules.

Chapter 2 has also revealed the development of existing rules has been based on practical experiences and evolving knowledge of the system's functions. The requirement to the projects of risk-based rule development implies a change in the foundation of the decisions of the modification processes.

In addition, Chapter 2 demonstrated that there are strong links between the rule tradition and the knowledge management of the Norwegian railway system. When studying modification processes the study intends to focus upon the influence of the hierarchical and the risk-based approaches upon knowledge. Chapter 1 argued that both of these new approaches belong to the same tradition of rationality. In the terminology of March (1994) this is the "rational" choice based decision-making. Chapter 1 also argued that this form of rationality differs from the rule and identity based form of rationality that was commonly used in the decision-making of the Norwegian railway system. As revealed, March (1994) finds that perspectives upon rationality are closely related to perspectives upon knowledge.

Therefore, as a theoretical framework for the study these elements and their relationship are illustrated like this:

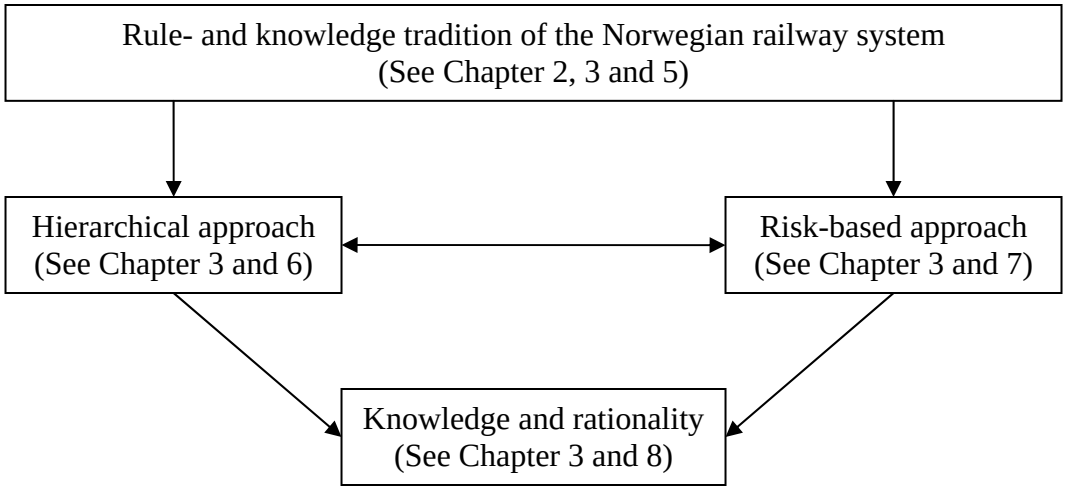


Figure 3.1 Theoretical framework for the study

This theoretical framework is to be considered as a conceptual model structuring the main subjects and work hypotheses of their influence upon knowledge. The elements described in each box are the main concepts to be discussed. The arrows between the boxes illustrate that there are interactions between the concepts and hypotheses about their directions of influence. The arrows from the rule- and knowledge tradition towards the hierarchical and risk based approaches demonstrate a hypothesis that this fundament will influence the implementation of the two approaches. The two-ways directed arrow between the hierarchical and risk based approaches indicates that the approaches are expected to interact. The arrows from the two approaches towards knowledge and rationality represent a hypothesis that the introduction of the approaches will influence existing knowledge and rationality.

The theoretical basis for the elements in the framework will be elaborated below. The theory will be supplemented in discussions of the study's results.

3.2 What is a safety rule?

The projects were encouraged to move from the prescriptive rule tradition and develop higher order rules; in the Traffic-rule project in the form of goal-oriented rules, in the Maintenance-rule projects in the form of triggering requirements. The study covers a meeting between different safety rule solutions with different rule-imposers positioned at different levels of the organizational hierarchy of the system. Hence the rules also have different levels of formality. Therefore, the notion of safety rules has a wide meaning. Hale & Swuste (1998) discuss what safety rules are. They consider safety rules as constraints imposed from outside on the freedom of choice of individuals or companies. They define a safety rule as

> *"…a defined state of a system, or a defined way of behaving in response to a predicted situation, established before the event and imposed upon and/or accepted by those operating in the system as a way of improving safety or achieving a required level of safety."*
>
> (Hale & Swuste, 1998, p 164)

For the purpose of the thesis, this wide definition of safety rules is applied. However, this study does not extract a modification process of pure safety rule. The rules to be modified serve both safety and other purposes. Therefore, it studies a modification process of safety rules together with rules serving other purposes. As mentioned in Chapter 2, the Norwegian railway system has traditionally distinguished between traffic safety and other aspects of safety. The major safety concern in the rules to be modified is traffic safety, that is to say, the means to prevent trains from derailing or collision (Ryggvik, 2004).

The form of rules can range from unwritten rules to written statutory codes (Hood, Rothstein & Baldwin, 2001). The work of the projects in this study focuses on formal written safety rules imposed upon rule-followers from outside. Rules issued at the level of the authorities are labeled laws and regulations and constitute the safety legislation. When found to be clarifying this distinction will be used. In other cases the general term "rules" will be used.

The necessity of safety rules is thoroughly discussed by Hale and his associates in several articles (Hale, 1990, Hale & Swuste, 1998; Hopkins & Hale, 2002). Their conclusion is that safety rules are needed. Regarding railways, the work of SAMRAIL illustrates that safety rules have an important role in achieving safety performance (European Commission, 2004c). Hale et al. (2003) argue that in a complex system like the railway, safety rules are needed to make the system behave in a predictable way for all system elements, both people and hardware. Further they are needed to show how the system must be managed to achieve its objectives.

However there is still a question whether safety rules are an appropriate solution for the control of risk at stake. The European Directive of Machinery Safety (CEN, 1991) illustrates that other solutions might be available and that rules can serve different functions. First the need for safety rules might be removed by better design. Further, if isolation or guarding is applied, these might have different forms and hence, require different rules. Safety rules might be applied to introduce and maintain safety barriers. As the last solution, rules can be introduced as compensation for lacking technical barriers.

The need for rules can also be related to the competency and motivation of the involved actors. Reason (1997) distinguishes between two main kinds of controls of a system's defenses against accidents. Safety rules represent the external control of the system's defenses. A system's internal control is derived from the knowledge and principles acquired through training and experience. Between these two are various blends and mixtures. Hale (1990) holds the position that it is not necessary to impose rules from outside if the normal rules that the regulated devise for themselves can cope adequately.

Hale & Swuste (1998) ask when it is best to leave the personnel taking the action to decide for themselves how to proceed safely and when it is appropriate and/or acceptable that their freedom of choice is limited by getting someone else to decide what the action should be.

The request for rules might be dependent on the context of control and enforcement. Hale & Swuste (1998) argue the more compliance is stressed, the more rules are used as a basis for assessing behavior by punishment or reward and the more disputes between parties over the behavior expressed in the rules, the more there is pressure to define the rule at a management or regulatory level in terms that are easy, quantifiable and verifiable. This reduces the complication and expense of disputes of interpretation.

Further, the competition between alternatives of safety and other benefits is a concern. DG Energy and Transport has performed case studies of European railways (DG Energy and Transport, 2000). These revealed that there are difficulties in acknowledging choice situations between safety and other benefits. The report concludes that due processes including clear and consistent decision rules for standard setting are particularly important for railways. The importance of explicit rules for policy criteria is underlined.

These discussions reveal that the use of safety rules raises a whole range of practical and ethical problems. The study is limited to the modification processes themselves. It does not include studies of, for instance, implementation and use of rules. Therefore, these issues will only be touched upon when found to be of vital importance for the purpose of increased understanding of modification processes.

3.3 The hierarchical approach

As the introduction of a hierarchical approach to rule modification in the Norwegian Railway system represents a meeting between two rule traditions, it is an ambitious task.

The rules to be modified in the projects had a history in the former NSB. As illustrated in Chapter 2 this organization had a typically bureaucratic, hierarchical structure. There was extensive use of prescriptive safety rules issued by the higher levels of the system and directed at the lower operative levels. This rule tradition is in accordance with the descriptions that Weber (2000) made of bureaucratic systems. He found that an important element in bureaucratic systems were rules related to professionalism. He argued that the main purpose of laws, requirements and rules issued by the higher levels of the system was to create predictability of behavior, especially at the individual lower levels of the organizational hierarchies. In the railway tradition the rules were directed at predictability regarding safe and predictable traffic performance. They were developed with evolving knowledge of the technical system and practical experiences.

Accordingly, safety rules were not differentiated and organized in a hierarchy. First, they were not differentiated regarding different rule principles. Second, the general pattern was that rule-imposers were centralized instead of distributed in the organizational

hierarchy of the system. Third, safety rules were usually not developed for different levels of rule-followers. However, occasionally the management was held responsible when accidents happened (Ryggvik, 2004).

The ongoing changes of the Norwegian railway system described in Chapter 2 have changed the conditions for such a system. The context has become more dynamic and influenced by international development. The system had developed into a more divided organizational structure with more actors and changed distributions of responsibilities and authority. The introduction of the internal control principle by the Inspectorate and the expectation to the projects to introduce goal-oriented and triggering requirements represents a break with the former prescriptive rule tradition. The Inspectorate's choice of applying the internal control principle and the limited use of democratic principles for traffic safety also implies a predominantly deductive approach to rule development in this field. In addition, the changes include increased emphasis upon competition and cost-effectiveness that can be seen as a more hostile environment, a less homogenous work force and uncertainties related to the educational system.

All together this development represents moves towards a more hierarchical approach to rule development regarding all four dimensions introduced in Chapter 1. These are the rule hierarchy, the hierarchical positions of the rule-imposer and the rule-follower in the organizational hierarchy of the system and a predominantly deductive strategy for rule development.

This development is also reflected in the two rule modification projects to be studied. The suggested rule solutions introduce new types of rules that can be seen as overarching rules for prescriptive rules. This strengthens the opportunities for alternative solutions regarding rule principles. The rules had to be related to the new distribution of responsibilities and authority within the railway system. This refers both to potential rule-imposers and rule-followers. The work is done within the frames of internal control principles and the application of these upon the field of traffic safety.

The four dimensions will be elaborated in the next sections and related to the current development of the Norwegian railway system.

3.3.1 Hierarchy of rule solutions

The fist hierarchical dimension at stake is the hierarchy of rule solutions. As will be discussed below, the different rule solutions are associated with different control principles. Furthermore, they contain different requirements and are seen to be more or less suitable for different contexts.

3.3.1.1 Rule solutions, their control principles and their interrelationship

The suggested rule solutions for the projects represent a change in the inherent control principles of the rules compared to the prescriptive rules of the former NSB

Goal-oriented rules such as the Traffic rule case was encourages to apply are rules formulated as goals and linked to the strategy of management by objectives. Such rules are based on feedback output control that is predominantly discretionary (Reason, 1997). Here the rules specify the goals of the safety output but not the rules for the direct risk control function. In other words, they impose no rules as to how the goals should be achieved (Hale & Swuste, 1998). Such rules require frequent comparisons of performance with goals; the system is controlled by closed-loop feedback strategies (Rasmussen & Svedung, 2000). This also requires performance indicators (Kjellén, 2000). Output control depends primarily upon organizational control by social (or group) controls and self- (or individual) controls (Reason et al. 1998). Such rules communicate expectations and explain why certain actions have to be taken. This means that they have a "BECAUSE" content (Hale, 1990). The focus of the goal-oriented rules can be directed towards technical equipment, human performance and organizational conditions.

An example of a goal-oriented rule directed at organizational conditions is § 5 in the new regulation for education:

> *"The one who runs railway activities has to decide scope and frequency for repetition of education for those tasks mentioned in § 1 to ensure that built up knowledge, built-up skills and attitudes are maintained."*
>
> (Samferdselsdepartementet, 2002)

This rule describes a goal to maintain built-up knowledge, skills and attitudes. Further, it describes why certain actions have to be done, i.e. a BECAUSE element but not exact descriptions for how they shall be done.

Prescriptive rules such as the traditional rules of the former NSB represent process control that attempts to standardize the work process (Reason et al., 1998). They prescribe what to do in response to certain situations. This means that they have an IF-THEN form (Hale, 1990). The prescriptive rules are based on the principles of feed forward process control (Reason, 1997). Here the system is controlled by pre-planned strategies and prescriptive procedures (Rasmussen & Svedung, 2000). The process control relies wholly upon direct guidance from centralized management (via rules and procedures) (Reason et al., 1998).

An example of a prescriptive rule is §2.24 in the regulations concerning traffic control and rail traffic on the national railway network and connecting private tracks that are under revision:

> *“ When colliding with large wildlife or livestock the engine driver shall as soon as possible give notice to the train dispatcher or the traffic controller with information about what kind of animal was hit, where the animal went, or is lying and what has been done with it.”*
>
> (Samferdselsdepartementet, 2001b)

This rule prescribes the actions that the rule-follower, in this case the engine driver has to take under certain conditions, i.e. IF-THEN prescriptions. Furthermore, it prescribes in detail how these have to be done.

Reason (1997) also describes the mixture between the two underlying control principles of the goal-oriented and prescriptive rules, i.e. a *mixed feedback and feed forward control.* Here output measures are frequently compared with organizational objectives. The deviant performances are corrected and the congruent performance is stored as rules and procedures. The triggering requirements that the Maintenance-rule project intended to implement combined both feedback and feed forward control principles. First the defined standards, i.e. the IF-condition of the rules, had a function both as a condition that required action and as reference for the maintenance activities. Accordingly the IF condition of these rules had elements for feedback and outcome orientation. Second, the requirements to act, i.e. the then condition of the rules represent a feed forward element prescribing an action. However, the intention of these rules was not go into detail describing how the prescribed actions should be done.

An example of a triggering requirement can be taken from the revised Maintenance-rules of the Superstructure case. The rule is developed for controlling quality of wooden sleepers:

> *“If 3 or more sleeper screws for each plate are loose after tightening until 150 Nm, the tie shall be changed.”*
>
> (Jernbaneverket, 2004, Chapter 2, no. 8.3)

This requirement contains a prescriptive IF-THEN element that a sleeper has to be changed if it is so weak that it does not hold three or more of the screw sufficiently tight after the described tightening but not how this change should be done. Implicit here is a goal that ties should be in a better state than this; ties have to be changed BECAUSE they are weaker than the condition described in the rule.

These rule solutions can be placed in a hierarchy with respect to each other. The prescriptive rules are supposed to describe the control functions that serve the purpose of safety goals expressed in safety rules. Accordingly, goal-oriented rules can be considered as higher order rules while the prescriptive rules as lower order. The mixed solution that triggering requirements represents, can bee seen as a rule solution that belongs to the mid-range level.

This mixed mid-range solution is different from that suggested by Hale (1990) and followed up by Hale & Swuste (1998). Their suggestion is to introduce a mid-range type

of rule that prescribes *procedures for arriving at decisions* about IF-THEN rules. These rules limit the freedom to choose how decisions are arrived at regarding the translations between goal-oriented rules and prescriptive rules. An example of this latter solution is found in directives and standards issued by EU (See for instance the European Directive of Machinery Safety (CEN, 1991). The same is seen, for instance, in later changes in standards issued by the ISO where there is an increased emphasis upon processes (See for instance the ISO 9000 publications)

In this study the hierarchy of rule solutions will distinguish between high order-, mid range- and low order rules. The high order rules are the rules directed at management and decision-making, i.e. internal control and goal-oriented rules. The mid range rules are rules that combine feedback and feed forward control such as the described triggering requirements or procedures for arriving at prescriptive rules such as described by Hale & Swuste (1998). i.e. triggering requirements. Low order rules are the prescriptive rules such as the ones traditionally dominating the Norwegian railway system.

3.3.1.2 Inherent requirements in the solutions

Inherent in the rule solution there are different requirements to rule-imposer's and rule-follower's competency.

With respect to the *goal-oriented rule solution* Hale (1990) argues that general principles such as objectives can be formulated quite generally. To develop such rules it is not necessary that the rule-imposer possess detailed knowledge of the context of the rules, the emphasis is upon the results of the regulated activities.

Regarding the rule-follower, Rasmussen (1983) distinguishes between skill-, rule-, and knowledge based levels of functioning. Hale & Swuste (1998) discuss this distinction and links goal-oriented rules to the knowledge based levels. According to Rasmussen & Svedung (2000), this level of functioning requires understanding of the relational, causal structure of the work system, that is, a correct mental model of system. Furthermore, it requires knowledge about system goals, safety conditions and regulatory constraints on performance. Rasmussen & Svedung (2000) argue that at this level the control is based on deduction of rules for action. This also requires time to think and decide. Baumard (1999) considers the construction of mental models to be a learning process. In accordance with this Reason (1997) argues that the discretionary feedback output control associated with goal-oriented rules is based on training and experiences.

With respect to the *prescriptive rule solution* Hale (1990) argues that the condition IF must be possible to perceive and understand, the actors has to be familiar with it and it has to equate the reality. This put demands on the competency of both the rule-imposer and the rule-follower.

Regarding the rule-imposer, Hale (1990) finds that prescriptive rules require good understanding of the context of the rules by the rule-imposer. The rule imposer has to

posit the ability to define safe actions/states in advance (Hale & Swuste, 1998). This also requires that it is possible to foresee what a safe action or state is. Reason et al. (1998) add that the immense variety of potentially hazardous situations requires that much of the fine control for safe behavior is delivered at the level of the individual work group. Further, prescriptive rules necessitate the ability to modify the rules in accordance to changing conditions. It is a challenge to follow up such rules under rapidly changing conditions (Rasmussen, 1997). Hale (1990) warns that an organization that becomes too obsessed with codifying the existing situations may trap itself into a lack of flexibility or the belief that it has developed its rules once and for all.

Regarding the rule-follower, Hale & Swuste (1998) state that procedures and work instructions, i.e. prescriptive rules are in accordance with the skill- and rule-based levels of functioning of Rasmussen (1983). Rasmussen & Svedung (2000) argue that at the skill-based level of functioning control is based on sensory-motor routines that relate to familiar circumstances. Competence at this level is achieved by development of a repertoire of dynamic behavioral patterns that are synchronized effectively with the behavior of the workspace. Accordingly this level of functioning requires little time to think. At the rule based level of functioning control is based on the actors' choice of two or more familiar patterns. The rule based level requires enough competencies to recognize the situation, knowledge of suitable alternative actions, the ability to choose the right option and to carry this action through. Hence, when risk control is based on prescriptive rules, the requirement to the rule-followers' competency is to perform routines quickly and smoothly and/or to recognize the situation sufficiently to make the right choice between known options for action. Reason (1997) argues that the longer and more intensive an individual's training is the less likely it is that this person is governed by rigid feed forward controls and conversely.

With respect to the two mid range rule solutions these contain different requirements. The *mixed solution* including both feed forward and feedback control principles. Accordingly it requires that the rule-imposer has both the ability to formulate objectives and possess enough contextual knowledge to be able to express what safe actions or conditions are. The rule-followers must posses the qualifications required for both goal-oriented and prescriptive rules.

Concerning the *procedural rules for decision-making* the content of such rules as described by Hale & Swuste (1998) implies that the rule-imposer might be able to define the people who must be involved in the decision, the methods to be used for searching, the parameters which must be considered in judging the appropriateness of the course of action etc. The rule-follower must be able to apply the required methods, define the course of action and judge the appropriateness of the latter with respect to the parameters.

3.3.1.3 Suitability of rule solutions for different contexts

As already revealed in Chapter 1, *goal-oriented rules* are considered to be more flexible and adaptive to changing conditions than prescriptive rules (Becker, 2002; Maidment,

2002; Rasmussen, 1997; Rasmussen & Svedung, 2000; Reason et al. 1998). They don't contain prescriptions made in advance about how to proceed safely (Hale & Swuste, 1998)

Becker (2002) comments upon the development towards increased use of goal-oriented rules in legislation. He argues that one of the driving arguments is that goal-oriented rules will keep pace with technological change and permit better adaptation to the increased competition on the worldwide markets. Further Reason et al. (1998) find that this solution is often necessary when tasks are complex. Such tasks that are non-routine, poorly structured and unpredictable do not lend themselves to proceduralization. This is because there are too many exceptional cases. Hale (1990) argues that goal-oriented rules can be useful in situations where there is a danger of erosion of the more prescriptive rules. His examples of such situations are when there are conflicting interests between actors and/or where the value of the rules cannot be shown in the short term.

The requirements of the goal-oriented rules discussed above to characteristics of the rule-imposers and rule-followers competency can also be seen as important contextual factors that makes goal-oriented rules more or less suitable to the actual context. Furthermore, this type of rules requires that there is sufficient time to translate goal-oriented rules into prescriptive action or state rules.

The prescriptive rules are based on preplanned control and require predictability (Rasmussen & Svedung, 2000). The decision how to proceed safety is taken in advance (Hale & Swuste, 1998). Tasks which are routine, repetitive and easy to perform lend themselves to rules (Reason et al., 1998). Hence, prescriptive rules require some degree of stability but little time to think when the tasks are performed (Rasmussen & Svedung, 2000). Minzberg (1979) consider standardization of work processes and standardization of skills to be important coordination mechanisms in bureaucracies with predictable environments. As will be further elaborated in the next subsection, Perrow (1999) also discuss coordination in his Normal Accident theory. He finds that centralized coordination, i.e. prescriptive rules issued from a central level of an organizational system is necessary when a system is linear with tight coupling.

The requirements of the prescriptive rules discussed above to characteristics of the rule-imposers and rule-followers competency can also be seen as important contextual factors that makes prescriptive rules more or less suitable to the actual context.

One challenge with prescriptive rules is that it is difficult to develop rules to cover all dangerous situations. Building upon Ashby's law of requisite variety, Reason (1997) argues that the procedures necessary to govern safe behavior will always be less than the possible variety of unsafe situations. It is also impossible to foresee all local contingencies of the future work context (Rasmussen & Svedung, 2000).

As Section 2.1 revealed, there are ongoing organizational changes in the Norwegian railway system. In general these have moved it towards a less stable, more competitive system. The competition implies that the organization face a potentially, more hostile environment. According to Minzberg (1979) such conditions might make the system less

predictable and standardization of the work processes and skills must be able to react faster to follow up the development. If not, the system must look for alternative coordination mechanisms in the activities.

However, the challenge of reduced stability in the Norwegian railway system is not necessarily solved with the introduction of more outcome-oriented rules. Outcome-oriented rules are more flexible regarding alternative solutions for work processes and competency as long as outcomes of activities are in accordance with the requirements in the rules. This can be seen as if the main coordination mechanism of the safety work moves towards more standardization of outputs. The problem is that according to Minzberg (1979) this coordination mechanism also calls for stability.

3.3.1.4 Changing rule solutions

All together the discussions in this section illustrate that the plan for the projects to move from low level prescriptive rules towards mid range triggering requirements and higher level goal-oriented rules is rather challenging. First, it represents a change in the control principle and hence in the focus of the rule development. The outcome of activities is the main factor that receives attention. Second, the suggested rule solutions require different competencies by the rule-imposers. The development of prescriptive rules requires good knowledge of how things have to be done to achieve safe performance in a given context. The development of more outcome-oriented rules require more general understanding of the safety purpose of the activities; it is necessary to know why activities have to be done. Third the suggested rule solutions require different competencies by the rule-followers as well. The rule-follower has to possess and be able to use mental models of the system function to search for suitable solutions that fulfill the requirements of the rules. Fourth, the higher order solutions require certain conditions of the situations. The situation must be understandable, there must be time enough to decide what to do and if safe decisions require special conditions in the given context. In addition the suggested solutions might not solve the challenges of less predictable conditions.

Hence, to choose rule solutions is complicated. Different conditions must be taken into consideration. In the projects of the study, preferences for rule solutions were given in advance. What if the solution does not fit the actual conditions?

3.3.2 Rule solution and hierarchical position of rule-imposer and -follower

The second and third hierarchical dimensions to be discussed are the hierarchical positions of the rule-imposer and the rule-follower. In the following it will be elaborated that there might be some parallels between these positions and rule solutions. However, it will also be elaborated that when choosing rule solutions for the actual situations there are other factors than these hierarchical positions that can come into play.

3.3.2.1 Indications of links between rules' hierarchy and organizational hierarchies

One of the purposes of the projects was to develop the rules in accordance with changed responsibilities in the Norwegian railway system. As already indicated, there are two main actors involved here; the rule-imposer and the rule-follower (Hale & Swuste, 1998). The rule-imposer creates rules that are imposed upon the rule-follower. The rules restrict the action freedom of the rule-follower. To be able to impose the rules, the rule-imposer must have authority over the rule-follower.

Many theorists apply a hierarchical approach to organizational systems (See for instance Hale & Swuste, 1998; Rasmussen, 1997). At the top is the macro level of national and international systems that includes political and regulatory institutions. The mid range levels or meso levels include company or industry levels, in other words the management. The lowest levels called the micro levels, relate to small work groups and individuals.

In hierarchical systems the power of the rule-imposer to impose rules upon the rule-follower is usually related to their placing on the hierarchy, i.e. the rule-imposer is positioned at a higher level than the rule-follower.

In the 1960s and 1970s there was a trend that advocated for framework rules formulated as goals, to be filled in lower down in the system hierarchy with detailed action rules (Hale et al., 2003). The internal control principles can be associated with this trend. As revealed in Chapter 1, these principles imply a logical chain of inferences between authorities, companies and parties (Flagstad, 1995).

Hale & Swuste (1998) ask who is best placed in what types of situations to impose what level of limitation. Furthermore, Hale et al. (2003) find that to decide which of the overarching rules that needs to be explicitly defined and imposed to one degree or another on the system actors are the step in rule development that is most controversial and where there is least guidance.

Hale et al. (1997) distinguish between three levels of activity. At the execution level the actions of those involved directly influence the occurrence and control of the hazards (deviation). The system structure and management level is concerned with the overall principles of the safety management system, how it is set up and maintained and how it functions. The planning, organization and procedure level is concerned with devising and formalizing the actions to be taken at the execution level in respect to the whole range of expected hazards. They underlines that these three levels are abstractions that are not to be seen as contiguous with the levels of the organizational hierarchy. On this foundation Hale & Swuste (1998) find goal setting and evaluation to be linked to the highest level of the safety management system, policy development and procedures to the mid range and execution of work instructions to the lowest. They avoid any specification of who the rule- imposers and rule-followers are.

Hale et al. (2003) follow up these discussions of safety rule management. They summarize the general proposal that goals should be set high in the organization. These

should be translated in a level below into procedures for arriving at decisions. Where necessary, as close as possible to the work floor (or other on-line risk control point) the goals should be translated into specific action steps. Only when there are overarching reasons action/state rules should be specified high in the organization.

Reason (1997) provides and additional argument for this approach. He argues that the balance between feed forward and feedback control modes will depend on an individual's position within the hierarchy. The higher the individual's position within the organization, the harder it is to proceduralize the job. In relatively bureaucratic organizations Reason expects top management to operate mainly by feedback driven output controls, with the reverse being true for those at the "sharp end". Middle management and first-line supervisors would occupy intermediate positions. Accordingly they fit the solutions that mix feed forward and feedback principles.

The preceding discussions can also be related to the rule-imposer's proximity and knowledge of the actual context already discussed in the previous subsection. As discussed, general principles and objectives are not context specific and do not require context specific knowledge to the same extent as prescriptions. For this reason Hale (1990) argues that such rules can be worked out centrally, i.e. at the higher organizational levels. The context specific prescriptive rules must be worked out more locally. If not, they will have too many exceptions to be useful. Along with this, Hale & Swuste (1998) argue that the more rapidly innovation takes place in a system, the lower the level at which the translation to action/state rules needs to be.

Hale et al. (2003) go further and discuss where the expertise lies. They argue that detailed rules for risk control of a given technology can only be written by experts with deep experience of designing or operating that technology. There is a question whether the government regulator has or can buy such expertise. They also ask what expertise is brought to bear and in which way in testing the appropriateness and applicability of the rules.

These discussions raise the question of participation in the rule development. Hale (1990) argues that detailed rules formulated at the central level will be represented as being imposed from outside by people who have no understanding of the realities of the specific situations. This implies that participation might influence the attitudes towards the rules and hence the motivation to comply. Hale et al. (2003) suggest to involve the rule-followers in rule development and reviewing the rule system.

Hopkins (2000) argues that framework rules leave more responsibility to the actors themselves to decide their means in the safety work and require active employee participation. He finds this to be on line with the democratic development. As presented in Chapter 1 the internal control principles also includes elements of participation and industrial democracy (Hovden, 1998a).

The discussions above indicate a link between the hierarchy of rule solutions and organizational hierarchies. The hypothesis is that a high position of rule-imposer in the

system's organizational hierarchy calls for higher order rule solutions directed at rule-followers at lower levels. The lower levels in the organizational hierarchy translate these rules into lower level prescriptive action/state rules.

The incitements to the projects of the study fit in with this hypothesis: The Traffic-rule project with a rule-imposer positioned high up in the organizational hierarchy of the Norwegian railway system has got an incitement to apply goal-oriented rules positioned high up in the rules' hierarchy. The Maintenance-rule project with a rule-imposer at a mid range position has got an incitement to apply the mid range rule solution of triggering requirements.

However, in the theory presented above it remains a question at what level of the organizational hierarchies the translations from higher level rule solutions to lower should occur. The discussions above have also revealed that the link between the two hierarchies is not simple and straight forward.

3.3.2.2 Factors confusing hierarchical links

Theory discusses several elements that confuse the links between rules' hierarchy and organizational hierarchies.

A hierarchical organizational structure?

The hierarchical structure of a system can be questioned. The above discussions of Hale and his associates refer to hierarchies of activities or functions associated with safety management systems (Hale et al., 1997; Hale & Swuste, 1998; Hale et al., 2003). These do not necessarily parallel organizational hierarchies. Furthermore, Minzberg (1979) has illustrated that organizations might consist of at least five interacting parts. He sees the organization as a system of flow processes where the different flows can be in many directions that do not necessarily parallel the organizational hierarchy. The flow of formal authority might have a hierarchical structure while the operating work-flow, the flow of control information and decisions and the flow of staff information might have other features. Further he points to the important role of the flow of informal communication, work constellations and ad hoc decision processes. Lave & Wenger (1991) illustrate that there might exist important communities of practice based on what their members understand as important. These do not necessarily follow the formal organizational structures and division of tasks. In addition, the increasing reorientation from hierarchical systems towards more horizontal organizing and coordination and networking confuse the hierarchical picture (Ellström, 2001a).

Even though the Norwegian railway system has a tradition of a bureaucratic hierarchical organizational structure, the theories of Minzberg (1979) and Lave & Wenger (1991) illustrate that there might have been and still can be important flow processes and communities of practice that follow other structures. For instance, Section

2.2.demonstrates that the rule-developers of the former NSB often included a dialogue with their network within the organization in their modification work. The network was influenced by recruitment patterns and the educational system of the organization. Further, the division of the system into separate organizations and the increased use of subcontractors might result in different organizational solutions.

Characteristics of the system

The Norwegian railway system as such also holds certain conditions. In his Normal Accident theory, Perrow (1999) argues that technical systems can be evaluated with respect to two characteristics. The first of these is the system's degree of complexity versus linearity. This refers to the system's spacing of equipment and subsystems and their connections, access to substitutes when equipment or subsystems fail, features of control systems, features of information flow and the involved actors' understanding of the system. The second is that of tight or loose coupling. This refers to the system's vulnerability for delays and changes in the order of sequences, delays in supplies, equipment and personnel. It also refers to the system's access to and form of buffers, redundancies and substitutes and the limitations it puts upon possible methods to achieve goals. Furthermore, Perrow (1999) discusses the position of the railways along these axes and considers the complexity of railways as linear and the coupling as tight. As revealed, he argues that systems characterized by linearity and tight coupling are best when their coordination is centralized. Hence, his theory supports the practice of the former NSB with extensive use of centrally issued prescriptive rules.

Hale & Swuste (1998) build upon this theory of Perrow. They argue that when there is much interaction between individuals and small groups, it is important that these individuals or groups follow the same rules and the individuals or groups are spread over different physical regions or different organizations, action/state rules must be agreed and imposed at high levels of the system. Hale et al. (2003) discuss this and consider railways to be such a system. Also, in contradiction to the hierarchical approach, many of the Technical Specifications for Interoperability (TSI) at the European level are written as specific action rules (European Commission, 2004b). However, Hale et al. argue that to harmonize detailed rules across a distributed system will require that extra efforts to involve and inform the rule-followers of how and why the final rules have been arrived at.

The ongoing changes of the Norwegian railway system seem to influence its position regarding the characteristics of complexity versus linearity as described by Perrow (1999). In spite of linearity in activities, the division of the system and the new actors might create more complex communication patterns. The communication might be even more complex because the new organizations might develop different types of organizational structures. New actors, division of the system, pressure on costs of education and training and a less stable work force might also make the actors themselves experience the system as more complex than before. In addition the increased emphasis on cost-efficiency might cause a development towards tighter coupling of the regulated areas. This is apparent in reduced staffing and tighter timeframes that allow for less slack. According to Perrow

this development might create a tension between the modes of centralization and decentralization. This happens in a time when the division of the railway system also reduces the system orientation (DG Energy and Transport, 2000).

Furthermore, LaPorte & Consolini (1991) have studied organizational preconditions to safe and reliable operations in "High Reliability Organizations" (hereafter labeled HRO). These are organizations operating in high-risk contexts where prevailing structural properties of work tasks are ones of high complexity and tight coupling. These organizations had a work force of highly trained experts who were involved in intense consultation, mutual checking and communication about safe actions. Rosness (2001) termed this recovery capability "organizational redundancy". According to LaPorte & Consolini flexibility is one of the defining properties of such organizations. They related flexibility to resilience and competence that made it possible to switch between different modes of operation dependent on requirements of the situation.

Rosness (2003) discuss that the detailed prescriptive Traffic safety rules of the Norwegian railway system are a means to build organizational redundancy, i.e. to build a setting where most erroneous actions are detected and corrected by other actors before they lead to an accident. Further, with reference to Perrow's Normal Accident theory he discusses the role of detailed prescriptive rules as a means to coordinate safety critical activities when the technology is tightly coupled such as in the Norwegian railway system.

In addition, as revealed in Chapter 2 the work force of the system has been highly trained railway personnel. In some activities organizational conditions allowed for mutual checking and communication for instance in the former practice where there were two engine drivers in trains. However, as demonstrated the demands of cost-efficiency has caused pressure to shorten the railway education including the trainee periods and staff reductions, for instance as seen in the reduction of the number of engine drivers from two to one[22].

Translation of rules and democratic elements

The task to translate goal-oriented rules at the lower organizational levels and the democratic element of this can be questioned. As already revealed when discussing the inherent requirement of the different rule solutions, the translation from higher order goal-oriented rules to prescriptive rules implies a possibility to foresee potential dangerous situations and to identify what safe actions/states are. This includes that those involved in the task are capable of functioning at a knowledge based level. The translation also requires that there is sufficient time to make proper decisions. (See for instance Hale 1990; Hale & Swuste, 1998; Rasmussen & Svedung, 2000).

One challenge with the goal-oriented rules discussed in the Norwegian oil industry is that a to abstract and academic rule form might weaken possibilities for lay opinions (Hovden, 2002). In Norway inclusion of the lay opinion of the employees is regulated by law in the

[22] Information from interviewees

Working Environment Act (Arbeidsmiljøloven) (Friberg, 1995). As mentioned in Chapter 2, the Norwegian railway system has had a tradition to involve highly competent rail professionals in the rule modification work of rules directed at traffic safety, but not trade unions or operative staff in a more democratic sense. Furthermore, the Inspectorate has not emphasized the democratic elements in their application of the internal control principles on this field.

In addition, Hale et al. (2003) find that in the Dutch railway system, there is no such thing as a cohesive work group. This is attributed to the distributed nature of the system with constant traveling of the majority of the staff, limitations upon communication and the recent division of former monopolist into different companies. As will be described in Chapter 5 this is also a problem for the Norwegian railway system.

There is a question of trust when translating goal-oriented rules. Kirwan et al. (2002) question whether to discover and define risk is a task for the regulator or the regulated. They conclude that the preference seems to be placing this task with the creator and manager of the risk, not on the regulator. However, they raise the question whether this is satisfactory. They ask if actors can be trusted to discover and reveal their own problems, when this causes them to incur the costs to control them. The accident reports of the two recent serious railway accidents have also raised this question to the Norwegian railway system (Justis- og politidepartementet, 2000b). Furthermore, Rosness (2004a) questions whether competing organizations such as those of the Norwegian railway system are the most relevant actors to be responsible for the coordination and cooperation of risk control.

Rasmussen (1997) discusses the relationship between the rule-followers and their context. He argues that there is a danger that pressures of efficiency and least efforts might cause migration towards the boundaries of safe performance. Rasmussen & Svedung (2000) follow up this thinking and find it necessary to identify the decision-makers and actors who are involved in the control of the productive processes at the relevant levels of the system. The ongoing changes in the Norwegian railway system with organizational changes, division of the former system and new actors might make it more difficult to get an overview of decision-makers.

Inherent in the ongoing privatization process of the Norwegian railway system there is also an intention to prepare conditions that enhance competition. This includes making it possible for new actors to enter the field and to make the existing actors able to compete. Becker (2002) argues that it is not a simple task for the regulated organizations to follow up goal-oriented rules imposed upon them with local rules. Accordingly, the use of goal-oriented rules might favor organizations that already possess rules that can be seen to follow up goal oriented rules.

A potential problem for the cases

Even though the suggested rule solutions fit neatly into a hierarchical thinking of rule solutions and organizational hierarchies, the discussions above demonstrate that there might be a question of their suitability to the actual conditions. This raises the question for the study whether the cases faced the problem that the suggested rule solution did not fit the actual conditions. If yes, the follow up question becomes how they solved this problem.

3.3.3 A hierarchical top-down approach to the development of rule systems

The last element of the hierarchical approach is the direction of the task to develop rule systems. Should the development be driven deductive top-down or inductive bottom-up, in other words, should the development start with the higher order central rules and end with derived lower level prescriptive rules or the opposite? Or may be the development should combine the two approaches such as the internal control principles does?

There are many incitements in favor of a deductive top-down approach to rule development. First, when higher order rules are applied at the governmental level, this approach is often labeled self-regulation (Hopkins, 2000; Reason, 1997). It is up to the enterprise to work out how to achieve safety, the governments provide a legislative framework to achieve this outcome and remain willing to take enforcement action when necessary (Hopkins, 2000).

Second, Hale (1990), Hale & Swuste (1998) present the thesis to see the rule as a progressive limitation of freedom of choice; limiting first the goals, then how decisions are arrived at and finally limiting the actions themselves.

Third, Reason (1997) argues that the stage reached in the organization's life history will influence the opportunities for feed forward and feedback control modes. In the early stages the work will be governed mainly by trial and error and feedback control where the focus is on zero deviations between output measures and organizational goals. As organizational learning proceeds and the work becomes increasingly standardized, feed forward controls start to dominate feedback controls.

Fourth, as discussed, this approach is also an inherent element in the internal control principle (Flagstad, 1995; Hovden, 1998a). This implies a deductive top down approach to rule development. As both Hovden and Hopkins (2000) discuss, if democratic elements are included in the rule development, there might also be an inductive bottom-up element in this approach. However, the introduction to the Norwegian railway system revealed that this element is weak in the application of internal control principles upon traffic safety. Therefore, one can say that here the deductive top-down approach dominates.

Fifth, a degree of central top-down regulation is inevitable in order to achieve harmonization and allow inter-operability within the EU (European Commission, 2004b).

These five points constitutes the fundament for a hypothesis for this study that the projects will apply a deductive top-down approach to the rule development.

However, like many other elderly systems, the Norwegian railway system already has rules in the lower order prescriptive form but lack the higher order rules. The theory of Minzberg (1979) discussed above, indicates that these might have an important role in the system's coordination of activities. Also, Chapter 2 showed that the rules have an important role in the system's knowledge management, in particular regarding the education of railway professionals.

All together this discussion of the strategy for rule development and the situation in the Norwegian railway system illustrates a problem for the project. Which strategy to choose for rule development with incitements for a top-down strategy in a context where prescriptive rules already exists?

3.3.4 Problems revealed in theory

This theoretical introduction has so far enlightened four different elements of what is labeled a hierarchical approach to rule development in this study. They represent different types of hierarchy and the theory provides normative suggestions for solutions.

However, the theory illustrates that these normative suggestions are not simple and straightforward and the discussions above have revealed that a number of conditions might influence the modification work. An overview of the elements of the hierarchical approach, the normative suggestions and associated problems are illustrated in Table 3.1

Table 3.1 Hierarchies inherent in what is labeled the hierarchical approach, normative implications and related problems

Name of hierarchy	Type of hierarchy	Normative implications	Problems revealed
Rule solution	Type of rule solution: o High level management- and goal-oriented rules o Mid range mixed solutions or decision rules o Low level prescriptive rules	Different rule solutions require different competency both from rule-imposer and rule-follower. The rule solutions differ in their suitability to different contexts The rule solutions differ in their vulnerability to contextual changes	What if the suggested rule solutions do not fit the actual situation with respect to o Competency of rule-imposer o Competency of rule-follower o Rule context
Position of rule-imposer	Level of authority of the rule-imposer: o High level international and governmental level o Mid range company and management level o Low level operative management	High level rule-imposers impose high level rules Mid range rule-imposers impose mid range rules Low level rule-imposers impose low level rules	
Direction of rule development	Type of rule solution to use as starting point for the rule development	Start at higher order rules and deduce lower level rules from these	What work strategy to choose if low level rules already exist?

3.4 The risk-based approach

Safety rules are directed at the control of risk. As revealed in Chapter 1 the internal control and the hierarchical approach to rule modification requires some kind of risk assessment in the work to identify risks and decide means for their control. Further, as revealed in Chapter 2 the projects are directly required to apply risk analyses as decision support in the modification work.

However, this requirement needs a more thorough introduction. One reason is that the concepts of risk and risk-based can have different meanings. Another reason is that there exist different methods for risk analyses. In addition the requirement to apply risk analyses represents a change in the rule modification tradition of the Norwegian railway system that might solve some problems but not all.

3.4.1 Meanings of risk and risk-based

The fact that the concept of risk might have different meanings implies that there might be different conceptions of the term represented in the modification work. Furthermore, in the projects the application of risk analyses in rule modification work was not specified. Below, theory upon these issues will be elaborated.

3.4.1.1 The concept of risk

Due to the central role of the concept of risk it is a problem that there is no commonly accepted definition for the term "risk". Klinke & Renn (2001) discuss that the different meanings given to the term creates the immediate danger that when talking about risk, everybody talks about something different. As will be demonstrated in Chapter 7, this is also a challenge for the Norwegian railway system.

The different understandings of risk can be linked to history. Lupton (1999) argues that the concept of risk has changed its contents over time in accordance with the historical development and changing views of dangers, preventive means and perspectives upon rationality. She illustrates that the concept might range from the inclusion of everything to the perspective where risk is defined as probability multiplied with consequence. Shrader-Frechette (1991) links these extremes of the concept to the debate over what methodological norms, if any, guarantee the rationality of risk evaluation. The analysts are arrayed on a spectrum extending from the cultural relativists to the naïve positivists. According to her, the cultural relativists hold the position that risk evaluation is wholly relative, in other words the risk concept might include everything. They attempt to reduce risk to a sociological construct. On the other hand she finds that the naïve-positivists, maintain that risk evaluation is objective, in the sense that different risks may be evaluated according to the same rule, for example a rule stipulating that risks below a certain level of probability are insignificant, in other words the risk is a calculated entity.

In the risk assessment tradition that is derived from the nuclear and oil industries the two main dimensions of risk are the probability of occurrence of an unwanted event and the consequence of the anticipated unwanted event (Rausand & Øien, 2004). This has also been adapted to railways. SAMNET, a thematic network with the purpose to accompany EU harmonization in the railway transport field are on line with this and defines risk as "*Likelihood of an event occurring and its consequences*" (European Commission, 2003a, p 8).

However, the Norwegian railway system has a long history. To cover the historical development of the risk concept that is most probably reflected in the Norwegian Railway system, a wider definition is needed for the study. Klinke & Renn (2001) provide an alternative. They argue that all risk concepts share the distinction between reality and possibility and offer a definition of risk. According to them:

> *"Risk refers to the possibility that human actions or events lead to consequences that affect aspects of what humans value."*
>
> (Klinke and Renn, 2001, p 160)

This definition will be applied in the study. However, regarding the term "what humans value", the study will limit itself to look into risks that can cause accidents that harms people, railway material, railway infrastructure, properties outside the railways or environment, i.e. accidents mentioned in the Norwegian Railway Act (Samferdselsdepartementet, 1993). The discussion of the concept raises the question whether a wide inclusive or a narrow risk analytic definition of risk is applied in the modification work of the projects.

3.4.1.2 Risk-based and risk informed

The question of what is meant by the requirement that the projects' rule development should be based on risk analyses can be understood as if the results of the risk analyses serve as the core fundament for the decisions, i.e. it is completely risk-based. However, the limitations of risk analyses are highly recognized (See for instance Aven, 2003; Chapman & Dimitrijevic, 1999; Jaeger et al. 2001; Klinke & Renn 2001; Perrow, 1999; Rausand & Øien, 2004; Rouhiainen, 1993; Shrader-Frechette 1991). Therefore additional approaches are commonly used as decision support, for instance occurrence of accidents, redundancy and diversity of equipment and operator reliability (Chapman & Dimitrijevic, 1999). This means that risk analyses are seen as a useful but not sufficient instrument to support decision-making; it needs to be supplemented with additional strategies (Aven, 2003; Jaeger et al. 2001; Klinke & Renn 2001; Perrow, 1999; Shrader-Frechette 1991).

To emphasize the fact that risk information is not the sole basis for decision-making, the term "risk informed" is used for instance by the US Nuclear Regulatory Commission (NCR) (Apostolakis & Vesely (1999). Chapman & Dimitrijevic (1999) provide the following definition of risk-informed regulation:

> *"A regulatory approach in which deterministic principles and operating experience are used together with the analytical insights derived from probalistic safety or risk assessments to focus plant and regulatory attention on design and operational issues most important to safety and public health."*
>
> (Chapman & Dimitrijevic, 1999, p 251)

This illustrates that within the risk-based approach to rule modification, the risk analyses can be given different roles, i.e. the risk analysis results can be seen as the core foundation for the modification work or they can represent a supplement to the existing tradition.

When discussing probalistic risk assessment, Apostolakis & Vesely (1999) illustrate how this approach has focused on obtaining and managing dominant risk contributors. Those contributors that were not dominant were given low priority and did not attract much attention. Probalistic risk assessment can also be instrumental in identifying an unnecessary regulatory burden (Apostolakis & Vesely, 1999; Vesely, 1999).

The discussion above raises the question how the projects combined the existing evolutionary and practice oriented modification tradition with the requirement to apply risk analyses. This question is linked to the focus of attention in the modification work and the status of the risk analysis results compared to other possible inputs to the processes.

3.4.2 Risk analytic methodology

As already mentioned in the introduction, the risk-based approach belongs to the analytic management strategies developed for large-scale accidents (Rasmussen, 1997; Rasmussen & Svedung 2000). According to Rausand & Øien (2004), the influential oil industry builds upon methodology developed for the nuclear power industry. They explain that risk analysis is a method to identify and evaluate the possibility of unwanted events (also called accidental events) that can lead to damage upon humans, environment and material values. It can be qualitative and/or quantitative and have different levels of detail. They find the three core questions of a risk analysis to be:

a. What unwanted events might occur?
b. What are the causes of the occurrence of each unwanted event?
c. What can the consequences become if the unwanted events occur?

Rausand & Øien (2004) present the most commonly used methods. Checklists, Preliminary Hazard Analyses (PHA), FMECA (Failure Mode, Effect and Criticality Analysis), HAZOP (Hazard an Operability Study) and Accident statistics are commonly used methods to answer question (a). Fault Tree Analysis, Reliability Block Diagrams, Influence diagram, FMECA and data banks are commonly used methods to answer question (b). Event Tree Analysis, Consequence estimates, Reliability calculations, Models for evacuation and Simulation are commonly used methods to answer question (c).

Further, they comment that what are considered to be risk analytic methods varies between the different uses of these. In one connection a method can be called a reliability analyses while the same method can be called a risk analytic method in another. The term RAMS-method is commonly used (Reliability, Availability, Maintainability, and Safety). For instance many industries have implemented the RCM (Reliability Centered Maintenance) methodology to improve the cost-effectiveness and control of maintenance and hence to improve both availability and safety (Høyland & Rausand, 1994).

The research of SAMRAIL has revealed that the risk management approaches used by the railways are very similar to each other (European Commission, 2004c). They identify

six main steps in these approaches. Generally, a Bow Tie Model is used to explain these steps. The hazardous event occupies the center of the Bow Tie. Its left hand side contains the causes that potentially lead to the hazardous event. Also shown on this side are the controls or barriers to the hazard, i.e. preventive controls. The right hand side of the Bow Tie contains the event tree, which shows various outcomes that can potentially occur and the controls and barriers that are in place to limit or reduce their consequences. These are also called reactive controls or mitigation measures.

The SAMRAIL research illustrates that the preference of the studied European railways is for effective proactive control measures but reactive control is also essential to minimize harm in case a hazardous event accidentally slips through (European Commission, 2004c). The three types of risk analytic methods most commonly used are quantitative, qualitative and semi-qualitative. It is believed that there is no uniformity or consistency in their application. As selection criteria for control measures to address risk acceptance, different risk acceptance principles were used. Presently, scenarios used to identify hazards are not consistent with each other.

When discussing safety rule modifications, the SAMRAIL project suggests defining all of the significant ways in which the railway system can deviate from its ideal and safe operation (scenarios), so that accidents or other damage occurs (European Commission, 2004b). Based on this, risk analysis decisions must be made about which control measures can and will be taken to eliminate, prevent and mitigate the effects of these scenarios. The project considers that an important question to be resolved is the scope of the analyses, the coverage of potentially harmful results and hence the scope of the defined scenarios.

In the studies of safety rule modifications in European railways, the SAMRAIL project found that there is a lack of systematic identification of risk scenarios on a formal level. Typically people with a lot of experience within the railway system have the job to develop and write rules. Experience is a great advantage. However there is not much system and no theoretical education present in these matters. (European Commission, 2004c).

With respect to the question of the quality of the risk analyses, Rausand & Øien (2004) argue that the stronger the ownership to the analyses is at each level of the system, the better the quality of the analyses will be. They consider it important that the authorities deal actively with the analyses and the analytic processes. When the Safety case regime was introduced for the British railway system, Railtrack required that the highest levels of the traffic operators' management were able to present and explain their safety case and to answer related questions (Maidment, 1998). Rausand & Øien (2004) comment that inherent in such a requirement of ownership to the top there is also another requirement. This is that the management ensures involvement of people with sufficient competency of both the railway system itself and risk analytic methodology in the work. They range the railway competency as the most important. The Synthesis of the SAMRAIL findings comments that the use of standard risk analytic techniques and tools in the railway sector

requires special knowledge and that their effectiveness depends upon experience (European Commission, 2004c).

Furthermore, uncertainty is a problem for the risk analytic methods and it is not fully solved (Aven, 2003; Klinke & Renn, 2001; Scrader-Frechette, 1991). A related problem is that most risk analytic methods have their main focus on the direct cause of unwanted events and give limited attention to the underlying causes, for instance organizational changes (Rausand & Øien, 2004).

The discussion of the different risk analytic methods and the quality of the risk analyses raises the question of trust in the risk analytic methodology and results. The question of trust is also related to the attitudes of the participants. Rausand & Øien (2004) comment that risk analysis will always influence attitudes of the participants in the work. They also comment that this might be the most important result of the analyses.

This discussion about risk analytic methods and results implies that risk analyses can result in other results than conclusions drawn from other sources of knowledge. This raises the question whether the risk analyses fit in with the risk perception of those involved in the work or not. An associated question is how these people solve such problems if they occur.

3.4.3 What is new?

As revealed in Chapter 1 and 2, the internal control principle and the hierarchical approach applied in the Norwegian railway system calls for some kind of risk assessment as decision support in rule modifications. However, in theory the arguments for a risk-based approach go further than this.

The most important argument has parallels to the ongoing changes of the Norwegian railway system with the related changes. As already revealed in Chapter 1, Rasmussen (1997) and Rasmussen & Svedung (2000) argue that under conditions of rapid change the empirical management strategy faces problems. As the experiences of the past might not be suitable for the present situation they recommend more analytic management strategies. When control measures are introduced on the basis of risk analyses, the input to the control is not obtained directly by measuring the system performance, but indirectly through anticipation (Kjellén, 2000).

Furthermore, the privatization process of the Norwegian railway system has created a more competitive environment for the system. As already touched upon in Subsection 3.3.2 Rasmussen (1997) argues that under such conditions there is pressure from the combination of increased efficiency and least efforts that might cause the behavior of the involved actors to migrate towards the boundaries of safe performance. He sees the analytic strategy as a means to counteract such a development.

An important attribute of risk analyses is that they are systematic (Kjellén, 2000). Therefore, performing risk analyses implies a transfer of knowledge into the norms for the systematizing of the chosen risk analytic method, i.e. knowledge will be included and organized in accordance with the framework of the method. Further, implicit in the role that risk analyses play in internal control and the requirement that they are systematic, is a requirement that they are documented in a written form. Many methods provide ready-made schemas for the work. Hence, one can expect that the introduction of risk analyses to rule modification will influence the focus of attention and the organizing of knowledge about regulated activities and related risks. One can also expect the derived information to be transferred into a written form. Theories of knowledge will be further elaborated in Section 3.5.

However, in spite of the evolutionary and often experience-based rule tradition of the Norwegian Railway system, risk assessment was not a completely new approach for the system. As illustrated in Chapter 2, attempts were made to foresee risks when new technology was introduced and followed up with accident preventive steps, for instance by introducing rules. Risk assessment was also not new to railway systems in general, a primitive form of risk assessment had been practiced (Perrow, 1999). What was new was the introduction of the very academic and expert dominated risk assessment methods primarily developed for the oil industry. As revealed above, to perform analyses of good quality it is necessary that the rule-developers possess good knowledge of their methodology (European Commission, 2004c; Rausand & Øien, 2004). Further, the new methods represent an increased emphasis upon the future and a systematizing of knowledge in accordance with chosen methods (Kjellén, 2002).

3.4.4 Problems revealed in theory

This theoretical introduction to the risk-based approach has demonstrated that it is followed with some problems. An overview of the new aspects of the risk-based approach, normative implications and revealed problems are illustrated in Table 3.2.

Table 3.2 New aspects of the risk-based approach, normative implications and revealed problems.

New aspects	Normative implications	Problems revealed
New definition of the risk concept	Apply a less inclusive concept of risk than before as fundament for the work	What risk perspective to apply; a wide inclusive definition or the narrow risk analytic?
Risk analyses as decision support in modification processes	Use the risk analysis results as input to the rule modification, either as the core input or as one of more inputs.	How to combine expert dominated risk analyses with rule development in an evolutionary practice oriented modification tradition? What if the risk analyses do not fit the risk perception of those involved in the modification work?

3.5 Knowledge and rationality

In both the hierarchical and risk-based approaches decision-making is a central topic. Higher order outcome-oriented rules require decisions about what actions fulfill the requirements. The risk analyses are supposed to serve as support to these decisions.

As already indicated in Chapter 1, perspectives upon rationality and decision-making are related to perspectives of knowledge (March, 1994). This means that the increased emphasis upon rationalistic, choice based decision-making that the new approaches represents, also implies a change in knowledge perspectives. Therefore the introduction to theory of knowledge will start with an introduction to perspectives of both rationality and knowledge.

A central concept for the study is railway knowledge. This concept will be elaborated throughout this subsection and described more thoroughly in Subsection 3.5.6.

3.5.1 Perspectives of knowledge and rationality

As indicated, theory discusses different perspectives upon knowledge and rationality. However, theory also discusses limitations of different perspectives. These discussions will be elaborated here. Finally, the positions of the Norwegian railway system and the hierarchical and risk-based approaches within these perspectives will also be discussed.

3.5.1.1 Different perspectives upon knowledge and rationality

As demonstrated in Chapter 2, the former NSB had a bureaucratic tradition and its rule tradition fits in with the descriptions that Weber (2000) has given of such systems. He finds that in bureaucracies there is a strong belief in validity of legal laws and in objective competence that builds upon rationalistic rules. The normative ideal is judgments based on expert knowledge. As Chapter 2 revealed, in the Railway tradition the experts have been railway personnel who are respected in the system for their professional skills based on extensive practical experiences and railway educations or courses. Some held also external technical educations. They developed rules that gave rather comprehensive descriptions of what to do at the operative level.

Schön (1991) discusses professional knowledge applied in different fields including bureaucracies. He links this knowledge to technical rationality. This is a rationality that he describes as instrumental problem solving that is made rigorous by the application of scientific theory and technique. He argues that the systematic knowledge base of a profession of technical rationality is thought to have four essential properties. It is specialized, firmly bounded, scientific and standardized. The expertise is grounded in a cumulative empirical knowledge about the means best suited to chosen ends in stable contexts. Further, he finds that professional knowledge is seen as consisting of a hierarchy. Here "general principles" occupy the highest level and "concrete problem solving" the lowest.

However, Schön (1991) discusses how professionals think in action by reflective conversation with the situation, i.e. how they think in concrete problem solving situations at the lowest knowledge level. He demonstrates that when professionals discover phenomena that are incongruent with the initial problem setting they inquire into these. Evolving hypotheses are tested by experimental actions which also function as moves for shaping the situation and as probes for exploring it. Continuity of inquiry entails a continual interweaving of thinking and doing. He labels this form of rationality as Reflection-in-Action.

March (1994) sums up later theoretical discussions of rationality in relation to decision-making. He points to the views of rationalistic theories of choice based decision-making and the modified version of limited or bounded rationality. These forms of decision-making are preference based and supposed to apply the logic of consequence. This means to analyze possible alternatives and to choose between them in accordance with their contribution to preset goals or preferred consequences. Hence it is linked to utility. He argues that the logic of consequence makes great demands on the abilities of individuals and institutions to anticipate the future and to form useful preferences.

This scientific nature resembles the highest level of technical rationality of Schön (1991) described above. The strategy here is "First thinking and then acting" and Ellström (1996) labels the knowledge perspective of this tradition "rationalistic". He finds the dominating knowledge base of rationalistic knowledge to be theoretical and explicit and the treatment

of information to be analytical. In later discussions the highest level of technical rationality and choice based decision-making will be labeled “rationalistic”. Drawing upon the terminology of Ellström, the associated knowledge perspective will also be called “rationalistic”. Explicit, theoretical knowledge grounded upon this perspective will be called “rationalistic knowledge”.

March (1994) also points to the view of rule- and identity based decision-making. He links this to the logic of appropriateness that is to establish identities and to match rules to recognized situations. The logic of appropriateness puts great demands on the abilities of individuals and institutions to learn from the past and to form useful identities. Here the past is seen as imposing itself on the present through retention of experience in routines. Rules are seen as residue of the past. He argues that the rule- and identity based approach to decision-making fits with modern experiences of socialization and education of individuals into rules associated with the different roles of the decision-makers. The emphasis upon the dialogue with the actual situation resembles the Reflection-in-Action that Schön (1991) identified for concrete problem solving. The strategy here is to build upon familiarity and experience and Ellström (1996) labels the knowledge perspective of this tradition “intuitively-contextual”. Here Ellström finds the dominating knowledge base to be experience-based and implicit or in other words tacit. The information treatment is intuitively. In later discussions rationality that parallels Reflection-in-Action and rule- and identity based decision-making will be labeled “rule- and identity based”. Again, drawing upon the terminology of Ellström, the associated knowledge perspective will also be called “intuitively-contextual”. Tacit, practical knowledge grounded upon this perspective will be called “intuitively-contextual knowledge”.

Ellström (1996) underlines that his two categories of knowledge perspectives is a simplification. They represent complementary ideal typical views that are not mutually exclusive. Furthermore, March (1994) argue that both choice based and rule- and identity based forms of decision-making processes organize an interaction between personal commitment and social justification. He finds that choice based decision-making can be seen as a special form of rule- and identity based decision-making where the choices are made according to the rules of rationality.

3.5.1.2 Limitations of the discussed perspectives and calls for alternatives

Jaeger et al. (2001), Perrow (1999) and Schrader-Frechette (1991) discuss the role of the rational choice based tradition in the work of accident prevention and risk assessment. They show how this perspective is linked to considerations for economic utility. Their conclusion is that this rationality is not sufficient to deal with all types of risk. The tradition is criticized for not giving attention to the way risks are actually generated in organizations. Furthermore, they demonstrate the danger that concerns for cost-efficiency might confuse the attention to safety and that this approach might not take the interests of potential victims into consideration. In addition, March (1994) claims that within the theories of choice based decision-making, there is a tendency to ignore the rich processes by which rules are created, maintained, interpreted, changed and ignored.

The criticism of the rationalistic approach to decision-making both in general and in relation to risk assessments, has created discussions of alternatives. These have the common feature that they recommend to combine different perspectives in to take advantage of their potential gains.

March (1994) finds the logics of consequence and the logic of appropriateness are not distinguished by differences in their status as thoughtful action. He argues for a combination of the two logics.

On the same track Ezioni (1967) argues for a combination of rationalities and proposes a method of Mixed-Scanning. His approach extends the incrementalistic trial- and-error decision-making discussed by Lindblom (1959) under the heading “Muddling through”. However, as LaPorte & Consolini (1991) discuss this approach is only acceptable under certain conditions. This is when errors resulting from operational or policy discussions are limited and the consequences are bearable and reversible, with the costs less than the values of the improvements learned from feedback analyses. If not they find that the alternative is to strive for trials without error.

Shrader-Frechette (1991) argues for procedural reforms that includes risk negotiation and adversary assessment. Her advice is to take advantage different perspectives including those of risk analytic expert and potential victims. Perrow (1999) argues for an introduction of a third type of rationality that he labels social and cultural rationality. This emphasizes diversity and social bounding. Jaeger et al. (2001) also argue for supplying the rationality of the risk assessments with rationalities of other knowledge traditions. This solution makes it possible to take advantage of other forms of intelligence that might give positive contributions. However, they do not find these knowledge traditions mature enough to take over for the rational actor paradigm.

Klinke & Renn (2001) discuss the challenges of complexity, uncertainty and ambiguity or ambivalence. Regarding complexity they direct the attention towards expert based risk assessment. If the problem includes uncertainty they focus on knowledge acquisition and advice a broader involvement. If ambiguity is also a problem, they call for even more discursive strategies that also include representatives of potential victims.

Accordingly, these theories advocate for inclusion of different perspectives and actors in the safety work, and in particular under conditions of complexity, uncertainty and ambiguity. They also advocate for a search for decision-making process where the different perspectives, knowledge resources and interests associated with the actual risk are represented and participate in discussions, i.e. a discursive strategy. Klinke & Renn (2001) suggests that such a strategy might include strategies for consensus building, confidence building, introducing substitutes, improving knowledge and contingency management.

These theories have the core focus on environmental risk. However, their reasoning has parallels to the ongoing development within the railways. Furthermore, the Lillestrøm

accident where the whole center of the city could have blown up, provided an example of how extensive the consequences of rail accidents can be.

3.5.1.3 The perspectives of the Norwegian railway system and the new approaches

The Norwegian railway system can be seen to combine different perspectives of rationality and knowledge. Chapter 2 demonstrates that the bureaucratic tradition of the system was influenced by technical rationality that involved different levels of knowledge such as Schön (1991) describes. For instance this is seen in the recruitment of both engineers with a theoretical education, the internal education system and the use of accumulated knowledge derived from experiences with the system. Prescriptive rules held a strong position.

Chapter 2 also revealed that in the rule development the system has strived for increased safety. However, it also paid attention to practical concerns. The rule-developers had the task to decide what could possibly make the rail traffic run safe and smooth. This implies that an anticipatory element and logic of consequence was applied. Accordingly the rationalistic perspective of decision-making has been operative. The decisions were influenced by the theoretical and practical knowledge of those involved in the work. Experience-based intuitively-contextual knowledge of the practical railway field was combined with academic knowledge from the engineering field.

However, the introduction to the Norwegian railway system demonstrated that extensive practical training and trust was required to get the necessary position as railway expert and participate in the rule development. Accordingly, practical knowledge had a high status and the participants were well adapted or socialized to the railway system. Those participating in the rule development based the work upon cumulative empirical knowledge of the system's functions and risks that they themselves and their network possessed. To a great extent this knowledge was derived from experiences with operative actions and dangers and concrete problem solving. They used this comprehensive knowledge and understanding of the railway system's functions to analyze and anticipate possible effects of alternative strategies for increased safety.

The problem solving that was demonstrated in the work of rule development gives associations to the descriptions that Schön (1991) provides of Reflection-in-Action. The descriptions also show that logic of appropriateness and accumulated practical knowledge has held strong positions in the rule development. Accordingly, in spite of its rationalistic elements the rule development has been dominated by rule- and identity based decision-making where intuitively-contextual knowledge has been the main contributor. This conclusion is supported by Perrow (1999) who comment that in general risk assessments of railways held a primitive form compared to the more academic tradition of risk assessments founded on perspectives of absolute rationality.

As already discussed in Chapter 1 and the previous sections of this chapter, the hierarchical and risk-based approaches are grounded in the rationalistic choice based

decision-making tradition. Hence, the introduction of these approaches to rule modification implies a strengthening of rationalistic decision-making and knowledge in the processes.

Regarding the hierarchical approach, the background for its application in traffic safety has been linked to a deductive strategy where the lower order rules are supposed to be derived from those at the higher orders. Furthermore, it requires that the higher order rule-imposers are able to specify goals of importance for safety. It also requires that the rule-followers are able to translate these rules into decisions about how to fulfill the goals. Accordingly, the rule-followers must be able to answer questions of how they identified their risks and how they have elaborated possible means to control risk, the efficiency of these means and chosen between the alternatives.

Regarding the requirement of a risk-based approach this implies to apply the rationalistic procedures of risk analytic methods. As already discussed in Section 2.2 and 3.4, academic risk analytic experts with backgrounds from the oil industry hold strong positions in this field. Chosen methods provide a framework that defines which elements of knowledge will be taken into consideration and how these elements are systematized, expressed and documented.

To summarize, the dominating perspectives of rationality and knowledge in the rule tradition of the Norwegian railway system can be contrasted with the dominating perspectives of the hierarchical and risk-based approaches like this:

K N O W L E D G E

R A T I O N A L I T Y	*Rationalistic*	*Intuitively - contextual*
Rationalistic	Hierarchical and risk-based approahces	
Rule- and identity based		The tradition of the Norwegian railway system

Figure 3.2 The positions of the tradition of the Norwegian railway system And the hierarchical and risk-based approaches with respect to rationality- and knowledge perspectives

However, the figure represents a simplification. As discussed, the system has also had rationalistic elements and particularly in the form associated with technical rationality.

Figure 3.2 illustrates that the introduction of the two approaches can be seen as a strengthening of rationalistic, choice based decision-making in the predominantly rule- and identity based railway tradition. Furthermore, it can be seen as a strengthening of the rationalistic knowledge perspective in the predominantly intuitively-contextual tradition. Accordingly, the projects are left with the question of what knowledge base to apply as decision support in the rule development. The question to the study therefore becomes: What knowledge perspective(s) were applied in the modification work?

3.5.2 Differences in status of knowledge

The balance between rationalistic and intuitively-contextual knowledge and their different status is a subject for discussions in the literature. Schön (1991) is one contributor to these discussions. He argues that the general principles of professional knowledge in technical rationality occupy the highest status while the concrete problem solving holds the lowest. Further he argues that his theory of how professionals reflect and learn in action changes the status of professional experts with respect to their claim of authority and extraordinary knowledge that is isolated from action. Instead they have to accompany the professionals in their reflection in their actions in a reflective conversation. Here the professional expert recognizes that the expertise is embedded in a context of meanings where both the practitioner and the expert have a capability to know and plan. The expert join the practitioner in inquiring into problematic situations that needs to be solved. According to him practitioner may become reflective researchers in situations of uncertainty, instability, uniqueness and conflict.

Perby (1995) attacks the dominance of analytical thinking. The world of professional knowledge does not follow the logic that is connected to the analytical way of thinking where knowledge is divided, separated and bounded. She argues that the development of knowledge does not necessarily follow the “academic sequences”. Practitioners think in terms of practical situations. Much like Schön (1991) she finds that the professional knowledge is characterized by an unbroken wholeness of issues related to each other and connections that are essential to the practice and thereby impossible to separate.

However, the rationalistic knowledge is also seen to have an important role. Learning by experience appears to presuppose explicit knowledge that can not be acquired by experience. Zuboff (1988) argues that theoretical knowledge about production states improved the workers’ ability to understand information from the production process about variables and their interaction. Ellström (2001b) explains that learning by experience presupposes conceptual tools and explicit knowledge about the task and the work process. This can be used by the learning subject to identify and interpret experiences. Schön (1991) argues that there are kinds of research which can be undertaken outside the immediate context of practice in order to enhance the

practitioners' capacity for reflection-in-action. He mentions four different directions that this research that he labels reflective can have. First, it can be directed towards the ways in which practitioner frames problems and roles. Second, it can serve a function of accumulating and describing theories of action, modes or phenomena or techniques of control. Third, it can study fundamental methods of inquiry and overarching theories. Fourth, it can study the process of reflection in action.

This discussion implies that both rationalistic and intuitively-contextual knowledge seems to be important for good performance and hence for the task to develop good rules. As already discussed in Chapter 2 and the previous subsection, the expertise of the Norwegian railway system has been based on a combination of technical education and railway education and extensive practical experience has had a high status. The discussion of Ryggvik (2004) presented in Chapter 2, Subsection 2.2.2 illustrates that the Inspectorate and their emphasis upon the new approaches introduced another expertise to the modification work. This expertise had a highly rationalistic background originating from another context that according to the argumentation of Schön (1983/1991) and Perby (1995) often is associated with the highest status. The high status of the knowledge tradition of the new approaches leads to a hypothesis that this tradition will have a strong position in the modification work of the projects.

3.5.3 Differences in descriptions of knowledge

The discussions of Schön, (1991) and Perby (1995) in the two previous subsections demonstrates that different perspectives upon rationality and knowledge can be associated with different ways of expressing knowledge. The expertise of technical rationality described by Schön is concerned about providing description of general principles. These are rather context free and needs to become translated into the actual context. Furthermore, as Perby argues the rationalistic way of thinking divides knowledge, separates it from its context and makes it bounded.

On the other hand, Schön (1991) and Perby (1995) find that the concrete problem solving where the general principles are translated into the actual contexts and the wholeness is taken into consideration is given less attention. Baumard (1999) argues that organizations generally reduce their rich knowledge to information, measures and standards. The production of knowledge is subject to this reduction of complexity. He points at the problem that organizations manage the codification of knowledge rather than knowledge.

In addition, referring to his own terminology of absolute rationality and social and cultural rationality Perrow (1999) argues that different rationalities are associated with different types of descriptions of the system in focus. According to him, both absolute and bounded rationality create quantitative, precise, logically consistent, economical and value-free descriptions of the system. He classifies these descriptions as thin compared the descriptions that he associated with the social and cultural rationality. According to him, this type of rationality emphasizes diversity and cultural bounding. This creates thick descriptions where subjective dimensions and cultural values are recognized.

These theories indicate that the higher status and general emphasis upon rationalistic rationality and knowledge together with the tendency to reduce rich knowledge, represent forces that can pull the Norwegian railway system in a direction towards less context related, more rationalistic thin descriptions of the system. As revealed, the hierarchical and risk-based approaches also represent forces of the same direction. First, the projects started out with incitements to apply goal-oriented rules and triggering requirements as rule solutions. These solutions represent more abstract and thinner descriptions than the prescriptive rules. Second, the selection and systemization of knowledge that the risk analyses represent might reduce and divide thick descriptions of the reality. This happens in a period where the ongoing changes of the system have put the educational system under pressure to reduce the varied practice that also contributes with thick descriptions.

Perrow (1999) links the forms of describing systems to his Normal Accidents Theory. The thin descriptions are consistent with component failure accidents. These are accidents caused by failures that are predictable and understandable and in an expected production sequence. He argues that complex and tightly coupled systems are exposed to system accidents that involve different parts, units and subsystems of a system. According to him, thick descriptions reflect the nature of such accidents as the thick descriptions show skepticism about man-made systems and institutions and emphasize social bonding and the tentative, ambiguous nature of experience.

Perrow (1999) classifies rail transport as systems dominated by linear interactions with tight coupling. As already discussed in Subsection 3.3.2, the current development of the Norwegian Railway system indicates that the system is moving in a more complex and tight direction. Based on the Normal Accidents Theory one could therefore expect the preference for descriptions of the system to move from thin to thick. However, the introduction of the new approaches seems to represent a move in the opposite direction. If that is the case, Normal Accident Theory indicates that the combination of a move towards a more complex and tightly coupled railway system and thinner descriptions of that very system might make the system more prone to system accidents.

Also, at the more individual level and as already revealed in Subsection 3.3.1, Rasmussen & Svedung (2000) underline the importance of mental models of system function at the knowledge based level of functioning. This is the type of functioning required from the higher order rules. These are less visible in the thin descriptions of rationalistic knowledge.

This discussion indicates that there are forces that might pull the Norwegian railway system towards rationalistic thinner descriptions at the same time as the current development of the system calls for thick descriptions. Accordingly, a hypothesis for the study is that the projects will emphasis thin and written descriptions of the system, the activities and associated risks.

3.5.4 Creation of organizational knowledge

As mentioned in the introduction to the study, safety rule modifications can be seen both as a result of and as a part of a learning process, i.e. they are closely related to knowledge creation. Hence they are both dependent upon learning and represent potential for a positive contribution to railway knowledge. However, a SAMRAIL report discussing organizational learning from accident and incident reporting argues that the increased organizational complexity of railways in Europe has created barriers for organizational learning (European Commission, 2004a). The report underlines the importance of finding solutions that counteract the negative impact of the reorganization of the railway systems upon former learning arrangements. This directs the attention towards conditions for knowledge creation in the projects.

Below, theory of knowledge creation is discussed and related to the conditions of the Norwegian railway system.

3.5.4.1 Learning through transition between knowledge forms

In the theoretical discussions there has been increasing interest in the different forms that knowledge can have and their functions. Polanyi (1966b) emphasized tacit knowledge. Based on this distinction from explicit knowledge, Nonaka & Takeuchi (1995) argue that knowledge may be created by a continuous dialogue between tacit and explicit knowledge and describe four transitions between these two knowledge forms. The creation of organizational knowledge is the integration of these transformation processes, and develops along the dimensions of tacit and explicit knowledge and from the individual to the organization. They argue that none of the four forms of knowledge is sufficient in itself.

Baumard (1999) has developed the theories of Nonaka & Takeuchi (1995) with discussions of the interplay between the individual and collective tacit and explicit knowledge. He distinguishes between four inseparable types of knowledge. These are individual explicit knowledge, collective explicit knowledge, collective tacit knowledge and individual tacit knowledge. He argues that tacit knowledge plays a central role in our learning processes, although we are not conscious of it. He also finds that tacit knowledge is also instrumental to foster “unlearning” by consciously conferring upon knowledge that is by nature unconcious. He provides this illustration of the types of knowledge and their interaction:

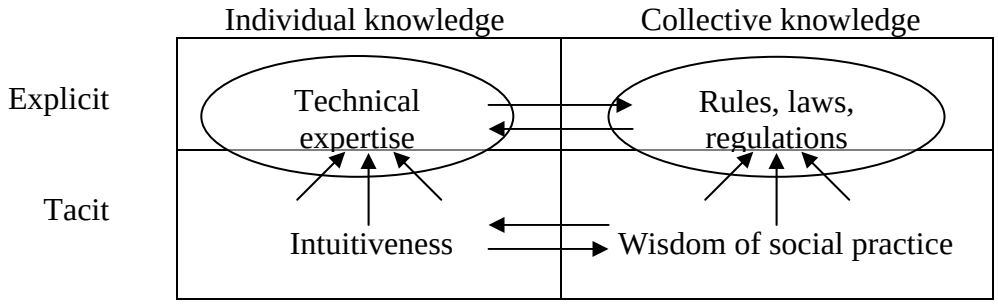


Figure 3.3 Four inseparable types of knowledge (Baumard, 1999, p 66, Figure 3.1, reproduced with author's permission.)

The arrows of influence in this figure of Baumard illustrate that the process of developing safety rules can be a process of learning and transferring collective and individual tacit knowledge and explicit individual knowledge into collective explicit knowledge.

According to Baumard (1999) the means for transitions from tacit to explicit might be an individual or a collectivity that functions as an articulator. This presupposes an organizational configuration to facilitate it. He also argues that changes can cause ambiguity that lead to articulation. In addition knowledge forms might compete and come into conflict with each other and cause ambiguity during transition processes. An articulator or a reader of the knowledge that is visible to some and invisible to others might solve this ambiguity.

The modification projects might represent organizational configurations such as transitions of knowledge require. Rule modifications imply changes that can cause ambiguity. Also, as discussed in Section 3.3, 3.4 and this section, the ambitions to introduce hierarchical and risk-based approaches to the rule modification represent additional elements of change.

However, the aim to make tacit knowledge explicit and to share tacit knowledge is opposed; all knowledge cannot be codified and made explicit and the two forms serve different functions (Baumard, 1999; Perby, 1995). Baumard (1999) finds it useful for organizations to change between dominating forms of knowledge according to the situation of the organization. He argues that the tacit knowledge does not need to be verbalized to be acted. Sometimes the tacit resources are most influential when left aside from the explication process of organizations. Further, he resists prescriptions which enforce tacit knowledge into destructive explanations. When remaining tacit they give more space for experimentation and action, a situation that might create learning and knowledge of new solutions. According to him one of the essential roles of tacit knowledge is the maintenance of organizational flexibility.

Ellström (2001b) underlines this dilemma of the codification or non codification of knowledge into rules. He shows that from a learning perspective there are different meanings regarding the question of formalization or publishing written rules and instructions. These range from considering formalization as likely to seriously impede organizational learning to viewing formalization as an important condition for quality development and organizational learning.

The interaction between knowledge forms and the role of tacit knowledge can also be associated with the discussions of rule-followers' competency and related needs for rules and suitability of different rule solutions that were discussed in the sections 3.2 and 3.3. No rules and higher order abstract rule solutions give freedom to make tacit knowledge come into play and for experimentation. The more rigid prescriptive rules limit this freedom. However, tacit knowledge might also play an important role in the ability to recognize the situations where rules are relevant (Hale, 1990; Rasmussen & Svedung, 2000).

The freedom to apply tacit knowledge that the higher order rule solutions allow for might be a two edged sword. The purpose of prescriptive rules is to limit the action space. Again this actualizes the question of LaPorte & Consolini (1991) about striving for trials without errors discussed in Subsection 3.5.1. As touched upon in Subsection 3.3.2, Rasmussen (1997) has illustrated that experimentation of involved actors might cause a migration towards the boundaries of safe performance. The prescriptive rules might prevent dangerous choices that can contribute to such a development. On the other hand, Rasmussen (1997) illustrates that the flexibility can be very useful for the adaptation to changing conditions and coping with the boundaries. However, this requires that the actors hold mental maps sufficient to understand the full consequences of their actions. As Rasmussen points out, this requires that they have the capability to function at the knowledge based level. Further this requires that they receive sufficient information about the status of the system to have full and updated mental maps and time to decide.

Taken together these discussions reveal that rule modifications represent an opportunity for knowledge transformation and learning. However, this requires that individual and collective, tacit and explicit knowledge are taken into consideration and that the knowledge forms can interact. The increased emphasis upon rationalistic knowledge of the development and the new approaches has raised the hypotheses that the projects will emphasis thin descriptions and written knowledge. This implies a favoritism of the collective and explicit knowledge form. This favoritism and the discussions above raise the question: What knowledge forms were emphasized in the modification work of the projects?

3.5.4.2 Learning through feedback and inquiries

Other theories emphasize the important role that feedback and inquiries play in organizational learning. Important exponents for this perspective are Argyris & Schön (1996) According to them organizational learning can be approached with a feedback

perspective where evaluation of outcomes and inquiry into these and problematic organizational situations are important elements. Individual inquiry feeds into and helps to shape organizational inquiry carried out by individuals. According to them an organization's learning system must contain feedback upon results of action. In addition, most organizations must develop their organizational ability from defensive to productive. The means to achieve productive learning suggested by Argyris & Schön resemble the ideals of rationality. This means to turn tacit knowledge into explicit and to develop it in accordance with the results of the inquiries. An open dialogue based on trust and confidence is emphasized. Ellström (2002) underlines the importance of time and knowledge as learning resources.

In theories of organizational learning the results are evaluated with respect to the character of changes in organizational practice. These characters are often classified as higher or lower orders of learning where the higher orders represent the most substantial changes and are considered the most difficult to achieve (Argyris & Schön, 1996; Ellström, 2001b; Hedberg, 1981). Hedberg (1981) calls irreversible substantial changes "turnaround learning".

Ellström (2001b) is concerned that the notion of feedback seems to have a somewhat paradoxical function in relation to learning. He distinguishes between adaptive and developmental forms of learning. While feedback is necessary in relation to adaptive forms of learning, it is both difficult to achieve and might impede the more developmental forms of learning.

The feedback perspective is also much applied in safety work (Kjellén (2000). As illustrated when discussing the practical experience-based tradition of the railway system, the feedback approach has been used in the Norwegian railway system, in particular in relation to experienced accidents. SAMRAIL research focusing upon Safety management systems revealed three learning systems, that is to say systems for feedback (European Commission, 2003b). These are first the auditing and management reviews, second the inspections and the monitoring of technical and behavioral risk barriers and controls and third the incident and accident registration and analyses. In addition the SAMRAIL research upon regulations, roles of rules and their unification revealed that instructors can contribute with feedback upon the efficiency of existing rules (European Commission, 2004b).

Hale et al. (2003) have included a feedback learning loop in their framework for research upon safety rule modification in the Dutch railways. Their studies revealed that the geographically distributed nature of the system makes it difficult to organize feedback about existing rules. This framework is further elaborated in the SAMRAIL study referred to above (European Commission, 2004b). In the European railways included in that study, unclosed learning loops were revealed.

In addition, an open dialogue might be a challenge for safety rule modifications. When discussing safety regulations, Kirwan et al. (2002) argue that the nature of the regulatory relationship is difficult. The reason is that it can contribute to a lack of trust or an

adversarial relationship between regulator and the regulated, i.e. the rule-imposer and the rule-follower.

On this background three questions can be phrased: First, did the modification processes include inquiries and feedback loops? Second, what knowledge served as the main source in the modification work? Third, what were the conditions for reflections in the projects?

3.5.4.3 Learning agencies and communities of practice as means

The SAMRAIL research upon accident and incident reporting underlines the importance of creating learning agencies that consist of peoples who have the assigned task to learn for the organization (European Commission, 2004a). Their role is to look into matters of concern and generate a lesson-to-learn and a learning product. The report underlines the importance of closed learning loops to make the learning agency function as intended.

Further this SAMRAIL research has illustrated how motivated railway people from different companies are setting up informal networks in European railways (European Commission, 2004a). This is done to foster learning from each other despite lacking formalized provisions. In Lave & Wenger's terminology introduced in Subsection 3.3.2, they can be said to have established "communities of practice" (Lave & Wenger, 1991). According to Wenger (1998) such communities are characterized by being mostly informal and distinct from organizational units. They differ from a network in the sense that they are not just a set of relationships; they are "about" something. A community of practice exists because it produces shared practice as members engage in a collective process of learning. Communities of practice go through stages of development. The community of practice's life cycle is determined by the value it provides to its members. Wenger considers such communities to be a company's most versatile and dynamic knowledge resource and that they form the basis for an organization's ability to know and learn.

With reference to the argument that safety rule modification can be seen both as a part of and a result of learning processes, this triggers the question: Did the projects play any role as learning agencies or communities of practice?

3.5.5 The mutable and fragile knowledge

The argument that modification processes can be both seen as a result of and a part of organizational learning directs the attention towards the storing of organizational knowledge.

3.5.5.1 Endangered knowledge and organizational memory

Storing of organizational knowledge is of particular interest for the study and for railways. Chapter 2 revealed a concern among members of the Norwegian railway system that ongoing changes might endanger important safety relevant knowledge. Storing of organizational knowledge is also a more general concern. For instance, the SAMRAIL report upon accident and incident reporting argues that ongoing changes in European railways have scattered relevant competent employees over many parties (European Commission, 2004a). However, this can also be seen as a positive contribution to distribution of knowledge. Another example is provided from Wolmar (2001). In his discussions of the Hatfield accident, he argues that the deregulation process in United Kingdom had a serious impact on knowledge and information processing. He exemplifies how this has resulted in overreactions with regulatory constraints after accidents.

Concerns for the dynamics of knowledge are also discussed in theory. Nonaka & Takeuchi (1995) argue that knowledge is essentially related to human action, i.e. knowledge is context specific and relational in that it depends on the situation and is created in social interaction among people. Starbuck (1992) notes that "creating, applying and preserving knowledge intertwine and complement each other. At least over long periods, merely storing knowledge does not preserve it. For old knowledge to have meaning, people must relate it to their current problems and activities". Baumard (1999) reflects upon this and concludes that knowledge is a mutable and fragile organizational entity. He finds that the sense of knowledge is derived from its application, and is lost once it is removed from the context of its utility. When the knowledge is out of the dynamics of its utilization, there is no knowledge which is more or less intense, or valuable, than any other. Brown & Duguid (1991) are on line with this. They reject transfer models of knowledge that isolate knowledge from practice.

Stein (1995) has provided a review upon organizational memory and defines the concept as "….the means by which knowledge from the past is brought to bear on present activities, thus resulting in higher or lower levels of organizational effectiveness." He distinguishes memories from information because memories are time functions that have intended and unintended effects. Rules are classified as concrete and prescriptive organizational knowledge, that is to say encoded knowledge for later transmissions.

3.5.5.2 Challenges of the Norwegian railway system

Regarding these concerns for the dynamics of knowledge and organizational memories, there are some challenges that seem to be of particular relevance for safety rule modifications in the Norwegian railway system.

First, there is the challenge discussed above, that knowledge is time function dependent upon context. The emphasis upon the more academic and abstract knowledge both generally, in the educational development of the Norwegian railway system and inherent

in the new approaches to rule modification, might weaken the linkage of knowledge to its context and direct utility. The SAMRAIL report upon accident and incident reporting suggests developing procedures for revising regulations, rules and work practices as means to enhance organizational memory (European Commission, 2004a). In addition and as already mentioned, the report suggests creating learning agencies. In the report it is argued that the closer these are to the actual context, the more they will be able to compensate for the loss of context that might have occurred when information is transferred in an organization.

Furthermore, the changing conditions of the Norwegian railway system might change the context. Stein (1995) points to the fact that organizational memory might produce barriers against learning, especially double loop learning. He underlines the importance of this element under changing conditions where the existing knowledge might be outdated. The ongoing changes in the railway systems might create situations where knowledge based on experiences from the past are irrelevant or even dangerous. For instance Hale et al. (2003) argue that the development of increased interoperability has made companies used to one national set of rules to operate on networks in other countries with other operating philosophies and safety rules. As revealed in Subsection 2.2.2, this situation is also apparent in the Norwegian railway system.

Second, knowledge is dependent upon social interaction (Nonaka & Takeuchi, 1995). The ongoing changes and in particular the division of the Norwegian railway system, new recruitment patterns and departing employees might remove former constellations and patterns of interaction among people. However, the previous subsection also demonstrated that the development can create new constellations, for instance communities of practice as described by SAMRAIL (European Commission, 2004a)

Patterns of social interaction might have consequences for the overview and access to the inherent knowledge of a system. Stein (1995) considered memories to be maintained if an organization has access to its knowledge and expertise. He demonstrates how easily organizational memories can be damaged.

Third, changes in context and patterns of social interaction are particularly challenging for tacit knowledge. Nonaka & Takeuchi (1995) explain that organizational learning often leads to systems or means that address explicit knowledge According to them this is only the tip of the knowledge iceberg. Further, Baumard (1999) argues that it is rarely recognized that non-codifiable knowledge could be collective. When the knowledge is tacit, it is therefore difficult to truly know the processes of acquiring, preserving and using this type of knowledge. Further he finds it difficult to reach any consensus about what constitutes generic knowledge and to achieve a good circulation of it.

The stable conditions, the emphasis upon practical experience and the stable work force in the former NSB implied rather good conditions for addressing tacit knowledge. These conditions make it reasonable to believe that this knowledge was rather collective too. However, as already discussed these conditions are now changing in the Norwegian railway system.

Fourth, the tacit knowledge of the Norwegian railway system might also be influenced by the fact that it is in a transition phase that can be experienced as a threat to peoples or groups. Baumard (1999) underlines that tacit knowledge is not necessarily unconscious. He distinguishes between the notion of knowing more than one can express of Polanyi (1966a) and knowing more than one wants to say. He illustrates how each actor will articulate their particular and tacit knowledge in a collective codification that enables them to position themselves according to common objectives. For instance actors might express and withhold knowledge according to incitements in their work conditions. Furthermore, this is related to what knowledge receives attention in more general terms. According to Krippendorff (1975), what knowledge is retained is reflective of group values. In addition Douglas (1986) illustrated that social systems systematically select some types of information for encoding and not others.

This discussion indicates that values, norms and reward system of the Norwegian railway system and the society in general will influence what knowledge becomes included in the modification processes. Here the privatization process and the higher status and increased emphasis upon the rationalistic theoretical knowledge perspective might come into play, i.e. the more practical and tacit intuitively-contextual knowledge might be less emphasized.

Fifth, the discussion above revealed that knowledge must be applied to be kept alive. This might also be a challenge for the projects. According to Stein (1995) organizational memories can be recalled to support decision-making and problem solving under certain conditions. One condition is that an inquirer is motivated to retrieve information if the inquirer values what has been done in previous contexts. The indications of changed status of knowledge and ongoing changes of the Norwegian Railway system might impede this condition. Another condition is that the desired information exists and the inquirer is aware of this. As presented in Chapter 2, there is a general concern that information and knowledge is lost. Furthermore, this requires an overview of what information there is. This is a condition that will depend on who became involved in the work and their background. A third condition is that the inquirer has the ability to search, locate and decode the desired information. Again, this requires an overview of where knowledge exists and enough know-how to decode the information. Finally, a fourth condition is that the cost to locate the information is less than re-computing the solution from scratch. He finds that retrieval of dysfunctional methods, values or prejudices is a case in point. Like Baumard (1999), Stein (1995) points to the fact that not all forms of knowledge maintained by the organizations are voluntarily retrievable.

This discussion about organizational memory and the Norwegian railway system can be summarized in two questions that has links to previous questions: The firsts is: How did the project include existing railway knowledge in the work? The second is: How did the project store railway knowledge in organizational memory?

3.5.6 What is railway knowledge?

The study is concerned with the influence of safety rule modification with hierarchical and risk-based approaches upon railway knowledge. In this study the term "railway knowledge" is used about the understanding of functions and interactions of the railway system. As the study concentrates upon safety and safety rule modification, the use of the expression will be limited to generic knowledge about issues of concern for these two topics. In particular this includes knowledge of the system itself, its activities and their interactions, the inherent risks and preventive means. It also includes knowledge about ongoing changes and current trends.

In the study railway knowledge will be seen to include the four knowledge forms presented by Baumard (1999) individual explicit knowledge, collective explicit knowledge, collective tacit knowledge and individual tacit knowledge. However, as discussed in Subsection 6.5.1 this knowledge is predominantly intuitively-contextual. Hence tacit knowledge holds a strong position.

In the following discussions I will also apply the term "knowledge of regulated area". This is applied for the more specific knowledge about functions and interaction of the subsystems that the rules of the four cases refer to. One element in this knowledge is the knowledge about "context and function of the rules". This refers to knowledge about the history and argumentation behind the rules and their intended function. Another element is "rule specific knowledge". This refers to the knowledge directly expressed in the rule texts themselves. All levels include knowledge of railway safety.

This study also applies the term "risk analytic knowledge". This refers to knowledge of risk analytic methods and their application.

3.5.7 Problems revealed in theory

This theoretical introduction to theory of rationality and knowledge and the discussions about the Norwegian railway system has illustrated that the hierarchical and risk based approaches represent a strengthening of choice based rationality in this system. This implies a strengthening of the rationalistic knowledge perspective. An overview of the new aspects of the approaches and normative implications are illustrated in Table 3.3. Furthermore, in the Table the questions raised throughout the chapter are reduced into three overarching problems to be discussed in the study.

Table 3.3 New aspects with increased emphasis upon rationalistic knowledge, normative implications and associated problems

New aspects	Normative implications	Problems revealed
Hierarchical approach	Increased emphasis upon rationalistic choice based decision-making	What knowledge base to apply as decision support? Did increased emphasis upon the rationalistic knowledge perspective change the predominantly intuitively-contextual railway knowledge? How did railway knowledge become stored in organizational memory?
Risk-based approach		
Increased emphasis upon rationalistic knowledge when developing rules	Synthesize and systematize knowledge in accordance with the higher order rule solution and the applied risk analytic methods o Thin descriptions o Explicit knowledge o Academic, expert based knowledge	

3.6 Research questions revisited and revealed problems

The overall research question of this thesis is:

How did the Norwegian Railway system respond to new requirements for safety rule modifications?

Regarding the sub-questions, the theoretical discussions of this chapter have revealed the following problems:

1) *The hierarchical approach:*

What work strategy to choose if low level rules already exist?

What if the suggested rule solutions do not fit the actual situation with respect to;

- Competency of rule-imposer
- Competency of rule-follower
- Rule context

2) *The risk-based approach:*

What risk perspective to apply; a wide inclusive definition or the narrow risk analytic?

How to combine expert dominated risk analyses with rule development in an evolutionary practice oriented modification tradition?

What if the risk analyses do not fit the risk perception of those involved in the modification work?

3) *The influence of new requirements upon railway knowledge:*

What knowledge base to apply as decision support?

Did increased emphasis upon the rationalistic knowledge perspective change the predominantly intuitively-contextual railway knowledge?

How did railway knowledge become stored in organizational memory?

4 Methods and material

4.1 Methodological approach and research design

The overall purpose of the study is to increase knowledge of safety rule modification. In the introduction I argued for an explorative and qualitative approach. Further I argued for empirical studies of contemporary and real rule modification processes. Accordingly the search of the study has been for systematic patterns and essences of the modification processes. Hence the research strategy is related to interpretivism and social anthropology (Miles & Huberman, 1994). Meaning and interpretation of possible research material about rule modification processes was of interest, i.e. the study has been influenced by hermeneutics (Wormnæs, 1987).

My prior knowledge has been brought to the research situation and will influence findings and interpretations (see Appendix B). Therefore it is important to describe what I have done in a way that makes the reader trust the results of the work and to make them able to make an independent evaluation of the findings.

4.1.1 Implications of the research questions for the research strategy

Safety rule modification can be described as a process with various process qualities. In addition, the study has been interested in the effect of the processes upon railway knowledge. Therefore the research questions are both descriptive and analytic.

The research questions make it important to look for and describe elements that influence the processes and their results. By asking “how” I looked for descriptions of relevant processes in a context. The research focused on the qualities of the processes that influence the implementation of the new rationalistic approaches and railway knowledge.

Furthermore, the study has been concerned with causal explanations for the development of the processes and its results, i.e. “why” questions. Because the research paid attention to the influence of the process and practical implications, there were also evaluative and developmental intentions. This contained a description of reality and comparison of reality to the intentions of the projects and to theory of knowledge and organizational learning. All together this shows that the overall research question for this thesis contained search for elements, descriptions of processes, explanations, evaluations and a discussion of possible development. However, the main purpose was to increase understanding, not to evaluate.

The strategy for the study was a mixture of case studies and grounded theory. According to Yin (1994) a case study is an empirical inquiry that investigates a contemporary phenomenon within its real life-context, especially when the boundaries between phenomenon and context are not clearly evident and the relevant behaviors cannot be

manipulated. He argues that case studies have a distinctive place in evaluation research. He also argues that case studies appear to be the best strategy when the main questions are “how” and “why”.

For case studies, theory development as a part of the design phase is essential (Yin, 1994). As Chapter 1 illustrates, the research has a purpose. Chapter 3 contributed with theoretical problems to elaborate and a few hypotheses. This means that it was necessary to keep an open and flexible approach regarding what variables to study. Grounded theory is suitable to identify and categorize elements and explore the relationships between them (Miles & Huberman, 1994). According to Strauss & Corbin (1998) grounded theory represents both an approach to qualitative research and techniques and procedures for this type of research. The method takes advantage of the researcher’s prior knowledge. By procedures for systematic verification and validation of the results of the analyses, the method is developed to overcome the problem of the influence of the researcher. The study drew upon grounded theory in the analytic work.

The arguments for the chosen approach were also the main arguments for not choosing other research methods. The focus of this study has been on naturally occurring, rather ordinary events in a natural setting. The purpose has been to give a handle on what is going on in modification processes. The processes were dependent on the context, conditions that cannot be controlled by the researcher. Further, there were not many modification processes run in parallel and the processes involved only a limited number of people in the main work. As argued, the limited scientific knowledge gave limited possibilities to develop theoretical hypotheses in advance. Hence the processes could not provide a foundation for controlled studies testing hypotheses with quantitative data by statistical analyses. More flexible strategies were required.

The modification processes had already started when the study began. Therefore more collaborative strategies such as action research and collaborative action research were not in question (Miles & Huberman, 1994). However, as the modification processes were still going on during the interviews and I discussed my preliminary analytic results with the project leaders (see section 4.3), there might be a possibility that my questions influenced later development of the work. The feedback upon the preliminary analyses influenced the further progression of the study both with respect to data collection and analysis.

4.1.2 Research design

The study is based on two ongoing projects of rule modification in the Norwegian railway system that represented four cases of safety rule modification. As shown in Chapter 2, the four cases had interesting similarities and differences. This offered some opportunities. First, each of the projects could be used as a single case study and used for “pattern matching” (Yin, 1994). Second, the Maintenance-rule cases gave the opportunity to conduct both a holistic and an embedded case study because they all belonged to the Maintenance-rule project (Yin, 1994).

4.1.2.1 Plans for data collection

Because of the wish for a flexible approach where elements and relationships that showed up in the field could be investigated, only qualitative methods were planned for the data collection. From the beginning I recognized two main potential sources for information. First, the projects involved people with different roles both in the projects and in the railway system. Second, there were documents related to the cases.

According to Whyte & Whyte (1984) interviews are used to obtain data about events and attitudes, and help us to interpret the significance of what we observe. Melia (1997) asks whether interview data are to be regarded as straight accounts of the interviewee's experiences or stories about that experience told as an exercise in self-presentation by the interviewees. This question can also be raised about written documentation that the participants produced. Further she argues that the effects of interaction between the interviewee and the interviewer cannot be denied. I chose to base the work on these data sources and to follow her advice to see interviews as a means of gaining insight into a world beyond the story that the interviewees and the documents told. In accordance with this advice I saw data from interviews and documentation as a means to get a handle on a more complex set of ideas than the ones that the interviewees are talking about.

I found it most both practical and suitable to interview the involved actors one by one. Group interviews could also have given desired information. However, the potential interviewees were busy and distributed all over the geographical area covered by the Railway system. Further they held different positions and interests.

I did not want to decide in advance what parameters to investigate and thereby limit the study. This gave me a lot of freedom in the data collection phase, but it made it also necessary to make sure that the collected data were relevant for the purpose of the study. This has two aspects. It had to be secured that leads that were of minor significance for the purpose of the study were not followed and that important data were not overlooked.

Therefore I developed interview guides for the interviews. According to Leiulfsrud & Hvinden (1996) such guides signalize the focus of the interview that the researcher wants. At the same time the interviewee, at least partly, has the opportunity to lead the interview into other tracks. Further they give the researcher an opportunity to prepare him- or herself in advance.

From the beginning, a standard interview guide was developed on the background of research questions and theory. The plan was to supplement this guide with special questions related to the roles and expected knowledge of the interviewees. The guide had an open structure that made it possible to explore phenomena that were not thought of in advance. It represented an opportunity to make sure that central themes were covered.

All together 77 questions were developed for the guide. These were divided between 12 sections. For many of these follow-up questions were prepared. The core content of the questions was directed towards the background of the actors, their attitudes towards risk

and safety, the safety work and the rule modification, their own role and participation in the work and their experiences. As the purpose of the study was to gather their understanding of the modification processes, the hierarchical and risk-based approaches were not stressed specifically. The intention was to integrate these subjects into the core questions. The guide also got a front page containing issues to be covered in the introduction to the interview and an end page with issues for rounding off the interview. The translated version of the standard interview guide is found in Appendix C. Reflections associated with each group of questions are presented in Appendix D.

I knew that the Traffic-rule project and the Overarching Maintenance project were rather well documented. The large amount of documents made it necessary to select the most central documents of the projects and for my research. Therefore I decided to ask the two project leaders for documents that described the background, purpose, development of the projects and topics of interest for my work.

4.1.2.2 Plans for data analyzes

The plan was to analyze the data in parallel with the data collection, so that the collected data could fuel the further data collection. Additionally, a qualitative approach was chosen for the analyzing. Miles & Huberman (1994) define qualitative analysis as consisting of three concurrent flows of activity: data reduction, data display and conclusion drawing/verification.

In parallel with the development of the research questions and the interview guide, a one page coding schema with preliminary concepts was developed. When almost all the interviews related to the Traffic-rule project were finished, this coding schema was developed into an analytic schema in the form of a matrix. An overview of the main headings is presented in Section 4.3, Table 4.4, page 94. The analytic schema in its full form is presented in Appendix E. To prevent bias from my prior knowledge of the Railway system, I decided to verify preliminary analytic results describing the modification processes and early causal explanations by the two project leaders, i.e. the leader of the Traffic-rule case and the joint leader of the Maintenance-rule cases.

Initially the intention was to follow the whole modification processes until the new rules were fully implemented in their planned context.

4.2 Data collection

In the beginning, official approval for the study was approved from the involved railway organizations. I also had meetings with the two project leaders; the leader of the Traffic-rule case and the leader of the Overarching Maintenance project. Here plans for the study and opportunities of information from existing documents, useful interviewees and status and planned progression of the projects were discussed. In addition, selection of cases

within the Maintenance-rule project was discussed. The plans were met with very positive attitudes. Free access was given to all information that the study needed.

As planned, data were mainly collected by interviews and document collection. First, initial data were collected from the Traffic-rule case. Thereafter the collection was done in parallel for both projects. For practical reasons, some of the data collection had to be made before analyzes of the already collected data were made, not in parallel as planned. With few exceptions the data collection was conducted intensively during four 3-5 days visits. The whole data collection period lasted for a period of one year.

The interviewees provided useful information about further data collection, both regarding people with special insight into actual issues and regarding written documentation. I also used my former network and knowledge of the system to discuss strategies to approach the field and potential sources for information.

In addition I got the opportunity to participate in meetings where railway safety was discussed, both in Norway and Denmark.

Due to the progress of the projects, the research had to be limited to follow the processes of developing the rules without looking into the implementation process. As already mentioned the Traffic-rule case could only be followed until the transfer to the Inspectorate.

In the following a presentation of the selection of cases, data sources and the data collection methods are presented.

4.2.1 The selection of cases and interviewees

The overall reason for the choice of the cases was that they were expected to serve the purpose and objectives of the study, see the introduction to the study in Chapter 1. Further they were chosen because they coincided with the study.

Interviews became the main source of information. Since the main focus of the research is on the rule modification process, I decided to focus on the people of the four cases that were directly involved in the core activities of rule development.

Below the selection of the cases and interviewees are presented more in detail.

4.2.1.1 The Traffic-rule case

The Traffic-rule project included only one case of safety rule modification.

The case had already worked for more than two years when it was chosen for the study. The first contact with the case was established in spring 2003. The main data collection

was done in the last 8 months before it was transferred to the Inspectorate. This means that parts of the information are given as reflections during the process, parts in retrospective perspective.

The organizing of the case

The case was administrated by the Traffic safety department of the Rail Administration and organized according to the guidance for project organizations of this organization. Figure 4.1 shows the organizational map that the project developed.

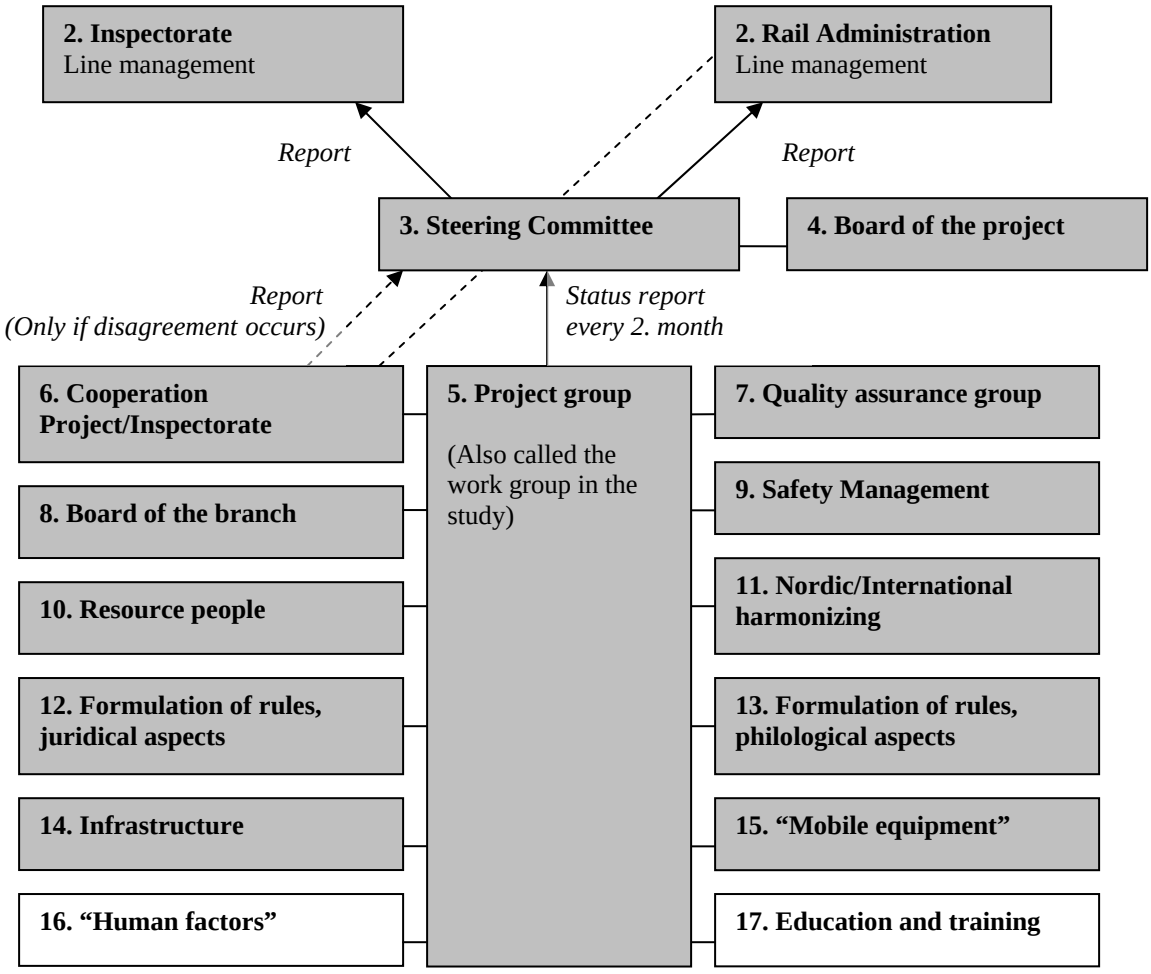


Figure 4.1 Formal organization of the Traffic-rule project[23].

[23] Project logg 695

In Figure 4.1, the elements of the organization that became included in the study are marked in gray. Many people were represented in more than one activity, i.e. in more than one box.

The intended function, the status, the number of participants and the number of interviewees from each element of Figure 4.1 are as follows:

1&2. The line management of the Rail Administration and the Inspectorate receive monthly reports about progression, economy and the development of the content of the work. The two people responsible for the project in these organizations, i.e. the Safety director of the Rail Administration and the Director of the Inspectorate were responsible for the reporting to their respective organizations.
Interviewed: The two people responsible.

3. The Steering committee was responsible for the final decisions about use of resources, organization, staffing, progression, methods and approval of the final results of the work. The committee consisted of the Safety director of the Rail Administration and the Director of the Inspectorate, the responsible person for the project in the Traffic safety department of the Rail Administration and the leader of the project.
Interviewed: Four out of four possible.
4. The Board of the project had an advisory function for the Steering committee. The board included the members of the Steering committee, representatives of the traffic operators and one representative of the Danish Rail Administration (Banestyrelsen).
Interviewed: Six out of twelve possible (some turnover in the group).
5. The Project group (also called the work group in the study) was responsible for the practical work of the project, either by themselves or by engaging others. The group had five members including the Project leader. Their background will be described in Subsection 5.2.2.
Interviewed: Six out of seven possible (some turnover in the group).
6. The group for Cooperation between the Project and the Inspectorate were established for clarifying issues that occurred during the progression of the work. Participation depended upon which issues were at stake. The project leader was a permanent member. From the Inspectorate usually one lawyer and one railway professional participated.
Interviewed: Nine out of twelve possible.
7. The Quality insurance group was responsible for reviewing use of methods and concluding presentations from the Project group. The task was performed by the Board of the project, the Board of the branch and the Resource People.
Interviewed: See the actual groups
8. The members of the Board of the branch had a function to contribute with railway knowledge about the regulated activities. It consisted of representatives from the different activities, mainly people who had extensive operative experiences and now had administrative functions in their respective organizations.
Interviewed: Fourteen out of twenty five possible (some turnover in the group).
9. The element of Safety Management was handled by the project leader who had experience with safety management.
Interviewed: One out of one possible
10. The project engaged Resource people and scientists for different tasks.

Interviewed: 3 out of 17 possible.(Their written reports were studied.)

11. The person responsible for the project in the Traffic safety department of the Rail Administration was responsible for the international harmonizing and cooperation.
    Interviewed: One out of one possible
12. The juridical aspects of the formulation of rules were handled by the lawyers involved in the group for Cooperation between the Project and the Inspectorate.
    Interviewed: Two out of two possible
13. The philological aspects of the formulation of rules were handled by the secretary of the Project group.
    Interviewed: One out of one possible
14. The questions regarding infrastructure were handled by the Project group who consulted key people and their network.
    Interviewed: Six out of seven possible (some turnover in the group).
15. The questions about Mobile equipment such as trains were handled by the Project group who consulted key people and their network.
    Interviewed: Six out of seven possible (some turnover in the group).
16. At an early stage of the work the project engaged one external expert of "Human factors"
    Not interviewed for practical reasons; he was working abroad during the data-collection.
17. Due to delays in the project, the planning of education and training for the implementation of modified rules did not start during the study.

The choice of interviewees

When choosing interviewees, I decided to start out with the most influential groups that were involved in the work. To decide upon this, the organizational map of Figure 4.1 and advice from the project leader were followed. Furthermore, the Project leader gave advice about which people could be useful for information. This advice appeared to be very valuable. To prevent bias I decided to interview representatives from as many subgroups as possible and when possible some supplementary people from the groups.

In total 24 persons directly involved in the case were interviewed. This number is lower than the sum of interviewed participants in each of the elements of the project organization presented above. The explanation is that many people held several roles in the project and therefore were repeatedly presented at different places.

Additionally 6 persons were interviewed for background information. These were involved in the professional education, the management of the core rule-followers and the safety work of the regulated activities. To find the people with most relevant information, I followed the advice of my interviewees and my own knowledge of the organization.

The total number of interviewees was 30. Out of these four persons had been involved in former modification processes of the rules.

The interviewees held different positions within the Railway system, see Table 4.1. Also in this table some people hold more than one position; again the total number is higher than the number of interviewees. The interviewee characteristics of the people are shown in Table 4.3.

Table 4.1 Main positions of interviewed people including people not directly involved in the Traffic-rule project
(Note: Some people held more than one role.)

Positions of interviewees and their organizational belonging	**Inspec-torate**	**Rail admin-istration**	**Traffic operators**	**Accident Investig-ation Board**	**Others**	**Total**
Upper management (Director level)	1	1	2	0	0	4
Middle management	0	2	0	0	0	2
1. line management	0	3	1	0	0	4
Operative staff	0	0	1	0	0	1
Safety staff	3	6	6	1	0	16
Educational staff	0	1	2	0	0	3
Contracted staff	0	0	0	0	5	5

The table illustrates that the study involved a rather differentiated group with respect to roles and functions in the Railway system. However, the operative staff is the least represented. This is due to their limited representation in the organized work. As the study focus on the process from the participants view, I find the representation of interviewees satisfactory for analytic purposes.

In addition to the interviews, I had seven meetings involving four persons and participated in two group meetings. These involved people from the Norwegian Railway system. The main purpose was to get background information and to verify my findings. Information from these meetings is included.

I knew two of the interviewees previously.

4.2.1.2 The Maintenance-rule cases

The other three cases belonged to the Overarching Maintenance project that was a pure Rail Administration project. As mentioned this study limits itself to look into the part of the project that is related to rule modification, the so-called Maintenance-rule project.

Also, the work of the Maintenance-rule cases had started before the study; approximately 6 months before the first contact was made. The study follows the work until the rules were carried into effect January 1/1 2003. The main data collection was done during the last three months of the project and the following three months after the rules was effected. This also means that here the information is given partly as reflections during the process and partly in retrospective perspective.

The organizing of the Maintenance-rule cases

The Overarching Maintenance project was also organized according to the guidance for project organizing of the Rail Administration. The formal structure of the project is shown in Figure 4.2. Here the Maintenance-rule project is marked in gray. As the cases were subprojects of the Maintenance-rule project, they are not illustrated in the organizational map.

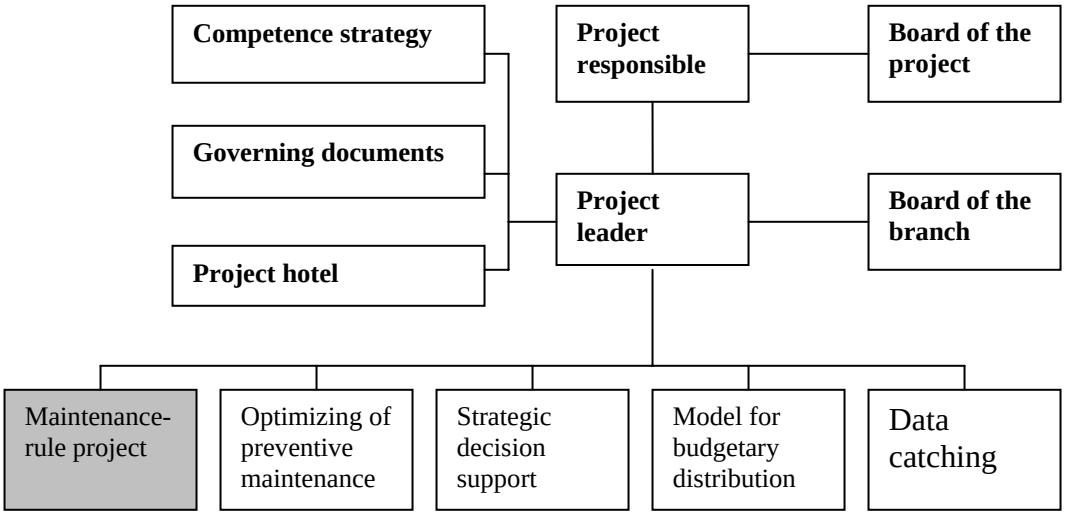


Figure 4.2 Formal organization of the Overarching Maintenance project. The Maintenance-rule project is marked with gray color.

The Maintenance-rule project and the cases had a rather simple and informal organizational structure compared to the Traffic rule case. Also the cases involved fewer people.

As mentioned in Section 2.4.2, the Maintenance-rules were organized according to the four main systems of the infrastructure, i.e. the Substructure, the Superstructure, the Power-supply and Signaling and interlocking.

The study limited itself to look into the processes of three Maintenance-rule cases. To choose cases for the study the leader of the Overarching Maintenance project and the present leader of the Maintenance-rule project were asked for advice. The selection criteria presented for them were: People involved in the work that had shown special interest or had strong opinions about the ongoing work, cases that were particularly illustrative of the processes or had different challenges related to rule modification. The cases were chosen according to their advice. The information that appeared during the interviews both about the chosen cases and the others, verified their opinion.

The cases and the number of participants and interviewees are as follows:

- Sub- and Superstructure work closely together, but the rule modifications of the fields were divided. As the modification of the Superstructure rules involved more actors than the Substructure, this case was chosen for the study and labeled the "Superstructure case".

  Most of the work of the Superstructure case was performed by two people. These were the two people at the Head office in the Technical department in the Rail Administration who were involved in regular rule modifications. One of these had the responsibility for the rules. The case had an established Board of the Branch. This board was also consulted during the work of risk analyses and rule development.
  Interviewed: The two people who performed the work.

- Power-supply consisted of three subsystems. Out of these, one was chosen as a representative for this system and labeled the "Power-supply case". The choice was made because the leader of this case had been much engaged in discussions of the Maintenance-rule project and out of practical reasons.

  In the work of Power-supply case two people did most of the work. One was the responsible for the rules at the Head office in the Technical department in the Rail Administration. He was also involved in regular rule modifications. The other was a person who was contracted from another part of the Rail Administration to perform the rule writing. The case also involved different people to participate in the risk analyses. These were involved according to their specific knowledge about the equipment to be analyzed
  Interviewed: The two most involved people from whom one had participated in the risk analytic work.

:

- The Signaling and interlocking was the third case to represent the Maintenance-rule project. This case became labeled the "Signal case" in the study. As this case had been a pilot for the Maintenance-rule cases it was of special interest.

  In the rule development there were two main actors. One was the responsible for the rules at the Head office in the Technical department in the Rail Administration. He was also involved in regular rule modifications. The other was a person who was contracted to perform the task.
  Interviewed: Both

As this case had a function as a pilot for the Maintenance-rule cases and the risk analytic work was isolated from the rule modification, one person involved in the risk analytic group was included in the study. He was chosen both on the background of recommendations and for practical reasons.

To some extent the cases had different contexts and processes. Therefore the Maintenance-rule cases are both treated together as a group and separately in the study; together when the issue at stake reveals no differences of importance between the cases and separately when there are important differences.

The rest of the Maintenance-rule project and the Overarching Maintenance project served as a context for the work.

The choice of interviewees

The presentation of the cases above reveals that the main actors directly involved in the modification work of the cases were interviewed, in total 7 persons. Because of their central role in the work, I also decided to interview the project leader of the Overarching Maintenance project and the former and current project leaders of the Maintenance-rule project. Based on advices I also interviewed one external risk analytic expert contracted by the Overarching Maintenance project and one auditor. (The two latter are categorized as “Others” in Table 4.2.)

The leader of the Maintenance-rule project was also the leader of the former Permanent rule modification project that traditionally had modified the existing rules.

The total number of interviewees was 12. Except for contracted staff, all were employed by the Technical department of the Rail Administration. An overview of the studied groups, their number of participants and the number of interviews are given in Table 4.2.

Table 4.2 The main positions of interviewed actors in the studied cases of the Maintenance-rule project.

Positions of interviewees and their distribution in cases	**Signal**	**Power-supply**	**Super structure**	**Others**	**Total**
Upper Management (Director level)	0	0	0	0	0
Middle Management	1	1	2	3	7
Involved in operative activities	1	0	0	0	1
Safety staff	0	0	0	1	1
Educational Staff	0	0	0	0	0
Contracted staff	1	1	0	1	3

The table illustrates that the study of these cases involved a smaller group of people who were less differentiated regarding roles and functions in the Railway system compared to the Traffic-rule case. Also in these cases the distribution of interviewees was according to the involvement in the project. As the upper management, the operative staff and the safety staff were not directly involved in the modification work they are not represented in the study. The only exception is the person involved in auditions who can be seen to represent the safety staff. Furthermore, the educational system was neither represented nor followed up for these cases. The reason is that the core education of most rule-followers is/was external, see Chapter 5, Subsection 5.3.2. With respect to the focus of the study I also find the representation of interviewees satisfactory for these cases.

In addition to the interviews, I had three meetings involving two persons. Again, the purpose was mainly to get background information and to verify my findings. Information from these meetings is included.

I knew three of the interviewees previously.

4.2.1.3 Interviewee characteristics

A total of 41 persons out of 43 asked were interviewed for this research. (One person was represented in both the Traffic-rule case and the Maintenance-rule cases) No one refused to be interviewed. For practical reasons, two interviews had to be cancelled. Table 4.3 shows the different characteristics of those interviewed.

Table 4.3 The interviewee characteristics of the two projects

	Traffic-rule project	**Maintenance project**	**Both projects**
Mean age	45.9	38,0	43,7
No. of men	24	12	35 (one person represented in both projects)
No. of women	6	0	6
No. with external technical education	12	12	23 (one person represented in both projects)
No. with internal rail – education	16	0	16
No. with other education	2	0	2

Everyone interviewed was Norwegian. As can be seen from the table, the two projects had rather different profiles regarding age, gender and educational background.

4.2.2 Data collection by interview

In the data collection most emphasis was given to the interviews. The interviewees were questioned in the topics of the interview guides. They were encouraged to open subjects they found particularly important.

4.2.2.1 The interview guide

Prior to the data collection, the first edition of the standard guide was tested on two experienced researchers in safety management. These researchers have carried out several research projects within the Norwegian railway system.

The standard interview guide was used as basis for the development of guides adapted to the roles and expected knowledge of the interviewees. In this work I used my prior knowledge of the system. The guides were used during the interviews. The intention to integrate questions about the hierarchical and risk-based approaches into the core questions was followed.

After the first interviews the standard guide was evaluated, both on the background of my own impression of the interviews and feedback from the interviewees. This only resulted in minor changes. The guides were also developed during the data collection period reflecting increased insight.

4.2.2.2 Accomplishment of interviews

The interviews were carried out in either the office of the interviewee or in meeting rooms that the interviewee had arranged. For practical reasons one interview was arranged privately. No other persons participated in the interviews. The interviews averaged 1 ½ - 2 hours, but ranged from 40 minutes to 3 ½ hours.

Each interview started with an introduction of the research project and my background. Further, an agreement for the use of the data was made.

All interviews were performed by me. During the interviews, the guide was used as a guideline, not as a questionnaire. To encourage the interviewees, I tried to make the interview situation more like a conversation. Therefore, the same questions were asked in different ways. During the interviews the hierarchical and risk-based approaches were discussed thoroughly. The interviewees were very concerned about the introduction of the new approaches. Therefore these topics were usually opened by the interviewees.

Except for two interviews, all were recorded. One of these was at the very beginning of the work and I was hesitant to use recording equipment. In the other, the interviewee did not approve of my use of the equipment. Some of the interviewees admitted that they became a little disturbed by the recording, while others took no account. Sometimes, the interviewees asked that particular sequences of the interview would not be quoted. In a few instances the recorder was tuned off when sensitive information was given. This usually happened when the interviewees wanted to tell anecdotes that they considered sensitive for the reputation of the railway system, other people or themselves.

On only two occasions were there problems with the recording. The data was later reconstructed by the help of the interviewees.

Most of the recorded interviews were fully transcribed to text files. The conversations were written as accurately as possible. Nonverbal communication such as laugher and pauses that might influence the understanding of the written text was also added. A few of the interviews of the most peripheral actors were transferred from the tapes to text files as thematical reports; 30 interviews were fully transcribed and 11 thematically reported. All transcription was done by me.

All interviewees were offered their transcription or report. Many of them wanted this and some came up with comments.

4.2.3 Data collection by documents

The document studies played an important role in achieving insight into the formal conditions of the project. This refers to the organizing, goals, philosophies, requirements, development and principled discussions and decisions. This information was used both in the presentation of the projects and was important as background knowledge when the interviews were planned and carried out.

Due to the large amount of project documentation and in particular in the Traffic-rule project, it was not practical to go through it all. As planned, the project leaders were asked to provide documents that they considered the main project documents describing the background, the purpose and the development of the projects and topics of interest for the research. Document lists for the Traffic-rule projects were also collected. I did not detect any strategies to hide documents from me. As the work developed I asked for more documentation that covered issues of special interest.

For the Traffic-rule project the later selections of papers were related to the communication between the Inspectorate and the project, the performed change analyses and reports related to principled decisions. The most up-to-date study plans for engine drivers and traffic control were also collected. Further a report from an audit that the Inspectorate did of the project was collected. For the Maintenance project the later selections were related to the internal work of the sub-groups for rule modification and the performed change analyses.

To get an impression of the framework of the work, the safety management system of the Rail Administration was briefly studied.

The requests for more documentation were always positively met.

I believe the selection of documents was satisfactory for analytic purposes.

4.2.4 Other sources of information

Because I already had a personal network in the system, it was natural to contact these people for advice about the potential for conducting the research in the system and how to approach it. These contacts contributed with useful information that made it easy to make contact with the projects and to get the necessary permission for the research. This was especially true in the beginning of the work. All personal contacts were and are open and above board.

The communication to achieve the necessary permission for the research was made by telephone, E-mail and face to face meetings. During this communication my research and topics related to this were discussed. The communication also provided useful information.

During the data collection period I had the opportunity to participate in the following activities:

- A seminar related to a project of the International Union of Railways (UIC) named "Safety culture at interfaces" arranged by SINTEF Technology and Society
- A one day meeting for instructors of engine drivers
- A two day seminar for the safety staff of the Rail Administration and a half day seminar about rail safety
- A half day seminar about rail safety arranged by SINTEF Technology and Society

In addition I was invited to the Danish Transport Research Institute for one week. During this week, meetings with representatives of Danish National Railway Administration and DSB (the traffic operator originating back to the former governmental Danish State Railway) were arranged for me.

Immediately after all the contacts field notes were made. All e-mails were stored. All together these provided valuable impressions of safety work in general and the role of rules and rule modification in particular. This also helped to generate propositions that could be further investigated in documents and interviews.

4.3 Analyses

Both the collected written documentation of the projects and the transcribed interviews gave a huge amount of data. It was therefore necessary to find a way to approach it.

As mentioned in 4.1.2, an initial one-page coding schema with preliminary concepts was developed. This schema was influenced by the developing research questions, literature on quantitative analyses (especially Miles & Huberman, 1994), the studies of theory and the project documentation made in the early phase of the study. The purpose of this was to keep in mind the analytic work when performing the interviews and to enhance sensitivity in the early stage of work with the data.

The coding schema was developed into the analytic schema on the background of the experiences of the concepts, the initial data collection and a perspective of the modifications as processes that could be divided into sequences. This was inspired by Strauss & Corbin (1998). The analytic schema with its main headings is shown in Table 4.4 below. As mentioned, the full version is shown in Appendix D.

Table 4.4 The main headings of the analytic schema

	What were the intentions of the project?	What happened in the project?	Why and with what consequences? Other comments	Consequences for railway knowledge
1.Introduction Presentation of the rule projects				
2. How are the processes of developing the rules run and why?				
3. What are the underlying perspectives dominating the ongoing modification of safety rules?				
4. What are the chosen rule solution				
5. Unclassified issues				

In the schema the horizontal axis contained headings that made it possible to compare the initial intentions with the actual path of the process, causal explanations and hypotheses about consequences for railway knowledge. The vertical axis contained headings related to the context and history of the project and the actual rules, the progression of the work, the use of risk analyses and the choice of rule solutions in particular, the involved actors and their perspectives and the chosen rule solution. In addition there was one row for unclassified issues.

When almost all the interviews related to the cases were finished, the transcripts of the interviews and the written documents of each case were worked through. The preliminary findings were summarized and filled into the analytic schema. The use of the analytic schema proved very helpful. It both developed my existing knowledge into explicit knowledge and revealed where more information had to be collected.

When this was done, information that could be related to individuals was removed from the schemas. These were then sent to the two leaders of the modification projects, i.e. to the leader of the Traffic-rule case and the leader of the Maintenance-rule project. In a following meeting we worked through the matrices, the project leaders supplemented missing information and verified the analytic results. A few misunderstandings were revealed and corrected. This process also showed that some information was still missing. Hence it gave input to further data collection. In this process the preliminary analyses was developed with respect to categories and became more nuanced. This gave the analytic schema more subheadings.

Based on the developed analytic schema more thorough analyzes followed. Here the verified initial results were compared and contrasted both with respect to information received from different sources within each case and between the cases. In parallel with the analyses I also started to write the thesis. The writing helped clarify my growing knowledge. Thus, the writing contributed to the analytic work. During this work some issues appeared to become of greater than expected importance. As my awareness of these improved, I had to turn back to the transcrips several times.

The content of the analytic schemas was then transferred into matrices and displays inspired by Miles & Huberman (1994).

At the end of the writing of the study, I went back to the raw data to verify the analytic work.

During this process I had to prepare a paper for PSAM 7/Esrel 2004. This was based on findings from the Traffic-rule case. The process of developing this paper also helped in relating my preliminary findings to the theory of organizational learning and knowledge. The paper was discussed with the project leader of this case.

4.4 Research quality

In the literature of methodology, questions related to the quality of qualitative research are discussed (See for instance Miles & Huberman, 1994; Yin, 1994; Kvale, 1996; Strauss & Corbin, 1998, Lincoln & Guba, 1985). In this study the main objective has been to create understanding and insight into the phenomenon of rule modification. The issue of quality raises the question whether the study answers the research questions and particularly enlightens the revealed problems. The study has contributed with some descriptions and explanations of the development within the studied modification processes. The main question to be answered here is whether these are trustworthy and applicable.

4.4.1 Objectivity/Confirmability

The main source for information in this research is qualitative interviews and written documentation from the cases. This raises the question whether the conclusions depend on the subject and conditions of the inquiry, rather than on the inquirer (Guba & Lincoln, 1981). To approach this question, the preliminary analytic results were verified by the project leaders of the Traffic-rule case and of the Maintenance-rule project. Further I went back to the raw data at the end of the study to verify my results.

However, the conclusions are also influenced by me because I did all of the work. Kvale (1996) argues that interviews are neither objective nor subjective. The essence of the qualitative interview is inter-subjective interaction. Strauss & Corbin (1998) point at the

problem to retain a balance between objectivity and sensitivity. The interaction between the scientist and the data both during data collection and analyses makes the researcher influenced by the data and the data influenced by the researcher. Therefore the steps described above were supplemented with comparison and verification of the information extracted from the documents and interviews. This was used to confront myself with my own assumptions and the assumptions of the interviewees. This particularly important as I had prior knowledge of the Railway system, had used my network and the initial data collection was based on advice from the project leaders.

4.4.2 Reliability/Dependability

The studied processes have been dependent on the context of the cases when the modification processes developed. As illustrated this context is undergoing changes. The reliability criterion presupposes stability, consistency and predictability whereas the notion of dependability acknowledges that change is always taking place.

Lincoln & Guba (1985) discuss dependability. They argue that to demonstrate dependability the researcher has to take into account both factors of instability and of phenomenal or design induced change. Further, Strauss & Corbin (1998) discuss reproducibility and argue that it is difficult to reproduce social phenomena. They argue that given the theoretical perspective of the original researcher, the use of the same general rules for data collection and analyses and the same conditions, other researchers should be able to come up with the same or similar theoretical explanations of the phenomena being studied. By providing thorough descriptions of the theoretical approach, the context of the cases, the data collection and the analyses I have tried to illustrate the dependability of the cases and the way the study is performed. However, the reproducibility has not been tested. Such a test could have revealed whether my work has been biased by my prior knowledge of the railway system or not.

4.4.3 Internal validity/Credibility

Kvale (1996) discusses validity and argues that this concerns whether the research investigates what it intended to do. Therefore an illustration of the relationship between the research questions, the data collection, analyses and the presentation of data is of vital importance. In this study the development of research questions, data collection, analyses and the presentation of data have been an iterative process where the elements have influenced each other. Hence, these elements were not preplanned in detail when the work started. However, during this development the choices have been made in loyalty to the overall intention to contribute with increased understanding of modification processes as seen from the perspective of the participants.

Validity and the related credibility, might be increased by triangulating different data sources. (See for instance Yin, 1994; Miles & Huberman, 1994, Lincoln & Guba, 1985). Different cases were chosen for the study. Further, a large number of interviewees

holding different roles and functions were chosen as interviewees. Information from the documents and in particular, minutes from meetings, were triangulated with the information from my interviewees. This functioned as compensation for not participating in the modification processes and for the rather short duration of the interviews, i.e. two aspects of credibility discussed by Lincoln and Guba (1985). The triangulation also built upon the analytic approach of Straus & Corbin (1998) where comparison of data from the different sources is an important element.

One challenge here is the handling of diverging results (Miles & Huberman, 1994). As will be illustrated in Part II, such instances are revealed and discussed with respect to possible explanations. Therefore it has also been necessary to give context-rich and detailed descriptions of the cases. This process can also be associated with the advice of Lincoln & Guba (1985) to enhance credibility by negative case analyses.

One question is whether the portrait given of the cases is ”authentic” (Miles & Huberman (1994). Strauss & Corbin (1998) use the concept ”saturated” when no more new and important factors emerge from data collection and analyses. However, the literature reveals that this concept is problematic (Miles & Hubermann, 1994; Melia, 1997).

I also found the concepts “authentic” and “saturated” problematic. To counter that important information may have been lost, I followed up the issues where I felt uncertain in later interviews. As the Traffic rule case involved much more people than the Maintenance-rule cases, this case had much better possibilities for this and for enlightening the work from different perspectives.

The involvement of the project leaders in the verification of the preliminary analyses results was also done as an attempt to verify the preliminary research findings and to reveal weaknesses. Together with the discussions of the conference paper for PSAM 7/Esrel 2004 with the project leader of the Traffic-rule case, this can also be seen as member checks as discussed by Lincoln & Guba (1985). However, this might also be a dangerous path. The results might be more influenced by these people than of others. Hence this might cause bias in their favor. The comparison of these preliminary results with later interviews, inclusion of more interviewees in the study and the review of data were means to counteract this.

The involvement of the project leaders in selection of interviewees and documents might also have been a source of bias. However, these selections were supplemented with other sources that did not indicate that this was a problem. As mentioned I did not get the impression of any hidden strategies.

Much of the study is based on interviews. Referential adequacy is attended to by taping interview and transcribing the central ones in detail and the rest as summaries (Lincoln & Guba, 2005). Further the collected documents are systematized and the verified initial analyses and flow charts are stored. Memos containing own reflections are also stored.

Kvale (1996) discusses validity in relation to transcription of interviews. He argues that this represents a translation from oral to written language where the conversation is decontextualized. To counteract this, I included a brief description of the interview situation in the transcriptions of each person. Further, I tried to describe emotional expressions in the transcriptions. However, this does not give a full picture of the communication during the interviews.

I did not participate in any systematic peer debriefing as advised by Lincoln & Guba (1985) However, I engaged myself in discussions with different colleagues, fellow PhD students and my mentors.

4.4.4 External validity/Transferability

The issue here is whether the conclusions of the study have any larger import (Miles & Huberman, 1994). To establish external validity of results one has to know both the sending and the receiving context, which is in fact a question of transferability (Lincoln & Guba (1985). Again the rather detailed descriptions in this thesis are a means to illustrate the sending context for comparison with eventual receiving contexts. Whether these are judged as sufficient might be depend on the evaluator's research tradition and what phenomena he or she is interested in (Wulff, 1997).

As all cases belong to the Norwegian Railway system and occured in a special period of transformation of this system, this implies some restrictions regarding transferability. However there are also many similarities between the features of this transformation and other processes influenced by New Public Management. Many of these are also under pressure for increased use of outcome-oriented rules and increased use of a risk-based approach. Further, the Norwegian railway system has many similarities with the railway systems in other countries.

Strauss & Corbin (1998) are more concerned about the explanatory power of the research than of generalizability. The philosophy is to see what can be learned from one case about other cases. The procedure of comparing implies registration of both similarities and differences and to see how relevant the results of one case might be for another case or where the cases might be different.

In the study, there are some variations built into the choice of cases, interviewees and documentation. Even though I have not developed one clear theory, I have attempted to provide explanations for the results that can contribute to increased understanding of other modification processes.

PART II: RESULTS AND DISCUSSION

Part II consists of a combination of results and discussions. The first chapter provides a short presentation of the context of the four cases that the two projects represent. The following three chapters answer the research questions. These chapters are organized according to the problems revealed in Chapter 3; each subsection presents, discusses and gives concluding remarks to one problem. The last subsection of the chapters provides the main conclusions of the actual research questions and associated problems.

This study follows the rule development of the Traffic-rule project until the work was transferred to the Inspectorate. The Maintenance-rule project is followed until the implementation date of the rules. Plans for future rule management that were developed until these times are included.

5 Contexts of the cases

The purpose of this chapter is to give an overview of elements in the near contexts of the four studied cases that influenced their modification processes.

5.1 Traditions and plans for the future

The overall purpose of the study is to increase the knowledge about safety rule revisions. As the studied modification processes appeared to be a part of a continuous process of rule development that influenced the work, a brief description of the modification traditions of the cases and plans for the future is necessary.

5.1.1 Modification traditions

The cases were rooted in the historical development of the Norwegian railway system described in Chapter 2. Accordingly, the rule sets to be modified had been developed on the basis of an extensive understanding of the applied technology and the interactions within the regulated areas and associated risks. Furthermore, many interviewees reported that rules had often become modified after unwanted events and accidents. They also reported that rules were modified when the technology of infrastructure or equipment was changed or new solutions introduced. These changes could happen as a result of discussions of anticipated consequences of planned changes or as a result of experience with the changes. In addition, the international development of railway regulations has influenced, in particular, regulations associated with the same technical solutions as applied at the Norwegian railway system.

When rules were modified all cases had the tradition of taking advantage of knowledge in rule-developers' network. Many interviewees also reported that these networks provided useful feedback to existing rules. As the eldest interviewee who had worked with rule modifications for many years expressed it: *"We did not have any system for receiving feedback. We had some of these eager souls who you know, for instance an engine driver who you had taught in the school, who call you up."* He explained that they called because he was well known in the system.

When found necessary modifications of the Traffic-rules were usually done by the staff of the former Safety Office of NSB. The general pattern was that these people recognized needs for changes in the rules due to technological changes and evolving knowledge, particularly from accidents and unwanted events. Before changes in existing rules or new rules were implemented, the solutions were often tried out in practice in the form of Safety directives, S-directives, for short. Sometimes more fundamental changes were made in the rule set. The most extensive changes were made in 1964 when remote control was introduced for coordination of traffic operations and in 1997 when it was decided that the remote control was used to such an extent that it was decided that the rules had to

be grounded upon this principle. The latest change was made by a project group. The documentation of earlier modification processes was scarce.

For the Maintenance-rules there had been a tradition to revise the rules every year with 1st of January as the date for implementation. Additional changes were made when found necessary. A group at the Head Office of the Rail Administration performed the work. The interviewees representing this group explained that during the year they collected information from those operating in the practical field and about the development of technology to be maintained. This knowledge was used when revising the rules. The people performing the work were mainly engineers. To track changes in the rules, a special schema was developed where the changes were documented.

As revealed in Chapter 2, the rules of the Traffic-rule case consisted of a major rule set and a set of supplementary advisory rules. They were all prescriptive, and they had not been accompanied by goal-oriented formulations or textbooks. The rules of the Maintenance-rule cases were all prescriptive, but they had different contents. They were accompanied by textbooks.

Both the Traffic-rules and the Maintenance-rules were developed for internal use in the former NSB and served both traffic safety and other purposes. The rules were not developed to function as isolated rules. They had bee a part of the entire rule system of NSB.

5.1.2 Plans for the future

There plans for future management of the cases' rule sets differed.

5.1.2.1 Uncertainty of the Traffic-rules

According to the project leader of the Traffic-rule case, the case developed the traffic-rules for the current needs. Due to ongoing developments within the Norwegian Railway system and of international laws and regulations for Railways, especially related to the harmonizing processes within EU, he expected the rules to be rather temporary.

However, the plans for future management of the traffic-rules were unsettled. In the final report of this case it is suggested to develop a strategic plan for the future development of this rule set[24]. The report argues that it is necessary to coordinate the technical development, the international rule development and the development of the traffic-rules. The Inspectorate will be responsible for future approvals of deviations and modifications of the traffic-rules. The interviewees of the Inspectorate did not report any clear strategic plans for future rule modifications of the organization, but the organization has established a forum for communication with involved actors at the organizational level.

[24] Project log 1208

Here the organizations have the opportunity to discuss subjects associated with the Traffic-rules. Furthermore, the Director of the Audit department of the Inspectorate reported that after audits, the auditors made notes about revealed weaknesses in existing rules. Also, the Director of this organization considered it important to find good solutions for revealing weaknesses in the rules.

5.1.2.2 Continuous discussions of the Maintenance-rules

As per the Traffic-rules, the Maintenance-rules were also developed for the current situation. The interviewees expected that the technical development of the infrastructure and the ongoing changes of the Norwegian railway system would require future rule modifications.

However, the situation for the future management of the Maintenance-rules was different from that of the Traffic-rules. The project leader of the Overarching Maintenance project explained that the Overarching Maintenance project developed a plan to make the Maintenance-rules a part of interaction processes between hierarchical levels of the Rail Administration. This was developed as a separate plan in parallel with the work of the Maintenance-rule cases. Here the rules are supposed to be subject to discussions and development in accordance with evolving knowledge and experienced needs of the practical field.

According to the plan, lower management levels of the Rail Administration can impose rules for their fields as long as these do not reduce safety. They should also not counteract rules issued by rule-imposers positioned at higher levels in the organizational hierarchy of the Norwegian railway system nor international laws and regulations.

Decision rules were formulated to handle situations where existing rules are inappropriate and rule changes or deviations are necessary. The plan is to link requirements to processes of rule change or deviation to the hierarchical position of the rule-imposer and the safety ranging of the rules. Rules imposed from rule-imposers with high positions or that are safety relevant require more formal proceedings than rules issued by rule-imposers at lower levels and rules with no safety relevance. Furthermore, decisions for deviations or modifications of such rules must be taken at higher organizational levels.

Before decisions of deviances and modifications are accepted, the consequences for risk control have to be analyzed and the conclusion must demonstrate that risk control is not reduced. As tools to support these processes, the Overarching Maintenance project initiated development of data programs. These were not ready when the rules were implemented.

During the work of the Maintenance-rule cases the Rail Administration also developed its Management system. This system has a hierarchical structure. The Maintenance-rules became subdocuments of the highest level of this system. The Management system also had one special section for safety. This required that the safety management of the Rail

Administration must be based on risk analyses. Future rule development has to be in accordance with the governing principles of this Management system. This implied to apply risk analyses in the modification work in accordance with prescriptions in the section for safety. It also implied a requirement to use risk analyses as evidence that rule changes or permission to deviate from rules do not represent reduced safety.

5.2 Organizing of the work and characteristics of the rule-imposers

Chapter 3 revealed some theoretical problems to be elaborated in the study. The discussions of the both the hierarchical and the risk based approach directed the attention towards the competency of the rule-imposers. The discussions of the hierarchical approach also directed the attention to their positions in the organizational hierarchies and the safety management systems. The discussions of knowledge and rationality reveal that the organizing of the work might influence the knowledge base for the modification work and conditions for changes in the railway knowledge. Therefore, in the following the hierarchical positions of the rule-imposers, the competency- and experience base that was included in the work and how the modification work was organized will be elaborated.

5.2.1 Hierarchical position of the rule-imposers

The cases were not directly involved in the decisions about the hierarchical positioning of their rule-imposers in the organizational hierarchy of the Norwegian railway system. Therefore these decisions are not studied here. However, the research touches upon their consequences.

When the former NSB was divided, the rule-imposer of the Traffic-rules became the Rail Administration. As the Traffic-rules functioned at a national level, the function as rule-imposer of these rules soon became a matter for discussions. In 2001, that is to say during the work of the Traffic-rule case, the function became transferred from the Rail Administration to the Inspectorate. This meant that the role as rule-imposer was moved from the upper mid range level to the highest and strategic level in the Norwegian railway system's organizational hierarchy. Accordingly, the rules had the status of national regulations. Above these were national laws and international laws and regulations.

Also the Maintenance-rules came under the responsibility of the Rail Administration when NSB was divided. The rule-imposer of the Maintenance-rules became the Technical department at the Head Office of the Rail Administration. This means that the function as rule-imposer became positioned at the mid range and planning level in the Norwegian Railway system, below the Inspectorate and the upper management of the Rail Administration. This position was not changed during the modification work.

The modification work was delegated to some people performing the task. Who they were and how their work was organized differed between the cases.

As revealed in Subsection 4.2.1, the modification work of the Traffic-rule case was organized as a project according to the guidance for project organizations of the Rail Administration and had an extensive and formalized organizational structure, in particular regarding involvement of the management level of the rule-imposer, the rule-follower and for communication channels. When it was decided that the Inspectorate should have the function as rule-imposer, the organization became more involved in the work.

The complex organizational structure with so many involved actors required that the Traffic-rule case developed written documentation of its processes, in particular agenda papers and minutes from meetings. These present issues of concern, arguments and decisions.

Subsection 4.2.1 also revealed that the organizing of the Overarching Maintenance project followed the guidance for project organizations of the Rail Administration. The Maintenance-rule cases can be seen as work groups of the Maintenance-rule project that again is a subproject of the Overarching Maintenance project. At the level of the Maintenance-rule project and the studied cases these had an informal organizational structure with few requirements to involvement and documentation of the process. Agenda papers and minutes from meetings were limited. They mostly covered discussions of principle matters or issues that needed coordination such as the aim of a more unified rule system for maintenance activities.

5.2.2 Competency and experience base of the core participants of the work

The interviews revealed that the cases differed in their organizing and inclusion of competency and experience on behalf of the rule-imposers.

In the Traffic-rule case, the five people of the work group did the practical work. These were involved both in the risk analyses and the rule development. The Maintenance-rule cases organized the task of rule development differently. In the Superstructure case the two people involved in the regular modifications did the rule development and the risk analyses together. They also involved their Board of the branch that consisted of skilled and experienced rule- followers representing the different geographical regions of the Norwegian railway system. In the Power-supply case the rule-responsible delegated the task to develop the rules to a hired person. Depending on the technical equipment to be analyzed, he also involved different people in the risk analyses. Also, in the Signal case the rule-responsible delegated the task to develop the rules to a hired person. A special group of skilled and experienced rule followers were established to perform the risk analyses. As will be discussed in Section 7.2, in these cases the overlap and interaction between the people performing the risk analyses and the rule development varied.

All four cases involved people that had experience with former rule modifications of the actual rules.

The interviewees revealed that cases included different railway knowledge. With respect to formal railway related educations, the educations represented in the work group of the Traffic-rule case included both external technical and administrative education and more internal practice-oriented railway education. The Maintenance-rule cases included mainly external technical education. With respect to included railway experience, the experience-base of the group performing the work of the Traffic-rule case was varied and extensive. It included experience from the practical operative level, at the mid range administrative level and from safety work. The participants of the Maintenance-rule cases had most of their experience bases in the mid range administrative level. However, the risk analytic work included people from the practical field. These were chosen on the background of their reputation as very skilled professionals.

This implies that all cases included both intuitively-contextual knowledge and rationalistic railway knowledge. However, the Traffic-rule cases held the strongest elements of intuitively-contextual railway knowledge.

Regarding risk analytic competency, the inclusion of formal education and experience varied. One member of the work group of the Traffic-rule case had courses in risk analytic methods. When this person left the work group a risk analytic expert was engaged. In the Maintenance-rule cases only one person in the Signal case had prior education in the chosen risk analytic method. This case was also chosen as a pilot case for the Maintenance-rule project. None of the people with former experience with rule modification had experience of risk-based rule modifications.

5.2.3 Supporting knowledge resources

In several aspects the opportunities to draw upon knowledge of others varied. First, the Traffic-rule case started before the Maintenance-rule cases and the Rail Administration developed its Management system between their starting points. The cases of the Maintenance-rule project also started at different times. Hence the cases had different opportunities to lean upon others' work and experiences. This also gave the cases different access to ready-made decisions to draw upon, for instance, defined top events and risk analytic methods.

Second, the Traffic-rule case had more formalized resource groups to draw upon than the Maintenance-rule cases. The interviewees revealed that the most important were the Steering committee of the project, the Board of the project, the Board of the branch and the Cooperation committee between the Project and the Inspectorate, see Subsection 4.2.1. Among the Maintenance-rule cases, the Superstructure case had a Board of the branch that it included. The other cases did not have such operative boards during the modification period but as revealed the cases involved skilled professionals representing the rule-followers. As Maintenance-rule cases were a part of the same rule project they could use each other as resource groups.

Third, all cases had established systems for communication with the organizations of the rule-followers. However, these systems were different between the Traffic-rule case and the cases of the Maintenance-rule project. The Traffic-rule case had formalized interaction with the organizations of the rule-followers through the Board of the project and the Board of the branch. The organizations were mainly represented by administrative staff, not the rule-followers themselves who were the operative staff. Through the established system for rule modifications, the Maintenance-rule cases had already established communication with rule-followers and the work built upon this tradition.

Fourth, the Traffic-rule case had better access to economic funds than the Maintenance-rule cases and could hire in expertise. As a pilot project, the Signal case had a little better opportunity to take advantage of external risk analytic experts hired by the Overarching Maintenance project than the other cases, see Section 7.2. This person was also hired by the Traffic-rule case when they developed their methods.

Fifth, the interviewees demonstrated that the people involved took advantage of their personal networks. They also showed that long lasting, varied practice in the railway system and many involved actors implied a rich network for the cases to draw upon. Accordingly the Traffic-rule case had a richer network than the Maintenance-rule cases.

In accordance with the established practice of the safety work, the affected trade unions were not directly involved in the organizing of any of the cases. Furthermore, the users of rail services such as passengers and senders and receivers of cargo were not represented.

5.2.4 Organizational conditions of the work

The cases differed regarding conditions for interactions, cooperation and concentration. The Traffic-rule case had a common place where they performed their work. The work group of this case was employed for the work on half time basis.

The main actors of the Maintenance case were given the work as an extra task, but the task was closely related to their regular duties. The contracted people performing the work for the Power-supply case and the Signal case were hired on an hourly basis. The people who were responsible for the rules of these cases at the Head Office of the Rail Administration coordinated the work. To some extent they also participated. The hired people were not located together with these rule-responsible people. The two people who performed the regular rule modification of the Superstructure case also did the work of this rule modification. They were located close together. As the Signal case had a role as a pilot project the participants of the risk analytic work group had some allocated time for the task.

5.3 Characteristics of the rule-followers

The discussions of the hierarchical approach in Chapter 3 also directed the attention towards characteristics of the rule-followers. In particular, the attention was directed towards two issues. One issue was whom they were with respect to positions in the organizational hierarchies and the safety management systems, the other was their competency- and experience base. In the following these issues will be elaborated.

5.3.1 Hierarchical position of the rule-followers

The Traffic-rules were directed at rule-followers involved in operative activities. These were mainly engine drivers, traffic controllers, train dispatchers, shunting personnel and personnel responsible for work safety. These groups of staff are positioned at the lowest level of the organizational hierarchy of the Norwegian railway system. The engine drivers were constant traveling within the geographically distributed system. The personnel responsible for work safety were also a rather mobile group.

The Maintenance-rules were directed at the managers of the operative work and those actually performing the tasks. These were the line managers, i.e. the lower level management responsible for planning the maintenance activities of each line, the leaders of the different occupational groups and sometimes also those performing the practical work, that is to say the executive level. In other words, the rules were directed at rule-followers positioned at the three lowest levels of the organizational hierarchy of the Norwegian railway system. Those performing the practical work were a rather mobile group, but most commonly within the framework of their region.

At the beginning of the work, it was discussed in the Traffic-rule case that the rules should be directed more towards the traffic operators than they did for the time being. Only when found necessary for safety reasons should they be directed towards operative staff. The Maintenance-rule cases discussed that the main rule-followers should be the line manager, i.e. those rule-followers that held the highest position among rule-followers of existing rules. As the responsible for the rules of the Superstructure explained:

> *"…to put it bluntly, there has been an understanding or somebody has said that we write the rules for the line manager; the owner of the infrastructure. Then he is supposed to order the job. Accordingly the one performing the job does not need to know the rules very well. But in practice it is not like that …. Until now the line manager has ordered a job and said: "Do this and this and do it in accordance with the rules." Then it is evident that those who will do the task have to know the rules to the point!"*

5.3.2 Competency and experience base of the rule-followers

Traditionally the rule-followers of the rule sets of each case were rather homogenous and had an extensive understanding of the processes of the Norwegian railway system. The interviewees were concerned that the ongoing privatization processes were changing this. This matter will be elaborated upon further in Chapter 6.

The interviews revealed that the core rule-followers of the Traffic-rule case had their professional education in the internal educational system of the Railway system. Here the rules and knowledge of their context and intended function have served as the fundament of the education. The education has included extensive trainee programs. Accordingly a practical approach has been emphasized. The duration of the educations has been shortened and the educational system is under discussion.

The core rule-followers of the Maintenance-rules had predominantly external technical educations, often with a rationalistic academic approach. Traditionally external educated rule-followers had to undergo railway related courses when they started in the railway system. Also in these courses the rules and knowledge of their context and intended function played an important role. The rule-followers also had to have extensive practice before they were considered competent enough to take the full responsibility for the railway tasks. However, some interviewees were concerned that this practice is now not followed up to the same extent as before.

Many interviewees considered the rule-followers' knowledge of the context and the function of the rules as important for safe performance. This was associated with possibilities for correct rule use, attitudes towards compliance and discoveries of rule weaknesses.

5.4 Other stakeholders

Interviewees of both the Traffic-rule case and the Maintenance-rule cases revealed that there were other stakeholders in the rule modifications than just the rule-imposers and the rule-followers. However, the results revealed that these were not subject to their main concerns in the modification work.

The stakeholders that the interviewees mentioned most often were those responsible for controls and audits of performance, the timetables for the traffic operation, those involved in the educational systems and those involved in the control of the qualifications of the staff, i.e. the planning level. It was also mentioned that the content of rules could be of relevance for eventual subcontractors.

5.5 Characteristics of the rules' context

When discussing the hierarchical approach and knowledge in Chapter 3 the attention was also directed towards characteristics of the rules' context. This was particularly evident in the discussions about rule solutions with associated control principles and requirements to preplanning of activities and coordination. Below, the factors that appeared to be important for the studied modification processes are described.

5.5.1 Organizational development

The organizational conditions of the rules' context were changing due to the ongoing move towards privatization.

The Traffic-rules' area of regulation had become divided. First, NSB was divided into the Rail Administration that were given the responsibility for traffic control and coordination and the NSB that remained as a traffic operator. Second the remaining NSB was divided into different companies. Many interviewees were concerned that this had divided competency and reduced the opportunity to have and overview and understand the complex interactions between different activities of the system. As one member of the work group expressed it:

> "*Every time we have made such a step we have lost some of the whole and the thinking of the totality. Now, in a period we have been doing our own thing.*"

> *"…in other words, boxed thinking instead of the former NSB where everybody was thinking the same. We were all there for those who entered and left the train and for those who were sending goods etc. And if everybody had continued this way of thinking you would also have more safety philosophy in the thinking."*

In addition to the division of NSB, new operators were also introduced.

In the Maintenance-rules' areas of regulation, the most important feature was discussions of outsourcing and exposure of activities to competition. This had increased the emphasis on cost-efficiency and led to reorganization of some activities and outsourcing of other. This had divided groups that earlier had closely cooperated into different groups. Some of these groups became divided into buyers and suppliers of services. A few interviewees expressed an expectation that use of the rules might be extended to regulate the interests between the Rail Administration and subcontractors or suppliers.

5.5.2 Geographical differences

The rules of the cases have been developed for a geographically distributed system that covers different conditions. Throughout Norway there are significant differences in

environment and climate. The climate also changes dramatically during the year. Accordingly the context for the activities of the rules varies.

Except for urban areas and stations, most of the infrastructure consists of single tracks. There are differences in the technological standards and energy supplies of the lines that create differences in recovery aids in cases of mistakes and failures. As already revealed, one of the purposes of the Maintenance-rule project was to remove unnecessary maintenance that had resulted in different standards of infrastructure[25]. There is also an ongoing technological development that opened for new solutions in all four regulated areas. For example, remote control has gradually been introduced on the different lines. This has resulted in different relevance of some Traffic-rules in different areas. The suppliers of technical equipment to the infrastructure develop their products and there are differences in the introduction of these. The development with introduction of new actors and suppliers will most probably create even more differentiated technical solutions.

In addition, the traffic volume and density varies with the population and infrastructure of the geographical areas. This is also undergoing change and there were examples of both increases and decreases in the regions. There was also increased attention to the relationship between traffic volume and economy, i.e. cost-efficiency.

One interviewee of the Maintenance-rule cases explained the consequences of these geographical differences like this: *"In general, rigid systems will be met with distrust because the railway system is as differentiated as it is".*

5.5.3 Slack

The activities of both traffic operation regulated by the Traffic-rules and maintenance activities regulated by the Maintenance-rules were related to the time schedule for the traffic performance. The schedule regulated the activities of the traffic operation most directly.

Traditionally there have been some periods of slack in the time schedules. Some of the interviewees explained that delays have been possible but unpopular, both among the employees of the railway system and the customers. Delays have also been considered to represent a dangerous situation. The privatization processes has increased the focus of both the organizations of the Railway system and the customers upon precise traffic performance. The increased emphasis upon cost-efficiency has also contributed to tighter time schedules. In all, this has contributed to reduced slack in the activities.

[25] Homepage of the Overarching Maintenance project

5.5.4 Coordination and communication

The rules of the cases regulate activities with different requirements to coordination, communication and levels of functioning:

The Traffic-rules regulate traffic operations. The interviewees described how this activity involves many actors and organizations that interact with each other. Their safety is dependent upon the performance of the other actors. Many of the activities do not give time for thinking and/or consultation before acting and have to follow a rather rigid pattern of sequences. Many of the tasks are performed by lone people, for instance trains transporting goods are staffed with only one person; the driver. Therefore, to perform the tasks safely they found that the different activities have to be coordinated.

However, due to the geographically distributed nature of the system and the technical solutions there are limited possibilities for communication between the involved actors. The coordination and the communication have therefore been centralized in the Control centers. This means that the Control centers function as a common mode for communication between the actors. Accordingly, the communication between the actors becomes indirect and there are limited opportunities for feedback during the course of actions. Misunderstandings in the communication between the coordinators and the actors on the track and unforeseen actions can cause accidents. Therefore, the interviewees argued that communication has to be unambiguous and the actions of the actors have to be in accordance with the prescriptions of the rules.

The Maintenance-rules regulate the maintenance activities of one organization, i.e. the Rail Administration. When it is necessary to coordinate the maintenance activities with other actors on the tracks, the Maintenance activities are also regulated by the Traffic-rules. This means that the Maintenance-rules regulate the maintenance activities as such within one organization and the Traffic-rules coordinate the maintenance activities with other activities run by other actors on the line.

The interviewees explained that many of the maintenance activities are performed by groups. Some activities are also performed by lone people, for instance control functions. The tasks need to be coordinated with other actors on the track. This coordination is regulated by the Traffic-rules. As the traffic density of the different lines is very variable, the need for coordination of activities with other actors is very variable.

When it comes to the maintenance activities as such that are regulated by the maintenance rules, these usually require less coordination than traffic operation regulated by the traffic rules. Furthermore, they hold better opportunities for communication and consultation, time to think and feedback. This is especially the case when the work is performed by groups. During the work on the track the maintenance radio communication system, the train radio system and mobile phones are used to communicate with others. Therefore, with some exceptions this area of regulation is less dependent on strict communication patterns, predictable actions and gives the actors more time and freedom

to choose how to perform the activities as long as they do not conflict with the Traffic-rules.

5.5.5 Differences between the Maintenance-rule cases

The interviewees of the Maintenance-rule cases explained that these regulated areas held different characteristics.

First, the equipment of the Signal system has traditionally had the status as being most safety critical, the Superstructure system mid range and the Power-supply system the least. This was related to the risk potential in case of failure of the equipment.

Second, the equipment to be maintained by the cases differed in number of components and also the number of suppliers of the items. The Power-supply area had the highest, Signal was in the mean and Superstructure the lowest.

Third, the cases differed in the easiness to identify and delimit the items and to identify their status regarding failures. The items and their status were generally easier to identify for the Signal- and Power-supply cases than for the Superstructure case.

Fourth, the equipment of the cases differed regarding rate of change in technical solutions. The Signal and Power-supply had more rapid changes in solutions than the Superstructure.

5.5.6 Consequences of the ongoing transformations

All consequences of the ongoing changes of the Norwegian railway system were still not clear during the work of the cases. The interviewees provided their expectations and concerns but they also expressed that they did not feel that they were able to foresee the development. All together, this made the situation of the regulated areas rather ambiguous. Furthermore, the decreased homogeneity among the rule-followers and changes in the educational system might make the rule-followers experience the contexts for application of the rules with different levels of clarity; the better understanding of the regulated area, the less experience of ambiguity and vice versa.

The interviewees did not expect a decrease in the dynamics of these changes in the near future. For instance, they expected the privatization processes to go on, tenders were invited for traffic operation and maintenance activities. There was therefore a general concern for an adaptive rule management system among the interviewees representing both traffic operation and maintenance. The Traffic-rule case was especially concerned about the need to control the quality of the performance of the different traffic operators, the competency of the personnel at the operative level and the danger that knowledge might be lost. The Maintenance-rule cases were especially concerned to have the

opportunity to run the maintenance activities cost-effectively, to adapt the rules to the actual situation and at the same time keep control with the quality of safety critical items.

5.5.7 International development

The cases were also affected by international development. In parallel with the work of the Traffic-rule case, also Sweden and the EU were developing rules for traffic operation. The case was concerned about the development of TSIs within EU[26]. There was also communication with the Swedish project for rule development called the TRI-project because there are cross national traffic operations between Sweden and Norway.

Interviewees from the Maintenance-rule cases also reported that they followed the international development of rules, especially within the EU. They had an established practice to pay attention to both rules that were directly developed for railway activities and rules that were associated with their regulated areas.

[26] Project logg 1208, page 19

6 Hierarchical approach with a process of reverse invention

6.1 Introduction

This chapter is directed at the first of the three main research questions of this study:

How was a hierarchical approach to rule modification adapted?

The theory presented in Section 3.3 revealed two problems for the adaptation of the hierarchical approach. The first problem is linked to the work strategy for the new approach. The second is associated with the efficiency of conclusion derived from the new approach compared to the intentions of safe traffic performance.

The two following sections present results and discussions of these problems one by one. The structure of the presentation is shown in Table 6.1. The final section presents the conclusions of the research question.

Table 6.1 Structure for presentation of problems with results and discussions:

	Problem with answer	**Result**	**Discussion**
Strategy	Section 6.2, answer to the question of Problem 1: What work strategy to choose if low level rules already exist? A strategy of reverse invention for rule development	6.2.1 A cautious approach based on railway knowledge and existing rules	6.2.2 The strategy of reverse invention 6.2.3 Concluding remarks
Evaluation	Section 6.3, answers to the questions of Problem 2: What if the suggested rule solutions do not fit the actual situation with respect to 1. Competency of rule-imposer 2. Competency of rule-follower 3. Rule context? Choice of rule solutions with concerns for rules' context and rule-followers.	6.3.1 Rule solutions out of concerns for rules' context and rule-followers	6.3.2 The persistence of prescriptive rules 6.3.3 Concluding remarks

As revealed in Chapter 2, the two projects had low-level prescriptive rules directed at the operative staff of the Norwegian railway system from before. This staff was positioned at a low level of the organizational hierarchy of the system. The projects were aiming at higher order outcome-oriented rules, in the Traffic-rule project in the form of high order goal-oriented rules and the Maintenance-rule project in the form of mid range triggering requirements. These rule solutions fit in with the positions of the rule-imposers in the

organizational hierarchy; the rule-imposer of the Traffic-rule project had a high position and the rule-imposers of the Maintenance-rule project had a mid range position.

The ambitions of the projects to introduce outcome-oriented rules were not only in accordance with the hierarchical approach. They were also in line with a general trend within railways. Here there is an ongoing shift away from prescriptive rules towards performance-based controls, i.e. from a feed forward mode of control towards a feedback control. (Reason, 1997; Becker, 2002; Maidment, 2002).

6.2 A strategy of reverse invention for rule development

The first problem at stake is what work strategy to choose to follow up the intentions of outcome-oriented rules when there already exist low order prescriptive rules. As will be discussed below, all four cases of the two projects tried to follow up the intention to develop higher order rules. However, in these attempts the cases did not follow the deductive top-down strategy as expected. Furthermore, the cases questioned the proposed rule solutions that paralleled the hierarchical position of the rule imposer in the organizational hierarchy.

6.2.1 A cautious approach based on railway knowledge and existing rules

Ths presentation of the results of the cases is divided between the results of the Traffic rule case and the Maintenance-rule cases. The results of the Maintenance-rule cases are presented together because there were only minor differences in the results of these.

6.2.1.1 The developmental process of the Traffic-rule case

The Traffic-rule case did not implement goal-oriented rules; it stayed with the prescriptive rule tradition. However, the case made attempts to develop such rules.

Attempts to develop goal-oriented rules

At the beginning of the attempts to develop goal-oriented rules, the case intended to start from scratch and base these upon the overall purpose of safe traffic performance and risk analyses. As the work proceeded, the participants did not find this to be a good solution. Therefore they decided to change the work strategy and build the goal-oriented rules upon existing prescriptive rules. As one participant of the work group expressed it:

> *"When were sitting in the preparatory meeting I really believed that we had to start from scratch (to develop the rules, my comment). But during the course I understood, and I also think I influenced, that we had to keep the old (rules, my comment) and write the new out of that. And I think I participated in that process.*

But I really did believe that we should manage to start at scratch, but that had to be reversed!"

The main reason for the changes in the strategy was that the competency of the former rule-developers was highly respected by the participants of the work and it was experienced as both risky and a waste not to build upon this knowledge. One member of the work group described the work processes of earlier rule development processes and the trust in the competency of their participants like this:*"… the point was that there were skilled people sitting around a table discussing advantages and disadvantages with the rules. In a way I consider this to be analytic, but it was not put into a system, it was not presented in an analytic way."*

Accordingly, in the development of the goal-oriented rules the work group used existing prescriptive rules as starting point instead of risk analysis results as basis for the work. To decide upon goals, they inquired into the intended function of existing prescriptive rules, their context and their efficiency compared to their intentions. When available, risk analyses were used as a supplement. This strategy was also convenient for the progression of the work because the risk analytic work became much more time consuming than expected.

The results of the inquiries and discussions and the available risk analyses were used as input to development of goal-oriented rules. The work group did not find it easy to settle goals and found that they had to discuss existing rules and detailed railway knowledge before they were able to formulate goal-oriented rules. As one interviewee expressed it: *"…it is very difficult to make goal-oriented rules without going into details. Sometimes one must make the detailed rules to be able to see that; yes, then it is this that must be the goal-oriented rule."*

The work group also discussed the goal-oriented rule suggestions with their network and the resource groups and in particular the Board of the project and the Board of the branch.

Abandoning the goal-oriented rule solution

However, in spite of these serious attempts to develop goal-oriented rules, the case soon started to question this rule solution.

Already in the beginning, the Traffic-rule case was concerned about rules' efficiency as a contribution to safety. It engaged external researchers to collect information about the rule-followers' experiences and views of strengths and weaknesses in existing rules. Furthermore, the researchers collected information about rule-followers' opinions regarding future needs for rules and what they considered as good rules. A review of literature with relevance for the task to formulate rules was also provided. The core conclusions of the report were that the rule system had to be unambiguous, easy to understand, easy to approach and have a practical handy physical form[27].

[27] SINTEF report for the Traffic rule project, no STF38 F03408

As the work proceeded, the participants in the modification work were very concerned about the ability of the goal-oriented rule solutions to prevent accidents. The work group of the case inquired into and discussed the efficiency of this rule solution to serve this function within the group itself, with the network of its members, the Board of the project and the Board of the branch. The group did not trust that this rule solution was capable of securing safety to the same extent as the existing prescriptive rules could. One member of the work group provided this description of their growing concern:

> *"We started with some processes: To drive trains and prepare trains. We started with some thoughts that we also continued when building up the rules. But it did not work.... We agreed that those who made these (the previous rules, my comment) were not stupid either! So it became a natural consequence in a way."*

Therefore, the work group argued for less dramatic changes in the rule system. They wanted to keep the existing prescriptive rule solution and to experiment with goal-oriented formulations either as overarching rules that could serve as reference for the prescriptive rules, or in the textbook that was planned to follow the rules. Their argumentation built upon results of the inquiries and discussions. Much of this argumentation became written into agenda papers and minutes from meetings. The argumentation of the work group was accepted by the Board of the project. As the Safety director of the Rail Administration expressed it: *"The challenge was to see that one could not be as ambitious as first planned. It was one of these meetings with reality."* Many interviewees spontaneously mentioned that the railway competency that the members of the work group posited was highly respected. Therefore, there was no reason to question their professional judgments.

The result of the decision was that the Traffic-rule case stayed with the tradition of prescriptive rules. One consequence of this was that the core rule-followers continued to be the operative staff positioned at the lowest level of the organizational hierarchy of the railway system. This happened in spite of the transfer of the function as rule-imposer from the Rail Administration to the higher positioned Inspectorate. The plan to introduce goal-oriented formulations, preferably in the textbook, remained a question until late in the project. Then the Inspectorate decided to cancel the plan because of limited resources for its development.

<u>The development of prescriptive rules</u>

Also in the development of the existing prescriptive rules the Traffic-rule case used the overall goal of safe traffic performance and existing prescriptive rules as the major foundation for the work. The work group inquired into the rules' original context, their intended function and their efficiency to fulfill these intentions in the current context. Again, they used each other, the network of its members and its resource groups for inquiries and discussions. In particular they included the Board of the project and the Board of the branch for discussions and feedback upon the evolving rules. The members

of these boards also discussed the evolving work with their own networks. One of the participants in the Board of the branch gave this typical description of her function and her use of own knowledge and network: *"It (her function, my comment) is to attend to the rule sets or the rules; their content for users in traffic management, or in other words for train dispatchers and traffic controllers. I can see it by myself because I have that experience. At the same time I have a network that I can use as a supplement."*

The work group also arranged meetings with people who were expected to have objections to the evolving rules. Furthermore, the work was checked against reports of unwanted events and accidents. At the Euorpean level, the project followed and discussed the ongoing development of TSIs. Finally, to prevent bias and to reveal safety status after the changes compared to status in the beginning, the developed rules were reviewed by future rule-followers who were active in or close to the operative field, i.e. a so-called change analysis or HUL-analyses. The basic principle of these analyses was to decide whether the rule changes had made the risk higher, unchanged or lower. (The name HUL refers to the first letters of high, unchanged or lower.) The work group also checked that no new or changed rules came in conflict with old rules in such a way that adherence to old rules could result in dangerous situations. The trade unions were kept informed but not included in a systematic way.

The interviewees of the work group explained that feedback was discussed in the group. Decision criteria were not explicitly formulated in advance. The professional judgments of the participants and their trust in the quality of the feedback served as the fundament for the decisions. When found reasonable, feedback was taken into account. The Inspectorate will be responsible for the formal hearing process before the implementation of the rules.

Most commonly the participants of the work reported that their main and most useful contributors were representatives of the operative and educational staff. One interviewee found the questions of the Inspectorate's lawyers who were unfamiliar with the railway activities and terminology to be important for clarification of vagueness and ambiguity in evolving rule texts.

Modification results

The described modification process did not result in fundamental changes in the main rules that served the purpose of safety. In the formulations of these rules this case used the verbs "shall" and "must"[28]. This is in line with the tradition to consider these rules to be safety rules where strict compliance with the rules is necessary. In a few instances the verb "can" was used to show opportunities for exceptions and simplifications under

[28] In Norwegian the verb "skal" is used. This means mandatory in accordance with the definition of ENV50129. "Must" is a translation of the Norwegian verb "må" that also means "have to". This verb is also mandatory.

special conditions[29]. Supplementary advisory rules and rules that were seldom in use were removed.

One interviewee expressed a concern for the cautious attitude towards changes in the rules that case demonstrated. She asked if dangers associated with unchanged rules should not have been analyzed.

The main arguments for changes of existing rules were written and stored in a database.

Difficulties to retrieve knowledge

Some of the interviewees reported that the inquiries had revealed instances where knowledge of existing rules' original context and intended function was difficult to retrieve. The main reason was considered to be that this knowledge had not been written down when the rules were made. Furthermore, organizational changes and downsizing with staff reductions had made this knowledge scattered around within the organization A few examples were given where such knowledge was lost because people had left the organization. Because the work group had participants who had worked in the system for decades and with different functions, they were both very skilled railway professionals and had a strong network. Furthermore, the work group took advantage of the knowledge of their resource groups and in particular the Board of the branch that also consisted of very experienced railway professionals with strong networks. Therefore, retrieval of knowledge was not reported as a serious problem for the case.

Articulation and combination of knowledge

The inquiries that the work stimulated caused an articulation of knowledge and knowledge from different sources was discussed and combined. The organizing of the work group where the members had scheduled time for the work and were located together made it possible for the group members to cooperate very closely. Furthermore, they could take advantage of each other's network and the different resource groups. This was found to be positive for the work. One member of the group described the discussions like this: *"We had many fruitful discussions, but I cannot say that we had any – not as I remember, at least not at my level or position – experiences of large conflicts."*

6.2.1.2 The developmental process of the Maintenance-rule cases

The Maintenance-rule cases implemented the intended higher order rule solutions of triggering requirements. When found necessary these were supplemented with prescriptive rules, mainly in the form of work instructions.

[29] The verb "can" is a translation of the Norwegian verb "kan".

The development of triggering requirements

From the beginning, the intention of the Maintenance-rule projects was to base the development of triggering requirements upon goals formulated at higher levels of the Rail Administration's organizational hierarchy, their safety management system and risk analysis results. However, this did not happen. The project leader of the Overarching Maintenance project explained that when developing the triggering requirements, the cases did not follow a logic structural approach in the work. Instead they used existing rules as a starting point because they were rather sure that these covered up the laws and requirements of the authorities. In addition, the work built upon existing knowledge and experience.

The cases also revealed other reasons for this strategy. One reason was the late timing of the final decision to apply risk analyses in the modification work. When this decision was made the Power-supply case had already started the work of rule development and the Superstructure case had already finished their work. Accordingly, the rule development that was done before these decisions could not be based upon risk analysis results. The different use of the risk analyses will be elaborated in Chapter 7.

Based on the encouragement to "think new", the Power-supply case and the Superstructure case began the development of triggering requirements with attempts to define the state of the technical equipment that defined needs for maintenance activities. However, the participants of the developmental work did not find this to be a good solution. The main reason revealed was that they respected the competency of former rule-developers. This made them also respect the inherent knowledge of the rules and they found it important for safe performance. Accordingly, they wanted to bring this knowledge forward to the new triggering requirements. One exception was found in the Power-supply case where some of the existing rules were maintenance instructions provided by the equipment's suppliers. If these were considered to serve the interests of the supplier instead of interests of the Rail Administration and safety, they were given limited attention.

In the Signal case the risk analyses were finished before the rule development started. In spite of this, the case decided upon the same strategy as the other cases. The rule writer of this case tried to develop triggering requirements on the background of the risk analyses. However, as the work proceeded, he and the rule-responsible at the Head Office of the Rail Administration changed their mind. The rule writer provided this description of the processes: *"Gradually, we have seen that the descriptions of instructions inherent in the rules of today have a rather great value as input to the rules. Then you transfer the points of the checklists in the instructions into triggering requirements."*

In the work to develop the triggering requirements, the cases inquired into knowledge of the standard that the prescriptions of the existing rules were aiming at and under what conditions, in other words; the intended function and context of the rules. They also inquired into their efficiency compared to their intentions. One of the interviewees explained that: *"Some of the triggering requirements have been tacit knowledge."*

The people involved in the rule writing transformed rule specific knowledge and the results of the inquiries into triggering requirements. However, sometimes these cases also found it difficult to define outcome-oriented rules. The rule-responsible of the Signal case summarized the experiences from the work like this:

> *"…what I would say in hindsight, it is that all such processes (processes of rule development, my comment) should be almost like an iteration; that one starts top-down to see if it is possible to come down to the lowest level. And then you start from the bottom and build upwards again to see if it suits with the frames one made. It is a general consideration I suppose, that if you start in one end and go downwards, then it will become a mismatch at the lowest level. Or opposite, if you start at the lowest level without looking upwards, then it does not fit the frames one wants."*

Furthermore, the different cases faced different challenges. The Signal case found that it was not possible to settle triggering requirements for all of their items. The Power-supply case found it challenging to find a practicable solution for their many components and suppliers that had developed maintenance manuals for their equipment. This case decided to relate the rules to their first level of subcomponents and to give priority to the rules that became classified as safety critical. This case also found that the function of triggering requirements could be questioned because they were sometimes squeezed between requirements of the authorities and the prescriptive rules. The Superstructure case faced some problems to define clear triggering requirements for some of their items. The reason was that their status was difficult to define in simple terms.

The Maintenance-rule cases also used the results of the inquiries to supplement the triggering requirements with so called "explanatory texts". These provided explanations of the intended purpose of the triggering requirements. The explanatory texts were placed in direct relation to the rules.

The Maintenance-rule cases were also concerned about the efficiency of the rules and at the beginning it had a plan to invite rule-followers to comment upon existing rules. Of practical reasons, this plan was not followed up. However, the project received indirect information through a project about knowledge and competency run by the Overarching Maintenance project. The suggestions of the report from this project were that the rules must be adapted to the new ideas of decentralized decision-making that are introduced in the Rail Administration [30]. Furthermore, the report emphasizes that rules cannot compensate for professional judgment. This fits in with the plan of the cases to use triggering requirements as the main rule solution.

[30] SINTEF report for the Overarching Maintenance project, no STF38 F02902

Prescriptive rules as supplement to triggering requirements

However, as the work proceeded, the participants of the Maintenance-rule cases also became concerned about the efficiency of the triggering requirements as a means to prevent accidents. These concerns took another form than they had in the Traffic-rule case. Because these cases had the possibility to supplement their triggering requirements with prescriptive rules, the main inquiries and discussions about rule solutions were not whether to accept or reject triggering requirement as a rule solution. Instead they became concentrated around the need to supplement these rules with prescriptive rules.

The question about the need for prescriptive rules stimulated inquiries into railway knowledge and discussions about the results of these. Again, the focus of attention was their original context, intended function and their efficiency to fulfill these. This work was integrated in the work with the triggering requirements. Therefore, the inquiries and the discussions of the cases followed the same patterns for investigations and cooperation as described above.

The existing prescriptive rule tradition appeared to be more persistent than expected. The surviving prescriptive rules received the status as appendixes to the triggering requirements, i.e. they had a subordinated role. The project leader of the Overarching Maintenance project did not define them as formal rules. The leader of the Maintenance-rule project considered triggering requirements to be most useful for those controlling the work and the prescriptive rules to be most useful for the operative staff. Accordingly the hierarchy of the rule solution paralleled the organizational position of the rule-imposer and the rule-follower in the organizational hierarchy, i.e. the mid range triggering requirements for the mid range rule-imposer responsible for control and the low order prescriptive rules for the low level staff responsible for the quality of the practical performance.

The major reason the participants of the work gave for the persistence of the prescriptive rules was that they were suspicious about the ability of the triggering requirements to prevent accidents compared to the prescriptive rules that they had experience with. Therefore they wanted to bring forward the latter rules, especially because they built upon and were in accordance with trusted railway knowledge. One of the rule writers explained it this way:

> *"I do feel that it is very important to bring forward the history related those requirements that are in the existing work instructions. I feel that there will not be enough time to just remove them and say that it is not necessary to bring them further. Then I feel it is better to bring them forward into the new rule set as a first round until we get more experience with it"*

This explanation is also in accordance with the general impression of the head of the Maintenance-rule project. He explained some of the difficulties to give up the existing prescriptive tradition like this: *"It (triggering requirements, my comment) is difficult to*

apply upon many things Therefore it often becomes supplemented. It is difficult to simply give up what one has; in a way what one has becomes continued."

The leader of the Overarching Maintenance project also commented that it was easier to limit the rule sets to only contain triggering requirements when there was less acute risk.

The development of prescriptive rules

When the prescriptive rules were developed, the existing prescriptive rules were used at the starting point just as they did for the triggering requirements. Risk analyses were used as a supplement to the work when they were available. Furthermore, as the work followed the development of the triggering requirements, it followed the same patterns for inquiries, discussions and cooperation that the cases revealed for their development.

The use of verbs

The Maintenance-rule cases had also an additional task in their modification work. The decision of the Overarching Maintenance project that the use of verbs in the rule texts should be differentiated was followed up. To distinguish between safety related rules and other rules in the rule sets, the verb "shall" was used for rules related to safety and regulations of the authorities[31]. In addition the safety related rules were given a special marking; a "tag". The verb "should" was used for the other purposes[32]. Also in this task the cases followed the described patterns for inquiries and discussions.

Feedback upon the work

Those directly involved in the rule development searched for feedback upon the evolving triggering requirements and prescriptive rules. They used each other and their network. As one interviewee explained:

> *"Then I send it to those who I know have opinions about it, and preferably those who I know will come up with comments – those who I know really care. And may be I send it to those who I know will not come up with comments, but who will complain afterwards. Then they have at least had their opportunity to come up with their opinion."*

In addition the Superstructure case used its Board of the branch for feedback upon their work. The cases also compared their work with the development of accident reports from accidents and unwanted events.

[31] In Norwegian the verb "skal" is used. This means mandatory in accordance with the definition of ENV50129.
[32] In Norwegian the verb "bør" is used. This means recommended in accordance with the ENV50129

At the end, the Maintenance-rule project organized a joint two-step hearing process. First the rules were presented for rule-followers in each region and discussed. Shortly after, the rules were sent to each region for formal hearing. According to the interviewees, the regions differed in the efforts they put into the hearing work and who they involved. Furthermore, interviewees from two of the cases mentioned that they were disappointed that they did not receive more comments upon the triggering requirements. The Maintenance-rule project performed change analyses to reveal the safety status after the changes compared to the status at the beginning. Also in these analyses the rule changes were judged with respect to their contribution to higher, unchanged or lower risk. These engaged different people for the different cases. The trade unions were not incorporated in the processes in any systematic way.

Also in the Maintenance-rule cases, the feedback was discussed and incorporated in the rules when found reasonable by the people involved in the developmental work. Again, the decisions were based on the professional judgments of the participants without preset criteria.

The interviewees of these cases also found the operative staff to be the most useful contributors to the modification work.

To some extent the cases wrote the main arguments for changes in the prescriptive rules and stored them in databases.

Difficulties to retrieve knowledge

In the inquiries the Maintenance-rule cases found that some knowledge about context and intended function of existing rules was difficult to retrieve. The interviewees gave the same explanation for this as those reported for the Traffic-rule case. A few interviewees said that problems in retrieving such knowledge made it difficult to judge the relevance or quality of these rules. The leader of the Maintenance-rule project explained that the rule-developers had a lot of respect for the railway knowledge of their predecessors. Furthermore they did not always feel confident that they themselves had the full overview of all of the rules' functions. Therefore, they were hesitant to change or remove rules where they felt that knowledge of the rules' original context and intended function was limited.

Different conditions for articulation and combination of knowledge

The organizing of the cases differed and this made their conditions for the inquiries and discussions of the evolving work very different. The Signal case hired an external consultant for the rule writing. He performed much of this task by himself. However, as he was a former employee of the regulated area, he used his network for inquiries about the context and intended function of the rules and their efficiency. He also used this network for discussions about the evolving triggering requirements. He reported to the

rule-responsible at the Head Office of the Rail Administration. The work was under time pressure.

The Power-supply case also hired a consultant from another department of the Rail Administration for the rule development. He did much of the rule development alone. This consultant had also worked in the regulated area before. He interviewed experienced staff from his network about the context and intended function of existing rules and their experiences with the rules. He also discussed the results of the evolving work with this network and the rule-responsible at the Head Office. The work was under time pressure.

In the Superstructure case the majority of the work involved the rule-responsible and the railway professional that usually cooperated in the management of the rules. As rule modifications were seen as a part of their responsibility they did not get specific time for the task. These two people were located together. This made it possible for them to use each other and cooperate in the inquiries, discussions and the developmental work of the rules. The two rule writers also involved their network and the Board of the branch in the inquiries and the discussions of the evolving work.

Accordingly the conditions for articulation of railway knowledge and combination of knowledge from different sources varied between the cases.

6.2.2 The strategy of reverse invention

In the presented results a common pattern can be seen: First, the cases explored and evaluated the elements of the hierarchical approach. The results of these processes made the cases abandon the suggestions derived from the hierarchical approach. Instead they built the rule development upon existing railway knowledge and rules. Below, these findings are discussed and related to theory.

6.2.2.1 Exploring and evaluating the hierarchical approach

In their modification work the cases took the hierarchical approach into account. All cases intended to develop rule solutions at a level of the rule hierarchy that matched the positions of the rule-imposers in the organizational hierarchy of the Norwegian railway system. Two out of four cases intended to develop higher order outcome-oriented rules with the help of risk analysis results. From the beginning, the two others were not given this opportunity. Furthermore, all four cases intended to deduce lower order prescriptive rules from the outcome-oriented rules if found necessary.

The top-down approach to the rule development would have applied a choice based mode of decision-making as discussed by March (1994). According to the ideals of this form of decision-making, the starting point of the work would have been preferences formulated as goals that were derived from risk analyses. Then the work should have proceeded into inquiries of alternative means to achieve these goals. Prescriptive rules might have

appeared as one means. This is in accordance with the encouragements to the cases to "think new" and the idea to start the work from scratch. This is also in accordance with discussions of Lindblom (1959). He argues that the rationalistic strategy implies that decisions have to start from new fundamentals each time. They only build upon the past when experiences are embodied in a theory. The decision-makers are always prepared to start from the ground up, i.e. from scratch.

Furthermore, the proposed outcome-oriented rule solutions built upon the feedback control principle. The rule specific knowledge encoded in such rules is knowledge about wanted outcomes or what to achieve. When applying this principle the rule-followers are supposed to choose the best solutions based on feedback upon their activities where the goals of the rules are used as reference. Furthermore, they are supposed to explore possible means to bring forward a development towards the goals and to implement the best means in their activities. Therefore, this control principle can also be associated with the choice based decision-making discussed by March (1994).

All cases made serious attempts to follow up their intentions. In this way the ideals of the hierarchical approach were explored. However, the cases soon started to question these ideals. The main reason was that they did not bring forward existing railway knowledge, including existing rules, and that the ability of the suggested rule solutions to prevent serious accidents became an issue of concern. Therefore they inquired into railway knowledge to judge the efficiency of hierarchical ideals. Accordingly, railway knowledge served as a reference for good solutions in the evaluation of the hierarchical approach.

6.2.2.2 Abandoning suggestions for the hierarchical approach; building upon the existing

The main conclusion that the cases made from the inquiries was that the existing railway knowledge and in particular the knowledge associated with exiting prescriptive rules was too valuable for safety to be abandoned.

Therefore, the cases did not approve the deductive top-down strategy as suggested for the hierarchical approach. Chapter 2 revealed that, the Norwegian railway system had a long history where a prescriptive rule tradition had evolved. The development of the rules gives association to the arguments of Reason (1997) that the stage reached in the organization's life history will influence the opportunities for feed forward and feedback control. In other words, the system has had a long enough history to develop prescriptive rules in accordance with feed forward control principles. Furthermore, the participants of the studied modification processes found this tradition valuable to build upon for the purpose of safe performance. The prescriptive rules were seen as important elements in the Norwegian railway system's organizational memory as discussed by Stein (1995).

Instead, the cases decided to apply another type of rationality in their developmental work. This was based on an inductive bottom-up strategy where the existing prescriptive rules were used as the starting point for rule development. This made it possible to build

upon the accumulated knowledge associated with the prescriptive rules and in particular knowledge about their former and existing context, their intended function and the experiences of their efficiency to fulfill these intentions. In March's terminology, the work became based upon a more rule- and identity based type of decision-making (March, 1994). The existing rules and associated knowledge served as a fundament to judge what was considered to be appropriate outcomes of the regulated activities. In this way, knowledge associated with existing rules was brought forth into the new descriptions of wanted outcomes and the work did not have to start from scratch. This can be seen as a cautious strategy to fulfill the requirement of outcome-oriented rules in a prescriptive rule tradition.

The change in work strategy from a deductive top-down approach to the rule development towards the inductive bottom-up approach means that the cases left the dominating rationalistic form of rationality of the hierarchical approach. The work was brought in accordance with existing railway knowledge

Furthermore, the inquiries that the cases made into railway knowledge made them cautious to replace existing prescriptive rules with outcome-oriented rules or change them. In particular, they were cautious if they did not feel confident that they had sufficient knowledge of the original context and intended function of these rules. Therefore, the prescriptive rules appeared to be more persistent than expected. In the Traffic-rule case the outcome-oriented rule solution was abandoned and the prescriptive rules became the only solution. In the Maintenance-rule cases the triggering requirements had more appendixes with prescriptive rules than intended.

The persistence of the prescriptive rules means that the cases were hesitant to change the rule specific knowledge encoded into written rules from "what to do" towards "outcomes" or what to achieve. To draw upon discussions of rationality and knowledge, they were hesitant to abandon thick descriptions of the necessary activities for safe performance for rationalistic thin descriptions of their intended outcome (Baumard, 1999; Perby, 1995; Perrow, 1999; Schön, 1991).

This implies that they were hesitant to leave the rule- and identity based decision-making of the prescriptive rules and to base the activities of the regulated area upon the rationalistic decision-making of outcome-oriented rules. The results reveal that the cases found the feed forward control principle to be important for safe performance. In other words, they wanted rule-followers to work according to the principles of rule- and identity based decision-making (March, 1994).

The cautious bottom-up strategy and the unintended strong position of the prescriptive rules mean that the cases left the dominating rationalistic form of rationality of the hierarchical approach. Knowledge associated with the existing prescriptive rules was brought forward indirectly and directly: indirectly by the use of prescriptive rules as starting point for the development of outcome-oriented rules and directly by the survival of the prescriptive rules. In this way the work was brought in accordance with existing railway knowledge.

Cautiousness associated with changes is also discussed in the safety literature. When discussing High Reliability Organizations, LaPorte, & Consolini (1991) warn against experimenting when the consequences of the experiments might be dangerous situations. Becker (2002) argues that the transition period between two regulation systems might be very dangerous and introduce new risk. According to Becker increased regulatory attention is needed in such cases, instead of reliance on a good track record in the past.

However, the results also revealed that all cases wanted outcome-oriented formulations together with the prescriptive rules. The decision of the Traffic-rule case to abandon the textbook where such formulations were planned to be an important element, was made out of resource concerns, not because the idea of outcome formulations was completely rejected. Therefore, the results also reveal that the cases found rules building upon principles of choice based decision-making communicating what to achieve, to be useful.

The arguments that the cases used for the different rule solutions will be elaborated upon in the next section. The discussions of rationality and knowledge will be extended in Chapter 8.

6.2.2.3 Railway knowledge as a reference for good solutions

The persistence of the prescriptive rule solutions that the cases demonstrated implies that the cases representing the rule-imposers, took the responsibility to translate intended outcomes into action/state rules such as discussed by Hale and his associates (Hale, 1990; Hale & Swuste, 1998; Hale et al, 2003). The Traffic rule case made this translation on the basis of the overall goal of safe traffic performance. The Maintenance-rule cases both developed triggering requirements on the basis of goals formulated at higher levels of the Rail Administration's organizational hierarchy and their safety management system. They also translated some of these into more prescriptive action state rules.

The decision processes of the strategy for the rule development and the choice of rule solutions revealed that railway knowledge served as a reference for the good solution and that the cases preferred solutions that were in accordance with this knowledge. First, this knowledge was used to judge the appropriateness of the deductive top-down approach to the development of outcome-oriented rules. Second, it was used as a reference to judge the appropriateness of rule solutions. Third, this knowledge, with the existing prescriptive rules, was used as the basis for the development of both outcome-oriented rules and prescriptive rules and in the evaluation of the quality of the evolving rules. In particular knowledge of the rules' original context and intended function and their efficiency in the current context appeared to be important. This knowledge was necessary to judge the relevance of the existing prescriptive rules that appeared so central to the work and to reveal needs for modifications.

When contradictions between the railway knowledge and the solutions of the hierarchical approach occurred, the first appeared to engender most trust. Accordingly the decisions

were brought in accordance with railway knowledge. One can say that the processes built consensus around the validity of railway knowledge. This also demonstrates that the railway knowledge, including existing rules that were included in the work, was very important for the quality of the work.

The fact that the work group of the Traffic-rule case got acceptance for their argumentation in favor of prescriptive rules, demonstrates that the confidence in the group's railway knowledge was high. This was attributed to the composition of the work group. In the beginning, the case intended to develop an outcome-oriented rule solution that is supposed to require less knowledge of details in rules' context than prescriptive rules (Hale, 1990). In spite of this, the case had engaged a work group that possessed extensive, updated and varied railway knowledge. The extensive and varied practice of the participants made the work group possess a wide network that was included in the work.

The closeness to the rules' context and the rule-followers was also strengthened by the established resource groups for the case. However, even though many of the representatives of these groups had railway educations for the operative fields, most of them held administrative positions. Accordingly, the executive staff was poorly represented in these resource groups and their trade unions were also not involved. Therefore the closeness to the rule-followers was not established in the more democratic sense like the more general trend discussed by, for instance, Hopkins (2000). Such an element might have made it easier to involve, inform and explain why the final rules have been arrived at (Hale et al., 2003). However, it might also have introduced more opinions and other motives and hence caused more conflicts.

Taken together, the Traffic-rule case had the capability to develop both outcome-oriented and prescriptive rules in the IF-THEN form suitable for the current situation as Hale (1990) discusses. Furthermore, they had the ability to judge the appropriateness of rule solutions for the actual situation. With reference to the question of Hale et al. (2003) whether the government regulator has or can buy in sufficient expertise for the work, one can say that the answer is yes in this case. The competency and the network that the case took advantage of had evolved over time in the former stable NSB-organization.

As the Maintenance-rule cases could play upon different rule solutions in their modification work, they did not have to argue heavily for their choices. Hence, the confidence in their judgments cannot be confirmed to the same extent as in the Traffic-rule case.

Chapter 5 has revealed also that the Maintenance-rule cases possessed strong railway knowledge. However, neither through education nor through practice was this knowledge strongly linked to the context of the different regulated areas to the same extent as the knowledge of the Traffic-rule case. Furthermore, the work of each case included relatively few people. Accordingly, the network involved in the work did not appear as rich as the network of the Traffic-rule case. Among the cases, the Superstructure case appeared to have the strongest context related knowledge as this case included their

Board of the branch in their work. The hearing process also created an interface between the rule solutions and knowledge of the rules' context. In spite of this, one cannot say that these cases included the rule-followers in a democratic sense as Hopkins (2000) discusses.

The main rule solution of the Maintenance-rule cases, i.e. the technical triggering requirements, is not as concrete as the prescriptive rules of the Traffic-rule case. Accordingly they are not as dependent upon context specific railway knowledge as these (Hale, 1990). However, these cases also made extensive use of prescriptive rules and these rules were used as starting point for the development of triggering requirements and the judgments of the need for prescriptive rules. Therefore, these cases needed extensive knowledge of the regulated areas too.

The conditions of these cases indicate that they had less access to extensive and updated railway knowledge than the Traffic-rule case. This might be one explanation as to why these cases also expressed more concerns for limited access to the original knowledge of rules' context and intended function than the Traffic-rule case. As revealed, this created problems for the modification work regarding the judgments of rules' relevance and modification needs and a precautionary attitude towards changes.

The question of the relevance of existing prescriptive rules for the actual situation is especially important due to the ongoing changes of the Norwegian railway system. March (1994) suggests that rules represent an impact of the past upon the present; they can be seen as residue of the past. The past can also be encoded in the future by environmental selection of rules. In this process, the composition of the rule change but not the individual rules. According to March, the learning process that change rules as a result of experience must include information about what happened, why it happened, and whether what happened was satisfactory or unsatisfactory. He finds that this is not always possible to achieve and learning might be limited.

The difficulties to retrieve knowledge about the original context and intended function of the existing rules and the importance of this knowledge in the work demonstrate that this is a relevant concern. Taken to the edge, this might have contributed to a development where the modification work was based upon false assumptions, i.e. assumptions that were not in accordance with the actual situation. However, through the feedback processes that the cases initiated for the evolving rules, they took steps to counteract this danger. Still, this discussion demonstrates that extensive use of prescriptive rules as starting point for the work might be vulnerable for rapidly changing conditions with poor feedback upon their relevance and efficiency to achieve their intentions. This also actualizes the question raised by one of the interviewees about performing analyses about the consequences of no changes in existing rules.

6.2.2.4 The rigidity of chosen solutions: Implications for future modifications

The processes associated with the hierarchical approach and the chosen rule solutions might have implications for future rule modifications.

The rule solutions of the cases with extensive use of prescriptive rules and the verb "shall" represent rigid rule solutions that require strict adherence. As Minzberg (1979) argues, the chosen rule solutions require fast reactions to follow up the development with updated rules. Bourrier (1998) discusses how organizational designs can facilitate necessary rule changes. The issue is how the need to adjust and correct policies and procedures is handled in the organizations, because this will have consequences for the need to violate rules. The need to violate rules will again have consequences for the possibility for open flow of information that is important for the organizations' ability to learn and develop.

This represents a challenge in the current dynamic and competitive context of the Norwegian railway system. In general, dynamic contexts make it more difficult to define the conditions for prescriptive rules, i.e. the IF condition (Hale, 1990). Further, it makes it more difficult to proceduralize the tasks (Reason, 1997).

For the Traffic-rules, the communication of future needs for modification and deviance will be dependent both upon the communication channels within the regulated organizations and between these organizations and the Inspectorate. These communication channels have to cover a rather long distance between the hierarchical positions of the rule-imposer and the rule-followers. They were still not settled and systematized when the data collection of this study was finished, except for the communication channels that the internal control principle provides. Hence there are also uncertainties related to future feedback loops upon the efficiency of the existing rules. Accordingly, there are also uncertainties regarding learning loops that might contribute to improvement of the rules as discussed by March (1994). In addition there were uncertainties regarding the continuity of the future development of the rules as the modification work became transferred from the Project to the Inspectorate.

For the Maintenance-rules there already exists a tradition for communication between the rule-imposer and the rule-follower. The planned system for a continuous dialogue about the rules provided by the other sub group of the Overarching Maintenance project might be one way to counteract negative effects of the constraints upon flexibility that the prescriptive rules and "shall" formulations represent. This system might also strengthen the context specific knowledge of the rule-imposer. In addition these plans give a more active role to the rule-followers themselves. The planned system also provides decision rules related to changes and deviance from the rules. This is in accordance with the suggestions of Hale & Swuste (1998) to establish rules for the translation of goals into action/state rules. The Maintenance-rule cases have also the advantage that when it comes to those responsible for the modification of the rules for the respective fields, there are no plans for changes in the staff involved in the studied modification processes and future processes. This allows for more accumulation of knowledge.

The discussion above reveals the paradox that the rule-imposer of the Traffic-rules, i.e. the Inspectorate, with the greatest challenges had the least plans for communication with the rule-followers and for future management of the rules.

The ongoing changes of the Norwegian railway system are also a problem for the important role that the network of the work participants had for retrieval of knowledge. The ongoing changes might change the conditions for the development and survival of such networks. The networks were concerned about safety, i.e. they were "about" something. Accordingly, in Lave & Wenger's terminology there seems to be a community of practice for safety where the members develop knowledge within the Railway system (Lave & Wenger, 1991). As Wenger (1998) suggests, such communities are fragile and are weakened as soon as their content receive less attention. As will be revealed in the next section, there are indications that increased emphasis upon competition and cost-efficiency competed with the emphasis upon safety. These networks were also primarily based on contacts and knowledge from the time before the ongoing privatization process. Hence, if no counteractive steps are taken, the changes might endanger communities of practice about safety that could be useful for future rule modifications.

6.2.2.5 Influence upon railway knowledge

The impact from the hierarchical approach upon railway knowledge will be elaborated upon, and discussed in Chapter 8. However, at this stage I want to draw attention to some results of particular interest for the later discussions.

First, the inquiries into railway knowledge and the following discussions made knowledge from different sources become more articulated, combined and shared between more people. However, the way the cases organized the work created different conditions for inquiries and hence inclusion of knowledge and to what extent knowledge became articulated and shared.

Second, the inquiries revealed that fundamental knowledge of the existing prescriptive rules about their context and intended function had become weakened over time. In particular, this knowledge was undermined by the ongoing organizational changes where people had changed their positions or left the system. This problem is not unique to the Norwegian railway system, it is also revealed in other European railways (Hale et al., 2003; European Commission, 2004b).

Third, selections of included knowledge became encoded into written texts. Some of it was expressed in the rule formulations. Some of it was expressed in the argumentation for rule changes and stored in databases. In addition, selections of the railway knowledge that were central in the argumentation for the chosen rule solutions were encoded into the written texts of agenda papers and minutes from meetings. These are stored in electronic archives.

6.2.3 Concluding remarks

The four studied modification processes did not follow the ideals of the hierarchical approach. Instead the modification work of all the cases turned into processes that I have called ‘reverse invention’ in this study.

In the process of reverse invention the cases explored and evaluated the rationalistic ideals of the hierarchical approach. In the exploration and evaluation of their ideals, the major concern was their ability to include railway knowledge seen as important for prevention of unwanted events and accidents in the modification work, and the rule solutions. Railway knowledge served as a source for information gathering and as a reference for evaluation.

When divergences occurred in the evaluations, these were inquired into. Bringing the strategy and the rule solutions into accordance with railway knowledge solved such problems.

Railway knowledge, and in particular rule specific knowledge of existing prescriptive rules and knowledge about their context and intended function, served as fundament for the rule development. When available, risk analyses contributed as a supplement. The process of reverse invention is illustrated in Figure 6.1 below.

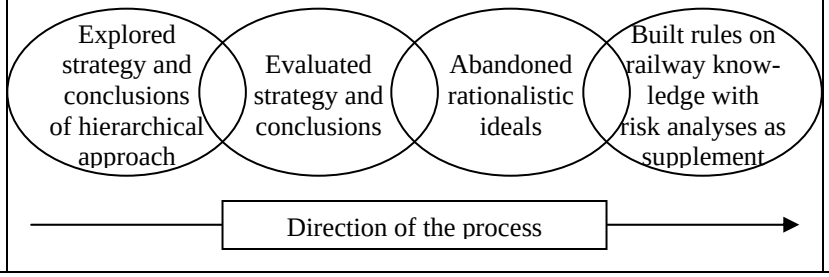
Pheno-menon	**The adaptation of all cases to the hierarchical approach**	**Conse-quences**
Reverse invention		Railway knowledge and prescriptive rules were persistent out of concerns for safety.

Figure 6.1 The strategy of reverse invention for the hierarchical approach.

The circles demonstrate the stages of the process. Their overlap illustrates that there were overlap between the stages. The arrow from left to right demonstrates the direction of development for the process.

The main elements in the development towards the strategy of reverse invention were as follows:

- None of the cases used the ideals of a deductive top-down strategy of the hierarchical approach to rule development in practice. The main reason was that this method did not include knowledge associated with the existing prescriptive rules.

- Instead, all cases chose an inductive bottom-up strategy. Knowledge about context, intended function and the experience of the efficiency of the rules to fulfill these intentions was inquired into and used as the basis for formulations of wanted outcomes.

- The bottom-up strategy made it possible to build the outcome-oriented rules upon knowledge associated with existing prescriptive rules, and in particular knowledge of these rules' context and intended function. This knowledge was inquired into and discussed. When the rule formulations were made, the rule specific knowledge prescribing what to do became reduced into outcome-oriented rule formulations describing what to achieve.

- However, the anticipated ability of these outcome-oriented rules to ensure safe performance was also evaluated. Accordingly, the rule solutions of the hierarchical approach stimulated questions to railway knowledge, i.e. this knowledge became inquired into and railway knowledge served as reference for good rule solutions.

- The results of the inquiries were that the ability of the outcome-oriented rules to prevent unwanted events and accidents became doubted. On the other hand, the existing prescriptive rules that had been developed over time by highly respected railway professionals received increased trust.

- Therefore, the prescriptive rules appeared surprisingly persistent compared to the intention of the projects. One case abandoned the outcome-oriented rule solution and kept prescriptive rules. This case wanted to supplement the rules with formulations of outcomes but had to cancel the idea. Three cases chose outcome-oriented triggering requirements combined with prescriptive rules. The number of the latter exceeded the intentions of the work.

- The persistence of prescriptive rules implies that the rule imposer took the responsibility to translate formulations of outcomes into prescriptive action/state rules. There was no explicit decision-rule for this task. The applied rule was to use available railway knowledge as reference for good solutions.

The inquiries revealed that knowledge about the original context and intended function of existing prescriptive rules was not always easy to retrieve. This made it difficult to judge their relevance for the current context. This was less evident in the Traffic-rule case that possessed the strongest knowledge sources than it was in the Maintenance-rule cases.

The theory of March (1994) and the problems associated with difficulties to retrieve knowledge of rules' context and intended function, implies that when conditions are changing, the process of reverse invention and the prescriptive rule solution is vulnerable. Without feedback about the development of prescriptive rules' context and their efficiency to fulfill their intention, the work might be based upon outdated knowledge.

This might result in irrelevant or dangerous rules. It is therefore a paradox that the case that chose prescriptive rules as the rule principle has the weakest plans for future feedback processes.

Through the inquiries and discussions that the hierarchical approach stimulated, railway knowledge became articulated, shared and knowledge from different sources became combined. Selections of this knowledge were encoded into written texts. These findings will be followed up in Chapter 8.

6.3 Choice of rules with concerns for rules' context and rule-followers

The second problem to be discussed regarding the adaptation of the hierarchical approach is the suitability of rule solutions to the actual situation. In spite of the intentions and the attempts to develop outcome-oriented rules, the previous section revealed that existing prescriptive rules became more persistent than planned. Below, the main arguments of the cases for different rule solutions will be presented and discussed.

6.3.1 Prescriptive rules out of concerns for rules' context and rule-followers

The presentation of results starts with results associated with the surprising persistence of the prescriptive rules. Also here the results of the Traffic rule case are provided separately while the results of the Maintenance-rule cases are presented together. Then the main reasons that the cases provided for positive attitudes towards outcome oriented rules will be presented. At the end, the limited attention that the cases showed for rule-imposers' characteristics will be elaborated.

6.3.1.1 The survival of prescriptive rules in the Traffic-rule case

Needs for coordination and severity of accidents

The major argument for prescriptive rules of all interviewees from the Traffic-rule case was that mistakes by the staff could lead to serious accidents. This was mainly attributed to the characteristics of the system for traffic operation where different actors operate together and their safety is dependent upon others' decisions and actions. The extensive use of single track in the Norwegian railway system with the potential for head-on collisions was seen to make the system particularly vulnerable. An additional factor was limited access to technical solutions for communication between the involved actors and for feedback to them during their course of actions. This made it necessary that the actors knew exactly what other actors were about to do. One member of the Board of the project said: *"And regarding those topics where they have to interact, there must be no doubt about how the other will perceive what one says and how to react. One is operating on the same track, whether one likes it or not."*

In addition, many activities were seen to require immediate decisions and/or actions. Accordingly, they allowed for limited time to think or for consultation with others. These characteristics were judged to make central coordination of the activities of the traffic operation necessary. They were also judged to make it necessary to preplan the action of the actors in detail and to prevent any kind of misunderstanding in communication. For these reasons, all interviewees of the case found prescriptive rules to be necessary for safe traffic operation. However, the final report of the project recommended increasing the use of technical solutions such as Automatic Train Control (ATC). By some interviewees this solution was seen to imply a reduced need for prescriptive rules. The reason given was that the introduction of ATC was considered to function as a barrier against human mistakes that was otherwise were prevented by prescriptive rules.

Responsibility and rule followers' wishes

The potential of mistakes to cause severe accidents also created an attitude that the responsibility for safety should not be left to individuals directly involved in the activities. As one member of the work group explained: *"…because wrong actions give such extensive consequence, it cannot be up to each one how to manage a situation and the other actors that also are part of the picture have to know what procedures that come into play."*.

This was also the main explanation the interviewees gave for their observation that the rule-followers themselves wanted prescriptive rules. As one member of the Board of the project said : *"…what I learned a bit about during those discussions (about rule solutions, my comment) was that it was the operative staff who wanted precise procedures that released them from making judgments that could mean that they might make mistakes."*

The impression that the rule-followers wanted prescriptive rules was confirmed by the report of the external researchers who inquired into the rule-followers' opinions about rules[33].

Some of the interviewees also associated this wish of the rule-followers to be covered by rules with the practice of the former NSB to sanction mistakes of the staff in the operative field and especially if they had or could have led to serious accidents. As a means to be able to learn from accidents and unwanted events, the organizations involved in traffic operation now tried to counteract this practice. However, as some interviewees pointed out, the question of guilt and sanctions is taken over by external bodies such as the Inspectorate, the Accident Investigation Board, the court and the media. The latter two were especially attributed to experiences from the two accidents in the year 2000.

[33] SINTEF report for the Traffic rule project, no STF38 F03408

Rule-followers' background

Many of the interviewees were concerned about the characteristics of the rule-followers themselves. In particular they were concerned that such a fundamental change of rule principle that a change from prescriptive to goal-oriented rules represented, also represented a change in the rule- and knowledge tradition of the rule-followers. They argued that this would have to be accounted for if outcome-oriented rules should be introduced. The report concerning rule-followers' opinions about rules also recommended a restrictive attitude towards changes in terminology[34]. The argument here was that rule-followers had invested much in getting to know existing rules. The report also underlined that if the structure of the rules is changed, it is necessary to make educational steps for the rule-followers.

The representatives of the case found it difficult to cover these concerns through a short introduction course. Also, they found it unrealistic to carry out a more extensive educational program in the current situation of the railway system. As the Safety director of the Rail Administration expressed it: *"…when we see that we cannot allocate more than two days for education for each person, it limits how visionary you can be, how extensive you can make the changes."*

The main explanation to the problem of allocating time for an introduction course was a combination of scarce personnel and limited access to replacement staff, and pressure for stable traffic performance. Furthermore, the work group argued that the education and training of the entire staff must be completed within a limited period of time. If not, the new knowledge might be forgotten before it is brought into practice. The group also argued that the rules must be introduced at the same time in the whole system.

Worries for rule followers' competency and motivation

The influence of the ongoing changes of the Norwegian railway system upon the characteristics of the rule-followers was also an issue of concern. Many interviewees both from the work group and representatives from the different actors expressed a concern that the future competency and motivation of the core rule-followers were rather uncertain. They were worried that the changes could lead to reduced competency and motivation and that this would be in disfavor of safety. The arguments were that the introduction of new traffic operators and new recruitment patterns of staff created a more differentiated staff regarding educational background and socialization.

The worries about the competency and motivation of the rule-followers were strengthened by the use of abstract goal-oriented formulations in the new regulation for education (Samferdselsdepartementet, 2002). One interviewee argued that this had created a concern that issues of importance for safety should stay unregulated.

[34] SINTEF report for the Traffic rule project, no STF38 F03408

Furthermore, there was also a worry among many interviewees that increased pressure from economic considerations might influence the educational programs for the staff, for instance the duration of trainee programs. The member of the Board of the branch who generally advocated goal-oriented rules provided a representative description of these concerns:

> *"Yes, I do see the other side here. Now that there might gradually come more traffic operators here that might wish to make this as simple as possible and therefore do not give enough attention to safety, who reduce this to the level of least effort, then it will be better with detailed prescriptive rules that say: If you are going to drive trains in Norway, it has to be done in this way, you have to act according to this. In return, this gives us, as the others who travel along the track, a feeling of safety. One thing is what we are doing and how we drive our trains, but after all we are meeting trains on the tracks too. So I do see that there it might be an advantage to apply prescriptive rules.*

International rule development

As revealed, the work group followed the development of the parallel rules for trans-national traffic within EU, i.e. the TSIs. The group found that here as well, the development was in the direction of rather prescriptive rule solutions. However, as the implementation of these rules was expected to need time, this was not an important argument in the discussions.

6.3.1.2 The survival of prescriptive rules in the Maintenance-rule cases

Needs to follow an exact procedure and severity of accidents

Also in the Maintenance-rule cases the major reason given by the interviewees for the persistence of prescriptive rules was when mistakes made by staff could lead to severe accidents. However, here this was not associated with a need for preplanned activities because the system required central coordination. Instead, this was associated with situations where the safety of traffic operation was dependent upon the quality of maintenance activities and where this quality was dependent upon the way the task was done. For example, the rule-responsible of the Superstructure case explained: "*The reason why it is detailed is also that it is one exact work procedure, you have to follow one particular procedure there. If not it will turn out wrongly."* The rule-responsible of the Power-supply provided another example: "*If you are going to measure transition resistance to earth, you have to do it so and so, if not you will not get it right.*"

Responsibility and rule followers' wish

The interviewees of the Maintenance-rule cases also experienced that rule-followers wanted prescriptive rules when their activities were associated with serious risk. Again the explanations were the former tradition with sanctions of mistakes and the function of the Inspectorate, the Accident Investigation Board, the court and the media. The expectations were considered to be highest among the rule-followers of the Signal case. The main explanation for this was that traditionally their work had been considered the most critical for safety as failures here could lead to head on collisions. The expectations were least among the rule-followers of the Power-supply case as drop outs here made the system stand still. Hence, risks associated with moving trains were eliminated. However, because there were serious accident scenarios associated with stationary trains as well, this conclusion was questioned.

Rule followers' background

In the Maintenance-rule cases the interviewees also revealed that the persistence of prescriptive rules was linked to characteristics of the rule-followers. The leader of the Overarching Maintenance project believed that a thorough understanding of safety was necessary for triggering requirements and that competency was their Achilles heel. Therefore, he also believed that triggering requirements had to be related to a strategy for competency. In accordance with this, the leader of the Maintenance-rule project commented that there might not be enough discussions about requirements to the rule-followers' competency in the discussions of triggering requirements as a rule solution.

Worries for rule followers' competency and motivation

Also in these cases many of the interviewees expressed concerns that the ongoing changes of the Norwegian railway system had a negative effect upon rule-followers' competency and motivation for safety. The main arguments here were the development towards a recruitment and promotion pattern where railway experience was less emphasized, a reduction of introduction-courses for staff without railway educations and an increase in the turnover of staff. There were also concerns that existing structures for discussions about work performance and peer review that had been seen to make rules unnecessary, were being, or would be, broken up. These changes had released pressure from the organization towards more prescriptive rules as compensation for reduced competency. One interviewee expressed his concerns like this:

> *"I am very skeptical about the world we live in now, where you are supposed to have rules and procedures for everything you do. It is almost as if there is a belief that one can fire everybody and then employ the first 300 coming along Carl Johan (the main street, my comment) and tell them: Here are the procedures, run the enterprise! Because here is written all that you have to do."*

This quotation is also an example of the general skepticism revealed among the interviewees towards the attitude that rules can be sufficient to counteract a negative development in the competency of the operative staff. The leader of the Overarching Maintenance project believed that it was only possible to transfer a limited part of the necessary competency into rules. To be able to transfer knowledge he found it necessary to have continuity, history and to include practice.

The cases provided examples where rule-follower's attitudes towards the prescriptive rules were associated with the pressure of cost-efficiency and flexibility. Some interviewees had experienced that rule-followers had been resistant to a reduction of prescriptive rules because they found them useful to counteract pressure from interests of cost-efficiency. The attitude of the leader of the Maintenance-rule project was that this problem had to be faced with other means than prescriptive rules. However, one interviewee of the Superstructure case also referred to the opposite, where they received a wish to loosen up restrictive prescriptive rules to keep up with pressure from cost-efficiency. This attitude towards safety related rules was also rejected.

The responsible person for the rules of Power-supply, i.e. the case with very many components, found that to develop prescriptive rules at the central level was effective because it could ease the burden of rule development at the local level of the Rail Administration.

International rule development

There existed prescriptive external rules at both national and international levels that were linked to railway activities. Accordingly, they had to be followed up by the railways. For instance, such rules existed for electricity and electrical equipment.

6.3.1.3 Outcome orientation due to rule-followers' education and motivation

In spite of the persistence of the prescriptive rules that all cases demonstrated, many of the interviewees found that outcome-oriented rules or formulations could serve two interlinked functions of relevance for safety: the function as knowledge communicator and a function in motivation.

Arguments of the Traffic rule case

Many of the participants in the work of the Traffic-rule case, and in particular those involved in educational tasks, found that goal-oriented formulations were important for the communication about the purpose of prescriptive rules. This was considered to be useful for the understanding of the function of prescriptive rules. This was again associated with rule-followers' motivation for compliance with these. By the time there

was still a plan to develop goal-oriented formulations, the Safety director of the Rail Administration provided this demonstrative description of this aspect:

> *"And I believe that if one understands why the rule is there, what it is for, what function it is supposed to fill, then one will follow the rule much better. It is now in the Traffic-rule project that they are going to add such descriptions of functions to the rules to create this understanding. And new generations require that. If one does not know why, one no longer accepts to follow slavishly what is written. And also it is such learning that I do believe is very important, that learning is not only to memorize psalms, but also in a way to understand what is behind it."*

Furthermore, the goal-oriented formulations were considered useful as a reference for evaluations of the practical applications of the prescriptive rules and for evaluation of their relevance when their context was changing. The latter was seen as an important element for the ability to judge needs for rule modifications in the future. In addition the Project leader considered that to supplement prescriptive rules with goal-oriented formulations could prepare the rule-followers for increased use of goal-oriented rules in the future.

The informant who most strongly advocated goal-oriented rules added an additional argument that is not so closely related to the rule followers' education and motivation. This is that the flexibility of such rules makes it easier to introduce new technology that can improve safety.

Arguments of the Maintenance-rule cases

The Maintenance-rule cases introduced triggering requirements as planned. As already touched upon, these were seen as most useful for the control of the quality of the maintenance activities, i.e. in the judgments whether the activities were sufficient to achieve the quality of the infrastructure that the rules defined. Accordingly they were seen as an important reference for those with control functions regarding the maintenance activities.

However, the needs for triggering requirements were also associated with their ability to communicate the purpose of the prescribed activities. Instances were reported where the organizational changes with changes in the conditions for cooperation and discussion also increased the interest for outcome-oriented rules. The main reason was the same as one of the arguments for prescriptive rules, that former trusted and highly competent professional groups had been split up, outsourced or changed. Traditionally such groups had been considered capable of taking the responsibility for judgments of conditions that should trigger maintenance activities. Therefore, to ensure the quality of the railway infrastructure, the conditions that should trigger activities had to be expressed more formally in rules. As one interviewee of the Signal case explained it:

> *"In the old days the five people involved in the activity sat together in professional meetings and discussed what we should check and how to interpret what was written here, what we can accept. Today when everybody can do it (perform the activity, my comment) we must have something written because everybody thinks in different ways. So if you do not have any clear rules, you will clearly get different standards, it depends on who is out checking."*

And he underlined:

> *"…because that element of meeting caused that they did not need to have triggering requirements for everything, because then they had discussed it and knew completely clearly what was wrong. But today when everybody is supposed to do such activities, then you need clearer requirements."*

The explanatory texts following the triggering requirements were supposed to strengthen their effect. The leader of the Overarching Maintenance project explained that one of the purposes of these texts was to prevent short cuts regarding rule compliance. The leader of the Maintenance-rule project also saw these texts as important for the knowledge about the purpose of the rules. He found this knowledge to be useful both for the rule-follower's understanding of the necessity of compliance with the rules and for future judgments of the rules' relevance and needs for modification.

Also, these cases found that the triggering requirements could serve as reference for future judgments about the quality of prescriptive rules.

6.3.1.4 Limited attention to the characteristics of the rule-imposer

The presented results imply that the rule-imposers of all of the cases had the task to define prescriptive rules. The Maintenance-rule cases also had the task to formulate required outcomes as an IF condition in the triggering requirements. In spite of this, the characteristics of the rule-imposer were not given much attention when discussing rule solutions. However, some interviewees provided reflections about the issue.

<u>Relevance of rule solutions for the hierarchical position of the rule-imposer</u>

When rule solutions were discussed, there were some concerns for the relevance of the rule solutions for the hierarchical position of the rule-imposer in the organizational structure of the Norwegian railway system. The Traffic-rule case discussed if the existing prescriptive and very detailed rules as well as rules that had been included for more educational purposes, were suitable for the responsibilities of an Inspectorate. The major concerns were whether it was better to leave these rules to more local judgments and if they were related to matters of internal responsibilities of the organizations involved in traffic operation. As one member of the work group expressed it:

> *"But I felt that the discussion was more into questions of roles, whether the Inspectorate shall determine the goal-oriented rules and then the traffic operators shall determine the prescriptive rules or if – this is where I feel the discussion was. One did agree that details had to be described somewhere, it was only a question of who to throw the ball to."*

If the discussions concluded that these rules regulated issues that could be left to the organizations involved in the activities to control or they were developed for educational purposes, they were removed.

Also the Maintenance-rule cases related the existing rules to the hierarchical level of the rule-imposer. Before the work of the cases started, the Overarching Maintenance project had decided that the role as rule-imposer of the higher order triggering requirements and their attachments should be positioned at the central level of the Head Office of the Rail Administration. These rules could be supplemented at the lower organizational levels as long as these did not counteract rules at higher levels. Accordingly, these cases also had to decide what had to be regulated at the central level of the organization and what could be left to local judgments and decisions at lower levels of the organization's hierarchy. The Overarching Maintenance project set decision rules for these choices. This was not to delegate safety critical judgments and rules that were considered as means to fulfill regulations issued by authorities.

Railway knowledge of the rule-imposers

Another topic that was discussed was the railway knowledge of the rule-imposers. Representatives of all cases found railway knowledge to be important for the ability to manage rules.

Regarding the Traffic-rule case, many of the representatives of the Inspectorate itself were concerned about the railway knowledge. The Director of legal matters in the Inspectorate explained his concerns for the requirement to competency as a result of the chosen prescriptive and detailed rule solution like this:

> *"There are some challenges regarding the level of details (in the prescriptive rules, my comment). As you say, because the competency is not equally shared here, one expects that an enterprise has more detailed competency about their activities than an authority. So this has consequences for how one frames the rules. And this is just the great challenge here, that one goes all the way down to details and this requires that we also have the competency.*

Many of the interviewees that did not represent the Inspectorate were also worried about the limited railway background represented in the Inspectorate. It was seen as a great advantage that the organization had lately improved its railway knowledge through recruitment of personnel with Railway education and experience. However, the possibility of these people keeping their knowledge updated was also questioned. This

was associated with their distance to the rules' context and their control function that could represent a hindrance for open communication. In particular the combined effect of the requirement for public access to written documents of the authorities and the potential for negative effects from negative publicity upon reputation in a competitive environment were seen as a problem.

Many of the interviewees from the Maintenance-rule cases also underlined the importance of rule-imposers' competency. Representatives of all cases found that this required a good system for communication between the rule-imposer and the rule-followers and their context. Therefore they were positive towards the plans for communication about the rules of the Overarching Maintenance project. Those who had rule management as a permanent task at the Rail Administration's Head Office were very open about their limited opportunities to follow the detailed development of the regulated areas. As one rule-responsible expressed it:

> *"There are many of us sitting at desks here. We have to admit that we do not have the full knowledge about everything that happens out there. And we have to - we absolutely need their experience to make good rules, almost regardless of what level they are at. Of course, if it is supposed to be at the most paramount goal-oriented levels, one can almost say that the railway shall function safely and well, then we might be able to manage."*

Another pointed to the fact that the personnel managing the rules at the Head Office were mainly theorists while the rule-followers were practitioners.

In addition the rule-responsible of the Power-supply case who had many components and suppliers of equipment to deal with, were concerned about the division of competency between the Rail Administration and these suppliers:

> *"And here you are supposed to make evaluations about everything. First of all, there is the task to find people who are competent and have insight into all of this. Anyhow, I do not possess the competency of all this in detail, and then there is also a question of how deeply into detail one should go in all this. We might have a switch and a power breaker where the supplier has experts who are experts only on components within this switch and who know it. And it is clear that if we are to make triggering requirements and so on for this, then we do not have the competency for that in all possible ways. So we must, as much as possible, base our work upon the suppliers and their experience, but to communicate with them in a good way also requires experience."*

6.3.1.5 A summary of the main considerations

The results above reveal that there were both similarities and differences between the cases in their considerations of rule principles. In Table 6.1 below the main findings of

the cases are summarized and compared. As the major differences were between the Traffic-rule case and the Maintenance-rule cases, the latter are presented together.

Table 6.2 The main considerations of the cases in their judgments of rule solutions

Rule principle	**Considerations**	**Traffic rule**	**Maintenance rule**
Prescriptive	*Seriousness of potential accidents*	+	+
	Characteristics of rules' context		
	• Dependency upon other actors for safe performance	+	-
	• Constraints upon communication	+	-
	• Limited time for thinking and consultation	+	-
	• Dangers associated with misunderstandings	+	-
	• Activities have to be done in a particular way	+	+
	• Rule-followers should not be left alone with responsibility	+	-
	Characteristics of rule-followers		
	• Competency	+	+
	• Rule tradition	+	+
	• Preferences	+	+
	Characteristics of implementation phase		
	• Constraints upon time for educational means	+	-
	• Changes must be implemented simultaneous in the whole system	+	-
	Characteristics of ongoing changes		
	• New actors and competition		
	o Emphasis upon cost efficiency	+	+
	o Less homogenous work force	+	+
	o Reduced railway knowledge of rule-followers	+	+
	o Reduced motivation for safety	+	+
	• Organizational changes		
	o Changes in structures for work organization and cooperation	-	+
	o Knowledge leaves the organization	+	+
Outcome oriented Goal-oriented or triggering require-ments	*Communication of purposes with prescriptive rules*	+	+
	• Strengthening of rule-followers' competency	+	+
	• Strengthening of rule-followers' motivation for compliance with prescriptive rules	+	+
	• Reference for control of performance	-	+
	• Reference for evaluation of quality of prescriptive rules and modification needs	+	+

In Table 6.2 the sign + means that the consideration was given attention in the case/cases and the sign – that it was given limited or no attention. The Table demonstrates that the considerations in favor of prescriptive rules were more evident in the Traffic-rule case than in the Maintenance-rule cases. This difference was particularly evident regarding conditions in the rules' context.

6.3.2 The persistence of prescriptive rules

The cases' argumentation for their rule solutions has strong links to safety theory. In the following it will be discussed that generally theory gives support to the rule solutions of the cases. However, the discussions also reveal that there might be some potential dangers associated with them. The discussions converge around the requirement to coordination in the linear and tight coupled railway system, the characteristics of the rule-followers and the characteristics of the rule-imposers.

6.3.2.1 Severity of potential accidents and requirements to coordination in a tight coupled system

The interviewees revealed that the cases were concerned about conditions in the rules' context in their choice of rule solution. To achieve safe traffic performance they found that there were conditions in the contexts that made it necessary to constrain the decisions and action of the rule-followers with prescriptive rules. However, the argumentation of the cases differed. Chapter 5 also revealed that the context of the different rule sets held different conditions.

Coordination and conditions for feedback

In the argumentation for their prescriptive rule solution, the Traffic-rule case gave much attention to issues that can be associated with needs for coordination of the many activities and actors involved in traffic operation.

The issue of coordination of the Maintenance-rule cases was different. The rules to be modified by these cases were directed at the maintenance activities, i.e. activities responsible for the quality of the infrastructure of the system. As discussed in Chapter 5, when these activities are performed on the tracks the coordination of these activities with other activities and actors are regulated by the Traffic rules. However, this element of coordination was not striking among the informants of the Maintenance-rule cases.

Instead, the issue of coordination was evident in the argumentation for the modification project as such. One of the intentions of the Maintenance-rule project was to develop rules that contributed to a coordination of the maintenance activities with a cost/effective purpose. The prescriptive IF-THEN element as described by Hale (1990) of the

Triggering requirements was associated with this purpose. The IF-condition was supposed to function as a tool for defining more common standards. However, the concerns of the informants were more directed at the need for detailed rules concretizing what was required in the THEN condition. This need was associated with the need to perform the activity in a certain way to achieve the required standard of the IF condition.

One issue of concern that was connected to coordination in the argumentation of the Traffic-rule case was communication. First, there were limited possibilities for direct communication and feedback between the involved actors during the traffic operation. Second, misunderstandings in communication were associated with danger. As Chapter 5 revealed, the traffic operation is controlled centrally by Control centers and the communication between the involved actors goes through this center. Several actors operated on the same tracks that often had single lines. They were also often operating alone. To achieve safe performance these actors were considered very dependent upon the activities of each other.

The pictures of the Maintenance-rule cases were more differentiated. As discussed above the standards defined in the IF-condition of the triggering requirements can be seen as a reference for feedback to the maintenance work. Also, Chapter 5 revealed that during the task the actors could apply different means for communication. In addition, much of the maintenance work is organized around work groups. This gives better opportunities for communication and peer consulting and direct feedback. However, the ongoing changes of the Norwegian railway system appeared to influence the organizing of work in groups.

The different conditions for coordination through communication and hence for direct feedback during the course of actions of the involved actors are discussed in theory. Weak communication opportunities call for preplanned activities, i.e. prescriptive rules (Rasmussen, 1997; Rasmussen & Svedung, 2000; Reason, 1997). Clear prescriptive rules for communication are considered necessary when misunderstandings between the interacting actors might lead to accidents (Hale (1990). The international discussions related to Traffic-rules are also concerned about the dangers that misunderstandings during traffic operation might create. This is a concern in the current development TSIs within EU and in particular associated with traffic across borders (Weill- Fassina et al., 2003). However, as revealed the TSIs were not a central issue in the modification work of the Traffic rule case

Communication is also considered important for the opportunity to function at the knowledge-based level discussed by Rasmussen (1983) and Rasmussen & Svedung (2000). This level of functioning requires opportunities for access to information, inquiries and peer consultation and feedback during the task.

On this background, Reason (1997) argues that opportunities for communication will influence the balance between feed forward and feedback-control modes. Hale et al. (2003) discuss Dutch railways and are in line with this stance. They discuss the situation when prescriptive rules are necessary as a part of the apparatus to render the behavior of the various people sufficiently predictable for an open loop operation to succeed. In such

situations they find it necessary to specify rules high in the system. In their studies of the Duch railway system they find that this system still works to a significant extent on open loop, i.e. feed forward control, with a considerable delay in feedback.

According to these discussions, the conditions for communication give support to the rule solutions of the cases. The Traffic-rule case, with the weakest conditions for direct feedback, abandoned the outcome-oriented rule solutions and stayed with prescriptive rules. The Maintenance-rule cases that generally had better conditions for communication about the maintenance activities chose a mixed solution. This solution also fit in with the underlying intention to harmonize the standards for maintenance activities across the distributed infrastructure of the railway system. Harmonization of rules was also one of the arguments for prescriptive rules in the Power-supply case, but here and additional reason was provided. Centrally developed prescriptive rules were considered to ease the burden of rule development in the regions.

However, the ongoing changes of the railway system represent a problem here. Hale et al. (2003) argue that open loop systems can operate very effectively in a range of situations of the railway system, provided they remain reliable and hence predictable. However, in the existing situation of the Dutch Railway system they find that all the requirements for an open loop system are problematic. Their arguments parallel the ongoing changes described for the Norwegian railway system. These are staff reduction, privatization and decentralization, a move away from the 'family tradition' of employment and lifelong employment. To solve this problem they argue for changes in the railway system that increase the opportunities for closed loop, feedback control. In particular, they point at the need to increase the number of communication channels and their ability to be used, both by improved technology and by a change in the culture to fully utilize communication possibilities.

Like Hale et al. (2003) the project leader of the Traffic-rule case suggested to look at the development of rules and the development of technology in relation to each other. His suggestion of increased use of ATC might have improved the feedback system to the actors on the tracks and hence one of the conditions for outcome-oriented rule solutions.

Time for thinking, planning and reflection

Another issue of concern of the Traffic-rule case was that many of the activities of traffic operation require immediate action which implies limited time to think, plan or reflect upon how to proceed safely. This concern was not given much attention among the interviewees of the Maintenance-rule cases. Chapter 5 also revealed that this aspect is not as paramount in the maintenance activities that generally have more time for planning and reflection. However, due to the need to coordinate these activities with other activities on the track, the work is sometimes under time pressure, especially in the areas with high traffic density. Furthermore, in general the increased emphasis upon cost-efficiency and the reduction of "slack" might reduce the rule-followers' time for thinking, planning and reflecting.

The knowledge based level of function that outcome-oriented rules require demands more time to think than the rule based (Rasmussen & Svedung, 2002). As Hale (1990) and Hale & Swuste (1998) argued; such rules need to be translated into action/state rules. Hale and Reason (1997) discuss the time span for the execution of the rules, i.e. from seconds to minutes to longer periods. According to them situations with short time spans require more preplanned activities and accordingly more detailed and concrete rules based on feed-forward control principles. Hence, traffic operation seems to be more dependent upon preplanning and prescriptive rules than the maintenance activities. The majority of maintenance activities give time to translate outcome oriented rules into action/state rules. A reduction of slack might reduce the time to think in activities of all cases and hence make them more dependent upon preplanning, i.e. upon prescriptions about what to do. Again, this gives support to the solutions of the cases.

Coordination, coupling and linearity

As discussed in Chapter 3, Perrow (1999) classified railways as linear and tight coupled systems. However, the discussion above reveals that this classification needs to be nuanced. As traffic operation often require faster decision-making than the Maintenance-rule activities, the subsystem for traffic operation can be seen as more tightly coupled than the subsystem of the maintenance activities.

According to Perrow (1999), systems characterized by linearity and tight coupling can best be coordinated centrally. Rosness (2003) discussed the results of the investigation among the rule-followers of the Traffic-rules regarding centralization. He argues that this supports prescriptive rule solutions. Systems characterized with linearity and looser coupling such as the Maintenance-rule cases can be coordinated either centrally or decentrally. Hence the Maintenance-rule cases should be more open for mixed solutions. Accordingly, also this theory gives support to the rule solutions of the cases.

However, this might be changed in the future. As already indicated, the ongoing changes of Norwegian railway systems seem to be going in a direction towards a more complex and tighter coupled system. With reference to the theory of Perrow (1999), this might create tension between the modes of centralization and decentralization. This indicates that outcome-oriented rules might be more important in the future. This gives support to the wish of the Traffic-rule case to develop outcome-oriented formulations for educational and motivational purposes. This could have started the work of the rule-imposer to formulate intended outcomes. Furthermore, as the project leader argued, it could have made the rule-followers more prepared for the responsibilities and requirements of decentralized coordination. For the same reasons, this gives strengthened support to the Maintenance-rule cases' acceptance of triggering requirements.

This move of the Norwegian railway system towards more complexity and tighter coupling of the system might imply that it will need more of the characteristics of an HRO as discussed by LaPorte & Consolini (1991) in the future. However, the

characteristics of HROs are weak or are being weakened in the Norwegian railway system. First, pressure upon cost-efficiency is likely to reduce the redundancy of the system. Second, there is a general wish to reduce the use of safety rules. As safety rules can be seen as a means to build in organizational redundancy, this might weaken this characteristic (Rosness, 2003). Accordingly the solution of the Traffic-rule case to use prescriptive rules and the surprising persistence of the Maintenance-rule cases, can be seen as the means to build in redundancy. The distinction in the use of verbs and the tagging of safety relevant rules of the Maintenance-rule cases can also be seen as such a means. Third, the cases revealed that there is a growing concern for the education and training of the rule-followers of the regulated areas. In addition, the pressure upon slack and redundancy might weaken the available time to think and existing communication channels used for consultation, mutual checking and feedback that are seen as important features of HROs.

Support to the chosen rule solutions

The general conclusion of the discussions above about the rules' contexts is that theory supports the precautionary attitude of the cases toward the rule solutions of the hierarchical approach and also their choice of rule solutions. The theory also implies that to safely implement the ideals of the hierarchical approach it would have been necessary to look into the close relationship between control principles and characteristics of the system. It would also have required changes in conditions that did not fit in with the wanted rule solution.

6.3.2.2 Characteristics of the rule-followers and context for implementation

Another important argument given for the persistence of the prescriptive rules was the characteristics of the rule-followers.

Rule-followers' competency

The characteristic that was given most attention was the rule-followers' competency. This was particularly evident in the Traffic-rule case. The intended move of this case from prescriptive to goal-oriented rules also represented the most ambitious change of the cases as the Maintenance-rule could supplement the triggering requirements with prescriptive rules.

As several authors presented in Chapter 3 discuss, it is important that the type of decision-making is suitable to the knowledge base of the decision-maker (Hale & Swuste, 1998; Rasmussen, 1983; Rasmussen & Svedung, 2000; Reason, 1997). This implies that the required type of decision-making that rules impose upon the rule-follower should be coherent with their knowledge base. These authors discuss that prescriptive rules require the ability to perceive and understand which rule is suitable for the actual situation and

the ability to perform the required actions. In the terminology of Rasmussen (1983) and Rasmussen & Svedung (2000) this means behavior at skill- and rule-based levels of functioning. Their discussions also imply that outcome-oriented rules require a more extensive understanding of the function of the Norwegian railway system based on mental models. This is necessary for the translation of such rules into action/state rules for safe performance Hale & Swuste (1998). In the terminology of Rasmussen and Rasmussen & Svedung this means a knowledge-based level of functioning.

Accordingly, the suggested goal-oriented rule solution of the Traffic-rule case implied an extensive change in the level of behavioral function; from skill- and rule-based to knowledge-based. This also implied that the rule-followers had to achieve the ability to function at the knowledge-based level. This would require both educational steps and changes in control systems into a state with better conditions for feedback and time to think. In particular, opportunities for communication with other actors involved in activities and peer consultation appeared to be important elements.

The Traffic-rule case judged that to adapt the functioning of the rule-followers into the requirements of goal-oriented rules would require educational means and training. The case also judged that the current context for the implementation phase of the rules did not allow for a sufficient extent thoroughness of this. This was also an important argument in their decision to stay with prescriptive rules. This implies that the willingness to change the principle was associated with the conditions of the implementation phase of the rules.

However, the use of the rules to explain the function of the system during the education of the rule-followers, the emphasis upon varied practice, the recruitment pattern and the stability of the staff represented the potential for a more extensive understanding of the system. This is knowledge that can be activated for knowledge-based levels of functioning.

Also, the educational tradition of the rail professionals of this field is supported by Hale & Swuste (1998). They argue that when prescriptive rules are implemented at a high level of a system's organizational hierarchy it is necessary to involve and inform the rule followers of how and why rules have been arrived at.

The suggested rule solution of the Maintenance-rule cases combining different rule solutions allowed for all levels of behavioral functioning. Still, the leadership of the Maintenance-rule cases were concerned that the introduction of triggering requirements represented a change in the requirements to rule-followers' competency. However, because these cases were cautious about removing the existing prescriptive rules, the total solution did not require a dramatic change for the rule-followers. In addition the rule-followers of these cases had a more traditional academic background based on education outside the system than those of the Traffic rule case. Accordingly they were more used to abstract theoretical formulations such as the outcome-oriented rules represents. This also means that the competency of these rule-followers did not build as much upon the prescriptive rule tradition. Implicit in this tradition there is also less emphasis on practical experience and socialization into the railway system. These discussions provide an

explanation as to why the Maintenance-rule cases were both cautious about removing existing prescriptive rules and accepted the triggering requirements. The discussions also provide a possible explanation why these cases were not so concerned about educational means in the implementation phase.

These discussions also direct attention towards the concerns of the cases for the negative development of rule-followers' competency. It is a paradox that the introduction of outcome-oriented rules requiring a knowledge-based behavior came in a situation where there was a general concern for a negative development of rule-followers' knowledge. The concern for the level of education and training is not limited to the Norwegian Railway system; Hale et al. (2003) discuss the same problem in the Dutch railway system.

The results also revealed that concerns for rule-followers' competency stimulated wishes for more rules and in particular prescriptive rules. Reason (1997) argues that the safety rules constitute an important role as a record of the organization's learning about its operational dangers that the rules serve. He finds this crucial for the dissemination of safety knowledge throughout the system.

The dynamic context with increased emphasis upon cost-efficiency

The use of the verbs "shall" or "must" in the traffic rules and the distinction in the use of verbs for safety rules and the safety tagging in the Maintenance-rules strengthened the rigidity of safety rules. The ongoing changes in the Norwegian railway system with increased emphasis upon cost-efficiency also stimulated wishes for more rigid rules as a means to counteract this pressure.

These findings give associations to Rasmussen's theory that pressures of efficiency and minimum efforts might cause migration towards the boundaries of safe performance (Rasmussen, 1997). This also gives associations to a concern in the research of Vaughan (1996). She claims that in ill-structured problem contexts what is to be regarded as risk and in particular what is judged as acceptable risk, becomes a question of social negotiation rather than an objective property of artifacts or technical systems. With reference to these theories, more rigid rules can be seen as a means to give clear instructions about what to do and at the same time signaling that deviation from the rules is not accepted, the migration is prevented, at least where rules exist. To distinguish the use of verb is in line with the suggestions that Elling (1991) provided after his studies of rules and rule writing in Dutch railways, steelworks and chemical companies (Source in Dutch, referred to in Hale et al. 2003).

However, as Reason (1997) points out, the collection of rules will never be wholly comprehensive or universally applicable. Hence there is still a danger of migration. Furthermore, as Rasmussen (1997) argues it might be difficult to keep prescriptive rules updated and ensure compliance in such situations, in particular when the context is dynamic and competitive. In addition, Hale (1990) argues that when the context is

dynamic and changing it might be difficult for the rule-followers to perceive and recognize the IF-condition of prescriptive rules.

These concerns for the problems of prescriptive rules also give support to the positive attitudes of the cases towards increased emphasis upon outcomes. Rasmussen (1997) argues that functional abstractions such as goal-oriented formulations might contribute to make boundaries of safe performance more explicit. Further as Hale (1990) argues, when there is a danger for erosion of compliance with rules, "BECAUSE" formulations might be useful to communicate expectations and explain why compliance to rules is important. These might be formulated as goals. One of the arguments for increased use of goal-oriented legislation in German railways is the increased emphasis upon cost-efficiency (Becker, 2002).

Accordingly it is a paradox that the idea of goal-oriented formulations was not kept in one form or another for the Traffic-rule case. Again, the discussions give support to the regret of the Traffic-rule case that the planned textbook with goal-oriented formulations had to be cancelled. As the leader of the project argued, this could also have prepared for increased use of goal-oriented rules in the future. This also gives support to the solution with triggering requirements and explanatory texts of the Maintenance-rule cases.

Rule solutions and hierarchical positioning of rule-followers

The hierarchical positioning of the rule-followers in the systems for safety management and different contents of the rule solutions is discussed by Hale & al. (1997). In their terminology, one could say that the goal-oriented rules of the Traffic-rule case indicate an increased focus upon system structure and management; a focus suitable a high position in the hierarchy. However, the target group of this case became the same as before, the executive and lowest level in the hierarchy. According to the theory of Hale et al. this calls for a focus upon execution, just as the chosen rule solution of this case did.

The situation of the Maintenance-rule cases was different. The mixed rule solution of triggering requirements supplemented with prescriptive rules had focus both upon planning, organization and procedures and upon execution when found necessary. With reference to Hale & al. (1997) this fits in with the hierarchical position of the rule-followers of these cases.

The relationship between the core rule-followers of the cases and the chosen rule solutions is also consistent with the expectations Reason (1997). The rule-followers of the traffic rules are at the sharp end and the chosen rule solution is based on the feed forward principle. The rule-followers of the Maintenance-rules consists of middle management and first-line supervisors and the chosen rule solution occupy intermediate positions along the prescriptive-discretionary continuum.

Rule solutions and requirements to comply

One characteristic of the rule-followers that influenced the choice of rule solutions was that the rule-followers themselves wanted prescriptive rules. Theory gives support to the explanation given for this wish. According to Hale & Swuste (1998), the request for rules might be dependent on the situation. The more compliance is stressed, the more the rules are used as a basis for assessing behavior by punishment or reward, and the more dispute between parties over the behavior expressed in the rules, the more pressure there is to define the rule at a management or regulatory level in terms that are easily measurable and verifiable. This reduces the complication and expense, of disputes of interpretation.

Support to the chosen rule solutions

The discussions above about characteristics of the rule-followers also give support to the rule solutions and the arguments of the cases behind these. The discussed theory implies that to safely implement the ideals of the hierarchical approach, it would have been necessary to look into the close relationship between rule solutions and characteristics of the rule-followers. It would also have required preparing for potential needs for changes in rule-followers' competency.

6.3.2.3 Characteristics of the rule-imposers

The decision about the role as rule-imposer was done outside the project. However, to a great extent the choices of rule solutions of the cases imply that the rule-imposer took the task to define risk and to translate more or less specified goals about safety into action/state rules (Hale& Swuste, 1998).

Rule imposers' competency

When deciding upon rule solutions the cases did not give much attention to requirements of competency of rule-imposer. This is surprising as the results revealed that confidence in the competency and in particular the railway knowledge of the participants of the modification processes was very important for the processes and the solutions.

Furthermore, the processes and the extensive use of prescriptive rules and the use of the verb "shall" in the cases rule solutions implies that the question of Kirwan et al. (2002) about the responsibility for defining risk is given to the rule-imposer. This is in line with the general attitude of the Norwegian railway system where safety is not considered to be an issue for negotiation. However, Kirwan et al. argue that the task to discover and define risk should be placed with the creator and manager of the risk, not on the regulator.

The cases demonstrated that to define risk required extensive contextual knowledge. In addition, the use of prescriptive rules in all cases also requires that the rule-imposer has

enough knowledge to define what safe activities are. Also the technical triggering requirements of the Maintenance-rule cases require that the rule-imposer has sufficient knowledge to define the necessary standards of equipment to control identified risk.

Vaughan (1996) reveals that confidence in the rule-followers' competency might be a challenge. She builds up argumentation that shows how autonomy and dependence function as constraints on the regulatory process and the regulators' opportunity for acquiring and interpreting information on the author's side. Regulators tend to become dependent upon the regulated organizations to help them acquire and interpret information. As a result, both the regulator and the regulated generally try to avoid adversarial encounters and favor negotiation and bargaining over conflict and confrontation. With reference to Vaughan's (1996) theories of 'normalization of deviance' this might decrease safety.

One reason for the limited attention to the rule-imposers' competency might be that this has not been a serious problem before. The former rule-developers were respected for their context specific knowledge, i.e. railway knowledge. Another reason might have been that the participants of the modification processes studied here were rather strong in this aspect. A third reason might be that this was not expressed explicitly in the initial documents for the cases.

Challenges for the future

However, some interviewees provided reflection about the need for context specific knowledge for the future management of the chosen rule solution. They also provided reflections about the challenges associated with this need. These concerns are also supported by theory discussing rule solutions (Hale, 1990; Rasmussen, 1997; Reason & al. 1998). The rule-imposer of the Traffic-rule case, with the largest organizational distance to the rules' context, did not report concrete plans for future management of their competency. The dynamic system for the rule management of the Maintenance-rule cases can be seen as a means to ensure the future competency of the rule-imposers of these cases.

6.3.3 Concluding remarks

The persistence of the prescriptive rule solution demonstrates that the cases did not follow up the intention of the project; they did not choose rule solutions that paralleled the hierarchy of rule solutions with the position of the rule-imposer in the organizational hierarchy. However, the solutions paralleled the positions of the rule-followers in the hierarchy of the safety-management systems as discussed by Hale et al. (1997). Furthermore, all cases found rule solutions that gave attention both to prescriptions about what to do and to intended outcomes of these activities useful for the purpose of safety.

The major concern of the cases in their choice of rule solutions appeared to be characteristics of the rules' context. The chosen solutions were in accordance with their concerns. The most important factors were the severity of potential accidents, the need to follow distinct procedures to achieve safe results of activities, limited opportunities for feedback to the involved actors and that outcome-oriented rules were not seen as capable of coordinating activities of different actors in a tightly coupled system. Theory about control principles (Rasmussen, 1997; Rasmussen & Svedung, 2000; Reason, 1997) and about characteristics of systems (LaPorte & Consolini; Perrow, 1999; Rosness, 2003) give support to the chosen rule solutions and the argumentation behind these.

However, this theory also indicates that the ongoing development of the Norwegian railway system with more diversity, less predictability and an increased emphasis upon cost-efficiency will increase the need to focus upon outcomes and feedback control principles. The theory implies that such a development will require better conditions for feedback, communication and time to think in the future. It is a danger that the privatization process with increased emphasis upon cost-efficiency seems to reduce the latter condition.

Another important concern of the cases was the characteristics of the rule-followers and conditions for implementation of rule changes. The most important factors were the competency of the rule-followers and the rule tradition combined with constraints upon introduction programs for the changes. Theory that combines theory of control principles with requirements to the rule-followers' knowledge gives support to this concern (Hale & Swuste, 1998; Rasmussen, 1983; Rasmussen & Svedung, 2000; Reason, 1997). Also, this theory gives support to the concerns that a move towards outcome-oriented rules needs to be followed by a plan for preparation of the rule-followers for the change. It is therefore also strange that the plan for goal-oriented formulations was abandoned in the Traffic-rule case. Both the results and theory imply that such a plan needs to take the sanctioning function of the Inspectorate, the Accident Investigation Board, the court and the media into consideration (Hale & Swuste; 1998).

The characteristics of the rule-imposers were not an important concern for the choice of the rule solutions. However, interviewees, and in particular those representing the rule-imposers, were concerned that the extensive use of prescriptive rules implied requirements to the competency of the rule-imposers. They considered this to be a challenge for the future. This concern is also supported by theory discussing rule solutions and rule-imposers' competency (Hale, 1990; Rasmussen, 1997; Reason & al. 1998; Vaughan, 1996)

6.4 Conclusions to the hierarchical approach

6.4.1 Main conclusion

The four studied modification processes did not follow the intentions of a hierarchical approach. Instead, the modification work of the cases turned into processes that I have called reverse invention. Here the ideals of the hierarchical approach were carefully explored and evaluated and the solutions were adapted to existing railway knowledge. The process of reverse invention made it possible to build the modification work upon existing railway knowledge and in particular knowledge associated with the pre-existing prescriptive rules. When available, risk analyses contributed as a supplement.

Regarding the incitements to a deductive top-down strategy to rule development, this was left by all cases. Instead they applied an inductive bottom-up strategy. Here rule specific knowledge of existing prescriptive rules and associated knowledge about these rules' context and intended function served at the main fundament for the development.

Regarding the suggested rule solutions of the cases that paralleled the hierarchical positions of the rule-imposers in the organizational hierarchy of the Norwegian railway system, the cases showed a precautionary attitude. Instead of accepting these rule solutions as face value, the cases carefully judged their anticipated ability to prevent unwanted events and accidents. Railway knowledge was used as reference in the judgments and the solutions were chosen in accordance with this knowledge, not with reference to the hierarchical positions of the rule-imposers. The position of the chosen rule solutions in rules' hierarchy fit in with the hierarchical position of the rule-followers in the railway system's safety management system as discussed by Hale & al. (1997)

Existing prescriptive rules became more persistent than expected. This implies that the rule-followers took the responsibility to define risk and translate more or less explicit goals into action/state rules. The main reasons for the persistence were concerns for the characteristics of rules' context, the rule-follower and constraints upon the implementation phase of the rules. Characteristics of the rule-imposers were given limited attention. However, there were concerns about the ability of the rule-imposers to maintain sufficient railway knowledge for future management of the rules.

All cases also found attention to outcomes to be useful for safety. The main arguments here were their usefulness for educational purposes and competency of rule-followers, the rule-followers' motivation for compliance with the rules and the rule-imposers' control function.

Theory upon control principles and system characteristics give support to the safety concerns of the cases and the chosen rule solutions. Theory upon the requirements of control principles and systems' characteristics upon rule-followers' competency also give support to the concerns about rule-followers competency and rule tradition. Furthermore,

theory about the requirements of rule solutions to rule-imposers' competency give support to some interviewees' concerns about rule-imposers' future railway knowledge.

If the Norwegian railway system continues to develop in a direction that will require increased use of outcome-oriented rules, the concerns of the cases and theory implies that this development needs to be followed by a preparation of the rule-followers for this change and an improvement of the conditions for feedback and time to think. Furthermore, as Hale & Swuste (1998) suggests, it might be wise to develop decision rules for the translation of such rules into action/state rules.

6.4.2 The theoretical problems

The conclusions of the revealed problems are as follows:

1. *What work strategy to choose if low level rules already exist?*

All cases applied the strategy of reverse invention based on railway knowledge and where existing prescriptive rules and associated knowledge served as the main element. In the development of both outcome-oriented and prescriptive rule solutions, the cases applied an inductive bottom-up strategy where the former prescriptive rules were used as starting point for the work. This process inquired into railway knowledge and in particular the context and the intended function of these rules. Furthermore, it made it possible to build upon and pursue existing railway knowledge. However, it appeared difficult to evaluate the relevance of existing prescriptive rules when knowledge of their original context and intended function was not accessible.

2. *What if the suggested rule solutions do not fit the actual situation?*

The Traffic-rule case faced the problem that it did not find the suggested goal-oriented rule solution suitable for the characteristics of the rules' context, the rule-followers and the implementation phase of the rules. The case chose the solution that they found most suitable for safe performance under the actual conditions, i.e. the former prescriptive rule solution. The plan to develop goal-oriented formulations for educational purposes and as a strategy to prepare for future introduction of goal-oriented rules was abandoned because of limited resources. The case regretted this decision.

The Maintenance-rule cases could apply both prescriptive and outcome-oriented solutions. Hence, these cases did not face the problem that the intended rule solution did not fit the actual situation. However, the case made more extensive use of prescriptive rules than planned. This was done out of concerns for safety. These cases also developed explanatory texts for their outcome-oriented rules.

The hierarchical position of the chosen rule solutions in the rules' hierarchy paralleled the positions of the rule-followers in the hierarchy of the safety-management systems as discussed by Hale et al. (1997).

6.4.3 Needs for further research

The results of the hierarchical approach raise some questions for further research:

First, the findings of the process of reverse invention contradict the general rationalistic principles of the hierarchical approach. Due to the interest for these principles in literature and in practice, it is of interest to study if the process of reverse invention is applied in other contexts than the Norwegian railway system. It is also interesting to see if there exist alternative processes for the meeting of the requirements of the hierarchical approach. Furthermore, the strengths and weaknesses of the process of reverse invention regarding safety should be elaborated upon and evaluated.

Second, the strengths and weaknesses of the inductive bottom-up strategy to rule development compared to the deductive top-down strategy should be followed up with comparative studies. Furthermore, the third alternative of an iterative process between the two strategies that one interviewee suggested should be elaborated upon.

Third, the main arguments that the cases applied to explain their choices of rule solutions and that also deviated from the general hierarchical principles were supported by literature discussing rule context and characteristics of the rule-followers. However, it is still interesting to study if the arguments for the chosen rule solutions count for alternative contexts. Furthermore, it is interesting to elaborate if other modification processes pay attention to alternative conditions. Follow-up studies that evaluate the ability of the chosen rule solutions to prevent unwanted events and accidents are also of interest.

Fourth, the studied cases were not in position to decide who the rule-imposers of their rules should be. Therefore, there are still many questions associated with the discussion about who is best placed in what types of situations to impose what level of limitation (Hale & Swuste, 1998).

Fifth, the discussions and requirements of rule solutions and requirements of the rule solutions to rule-imposers' competency, imply that the rule-imposer must possess rather extensive knowledge about the rules' contexts. Potential solutions to achieve contextual knowledge and to manage future needs for rule modifications should be elaborated upon.

Finally, if the ongoing changes of the Norwegian railway system continue, this will imply a dynamic, tighter and more complex context for future rules. The discussions above revealed that this might imply increased use of outcome-oriented rules. At the same time the results revealed that the characteristics of the rule context and the rule-followers are not prepared for this rule solution. Possible solutions for more coordinated developmental

activities where characteristics of rules' context, rule-followers and the implementation phase are taken into consideration should be elaborated upon. The Traffic-rule case provided one example of a possible solution where technological solutions for management of traffic control parallel the rule development.

7 Risk-based approach with a process of reverse invention

7.1 Introduction

This chapter is directed at the second of the three sub questions of the study:

How was the risk-based approach to rule modification adapted?

For the adaptation of the risk-based approach, the theory presented in Section 3.4 revealed three problems. Again, the first problem is linked to the work strategy for the new approach. The second is associated with the efficiency of conclusions derived from the new approaches compared to the intentions of safe performance. The third is a special concern revealed from the discussions of the theory compared to the cases' starting point.

This chapter follows the same structure as the previous and presents results and discussions of the problems one by one. The structure of this presentation is shown in Table 7.1. The final section of the chapter presents the conclusions to the research question.

Table 7.1 Structure for presentation of problems with results and discussions:

	Problem with answer	**Result**	**Discussion**
Strategy	Section 7.2, answer to the question of Problem 1: How to combine expert dominated risk analyses with rule development in an evolutionary practice oriented modification tradition? Four solutions with a strategy of reverse invention with railway knowledge as reference	7.2.1 Four combinations based on railway knowledge and existing rules	7.2.2 Reverse invention with different functions of risk analyses 7.2.3 Concluding remarks
Evaluation	Section 7.3, answer to the question of Problem 2: What if the risk analyses do not fit the risk perception of those involved in the modification work? Evaluation of risk analyses with concerns for their ability to include	7.3.1 Evaluation of risk analyses with railway knowledge as reference	7.3.2 Persistent railway knowledge out of concerns for complexity 7.3.3 Concluding remarks
Concern	Section 7.4, answer to the question of Problem 3: What risk perspective to apply; a wide inclusive definition or the narrow risk analytic? Modification work with a wide inclusive perspective of risk	7.4.1 Focus upon safety and an inclusive perception of risk.	7.4.2 The wide inclusive risk perspective 7.3.3 Concluding remarks

As revealed in Chapter 2, all cases of this study had to use risk analyses in their rule modifications. The content of this requirement was not clarified and could therefore mean both risk-based and risk informed.

The method for the risk analyses and the top events that were used as the starting point for these was decided in advance for the Maintenance-rule cases but not for the Traffic-rule case.

7.2 Four solutions with a strategy of reverse invention

The first problem to be highlighted in this chapter is how the cases combined the expert dominated risk analyses with the rule development in an evolutionary practice oriented modification tradition.

In the following it will be revealed and discussed that all cases followed up the ambition to apply risk analyses in their modification work. However, they combined risk analyses with the rule development in four different ways. The different ways gave the risk analyses different functions in the rule development. In none of the cases did the risk analyses serve as the main fundament for the rule development. The cases questioned the trustworthiness of the risk analyses compared to the trustworthiness of railway knowledge.

7.2.1 Four combinations based on railway knowledge and existing rules

The presentation of the results of the cases is divided between the results of the Traffic rule case and the Maintenance rule cases. Furthermore, the study revealed that there were both common features of the Maintenance rule cases and differences. Therefore, again common features of these cases are presented together. The special features are presented separately for each case.

7.2.1.1 The Traffic-rule case: Interactive and iterative

Choosing risk analytic method and building risk analytic competency

For the Traffic-rule case no decisions were taken in advance about what risk analytic method to apply in the modification work. To find a suitable method the work group consulted external risk analytic experts who represented different risk analytic approaches. The work group explored and evaluated the suitability of different methods for their modification work and the regulated area[35]. The members of the work group discussed the analytical approaches with each other, with their network and with resource

[35] Project logg 577-IA

groups. The major concern was the ability of the methods to cover aspects that these actors considered important for safe traffic performance, i.e. their railway knowledge served as reference for good methodological solutions.

They settled on a risk analytic method that became applied in the work. Here top events were used as starting point for event trees and fault trees where safety critical functions were identified at the level of sub-top events. Existing and eventually missing barriers were analyzed against hazards[36]. The work group defined top events for the analyses. Accident statistics played an important role in the work to define these.

The chosen risk analytic method took advantage of both qualitative and quantitative data. It appeared difficult to retrieve trustworthy quantitative data at the lower levels of the analyses. Accordingly the analyses became more qualitative at these levels.

From the beginning, one of the participants of the work group possessed both railway knowledge and knowledge of risk analytic methodology. Furthermore, the members of the case participated in risk analytic courses. The inquiries into different risk analytic methods and their suitability for the regulated area contributed with additional competency. The core contributors of risk analytic knowledge were external experts. The project leader explained that the case preferred to develop the risk analytic competency of railway personnel instead of developing the railway competency of external risk analytic experts. Later in the process the risk analytic knowledge of the work group was strengthened by the employment of a risk analytic expert who also possessed experiences from the Norwegian railway system.

Progression of the work

The intention of the Traffic-rule case was to undertake the risk analyses first and then proceed to the rule writing. Therefore the work group started their work with the risk analyses. One of the group members explained the impact of this decision: "*No, we started with the analyses first and I think that was the right decision. We might say that we were never finished with the analyses because this is a dynamic world and we came up with new elements. However, it gave us the ballast to think in terms of barriers.*"

To ensure the quality of the initial analyses the case engaged an external expert to review them. The Board of the branch was also engaged to review some analyses.

During this initial work the scope and preconditions for the analyses gradually evolved. These were rather wide and no stop rules for the analyses were settled in advance. The risk analytic expert of the work group explained that this made those involved in the work rather confident that the analyses covered the elements that they considered important for the development of unwanted events and accidents. As the people involved became more experienced, they found themselves more capable to judge what was considered "*good*

[36] Project logg 689

enough" as the project leader expressed it. In these judgments their railway knowledge served as reference for the evaluations.

The work to decide upon a suitable risk analytic method and to perform the initial risk analyses appeared to be much more time consuming than expected and the work became delayed. The interviewees reported two major reasons for this. The most important reason was the wide scope for the analyses that made the analytic work very extensive. Another was that the context of the rules was changing so new elements had to be taken into consideration.

To accelerate the progression of the work, the case decided to start the rule development before the risk analyses were finished. In the following work the two tasks evolved in parallel. The leadership of the case found this to be an acceptable solution because the railway knowledge of the work group and the knowledge associated with existing rules was considered to serve as a foundation for the work. The work group itself considered existing railway knowledge and existing rules to be a more reliable fundament for the work than the risk analyses. For example, many members explained that the existing rules had been developed over years on the background of development in the technology and experience. The testing of these rules over time with good results made these rules so trustworthy that it was not reasonable to change them without very good cause. Some of them questioned if the risk analyses were a good enough reason because their results did not give a sufficient picture of the complex interactions of the activities of the Norwegian railway system. One of the engaged risk analytic experts gave support to this. He had experienced that participants of the work group had such rich cognitive maps of the railways that it was impossible to transfer these into the risk analyses.

The system of the chosen risk analytic method served as a framework for collection and selection of railway knowledge for the analyses. The evolving scopes for the analyses also influenced which knowledge achieved attention. Therefore, the framework and the scope influenced which questions were raised in connection with the analytic work and hence which knowledge was inquired into and seen as relevant for this task. Accordingly, the framework contributed to a selection of railway knowledge, i.e. some became included and some excluded. Furthermore, the framework was used to structure the included railway knowledge under the headings of the top events in accordance with its steps and concepts of the analyses, such as, for example, safety critical functions and barriers. This structure was also used when the risk analyses were transformed into the written texts of the analyses. These texts were stored in a database.

In the following work the activities went back and forth between risk analyses and rule development and the two tasks interacted. The project leader explained that the results of the inquiries into railway knowledge that the risk analyses stimulated and the results of the analyses gave information to, and raised questions to, the rule development. For example, those performing risk analyses could walk into the office of the rule writers and ask whether issues they were concerned about were taken into consideration in the rule texts. The inquiries of the rule development also gave information to and questioned the risk analyses in the same way. This was enhanced by the organizing of the work that

opened opportunities for interaction and close cooperation between the members of the work group.

Also in these processes the main contributors of railway knowledge were the work group itself, their network and resource groups. Furthermore, the work group searched for feedback to their evolving work. The main contributors from the network were railway personnel holding different functions that could see the rules from different points of views. The main contributors from the resource groups were the Board of the branch. However, one interviewee argued that it was difficult for people with limited experience with risk analyses to give feedback upon these.

The members of the work group found that the overlapping and interaction between the two activities gave flexibility to the work and opportunities to take advantage of new information and lessons learned during the work. This contributed to a development and refinement of both the methods for the risk analyses and for their combination with the rule development. This also contributed to the rule development. One member of the work group explained how the achieved knowledge of the risk analytic methodology made them think of their practical knowledge in another way. As he said: *"Also we (who mainly worked with the rule development, my comment) started to think of barriers. And we understood when reading a rule, that it might not be good enough."*

As the work proceeded, the work group structured the interaction between the risk analyses and the rule development into a described method for this combination[37]. A summary of the method is provided in Appendix F. The processes were divided into stages with defined meeting points between the risk analyses and the rule development. The project leader characterized this as *"…a method that came out of a process that adjusted itself on the way."* However, the informal interaction also continued during the work. Also, the time pressure of the case made the steps of the method more overlapping than the method describes.

Many of the participants of the work explained that the overlapping and interaction of the risk analyses and the rule development gave the risk analyses different functions in the modification work; they provided information and they corrected and validated the evolving rules. One member of the Board of the project explained that as the work of the risk analytic work gradually became delayed and the rule development proceeded, the risk analyses were increasingly used to verify the evolving rules.

Therefore the process for combining risk analyses with rule development of this case can be characterized as "*interactive* and *iterative*". This is illustrated below in Figure 7.1.

[37] Project logg 577-IA

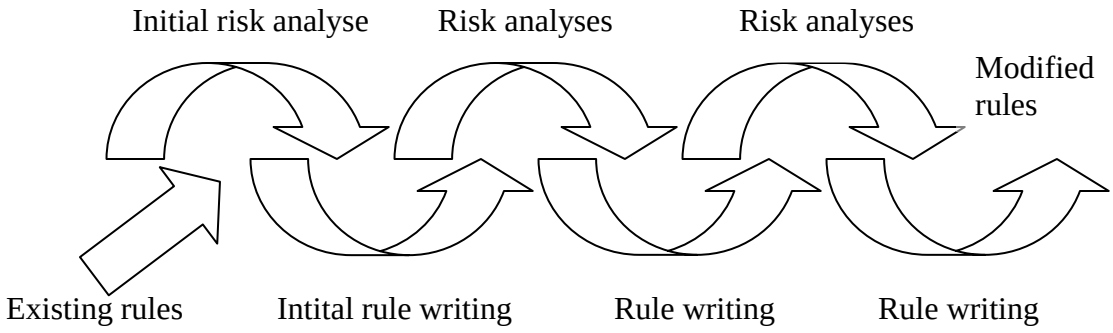


Figure 7.1 The interactive and iterative process of the Traffic-rule case

In Figure 7.1, the arrows show how the initial risk analyses and existing rules served as input to the initial rule development and that in the following work the rule development and the risk analyses interacted.

Evaluations of results

The participants of the work group also evaluated the evolving work after the initial phase. The major concern was the ability of the risk analyses to cover the knowledge that the involved actors had of conditions they considered important for safe traffic performance. Again, they drew upon railway knowledge of their own, each other and their network and the Board of the branch for feedback. This implies that the risk analyses were evaluated with railway knowledge as reference.

The members of the work group reported that they seldom disagreed with each other. If disagreements occurred these were concerning details. The project leader explained that the common pattern was that conclusions of risk analyses confirmed railway knowledge and existing rules. When this happened, the confidence in the actual railway knowledge, the rules and the risk analyses achieved increased trust. On the few occasions where divergences occurred in the conclusions, the common reaction was to question whether something of importance was left out of the analyses and to review it. In this way the conclusions of the risk analyses and the railway knowledge were brought in accordance with each other. When this happened the confidence was strengthened in the railway knowledge, the rules and the risk analyses. Therefore, the risk analyses contributed to the persistence of existing rules and railway knowledge described in Chapter 6.

As the work proceeded, the case decided to follow-up issues of concern with HAZOP analyses. Furthermore, as revealed the case decided to perform change analyses, i.e. HUL analyses. At the end of the project the Board of the branch was invited to review the main risk analyses and the modified rules. The work group also checked the analytic work against statistics as well as unwanted events and accidents that occurred during the work.

The interviewees of the Traffic-rule case explained that the different feedback on the work was discussed within the work group. The professional judgments of the participants and their trust in the quality of the feedback served as the fundament for the decisions to take the feedback into account.

7.2.1.2 Common features of the Maintenance-rule cases

Choosing risk analytic method and building risk analytic competency

For the Maintenance-rule cases the method for the risk analyses was settled in advance by the Overarching Maintenance-rule project. This was done because the method was supposed to serve as a fundament in the future management system for the maintenance activities.

In line with the, then settled, steering documents of the Rail Administration, the analyses of these cases also used top events as starting point for analyses with event trees and fault trees. The Overarching Maintenance project decided that the cases should apply a modified version of RCM analyses in combination with FMECA. One difference from the traditional RCM method was a generic approach where the analyses should be combined with local analyses when the plan for interaction processes between hierarchical levels of the organization was implemented. Other differences were a risk model based on barriers and use of models when deciding maintenance intervals. The method combined qualitative and quantitative data.

The Overarching Maintenance project arranged introduction courses in the chosen risk analytic method. These courses had participants from each of the regulated areas. The Signal case was given the role as a pilot for the cases. The main participants were the rule- responsible of each case and some railway personnel with long experience within the respective regulated areas.

During the courses and seminars the participants made their initial generic risk analyses. The analyses were done separately for each of the fields. The scopes for the analyses of the cases were settled and the methods tried out for the respective fields. The scopes were defined rather precisely and narrow. The cases received feedback from the teachers. Follow-up seminars were also arranged for the participants during their work. The courses and seminars were run by hired external consultants that were RCM analyses experts. Accordingly, these cases followed the same strategy as the Traffic rule case; to strengthen railway competency with knowledge of risk analytic methodology and not vice versa.

Progression of the work

There were some differences in the way the cases performed the risk analyses and combined them with the rule development. The most important difference was the timing of the risk analyses and the rule development. This will be elaborated under the following three headings. As the project leader of the Maintenance-rule project explained:

> *"…the analyses have been performed for each of the main systems of the infrastructure. There was not a common platform when the work started. One branch (i.e. the cases, my comment) had heard a bit about how it was supposed to be while another branch had some other words and so on. And then the branches had also interpreted it a bit differently and then one started in different ways. So maybe already at that time the foundation for differences was laid."*

He also explained that this made the cases perform the task in different sequences. Some started to write the rules according a framework that the Maintenance-rule project had developed and then they started to perform risk analyses while other started from scratch with the risk analyses.

Also, in these cases the chosen risk analytic method and the scope for the analyses influenced the collection and selection of railway knowledge for the analyses. As one interviewee explained: "*The risk analyses represented a new way of collecting information."* Accordingly, again the framework and the scope contributed to an inclusion and exclusion of railway knowledge. The framework of the analyses was also used to structure the included railway knowledge under the headings of the top events in accordance with its steps and concepts of the analyses and transforming the analyses into written texts. These cases also stored their risk analyses in a database. One interviewee commented upon this process like this: "*The risk analyses have been a tool to transfer existing knowledge into a new format.*"

The Maintenance-rule cases followed the same pattern as the Traffic-rule case, to compare risk analyses with railway knowledge to reveal if the analyses included the knowledge seen as important to recognize development towards unwanted events or accidents. Again the most important knowledge was the knowledge of those directly involved in the work. However, they also contacted their network and in particular representatives of the rule-followers who were known to be very competent in their respective fields. Accordingly, railway knowledge was used as reference for the risk analyses. There were some differences in the feedback processes that will be elaborated under the next headings.

Again the results revealed that the comparisons seldom reveal conflicting results. One of the rule-developers provided the following representative explanation for this phenomenon: "*So at this first stage, it is natural that you end up with much of the same as there already is in the rules because there are many of the same people and much of the same thinking behind it."* The leader of the Maintenance-rule project supplemented

this picture:*"…but sooner or later the issue of experience comes into the picture. Anyhow, one knows that one has to do it or has to do it in a special way."*

The leader of the Maintenance-rule project also reported that when the risk analyses gave support to the rules and the railway knowledge, the confidence in both increased. This was verified by some other interviewees too.

The cases also reported that the risk analyses diverged from the railway knowledge of those participating in the work or that they gave surprising results. As one interviewee said: "*When we looked through it, we started to ask questions like: "Is this right?" and "Can it really be like this?"*

In such instances the cases inquired into the reasons for conflicting or unexpected results. One interviewee described the challenge like this*:*

> *"And then (when results conflicted, my comment) we have to discuss if it is right that we have this requirement in the rules or if the rules are wrong. Or is it that something has been forgotten and the RCM analyses have to be revised? There should be some interactions here to make it conform."*

In the choice of strategy for these inquiries, the confidence in the involved railway knowledge and the risk analysis results played the most important role. As will be discussed in the next section, most commonly railway knowledge commanded more confidence than the risk analyses. One participant reflected upon the choice of strategy:

> *"In a way it is right to compare with the old maintenance manuals. Because then you can check if you have forgotten something. But what is the reason for not forgetting something? Is it that you have forgotten or did you consider it to be right? And if you considered it wrong you should not include it in the RCM analyses. If you do, the RCM as method, has lost its purpose."*

A few instances were reported where the inquiries led to changed railway knowledge. Most commonly this happened when the railway knowledge was already questioned and when the analyses questioned the necessity of maintenance activities that the rules required.

Many of the participants also discussed the use of the risk analyses in the decisions of the necessity of rules and of the choice of verbs for the rules. This will be elaborated in the next Section.

Evaluation of results

In the end, the Maintenance-rule project organized a joint two-step hearing process. Together with the rules, the risk analytical approach was presented to rule-followers in meetings with each region of the Rail Administration and discussed. Shortly after, the

analyses were sent to each region for a formal hearing together with the rules. The regions differed in how much effort they put into the hearing work and who they involved. One interviewee argued that the feedback was influenced by the fact that most of those who provided comments had limited knowledge of the chosen risk analytic methodology. In addition, the cases looked into statistics and reports of unwanted events and accidents.

The Maintenance-rule cases also discussed the feedback and when this was found reasonable by the people involved in the developmental work, it was incorporated in the rules. Again, the decisions were based on the professional judgments of the participants without preset criteria, i.e. their railway knowledge served as reference.

As revealed, the Maintenance-rule project performed change analyses based on the HUL principle, as did the Traffic-rule case. These analyses were performed by different people. The project leader of the Overarching Maintenance project did not consider these as risk analyses but as risk estimation.

7.2.1.3 Special features of the Signal case: Sequential

As a pilot project the Signal case was the first case to try the risk analytic method for their regulated area. This work became more extensive and time consuming than expected.

The risk analytic work group of the Signal case had one participant with prior knowledge of the chosen risk analytic method. The members of this work group cooperated closely and drew upon each other's competency. This was done in meetings between the participants. These were possible to arrange because the status as pilot project for the Maintenance-rule cases had provided the group with extra resources of time and money.
As a pilot case, their application of the risk analytic methods and the risk analyses in the modification work was discussed within the Overarching Maintenance project, the Maintenance-rule project and in the risk analytic courses. Also, the group took advantage of the railway knowledge of their network in the operative field.

The work of the risk analytic work group of the Signal case was influenced by existing rules and greatly built upon the participants' railway knowledge. The rule-developer of the Signal case described the function of the railway knowledge in the analytic work like this: *"Through their experience and competency, they in a way validated that the maintenance activities of today's the work instructions and that were brought forth are relevant."*

The risk analytic group finished the analytic work before the rule-developer started his work. The continuity of the work was broken between these two tasks because the rule-responsible gave the task to develop the rules to the external consultant alone. However, there was some communication between the people involved in the two tasks.

As this case finished the risk analyses before the rule development, the case could have based the rule development solely on their results. However, as discussed in Chapter 6, the rule-developer based much of the rule development upon his general railway knowledge and his knowledge of the existing rules and their context. Also the risk analysis results provided from the risk analytic group contributed. When he felt his knowledge was insufficient, he made inquiries into the knowledge of his network and in particular among rule followers. Due to the time consumption of the analytic work, the rule development came under time pressure. Therefore the rule-developer felt that there was limited time to look into the background of the rules. He did not consider this to be a serious problem because he had confidence in the competency of the former rule-developers and that the rules had good reasons. He also had confidence in the competency of the risk analytic group.

Due to the break in the continuity of personnel involved in the work, the process of this case can be characterized as "*sequential"* and illustrated like this:

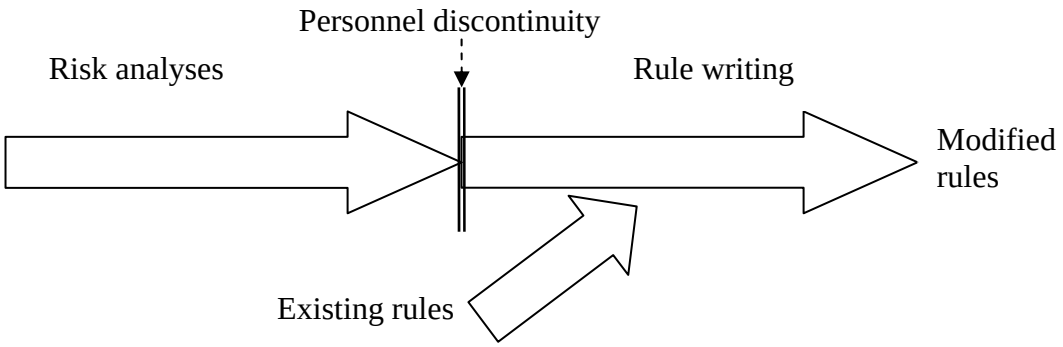


Figure 7.2 The sequential process of the Signal case

In Figure 7.2, the arrows show how the risk analyses were finished as a separate task before the rule development started and that existing rules served as input to the rule development together with these analyses. The vertical line illustrates that the two tasks were performed without overlap of the tasks or the personnel.

When the risk analyses and the rules were subject to the final hearing process, it appeared that there were some inconsistencies between the risk analyses and the rules. The leader of the risk analytic group felt that this demonstration of divergences to the rule-followers reduced their confidence in both the risk analyses and the proposed rules.
He believed that closer cooperation between the risk analytic group and the rule-developer would have prevented this.

Both the rule-responsible and the other participants regretted that time pressure had limited the involvement of the rule-responsible in the work. He saw his main role as a coordinator and communicator between the people involved in the two tasks.

7.2.1.4 Special features of the Power-supply case: Stepwise and iterative

Because the rule-responsible for the case at the Head Office delegated the work little by little to the hired consultant, the work of this case became divided into subtasks. When the subtasks were reported to rule-responsible, their results were discussed and the rule-responsible gave feedback on the work.

Much of the rule development was performed before the analytic work. As revealed in Chapter 6, the hired consultant did the work almost alone and used his general railway knowledge and knowledge of the rules and their context. When in doubt, he consulted his network. He also sent preliminary results to his network for comments. When the decision to apply analyses in the modification work of this case was made, the risk analyses contributed to the rule development; either with information or with feedback.

The Power-supply case applied the risk analytic method that was settled by the Overarching Maintenance project. As already revealed, the case involved different people in the analyses. These were chosen on the basis of good knowledge about the actual equipment to be analyzed and associated maintenance tasks. None of the participants of the risk analytic work had former education in the actual risk analytic method. It also varied who participated in the risk analytic course and the seminars.

The case faced challenges with the level of detail for the analyses and the work became time consuming. This case was also complicated by the many suppliers of equipment. Therefore the case decided to relate their work to the first level of subcomponents. Furthermore, the case did not finish their risk analyses before the rules were approved. Priority was given to elements considered important for safety. The plan was to continue the risk analytic work after the rule writing.

The process of this case can be characterized as *"stepwise and iterative"* and can be illustrated like this:

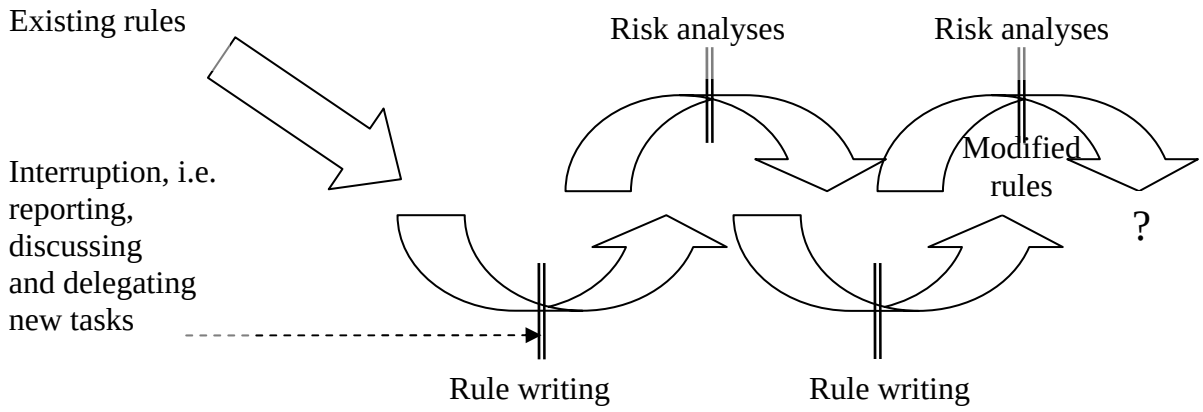


Figure 7.3 The stepwise and iterative process of the Power-supply case

In Figure 7.3, the arrows show how the existing rules served as the main input to the rule development and that the risk analyses supplemented the work when they were done. The vertical lines illustrate the milestones of the work where subtasks were reported, discussed and new task delegated. The last arrow of risk analyses continues after the modified rules and ends with a question mark because the analyses were not finished when the rules were approved.

The hired consultant who developed the rules found that the work would have been better for the development of the work if there had been a more holistic plan and if the tasks had been related more to each other from the beginning. Like the work group of the Traffic-rule case, the rule-developer of the Power-supply case found the iterative development useful.

7.2.1.5 Special features of the Superstructure case: Sequential and validating

The Superstructure case also applied the risk analytic method settled by the Overarching Maintenance project.

Neither of the two core participants of the work had prior knowledge of the chosen risk analytic method. The participants divided the participation in the introduction course between each other. When they participated in the course it was not yet settled that this case should apply risk analyses in the modification work. This was due to doubts concerning the suitability of the method for this field.

As the decision to apply risk analyses was decided late for the Superstructure case, the work group of this case had to use available knowledge as foundation for the modification work. When developing the rules, the two participants of the work used their own knowledge, their network of among rule-followers and their Board of the branch. The organizing of the case also made it possible for the two people involved to cooperate closely and to give feedback to each others' work.

Because this case started the rule writing rather early compared to the other cases, they were the main contributors to the development of a common framework for the organizing of the Maintenance-rules.

When the Maintenance-rule project decided that the case should perform risk analyses, this was done by the same people who developed the rules. During the analyses they followed the same patterns for retrieval of knowledge and cooperation as they did when developing the rules.

As mentioned in Chapter 6, the results were compared to the modified rules. Accordingly the risk analyses gave feedback to the rules and were not a part of the core process of rule development. No serious contradictions occurred and the risk analyses validated the modified rules.

The process of this case can therefore be characterized as "*sequential and validating*" and illustrated like this:

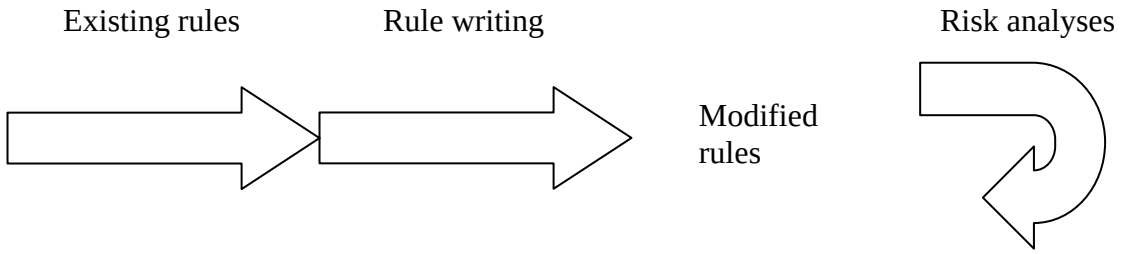


Figure 7.4 The validating process of the Superstructure case

In Figure 7.4, the arrows show how the existing rules served as input to the rule development and that the risk analyses gave feedback to the modified rules.

One of the two participants reflected upon the validating function that the risk analyses had in the work. He said:

> *"…now it sounds like we have put the RCM aside, but I really do not feel that it is what we are doing, at least you validate some things. And if you get a completely different result, you have to review your in data (of the risk analyses, my comment). Partly this is a kind of method for numerical calculations too.*

The two-step hearing process at the end of the Maintenance-rule project was also used as a hearing process for both the rules and the analyses.

7.2.2 Reverse invention with different functions of risk analyses

Also in introduction of the risk-based approach the pattern of reverse invention can be seen. First, the cases explored and tried out the principles of risk assessment, the chosen methods and the combination of these with rule development. Then the cases performed the rule development but not with risk analyses as the main fundament. As revealed in both in the previous chapter and in the results of this section, the rule development was done on existing railway knowledge and rules. Furthermore, the four different ways of applying risk analyses in the modification work gave the analyses very different functions. In the following, these findings will be discussed and related to theory.

7.2.2.1 Exploring and evaluating the risks based approach

Only the Traffic-rule case had the task of deciding which risk analytic method they should apply in the work. The results revealed that the case elaborated different readymade risk analytic methods. On this foundation they developed their own method that combined some of the readymade methods. In their choice of method, the main concern was whether the method covered issues seen as important for safe traffic performance or not. Again, the railway knowledge of participants of the work group, their network and their resource groups served as reference for good solutions. To draw upon the theory of March (1994) once more, this decision held strong elements of logic of appropriateness.

The chosen method included methods that could provide answers to all of the tree questions to risk analyses presented Rausand & Øien (2004) (see Subsection 3.4.2) The use of Accident statistics, Fault Tree Analyses and the focus upon barriers reveals that the method included most elements from their two first questions about which unwanted events might occur and what could cause and/or prevent these. The third question about consequences of the events was given some attention through the Event tree analyses.

For the Maintenance-rule cases the method was chosen in advance by the Overarching Maintenance project. This method built upon the principles of the Management system of the Rail Administration. The chosen method included RCM analyses in combination with FMECA analyses and attention is given to the technical components of the systems. Also here barriers against accidents were given attention. According to Rausand & Øien (2004), these are methods that have been developed for the purpose of maintenance activities and that emphasize cost-efficiency. The method of these cases was also capable of answering the three questions of Rausand & Øien. The chosen solutions include methods that according to Rausand & Øien are associated with identifying which

unwanted events might occur and what could cause and/or prevent these. The element of barriers can also be associated with their third question about consequences of events.

The emphasis upon cost-efficiency of the methods of these cases fits in with the increased emphasis upon cost-efficiency in maintenance activities and is in accordance with the intention of the Overarching Maintenance project. It also fits in with the plan of the project that the risk-based approach should ensure that the activities and limitations that the rules imposed were really necessary. Also Apostolakis & Vesely (1999) argue that risk analyses can be introduced for the purpose of removing burdens of unnecessary or rigid rules.

The fact that the chosen risk analytic methods of all four cases answered all the questions of Rausand & Øien (2004) also implies that their methods contained elements of both sides of the "Bow Tie Model" that SAMRAIL describe (European Commission 2004c). The two first questions contain the elements of the left side of the model that contains the causes that potentially lead to hazardous events and their controls or barriers to the hazards. The last question contains the elements of the right side of the model with various outcomes that can potentially occur and the controls and barriers to limit or reduce the consequences. SAMRAIL finds this solution to be in accordance with the general trend within European railways.

When it comes to choice of methods for combining risk analyses and rule development, the different cases had different conditions. The most important factors that influenced the choice of methods were the timing of decisions to apply risk analyses in the work and the progression of the work. However, confidence in rule-developers' railway knowledge and existing rules also influenced the decision.

7.2.2.2 Abandoning the ideals of the risk-based approach with different combinations of risk analyses and rule writing

The results reveal that all cases applied risk analyses in their modification work. However, only one of the four cases followed the rationalistic ideals to finish the risk analyses before the rule development started. Also, in the previous chapter it was demonstrated that the major foundation of the rule development was the existing rules and railway knowledge. The solutions of the cases made it possible to build upon the trusted existing railway knowledge and still include risk analyses in the processes.

When risk analyses were available they served as an additional element in the decisions. This means that the cases gave the requirement of a risk-based approach to the rule development, a content that fits with the description Chapman & Dimitrijev (1999) gave of the risk-informed regulatory approach (see Subsection 3.4.1).

Furthermore, with reference to the discussions of Rasmussen (1997) about different strategies for different types of accidents, the strategies of the cases were dominated by the traditional evolutionary strategy where knowledge derived from experiences with the

railway system and past accidents served as the main input to the rule development. The way the cases used the risk analyses means that this tradition was supplemented with the analytical strategy. According to his theories, the supplement with risk analyses and their anticipatory elements is useful in dynamic contexts. Accordingly, to supplement the existing tradition with risk analyses fit in with the more dynamic context of the Norwegian railway system.

The different solutions of the cases for the use of risk analyses in the work gave the risk analyses different functions in the rule development:

In the interactive and iterative process of the Traffic-rule case, the results of the risk analyses gave information to the rule development. Furthermore, risk analyses were used to elaborate matters of concern. Risk analyses were also used to give feedback upon the quality of the evolving rules and to reveal potential dangers created by changes in the rules. In addition, the organizing of the work caused that the process of the risk analyses raised questions and collected knowledge that were directly fed into the process of the rule development. Accordingly, the risk analyses provided both information through its written schemas and knowledge through the interactive processes with the rule development.

The Signal case had a sequential process where the continuity of the personnel was broken between the risk analytic work and the rule development work. Accordingly, the function of the risk analyses was limited to provide information to the rule development. This information was mainly limited to the written information that the schemas of the risk analyses provided.

The stepwise and iterative process of the Power-supply case meant the risk analyses had three functions. First, the results of the analyses gave input to the rule development. Second, they served as feedback to the quality of the rules. Third, the organizing of the work created meeting points where the risk analyses raised questions and collected knowledge that were fed into the process of the rule development. Accordingly, the risk analyses provided both information through its written schemas and knowledge through the meeting points.

The findings of the validating process of the Superstructure case revealed that in this case, the function of the risk analyses was to give feedback upon the quality of the modified rules. This feedback had the form of the written schemas of the risk analyses. As no important divergences were revealed, this function developed into one of validation.

Together the four cases showed that the risk analyses had functions where they provided knowledge, information, ensured quality of evolving rules and validated existing or modified rules.

It is worth noting that in the two iterative cases, i.e. the Traffic-rule case and the Power-supply case, the rule development also had a function regarding the risk analytic work.

First, the rule development raised questions to the risk analyses. Second, inquiries related to the rule development contributed with knowledge to the analytic processes.

The most evident reasons for the different functions were factors that influenced the timing of the risk analyses and the rule development. The order of the rule development and the risk analytic activities influenced how much the risk analyses could possibly influence the rule development. However, there were two underlying issues that allowed for the differences in the solutions. One was that the existing rules and railway knowledge was considered trustworthy enough to develop existing rules on this foundation. Another was that the risk analyses were considered as supplement to the existing evolutionary modification tradition, and too doubtful to replace the evolutionary rules and knowledge. Therefore, the work had to be based upon the evolutionary rules and knowledge anyway.

In addition, the organizing of the work influenced how much the participants of the risk analytic work interacted with the participants of the work of the rule development. As Baumard (1999) and Nonaka & Takeuchi (1995) argue knowledge has to be related to context and social interaction. Therefore the organizing of the work influenced to what extent the information of the written risk analyses were followed by supplementary knowledge.

7.2.2.3 Railway knowledge as reference for the quality of the risk analyses

The Traffic-rule case that could choose its own risk analytic method, compared different methods with their railway knowledge of the complex interactions of the regulated area and developed their method on this background. Furthermore, all cases compared the risk analyses with this railway knowledge. The purpose of the comparison was to control that known risk was included. Accordingly, railway knowledge again served as reference for good quality. Usually the risk analyses and the railway knowledge provided the same conclusions. When this happened, the confidence in both railway knowledge and risk analyses increased among the participants of the work and they experienced it as a validation of both knowledge sources.

It is not surprising that the risk analyses and railway knowledge often reached the same conclusions as it was railway knowledge that served as the main input to the risk analyses. Also, the top events that served as the starting point for the risk analyses had served as the fundament for many of the existing rules.

Due to the educational background and the practical experience of the main participants in the work and their network, the knowledge that the risk analyses could draw upon was rather extensive. With reference to discussions of Kørte et al. (2002) the operational environments of the regulated areas provided process knowledge and experience data that served as input data to the risk analyses. The analytical processes dealt with these inputs and information and transformed it into the framework of the risk analyses. In addition, it is reasonable to believe that the risk analytic work was given more or less conscious

feedback from the railway knowledge during its development, in particular in the two iterative cases. However, depending upon chosen risk analytic method and the scope for the analyses, only selections of available railway knowledge were included in the analyses.

If the risk analyses and the railway knowledge had conflicting conclusions, the reason for this result was questioned and inquiries initiated. In the next section it will be elaborated that the risk analysis results were less trusted than the railway knowledge. Therefore the most common strategy for the inquiries was to review the risk analyses. The major concern was whether the analyses had excluded important railway knowledge. When weaknesses in the analyses were revealed, the analyses were adjusted to the railway knowledge. Through this strategy the risk analyses were brought in accordance with the railway knowledge and consensus was established. When consensus was reached, the participants experienced this as if the risk analyses and the railway knowledge validated each other. Accordingly, also conflicting conclusions resulted in increased confidence in both.

Accordingly, like the hierarchical approach, the risk-based approach also increased the confidence in existing rules and railway knowledge. The discussions above make it reasonable to ask whether the risk analyses influenced the rule development. Even though the main fundament of the rule development was the existing rules and railway knowledge, I would say yes. One reason is that the confidence in both the analytic results and the railway knowledge increased. This made both existing rules and existing railway knowledge persistent. Another reason is that the introduction to risk analytic methods influenced the thinking and attention of those involved in the work. However, the impact of the analyses was not as extensive as the ambitions in the initial documents of the projects. Furthermore, as Chapter 6 revealed, they did not contribute to a dramatic reduction in the number of rules.

The processes discussed above imply that the risk analyses had limited ability to reveal risks that was not already known in the existing railway knowledge. This gives associations to Turner's theory about disaster incubation (Turner & Pidgeon, 1997). He describes disaster incubation as a discrepancy between the state of affaires and the culturally taken for granted. He argues that accidents arise from the interaction of a chain of unanticipated errors and misunderstood events in complex and ill structured state of affairs. In this development he is concerned about the link between power and officially approved knowledge.

The way railway knowledge functioned as reference for good solutions indicates that the approved knowledge in the modification work was the railway knowledge. This knowledge is based on the tradition of the Norwegian railway system. As already discussed the ongoing changes of the system have made the system more complex and difficult to overview. Therefore this knowledge might have problems to grasp a development of disaster incubation. This raises the question whether it would be wise to supplement railway knowledge with other knowledge both in the risk analyses and the development of rules.

The results revealed that the risk analyses represented a selection of knowledge that fit into the framework of the risk analytic method. The type of risk analyses applied in the studied cases directs much of the attention at the operative levels of the system. This is particularly evident in the type chosen for the Maintenance rule cases that focus at the system's components. Accordingly, the selection of knowledge of the risk analyses will disfavor knowledge associated with other levels of the system.

Reason (1997) argues that different actors' decisions and actions can produce latent conditions or patogens. These might lie dormant for a time until they combine with local circumstances and active failures and penetrate the system's many layers of defenses and an accident occurs. Reason claims that patogens arise from strategic decision and other top-level decisions and that they are present in all systems.

As the chosen risk analytic methods do not emphasize strategic and top-level decisions, they will have difficulties to reveal risks associated with decisions that might lead to latent conditions such as discussed by Reason (1997). The increased emphasis upon risk analyses at the level of authorities implies that the risk analyses might play a more important role in future rule modifications. This might result in reduced approval of railway knowledge that includes knowledge of the complex interactions of different levels of the railway system. If no means are taken that maintain attention to different levels, this can increase the risk of latent conditions in the system.

7.2.2.4 Influence upon railway knowledge

The impact from the risk-based approach upon railway knowledge will be elaborated and discussed in Chapter 8. At this stage attention is drawn to some results.

First, results revealed that the railway knowledge was extended with risk analytic knowledge. This was done trough the introduction of risk analytic methods to the participants of the work and their experience with the performance of risk analyses in the regulated areas. The different applications of the risk analyses in the rule development also developed knowledge about the use and function of risk analyses in combination with rule development.

Second, the introduction and accomplishment of the risk analyses initiated inquiries into railway knowledge. The focus of attention for the inquiries was dependent upon the framework of the chosen risk analytic method and the definition of scope for the analyses. The framework of the risk analytic method and the scope for the analyses also influenced the further discussion of the achieved knowledge and the selection of information that was transformed into the schemas of the analyses. Through these processes knowledge from different sources became more articulated, combined and shared between people.

Third, the work of the cases was organized differently. They differed with respect to how many people were included and who they were, what networks they had access to and

how they were organized for interaction and cooperation. Accordingly, the organizing influenced what railway knowledge was included and to what extent it was articulated, combined and shared.

Fourth, the results revealed that the framework of the risk analyses and their schemas caused that selections of included knowledge became encoded into written texts. These written texts became stored in databases.

Hence the risk-based approach directed attention to selections of railway knowledge that fit into the frameworks and the scope of the risk analyses. Furthermore, the approach influenced what knowledge became encoded into written texts for storage in databases. As the frameworks for risk analyses and associated schemas have evolved out of a rationalistic knowledge perspective, this implies that attention was given to railway knowledge that suited this perspective. Accordingly, it was predominantly rationalistic knowledge that became encoded into these written texts. Furthermore, this implies that more knowledge received attention in the analyses of the Traffic-rule case with wider scope than in the analyses of the Maintenance-rule cases with narrower scope.

This raises the question of what knowledge received little attention. The discussions of Jaeger et al.(2001), Perrow (1999) and Schrader-Frechette (1991) presented in Section 3.5 indicates that the richer intuitively-contextual knowledge might suffer. According to them this knowledge requires thick descriptions and is difficult to operationalize in economic terms. Therefore it might be difficult to adapt this knowledge into the framework of the risk analyses.

7.2.3 Concluding remarks

When the four studied modification processes introduced risk analyses in their work, they did not follow rationalistic ideals of the risk-based approach. Instead the modification work of all cases turned into processes that can also be classified under the label of “reverse invention”

In this process of reverse invention the cases explored and evaluated solutions for the use of risk analyses in the rule development. The major concern was the ability of the analytic methods and their combination with the rule development, to include knowledge known as important for revealing mechanisms that could lead to unwanted events or accidents. Railway knowledge served as source for information gathering and as a reference for evaluation.

The exploration and evaluation of solutions were constrained by conditions that influenced timing of the two tasks. Three out of four cases were not able to finish risk analyses before the rule development started. This decision to start rule development without completed analyses was based on strong confidence in existing rules and access to railway knowledge within the cases. Also, the last case had such confidence in existing

rules and railway knowledge that they decided to base the rule development upon this fundament in combination with information from the risk analyses.

The results of the risk analyses were evaluated with railway knowledge as reference. When risk analyses contradicted railway knowledge, inquiries were provoked. The main strategy was to question the risk analyses and bring them in accordance with the rules and the railway knowledge. The process of reverse invention for the risk-based approach is demonstrated below in Figure 7.5.

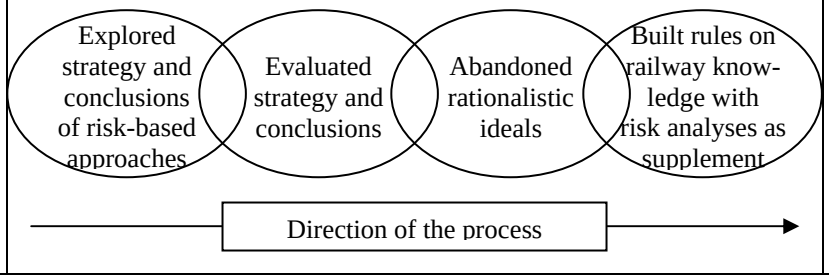
Pheno-menon	**The adaptation of all cases to the risk-based approach**	**Conse-quences**
Reverse invention		Railway knowledge and prescriptive rules were persistent out of concerns for safety.

Figure 7.5 The strategy of reverse invention for the risk-based approach.

Also in Figure 7.5 the circles demonstrate the stages of the process. Their overlap illustrates that there were overlap between the stages. The arrow from left to right demonstrates the direction of development for the process.

The main elements in the development towards the strategy of reverse invention were as follows:

- None of the cases used the risk analyses as fundament for rule development. The main reasons were timing of the tasks combined with strong confidence in existing rules and railway knowledge. The latter knowledge was seen as more inclusive than knowledge derived from risk analyses. The exploration and evaluation of the risk analyses and their methods stimulated inquiries into railway knowledge.

- Instead, all cases used knowledge associated with the rules and railway knowledge as fundament for the work. When available, the risk analyses served as a supplement. The cases included the risk analyses in the modification work in four different ways. This gave the risk analyses different functions; they provided knowledge and information, ensured the quality of evolving rules and validated existing or modified rules.

- The strategies for inclusion of risk analyses in the modification work made it possible to build the development upon existing rules and railway knowledge. In Rasmussen's terminology the strategy for rule development became mainly

evolutionary, but with more or less analytic elements (Rasmussen, 1997). The cases gave the requirement to apply risk analyses in rule development a "risk informed" content (Chapman & Dimitrijev, 1999).

- The ability of the risk analyses to reveal mechanisms that the participants found important for the prevention of unwanted events or accidents were also evaluated with railway knowledge as reference. This stimulated inquiries into this knowledge.

- When the risk analyses were not in accordance with railway knowledge, the risk analyses had the least trust. They became revised and brought in accordance with railway knowledge.

- When consensus between risk analyses and railway knowledge was reached, both achieved increased trust.

The risk analytic methods of the cases had their core elements in common. These were to use top events as the starting point for both fault tree and event tree analyses, identification and analyses of safety critical factors including analyses of barriers.

The introduction of the risk-based approach influenced rule development because it increased the confidence in existing rules and railway knowledge and influenced the thinking of those who developed the rules.

Through the inquiries and discussions that the risk-based approach stimulated, railway knowledge became articulated, shared and knowledge from different sources became combined. Selections of this knowledge were encoded into written texts. In addition, all cases supplemented the competency of participating railway personnel with knowledge of risk analyses. These findings will be followed-up in Chapter 8.

7.3 Evaluation of risk analyses with concerns for their ability to include

The second problem of this Chapter is how to handle a situation where the risk analyses do not fit the risk perception of those involved in the modification work.

The previous section has already revealed and discussed that the dominating strategy of such a situation was to trust the railway knowledge and suspect that there were weaknesses in the risk analyses. Below I will elaborated that the initial phase of the work was critical for the confidence in the risk analyses

7.3.1 Evaluation of risk analyses with railway knowledge as reference

In this subsection, the presentation of results starts with results associated with weak confidence in risk analysis results for then to go on with the strong confidence in railway

knowledge. Finally, findings of the function of risk analyses as a tool to legitimize rule solutions and to reduce the regulatory burden will be presented.

7.3.1.1 Weak confidence in risk analysis results

As revealed, the interviewees reported that the analytic results were questioned and railway knowledge served as reference for the judgments of their quality. When the analyses were not confirmed by railway knowledge it was the risk analyses that were mistrusted. The main suspicion was that the risk analyses had not included elements that the participants with the background of their railway knowledge considered important in the development of unwanted events or accidents. As will be elaborated below, the interviewees attributed the suspicion of the risk analyses to three main factors.

Confidence in chosen risk analytic method

One factor was the confidence that the cases had in the suitability of the chosen risk analytic method for the regulated area. Most of the interviewees of the Traffic-rule case expressed satisfaction with the methods and the combination of these with the rule development. However, one of the interviewees from the work group discussed the use of top events as the starting point for the analyses. He referred to the criticism that existing rules were too experience-based and that the risk analyses were seen as a means to counteract this tendency. He said:

> *"And this is what we have been bullied about, to be so event based. But this is exactly what we become when we turn from top events and downwards too (Derive the analyses from top events, my comment). We are very event based because we use the statistics to prevent events in the future."*

He also reflected upon difficulties associated with the anticipatory intention of the risk analyses.

> *"You cannot be ahead of something you don't know about. It is impossible to have control of what is unknown and abstract, and we don't manage it now either. We are supposed to have control over single errors, or the possibilities for single errors. How can we know all the possibilities for single errors, it is impossible!"*

Among the Maintenance-rule cases there were some differences. In general, interviewees from all cases considered the chosen risk analytic method to be most suitable for the Signal case. However, because of a high number of components the case had to limit the level of details in the analyses to the level of sub-components. The Power-supply case also found the method suitable but had the problem dealing with the high number of components provided from different suppliers. To make the work manageable, this case also performed the analyses at the level of sub-components. Due to relatively few components, the work of the Superstructure was manageable. However, this case faced

the problem that some of their components were difficult to delimit and their status difficult to decide precisely. As one of the interviewees from this case expressed it:

> *"…We chose a tool (the risk analytic method, my comment) that was suitable for questions like failure or no failure at the level of components and objects. Things on the tracks that I work with, are partly very abstract because they are geometrical figures, you can't touch and feel them. You can measure them, but you cannot remove and change them. However, you can correct them."*

Furthermore, some interviewees of the Maintenance-rule cases reported that it was difficult to retrieve data that the method required for the analyses of old equipment. Also, the use of experience data in the analyses made it difficult to analyze new equipment. In such instances the analyses had to be based upon anticipations based upon professional judgments and guesses. Some interviewees underlined that in such instances it was important that the participants held strong practical railway knowledge. Many of the interviewees were concerned that the RCM-methodology split the system into components and gave little attention to the important interactions between these.

However, many of the interviewees also stated that they saw advantages of the introduction of risk analyses, in particular in the long term. The most commonly reported advantage was the systematic work and the written documentation that the risk analyses represented

Seen together, these results reveal that the two cases that had been most involved in the initial exploration of the methods, i.e. the Traffic-rule case and the Signal case, expressed most satisfaction with the method.

Confidence in risk analytic competency

A second factor was the confidence in the risk analytic competency of those performing the analyses. From the beginning, the work group of the Traffic-rule case did not feel fully confident with their risk analytic competency and searched for feedback on their method. The case hired an external risk analytic expert to review the initial analyses. When the Inspectorate revised the project in April/May 2000, limited risk analytic competency was commented upon as a weak point[38]. However the competency of the work group developed as the participants became more experienced and in particular after the employment of the risk analytic expert.

Many of the interviewees of the work groups of the Maintenance cases said that they felt unprofessional at the beginning of their analytic work. During the risk analytic course, when the cases settled their scope for the analyses and made their initial attempts to apply the risk analytic method to their regulated areas, there was an opportunity to use their

[38] Audition report about the project from the Norwegian Railway Inspectorate: Statens jernbanetilsyn. 2000. Report no 3-00

teachers as advisors. Furthermore, they got feedback upon their work during the follow-up seminars. Also in these cases the participants of the work felt that their competency improved when they gained more experience from the work. As one interviewee from the Superstructure case expressed it:

> *"Just now I feel, for my own part, that I would have liked to do the RCM-analyses once more. Because when we started with the RCM analyses, we did not know so much about RCM and where we were going. So, at least for my own part, it would very useful to do the process once more."*

Confidence in scopes for the analyses

A third factor that the interviewees revealed regarding confidence in the risk analyses was their confidence in the scopes that were settled for them. The Traffic-rule case felt confidence in their scope. This was attributed to the wide scope that made it possible to include the complicated interactions of the field. The risk analytic expert that was employed in the work group after the work had started reflected upon this. She attributed the wide scope to the high competency of the railway experts engaged in the project group. The competency made them see all the intertwined interactions of the rail activities and the scope were developed to cover these. She thought that the risk analytic work would have been easier to cope with and less time consuming if the scope of the analyses had been more limited. However, she also thought that then they might have been less trusted.

Many of the interviewees from the Maintenance-rule cases expressed some distrust in the scope for the risk analyses; they felt that they were defined too narrowly. Hence, they did not feel confident that the analyses included important factors that could contribute to the development of accidents and unwanted events. One reason for the narrow scope was advice from the risk analytic experts to limit the work so it did not become too overwhelming. Another reason that also contributed to the limited confidence in them was that those performing the analyses had limited experience with the methods when they settled the scope. The lack of experience made it difficult for them to foresee the consequences of their decisions. The leader of the Maintenance-rule project commented upon this: "*What I feel is that what level you choose or build upon from the beginning has very important consequences for the end result (of the analyses, my comment). But I don't think anybody saw it at the beginning.*" In hindsight, he found that the analytic results would have been different if they had made other decisions at the beginning. He therefore found it reasonable to question the analytic results. However, this problem was not discussed among the interviewees of the Signal case. As revealed this was the case that both held the strongest risk analytic competency and for which the risk analytic method was considered most suitable.

Overview of main factors influencing confidence in risk analyses

The explanations of the limited confidence in the risk analysis results and the status of the cases are summarized in Table 7.2 below.

Table 7.2 Main factors influencing the confidence in risk analyses

Factor	**Traffic-rule case**	**Maintenance-rule cases**	**Comments**
Suitability of the risk analytic method for regulated area	Good	Signal: Good Power-supply: Mid range Superstructure: Mid range	The confidence in suitability of methods was highest among the two cases which were involved in the choice of these
Risk analytic competency	Gradually developed and strengthened with risk analytic expert	All cases gradually developed Signal case: One person with previous knowledge	The confidence in competency increased with growing experience and inclusion of risk analytic expertise
Width of scope for the analyses	Wide	Narrow	Both the Traffic-rule case with wide scope and the Signal case with narrow scope had more confidence that the analyses included important knowledge than the two other cases with narrow scope

Table 7.2 shows that in general the Traffic-rule case has better results on the factors that were considered important for the confidence in risk analysis results than the Maintenance-rule cases.

7.3.1.2 Strong confidence in railway knowledge

The weak confidence in risk analysis results can also be associated with a strong confidence in railway knowledge.

Confidence in railway knowledge of participants in the work and their predecessors

As already revealed in the presentation of the rule imposers' characteristics in Section 5.2 and the results and discussions about the same issue in Section 6.3 all cases involved staff with quite extensive railway knowledge. However theses chapters also revealed that there were some differences between the cases.

The railway knowledge of the work group of the Traffic-rule case included railway professionals with updated, extensive and varied practice. Furthermore, the group had a higher number of participants and together with the varied practice this implied an extensive network. The work group could also take advantage of resource groups that included representatives from different actors involved in the regulated activities.

Also many of the interviewees of this case spontaneously expressed that they considered the railway competency of the work group to be very strong. In particular, the railway competency of the two persons with pure railway background was often mentioned. This was attributed to their varied and extensive practice and their closeness to the operative field. In addition, the background of the project leader as a former leader in the railway system was acknowledged. Also, the railway knowledge of many of the participants of the Board of the branch was acknowledged, but some comments were given that many of these were not close enough to the operative field.

The presentation of the participants in the work of the Maintenance rule cases reveals that their railway knowledge can also be classified as good as all had educations of relevance for the regulated areas and experience from the actual fields. However, there was a lower number of participants involved in the work and it was variable as to how updated and extensive the practice of the participants were. Furthermore, their practice was generally less varied than that of the participants of the Traffic-rule case.

As these Maintenance rule cases involved less people than the Traffic rule case, the cases did not contribute with so many opinions about the competency of the involved actors as this case. However, the comments that the interviewees gave about themselves and others both in their own field and the other fields revealed that also in these cases there were confidence in the railway knowledge of the participants. In particular many expressed a strong confidence in the railway knowledge of the risk analytic group of the Signal case and the Board of the branch of the Superstructure case. This was attributed to their functions at the operative levels of the system. Also, Section 6.3 revealed that many of those most involved in the work of these cases spontaneously expressed that they did not find their own knowledge of the operative field to be sufficient, it had to be supplemented with knowledge from people working at this level. Therefore, their network had an important function in the confidence in the railway knowledge of the cases.

In addition, the participants of all cases expressed strong confidence in the railway knowledge of former rule-developers. One commonly cited quotation among participants from different cases was "*The old ones knew what they were doing!*" One interviewee explained:

> *"… it is mainly incidents, accidents and unwanted events that have been used for learning in the enterprise and that led to changes in the regulations. In former days, this was the normal way to work with the regulations. Back then thereto was not so much documented risk analyses, but there were extensive risk judgments. So I have respect for what they did at that time."*

If the participants of the work did not feel that their own knowledge was sufficient they inquired into the railway knowledge of other participants of the work, their network or when available, their resource groups. However, as Chapter 6 revealed, it was not always easy to retrieve knowledge. This was particularly evident in the Maintenance-rule cases.

Overview of main factors influencing confidence in railway knowledge

The explanations of the strong confidence in the railway knowledge and the status of the cases are summarized in Table 7.3 below.

Table 7.3 Main factors influencing the confidence in railway knowledge

Factor	**Traffic-rule case**	**Maintenance-rule cases**	**Comments**
Included people	Many, with different functions	Few, with more homogenous functions. The risk analytic work group of the Signal case was most stabile.	The confidence in railway knowledge was highest in the case with the highest number of included people who represented different functions and had better access to knowledge resources and network
Practice Updated, extensive and varied	Good	Signal case: Good Power-supply: Mid range Superstructure: Mid range	The confidence in railway knowledge was highest for the two cases with good practice
Formal education	Good	Good	This factor was not given much attention
Confidence in former railway knowledge of former rule-developers	High	High	The high confidence in former rule-developers caused a cautious attitude towards changes or removal of rules

Table 7.3 shows that in general, the Traffic-rule case has better results on the factors that were considered important for the confidence in railway knowledge than the Maintenance-rule cases.

7.3.1.3 Risk analyses as a tool to legitimize rule solutions and reduce the regulatory burden

The Traffic-rule case used their risk analyses in the discussions of the necessity of rules. Rules were wanted when the risk analyses revealed that the sub top events were not sufficiently backed up with technical barriers. The project leader explained that in general these conditions were known from before and were often the main reasons for existing rules. Furthermore, where barriers were lacking, it appeared that it was difficult to introduce any. Also the project did not have the mandate to change the context of the rules. Accordingly the risk analyses confirmed the necessity of existing rules.

In the database of the case the rules became linked to risk analyses that showed their necessity and function as barriers against accidents. In this way the risk analyses became the most important documentation of the necessity of the rules, in a way they represented the legitimacy of the rules. The case also supplemented the database with texts that explained why changes were made in rules.

As the rules of this case considered safety relevant, the risk analyses did not serve any important function in the choice of verbs. As revealed, with few exceptions the verbs shall and must was used.

Like the Traffic rule case and independent on the timing of the risk analyses compared to the rule development the Maintenance-rule cases used the risk analyses to support their judgments of the rules' necessity. In the databases the written documents of the risk analyses were associated with the rules, systematically stored and represented the main legitimacy of the rules.

However, as discussed in Chapter 6, some interviewees reported instances where the risk analyses did not confirm the necessity of the existing rules and that the cases were cautious to change or remove rules. They were afraid that changes could have consequences that they were not able to see. As the leader of the Maintenance-rule project expressed it: *"…one (the railway system, my comment) often introduces something new but never gets rid of something old. When one makes something new one brings with the bag containing all of the old. And then the bag becomes more and more heavy"*

To distinguish the use of verbs in the rule texts, the Maintenance-rule cases also used the risk analyses as a reference for the safety relevance of their rules. However, again the decisions were dominated by the railway knowledge. The reason was that this knowledge included a more extensive understanding of the interactions of the railway system, the participants of the work reported that it was sometimes difficult to exclude anything as not being safety relevant. The main reason was that many of the activities and much of the technology interacted and influenced each other. As one interviewee said: *"…it is very difficult when one has to express it: What is safety? What is meant? How far and deep to go? Yes, it is very simple to say safety, but it is a difficult area."*

These examples reveal that the risk analyses functioned as a tool to legitimize existing rules but not to reduce the regulatory burden upon the rule followers.

7.3.2 Persistent railway knowledge out of concerns for complexity

The results reveal that the confidence in the included railway knowledge in the work of the cases was strong and served as a fundament for the work. When conflicts between risk analyses and railway knowledge occurred, the cases refused to make the risk analyses overrule this knowledge. Below, the importance of railway knowledge, risk analytic knowledge and the chosen risk analytic methods will be discussed.

7.3.2.1 The important railway knowledge

The strong railway knowledge of the cases implies that the risk analytic work had good access to one of the two important competencies for the quality of analyses discussed by Rausand & Øien (2004) and SAMRAIL (European Commission, 2004c). Accordingly, theory supports the concern of the cases for this competency.

However, the main concern for the railway knowledge of the cases was not associated with the quality of the analyses but with the ability to judge the complex interactions of the regulated areas both as a reference for the risk analyses and as a foundation for the work. Anyhow, the strategy to evaluate risk analyses and review risk analyses when they provided surprising results, ensured that important railway knowledge became included in the analyses. The Traffic-rule case and the risk analytic group of the Signal case that had most confidence in the risk analysis results also had strong confidence in the included railway knowledge.

A problem occurred if the participants of the work did not manage to retrieve knowledge of the context and the intended function of existing rules that the risk analyses contradicted. Because the confidence in the competency of predecessors was generally higher than the confidence in the risk analysis results, the risk analyses were usually met with a cautious strategy where the rules remained unchanged. As already discussed in Chapter 6, this might be a dangerous strategy if the conditions have changed to an extent where the rules and the knowledge of the former rule-developers have become outdated (Rasmussen, 1997).

One of the intentions of the rule modifications was to make the rule sets of the cases simpler and more user-friendly. Also, the Maintenance rule case with the emphasis upon cost-efficiency wanted to make sure that rules imposed were really necessary. However, the cautious pattern that was demonstrated in the cases made it difficult to reduce the regulatory burden. As rules can be seen as one form of barriers against accident this directs the attention towards the use of barriers or defenses against accidents. Reason (1997) discusses the use of successive layers of protection, one behind the other, each guarding against the possible breakdown of the one in front. This approach is often called

"defenses-in-depth". He highly recognizes the advantages of this approach but he also comes up with a warning that defenses-in-depth are a mixed blessing. He argues that one of the more unfortunate consequences is that they make systems more complex, and hence more opaque, to the people who manage and operate them. Accordingly, the cautious approach might be a two edged sword; it gives the system many layers of protection but this might imply that the system also becomes more opaque and hence more difficult for the actors to understand and operate safely. This might make it more difficult for the different actors to foresee consequences of their decisions and actions.

7.3.2.2 The important risk analytic competency

The participants reported that at the beginning of the work they were concerned about their limited knowledge of risk analytic methods and their application. However, confidence increased as those performing the analyses became more experienced with the method and their application for the regulated areas. Risk analytic competency is the second condition that both Rausand & Øien (2004) and SAMRAIL (European Commission, 2004c) discuss as important for good quality analyses. Accordingly they give support to these concerns of the cases too. Furthermore, Aven (2003) argues that the weight that the decision-maker will put on the results of the analyses will depend on the confidence he has in the analysts.

In the initial phase of the analytic work all of the cases were organized so that they could receive feedback upon their first attempts with risk analyses. This is an important condition for learning and improvement (Argyris & Schön, 1996). However, as Subsection 7.2.1 demonstrated, in their following work their organizing for feedback differed.

The Traffic-rule case and the risk analytic group of the Signal case that had most confidence in the risk analysis results also possessed the strongest risk analytic competency. These were also the cases that had the best conditions for close interaction between the experts of risk analyses and the experts of the actual railway field during the analytic work, i.e. for feedback and learning.

The risk analytic competency was also reported as an important explanation when the cases suspected that the scope for the analyses had constrained inclusion of important railway knowledge in the analyses and hence reduced their quality. One important element here was the ability to understand consequences of the choice of scope. The hindsight realization that other scope than those applied would have given other conclusions for the analyses reduced the confidence in their results.

This also reveals that here there are opportunities for manipulation of risk analysis results. Baumard (1999) argues that as knowledge increases, actors can increase their ability to outsmart rules to serve their own interests, in other words, they can manipulate the scope of the analyses to direct attention towards what suits them the most. However, I did not receive any evidence that this happened in the cases. My impression from the study was

that those involved in the risk analyses were very concerned about their ability to cover the important factors that influenced the development of unwanted events or accidents. This implies that if such mechanisms were operating, they operated out of concerns for safety.

7.3.2.3 The important choice of risk analytic method

The results reveal that the suitability of the chosen risk analytic methods was experienced differently among the cases. The representatives of those two cases who were most involved in the choice and development of the methods also expressed most satisfaction with these.

One explanation might be that the involvement ensured that the chosen methods were appropriate for the regulated area. This is in line with the emphasis that Aven (2003) gives to this factor. He argues that the weight that the decision-maker will put on the results of the analyses will depend on the confidence he has in the analyses.

A possible additional explanation might be that participation created a stronger ownership to the method. As Rausand & Øien (2004) argue, ownership to the analyses at different levels of the system can influence their quality. It might be that the users involvement in these two cases made them feel more familiar with the methods and that this might have caused a more positive attitude, i.e. the involvement strengthened the familiarity and ownership to the solution.

This might also have been strengthened by the close interaction these cases had with the external risk analytic experts through their participation in the decisions and the experimentation with the methods. Hence, they received feedback upon their work and could cooperate with the experts in the adaptation of the abstract risk analytic methods to the actual context. This might have been a source for learning that improved the adaptation of the methods to the respective fields (Argyris & Schön, 1996).

The function of the method in the selection of railway knowledge and its translation into written texts and in the legitimizing of the rules will be discussed in Chapter 8.

7.3.3 Concluding remarks

Together, the cases revealed that the initial stage for the risk-based rule modifications was highly critical for the confidence in the risk analyses. Firstly, it was at this stage the participants in the work were chosen and the organizing of the work was settled. These conditions influenced what railway knowledge was included in the work. Secondly, it was at this stage the risk analytic methods were chosen and adapted to the regulated areas. Thirdly, it was also at this stage that those participating in the work built their risk analytic competency and got feedback upon their initial work. Finally, it was at this stage the scope of the risk analyses was settled.

Furthermore, these results pointed at an underlying concern that influenced confidence in the risk analyses. This was the ability of the analyses to take the complex interaction of the different activities in the regulated areas into consideration.

7.4 Modification work with a wide inclusive perspective of risk

The third problem of this chapter is what risk perspective to apply to the modification work. In the following it will be elaborated that the wide inclusive perceptions of risk of railway knowledge dominated the work and the concept of "safety" was commonly applied.

7.4.1 Focus upon safety and an inclusive perception of risk

The perspective of risk was both evident in the attitudes of the interviewees and in the work itself.

7.4.1.1 Risk perspective of the interviewees

The interviewees were asked how they defined risk. All gave an answer in accordance with the risk analytic conception of the term, i.e. the product of probability of occurrence and the consequence. However, some interviewees expressed this in a way that made me follow-up the question. This revealed that many felt that this was a simplification of their understanding of risk. They found this definition to be difficult for the inclusion of the complex interactions that might be behind an unwanted event or an accident, an aspect that they found important. In particular they were concerned about the interactions within the technical system and the needs to coordinate the many actors involved in the activities.

Also the interviewees demonstrated a common pattern where they favored to use the term "safety" instead of the term "risk". One interviewee described the relationship between safety and risk like this: "*Safety is to have control upon risk*". Other descriptions were "*avoid damage on humans, environment and materiel*" and "*to ensure that activities are performed without unwanted events or accidents*". However, the risk analytic expert who was included in both cases experienced the use of the term "safety" was difficult because it contained both descriptive and normative elements and was difficult to formalize and operationalize.

The Safety director of the Rail Administration also directed the attention towards different conceptions of the term "traffic safety". He found that the Inspectorate applied it in a very inclusive way, while many actors in the Rail Administration associated it with the traffic rules. Therefore, the concept was difficult for the organization to handle.

The wide conception of risk was also evident when the interviewees discussed the modification work. This was especially evident in their discussions of the risk analyses. As already touched upon, they often reported that the analyses did not go deep enough into the underlying causes and the interactions of the railway system that could lead to accidents. One interviewee from the Maintenance rule case provided an illustrative example that is representative for revealed attitudes of both the Traffic-rule case and the Maintenance-rule cases:

> *"…at least it is difficult for us when we are trying to make it concrete (the probabilities and the consequences, my comment). And another thing that I would like to mention while I am discussing this, is these barriers. Many of the things we have that serve as safety systems are parts of many things or many links. I can provide one example, the issue of ATC that are supposed to stop a train if anything goes wrong. ATC is one part of this and the engine driver another and then another important issue is whether the safety installation functions and that there might be something wrong here. But then there is also another issue called emergency disconnection. This is that you in emergency can disconnect the contact conductor on the lines where trains are run by electricity and then all the trains have to stop…. And then the question becomes: How much safety will you attribute to that emergency disconnection? Is this just as safety critical as the safety installation as such?*

Also, as touched upon, the wide conception of risk was evident in the Maintenance rule cases when they discussed the work of classifying the rules into safety relevant and not safety relevant. As one interviewee said:

> *"…the fact that we are marking something as safety related and something as not safety related is also difficult. Because there is almost no function in a railway system that you cannot figure out that for one or another reason will give you an accident if it fails. So complex is the system."*

7.4.1.2 Risk perspective of the work

The results presented in this chapter and the previous one, have already revealed that railway knowledge of those who became involved dominated the work. The cases chose approaches to their tasks where the work could build upon this knowledge.

The results have also revealed that one reason for the strong position of the railway knowledge was that this knowledge has an inclusive perception of risk. This was particularly evident in the processes of reverse invention where the rationalistic ideals of the hierarchical and risk-based approaches were abandoned and in the risk informed content given to the requirement of applying risk analyses in the modification work.

The strong position of the inclusive risk perspective was also demonstrated when the scope for the risk analyses were decided and later judged. In the case with wide scope

their inclusive nature was one of the explanations for the positive attitude towards the analyses of this case. In two out of three Maintenance-rule cases, one reason for the cautious attitude towards the risk analyses was seen to be narrow scope.

When the results of the risk analyses contradicted railway knowledge, most commonly the risk analyses were suspected to have excluded important information; information that the extensive railway knowledge of the participants were able to recognize.

In the presentation of the results associated with the judgment of rules' necessity it appeared that the cases were cautious to remove rules on the basis of risk analyses. The main reason was the confidence that the rule-developers had in the included railway knowledge and the extensive railway knowledge of their predecessors that made them able to see complex interactions in the railway system. However, the decisions of rules' safety relevance were also complicated because of the wide inclusive risk perspective. The understanding of how different activities and technology influenced each other made it difficult to consider anything as not safety relevant.

7.4.2 The wide inclusive risk perspective

The results presented above imply that both the wide conceptions of risk that were associated with railway knowledge and the more narrow risk analytic definitions were operative during the modification work. When conflicts between these two perspectives occurred, the wide conception of risk or the even more inclusive concept of safety served as reference for evaluations of conclusions and solutions. Hence, the modification work was brought in accordance with this wide risk perspective. Accordingly, this perspective dominated the modification processes.

In relation to the dominant role of the risk perspective associated with railway knowledge, I think it is important to be aware of other mechanisms that might come into play in such situations, for instance the role of power, private privileges and profits that make systems resistant to change and heuristics (See for instance Clegg, 1989; Hindess, 1996; March, 1994; Perrow, 1999). These are not elaborated in this study.

However, the fact that the interviewees preferred to present the risk analytic definition of risk first gives an impression that the risk analytic definition had higher status and was more legitimate than the other. This is also the dominating definition of both the Inspectorate and the Rail Administration. The Inspectorate requires that the actors of the railway system apply risk analyses and accept criteria, a requirement derived from the analytic management strategies that apply the risk analytic definition (Samferdselsdepartementet, 2001a). The Rail Administration directly applies this definition of risk in the Safety-handbook that is a part of their management system.

The results have demonstrated that the risk perspectives became important when the cases settled their scope and preconditions. It is interesting that the cases give contradicting inputs regarding the satisfaction with wide or narrow scope. Both the

Traffic-rule case with the wide scope and the Signal case with more narrow scope expressed satisfaction with this. Again one explanation might be that these cases were the ones that had been most involved in the choice of methods and that this might have made the actors more familiar with them. Furthermore, they had tried out the methods for their fields and seen consequences of different scope. Another explanation might be that the regulated areas held different features. The maintenance activities of the Signal case do not involve as complicated interactions between different actors as the Traffic-rule case. This might make the Signal case less dependent on inclusive scope. As already discussed, these groups were also seen to hold both the strongest railway knowledge and risk analytic competency, that are both considered important for the quality of risk analyses (Rausand & Øien, 2004; European Commission, 2004c).

The perspectives upon risk will be further discussed in Chapter 8 when perspectives of rationality and knowledge are discussed.

7.4.3 Concluding remarks

The participants of the work were well aware of the risk analytic concept of risk and this seemed to have the most legitimate status in the system.

However, in words and in practice, the cases reveal a much wider perspective upon the concept of risk. Their perspective also included the concept of safety. This wide perspective dominated the work. This implies that more of the existing railway knowledge about the interactions between activities and technology within the regulated areas was included in the work.

7.5 Conclusions to the risk based approach

7.5.1 Main conclusion

The four studied modification processes abandoned the ideals of the risk-based approaches in two interrelated ways. First, none of the cases used the risk analyses as the main foundation for the rule development. The main reason was that the risk analyses did not take existing railway knowledge that was believed to be important for safe performance sufficiently into account. Second, only one case finished the analyses before the rule development started, two cases developed the risk analyses and the rules in parallel as iterative processes and one performed the analyses after the rule writing. The main reasons for the differences were the timing of the decision to apply risk analyses, time pressure and experience that the risk analytic work stimulated questions to the rules and vice versa.

Instead, the modification work of all cases turned into processes of reverse invention where existing railway knowledge and prescriptive rules were used as the main fundament for the work. Accordingly, existing knowledge was brought forth.

However, all four cases performed risk analyses and used these as a supplement in their work. The chosen analytic tools built upon the same principles that are commonly used in other European railways (European Commission 2004c). The framework of the applied tools initiated inquires into railway knowledge and articulation, combination, selection, systematizing and documentation of this knowledge.

The evolving risk analyses were evaluated with railway knowledge as reference and brought in accordance with this knowledge. Existing railway knowledge became more persistent than expected. There were three interacting reasons for this. First, the risk analyses were not found to be as capable as the railway knowledge at including the underlying causes of potential accidents. This was particularly evident in two out of three cases that chose narrow scope for the analyses. However, the work of the case that chose wide scope became very extensive. Second, the participants of the work trusted the competency of the former rule-developers and the quality of railway knowledge more than their own risk analytic knowledge. Third, the cases differed in their experience of suitability of the chosen methods for their regulated areas.

Railway knowledge that had support from the risk analyses achieved increased trust because support from the analyses was seen as validation.

The four cases combined the risk analyses and the rule development in four different ways. Their methods for the combination reflected the timing of the decisions to apply risk analyses and the time pressure. They also differed in the degree of interaction between risk analyses and rule development. The interaction between the two tasks depended upon the organization of the work. One case has provided a written description of its method, see Appendix F.

The four different methods gave the risk analyses different functions in the modification work; they provided knowledge and information, ensured quality of evolving rules and validated existing or modified rules. Accordingly, one can say that the modification processes became risk informed, but that the function of the risk information varied.

7.5.2 The theoretical problems

The conclusions of the revealed problems are as follows:

1. *How to combine expert-dominated risk analyses with rule development in an evolutionary practice-oriented modification tradition?*

The strategy for introducing the risk-based approach had characteristics of reverse invention with railway knowledge as the main elements. The risk-based approach was

given content similar to the use of the concept “risk informed” in the studied modification processes (Chapman & Demitrijev, 1999). However, the cases applied the risk analyses very differently in their work. This contributed to the use of railway knowledge as the main fundament for the work. Furthermore, this gave the risk analyses very different functions in the modification processes. These were dependent on the timing of the decision to use risk analyses in the work, time pressure and the organizing and the interaction of the work.

The risk analysis results were compared to general railway knowledge and the conclusions were brought in accordance with each other. This increased the confidence in both risk analyses and railway knowledge.

The applied risk analytic methods built upon the same principles that are commonly used in other European railways (European Commission 2004c). One case provided one systematized and documented method for the combination of risk analyses and rule development (See Appendix F).

The introduction of the risk-based approach stimulated inquiries into railway knowledge and discussions that made this knowledge become articulated, combined, selected, systematized and documented.

2. *What if the risk analyses do not fit the risk perception of those involved in the modification work*

When the risk analyses did not fit the risk perception of those involved in the modification work, the reason was inquired into. Most commonly the reasons were attributed to the ability of the analyses to take the complex interaction of the different activities in the regulated areas into consideration. Therefore, the analyses were brought into accordance with railway knowledge that included these aspects. The results revealed that the initial stage for the risk-based rule modifications were important for the confidence in the risk analysis results.

3. *What risk perspective to apply; a wide inclusive definition or the narrow risk analytic?*

Those who participated in the work of the cases were well aware of the risk analytic concept of risk and this seemed to have the most legitimate status in the system. However, in practice, they revealed a wider perspective upon the term and they preferably applied the term “safety”.

7.5.3 Needs for further research

The results of the risk-based approach raise some questions for further research.

First, the findings of the process reverse invention also contradict the rationalistic ideals of the risk-based approach. Like for the hierarchical approach, the emphasis upon the use of risk analyses in theory and practice makes it interesting to study if this process is applied in other contexts where risk analyses are introduced as a tool in rule development. For the same reason it is interesting to study if there exist alternative processes and to elaborate strengths and weaknesses of the process.

Second, to improve knowledge about risk-informed safety rule modifications, the contribution and efficiency of the different applications and functions of the risk analyses for the quality of the rules should be explored and evaluated. Furthermore, to explore the usability of the different methods for application of risk analyses for other contexts, a follow-up study should be performed to reveal how the experiences with the methods are incorporated in later modification processes.

Third, the main factors that influenced confidence in the risk analyses were supported by theory. As the introduction phase of the studied modification processes appeared to be very important for these factors, it is of interest to study how risk analyses are introduced in other modification processes.

Fourth, due to the dynamic contexts of the regulated areas, the use of experience data and top events in the analyses were an issue of concern. As one of the reasons for introducing risk analyses in the modification processes was that existing rules were too experience-based, it is interesting to follow-up how the analytic results fit in with future statistical material.

Fifth, this study has not elaborated on many of the possible explanations for the strong position of railway knowledge and the associated risk perspective. For instance, it would be interesting to study the role of power, private privileges and profits that make systems resistant to change and heuristics would contribute with new understanding (See for instance Clegg, 1989; Hindess, 1996; March, 1994; Perrow, 1999).

8 Rule revision as revival of knowledge: Is revived knowledge saved?

8.1 Introduction

This chapter is directed at the last of the three sub questions of the study:

How did new requirements influence railway knowledge?

The research question of this chapter and the theoretical framework presented in Section 3.1 demonstrated an expectation that the introduction of hierarchical and risk-based approaches would influence railway knowledge. This chapter will explore this hypothesis.

The theory presented in Section 3.5 revealed three problems of special interest. The following sections present results and discussions of these. As this chapter builds upon the results presented in the three previous chapters, many of the empirical findings for the discussions are already presented and a few discussions have been started. These findings and discussions will be summarized and elaborated in this chapter.

The structure of the presentation of results and discussions is shown in Table 8.1 presented in this and the next page. Again the final section of the chapter presents the conclusions to the research question.

Table 8.1 Structure for presentation of problems with results and discussions:

Problem with answer	**Result**	**Discussion**
Section 8.2, answers to the question of Problem 1: What knowledge base to apply as decision support? Railway knowledge served as knowledge base	8.2.1 The combination of perspectives upon rationality and knowledge	8.2.2 The strong position of railway knowledge 8.2.3 Concluding remarks
Section 8.3, answers to the question of Problem 2: Did increased emphasis upon the rationalistic knowledge perspective change the predominantly intuitively-contextual railway knowledge? Railway knowledge was revived and changed	8.3.1 Changes in railway knowledge	8.3.2 The revival and change of railway knowledge 8.3.3 Concluding remarks

Problem with answer	Result	Discussion
Section 8.4, answers to the question of Problem 3: How did railway knowledge become stored in organizational memory? Revived but saved? Knowledge encoded into written form was systematically stored other knowledge was not.	8.4.1 Written texts systematically stored, weak or no systems for the rest.	8.4.2 Written texts systematically stored – what about the rest? 8.4.3 Concluding remarks

As discussed in Chapter 3, the Norwegian railway system has been dominated by rule- and identity based rationality with the related intuitively-contextual perspective upon knowledge. However, there have also been elements of technical rationality with the more rationalistic perspectives upon rationality and knowledge. As revealed in Chapter 5, the cases built upon this tradition. Chapter 3 also demonstrated that knowledge could be transformed and developed, kept alive or lost.

8.2 Railway knowledge served as knowledge base

The first problem concerns which knowledge to apply as decision support in the modification processes. Below it will be elaborated that the cases preferred to combine the new rationalistic hierarchical and risk-based approaches with the existing modification tradition. However, the modification work still became dominated by rule- and identity based rationality and predominantly intuitively-contextual railway knowledge.

8.2.1 The combination of perspectives upon rationality and knowledge

The strong position of rule- and identity based rationality and intuitively-contextual railway knowledge and the preference for combining these perspectives was particularly evident when the new approaches were introduced and in the choice of solutions for their implementation. In the following these issues will be elaborated.

8.2.1.1 Introducing the new approaches

All cases included people in the modification processes who had previous experience with modifications of the actual rules. The strategy to involve operative railway personnel both directly and indirectly through the network of the participants, made all cases include both intuitively-contextual and rationalistic knowledge in the work. This made it possible to take advantage of the rich cognitive maps of the practical field. However, due

to recruitment patterns and the educational traditions, the area of regulation of the Traffic-rule case was more influenced by rule- and identity based rationality and intuitively-contextual railway knowledge than those of the Maintenance-rule cases. For the same reasons, the areas of regulation of the Maintenance-rule cases were more influenced by technical rationality and rationalistic knowledge than those of the Traffic-rule case. These patterns were reflected in the personnel involved in the modification work too. In accordance with the tradition of the Norwegian railway system, trade unions were not included in the work in a formal way. The users of rail services were also not included.

The Norwegian railway system was already familiar with the hierarchical approach, in particular from the introduction of internal control and no educational steps were taken for its implementation.

The situation of the risk-based approach was different. As the risk analytical competency was limited from the beginning of all cases, the leadership of the projects found educational steps to be necessary. The chosen strategy of the cases was to supplement the railway knowledge with risk analytic knowledge. The cases did this in different ways.

In the Traffic-rule case the competency was developed gradually and related to the actual context. This was done by courses, by engaging representatives with different methodological approaches and by experimenting with their application at the area of regulation. Later also a risk analytical expert was involved in the work group. The members of this group worked closely together and took advantage of each other's knowledge.

For the Maintenance-rule cases the competency was developed in an intensive course led by external experts. The course included practical training where the participants experimented with the application of the methods at the regulated areas and adapted them to this context. The railway knowledge of the participants also played an important role. The leader of the Overarching Maintenance project found that the courses became a meeting place between two types of competencies and where both learned.

In the work to find methods for the inclusion of the new approaches in the modification processes, the cases inquired into and discussed railway knowledge, experience from former rule modification processes and the new approaches. Alternative methodological solutions were explored and evaluated by the members of the work groups but also in dialogue with their network and resource groups. Railway knowledge served as a reference in the evaluations. Such processes were particularly evident in the Traffic-rule case. For the Maintenance-rule cases the management system of the Rail Administration and the Overarching Maintenance project provided some preset conditions. However, also the Maintenance-rule cases had to find their ways to solve the challenges. In hindsight, the leader of the Maintenance-rule project reflected upon these processes and said: *"Many people think it should have been clearer from the beginning. Instead it evolved little by little."*

The inquiries, experiments and discussions associated with the introduction of the new approaches made railway knowledge in focus more articulated and shared. Furthermore knowledge from different sources became combined.

8.2.1.2 Solutions for the new approaches

When it came to solutions for hierarchical and risk-based approaches there were differences between the cases.

The solutions for the hierarchical approach

Regarding the hierarchical approach, the cases favored finding solutions that combined perspectives of the existing rule tradition with perspectives of this approach. This made the cases leave the proposals derived from this approach.

First, this favor of combinations was demonstrated in the attempts to develop higher order rules by the inductive bottom-up strategy for developing outcome-oriented rules. This strategy caused that the work of developing rules built upon existing prescriptive rules and railway knowledge. Furthermore, the participants used railway knowledge as reference when judging the rule solutions.

Second, the favor of combination was demonstrated in the choice of rule solutions. The Maintenance-rule cases had the opportunity to combine outcome-oriented triggering requirements with prescriptive rules and did so. Furthermore, in the discussions of the necessity of the prescriptive rules, both railway knowledge and available risk analyses was taken into consideration. The Traffic-rule case abandoned the plan for goal-oriented rules and stayed with the prescriptive rule solution. However, the case also wanted to supplement these rules with goal-oriented formulations for educational purposes of the rule-followers. Therefore many of the representatives of this case regretted that this plan was left. In all cases railway knowledge played the major role in the argumentation for the solutions. Also available risk analysis results contributed.

With respect to changes in the rules, the inductive bottom-up approach to rule development and the persistence of prescriptive rules that all cases revealed, demonstrated that they were cautious to change the rules. The argumentation for the solutions also demonstrated a strong trust in predominantly intuitively-contextual railway knowledge and rule- and identity based rationality. In spite of the persistence of prescriptive rules, all cases found the increased attention to outcomes of the suggested rule solutions to be useful for the safety work. This was attributed to their explanatory power for educational and motivational purposes and their function as reference for control.

The solutions for the risk-based approach

Regarding the risk-based approach; the case also favored finding solutions where perspectives of this approach were combined with perspectives of the existing rule tradition. All cases chose solutions where risk analyses were incorporated in the existing rule tradition. In their solutions, none of the cases followed the ideals of a risk-based approach where the risk analyses served as an important fundament for the rule development. Instead, the bottom-up strategy reveals that the work was based on railway knowledge and in particular knowledge associated with existing rules. The project leader of the Overarching Maintenance project explained that the goal had been to achieve more rational decision processes with increased use of risk analytic tools. However, he also explained that the cases did not apply what he called a logical structural approach. Instead existing competency and experience were applied to point out areas where control was considered to be important.

The cases chose different solutions for the interaction between the tasks of risk analyses and rule development. The different interactions between risk analyses and rule development gave the analyses different functions in the modification work.

Core participants from all cases expressed their preference to perform their task of rule development in interaction with the risk analytic task. Also, all interviewees of the two cases that were described as iterative, e.g. the Traffic-rule case and the Power-supply case, found the iterative decision-making processes very useful. The main reason given by the interviewees was that overlapping and intertwining of activities gave flexibility and possibilities to take advantage of lessons learned during the work. This made it possible to incorporate new information and knowledge that evolved from the inquiries and experiences of both the rule development and from the risk analyses. This developed and refined their methods for the accomplishment of rule modification with the new approaches. The Traffic-rule case made an explicit description of their developed method[39] (See Appendix F). Furthermore, the representatives of the Signal case and the Power-supply case where the organization of the work had made extensive interaction between the actors difficult, explicitly regretted the lack of continuity in their work.

In the risk analyses themselves, railway knowledge served as the main input. The risk analytic methods contributed with a framework for selecting, organizing and expressing this knowledge. The dominating perspective upon risk and safety also influenced which knowledge became included.

The results of the previous chapters revealed that when conclusions of the new approaches came in conflict with railway knowledge, this initiated inquiries and consensus building processes. Confidence in the ability of different conclusions to contribute to safety played an important role for the strategy to solve the problem. The common reaction was to question the conclusions of the new approaches. For example, as a reaction to conclusions the work group of the Traffic-rule case did not trust, they had an

[39] Logg 638-1A, Logg 689

internal expression saying: *"It is legitimate to use the head too!"* The only exception where conclusions derived from railway knowledge were questioned was when there already existed doubts about this knowledge. Therefore the dominating pattern of the consensus building processes was to adapt the conclusions of the new approaches to railway knowledge.

The preference for combined perspectives

Taken together, the results above demonstrate that all cases preferred solutions for both the hierarchical and risk-based approaches that combined perspectives of rationality and knowledge from the existing rule tradition with the perspectives of the new approaches. In other words, they preferred to take advantage of different perspectives. The rationalistic rationality and knowledge perspectives inherent in the hierarchical and risk-based approaches became adapted to the conditions of the context of the Norwegian railway system and the areas of regulation. In this way the solutions of the new approaches became more context specific. Contradictions that occurred can be seen as examples of confrontations between perspectives of rationalities and knowledge.

There were no preset decision rules to solve confrontations between the existing and the new perspectives of rationality and knowledge. However, the responses revealed that the railway knowledge functioned as reference for what was considered to be good solutions. Accordingly, the predominantly intuitively-contextual knowledge of the railway experts had more trust than the rationalistic knowledge of the conclusions from the hierarchical and risk-based approaches. Furthermore, the railway knowledge played the major role in the modification work. This happened in spite of the many resources that were invested in the new approaches. The leader of the Maintenance-rule project explained this cautious pattern like this:

> *"One brings with oneself a lot of tradition that is difficult to delete and that may be become very influential upon the new. I think it is difficult for many to disregard what one possesses and what one has done and to think new, - even if this might be the right thing to do."*

Three interviewees were worried that so many of the participants represented the tradition of the former NSB. One of these was the eldest and most experienced interviewee from the Traffic-rule case. Another expressed a concern that it was the railway professionals recognized as the best who become included in the work and hence served as the reference for good solutions. Accordingly the rules might be adapted to their needs, not to the needs of the average or weak rule-followers. One interviewee had also experienced that he had more influence in the organization when he was posited in the capital city compared to when he was posited in a regional office with the same type of job.

Both when the conclusions of the new approaches gave support to, and when they contradicted, the railway knowledge, the processes resulted in strengthened trust in this knowledge. In the first instance the trust was strengthened because the railway knowledge

became validated, in the second the trust was strengthened because the knowledge survived an attack. This was particularly evident regarding the rule specific knowledge of the prescriptive rules.

The inquiries, experiments and discussions associated with the solutions of the new approaches also made included railway knowledge more articulated and shared. Again knowledge from different sources became combined.

8.2.2 The strong position of railway knowledge

In the following, these findings will be discussed. The initial discussions will focus upon the strong position of predominantly intuitively-contextual railway knowledge when the new and predominantly rationalistic approaches was explored and applied. In the following, it will also be discussed that the rather ambitious intentions of introducing hierarchical and risk-based approaches did not have the expected impact upon the modification processes and their results. As will be elaborated, this can either be understood as attempts to counteract the intentions or as attempts to find good solutions for the new requirements.

8.2.2.1 Exploring the new approaches with railway knowledge as fundament

The incitements to the hierarchical approach were not followed by educational steps. However, the history of the Norwegian railway system presented in Chapter 2 revealed that earlier attempts to implement the internal control principle had not been without problems. In spite of this, all cases experimented with the hierarchical rule solutions. The way this was done resembled the descriptions of Reflection-in-Action provided by Schön (1991). With reference to this theory, the introduction of the new approaches represented a new problem setting that was inquired into. The evolving hypotheses of how this could be done were tested with experimental actions where railway knowledge served as reference.

The core elements in the strategies to supplement the railway knowledge with risk analytic competency were in accordance with the dominating educational traditions of the main participants in the work. The strategy of the Traffic-rule case that tried different solutions in practice was in accordance with rule- and identity based rationality and the intuitively-contextual knowledge perspective. This strategy also gives associations to the descriptions of Reflection-in-Action of Schön (1991). The introduction course of the Maintenance-rule case was more in the tradition of the rationalistic rationality and knowledge perspectives where academic experts teach those holding practical knowledge that, according to Schön (1991), holds lower status. However, in the experimentation with the chosen risk analytic method on the actual subsystems, the railway knowledge became included. Accordingly, the processes also had parallels to Reflection-in-Action here. This reveals that the introduction of the risk based approach mobilized both intuitively-contextual railway knowledge and rationalistic risk analytic knowledge.

However, the general strategy of all cases adding risk analytic competency to the railway knowledge and not the opposite, is the common approach discussed by Perrow (1999). Building upon his discussion, this strategy reveals an attitude that it is the predominantly intuitively-contextual railway knowledge that is weak and needs to be developed, not the risk analytic competency. The incitements with the ideals of the hierarchical approach in the tradition dominated by prescriptive rules for the low level rule-followers reflected much of the same attitude; it is the railway knowledge that needs to be developed in an abstract and theoretical direction. On the other hand, the results also indicate that the educational steps functioned as an arena where perspectives upon rationality and knowledge both met and were developed.

8.2.2.2 The role and function of the new rationalistic approaches in the modifications

The role and the function of the new rationalistic approaches were influenced by the way they were implemented in the existing modification tradition.

Implementation of the hierarchical approach

The attempts to apply the hierarchical approach in the modification processes demonstrated both intentions to enrich the existing rule tradition with solutions of this new approach and the strong position of the old railway tradition. This was particularly evident in the choice of the inductive bottom-up strategy to rule development. As discussed with reference to Lindblom (1959), a strict adherence to the deductive top-down strategy would have forced the cases to abandon the inherent railway knowledge of the existing rules. Accordingly, the work would have had to be based upon knowledge from other sources. In accordance with the tradition of technical rationality as discussed by Schön (1991) the natural source would have been academic and rather context free rationalistic knowledge. Following up both the principles of internal control and the incitement of a risk-based approach, the risk analyses might have been an important contributor.

On the contrary, the inductive bottom-up approach that the cases applied made the cases able to build upon existing knowledge of the prescriptive rules' context and function and rule specific knowledge, i.e. predominantly intuitively-contextual knowledge. It also made it possible to integrate this knowledge into higher order rules. In other words, the existing knowledge became transformed into the outcome-oriented form, i.e. the experimentation with higher order rule solutions transferred the rule specific knowledge of former prescriptive rules into the more abstract academic forms of outcomes.

The inductive bottom-up strategy of the cases showed that in the transition period when higher order rules were developed from lower level rules, the process activated both rationalistic and intuitively-contextual railway knowledge. Accordingly, this strategy made it possible to take advantage of different perspectives in the work.

Regarding the choice of rule solutions, the Maintenance-rule cases that could apply different solutions representing different perspectives built consensus for a combination of these. Also the Traffic-rule case was in favor of a combination of solutions that would have made it possible to include different perspectives upon rationality and knowledge. However, when divergences between the conclusions of suggested rule solution and railway knowledge became apparent, the case used railway knowledge to build consensus for a cautious pattern that favored the rule- and identity based rationality and predominantly intuitively-contextual knowledge. Furthermore, as this case had to leave their plan for a textbook, the inclusion of rationalistic perspectives in written texts associated with the rules was left. This did not happen without regrets from the main participants in the work.

In these decision-processes the cases' railway knowledge served as reference for good solutions. Accordingly, all cases applied a logic of appropriateness as described by March (1994). Here the reference for appropriateness was the predominantly intuitively-contextual railway knowledge. Hence, the decision processes of rule solutions were dominated by rule- and identity based rationality. The trust in professional judgments of railway experts fit in with the descriptions Weber (2000) made of the bureaucratic tradition. What is different from this tradition is that the knowledge base of the experts is more intuitively-contextual than one could expect in such a tradition.

Implementation of the risk based approach

The dominance of rule- and identity based rationality and intuitively-contextual knowledge was also evident in the application of risk assessments. The different processes that the cases demonstrated for combining risk analyses and rule development showed that the processes did not apply the rationalistic form of rationality where all knowledge is collected before decisions are made. Even if not always possible, the central participants in the work preferred to solve their tasks in a form resembling Reflection-in-Action as described by Schön (1991). Also here, the handling of the problem of divergences between conclusions of risk analyses and railway knowledge followed the logic of appropriateness. Again the predominantly intuitively-contextual railway knowledge was trusted to function as reference for appropriateness.

When performing the risk analyses, the predominantly intuitively-contextual railway knowledge served as input. Like Kørte et al. (2002) discuss, the operational environments provided updated process knowledge and experience data that served as input to the analytic process. Which knowledge was included was influenced by the chosen risk analytic method and the participants' perception of risk. As revealed in Chapter 7, the cases and in particular the Traffic-rule case applied a wide and more informal definition of risk than that of the risk analytic tradition. Accordingly, more of the railway knowledge became included in the work with the analyses. Again this knowledge was transferred into more rationalistic forms, this time in accordance with the structure and schema of the chosen risk analytic methods.

The combination of the perspectives

The discussions above demonstrate that the rationalistic new approaches became adapted to the predominantly intuitively-contextual railway knowledge and not the opposite. In contrary to theory, this implies that it was the rationalistic approaches that were developed and the rule- and identity based rationality and the predominantly intuitively-contextual knowledge that had the highest status (Perby, 1995; Schön, 1991).

The decision strategy of the cases resembled that of "Mixed scanning" presented by Etzioni (1967). Building upon his metaphor, predominantly intuitively-contextual railway knowledge represented a broad angled camera. This was used to scan the situation or in other words to get an overview of railway activities, related risks and experiences with existing means to prevent accidents, including safety rules. Then rule- and identity based rationality, applying the same knowledge, was used to zero in on those areas that required more in-depth examination. When available, the rationalistic risk analyses contributed to this work. Then risk analyses were applied for more detailed in-depth examinations of revealed risks and means to control these before, during or after the rule development.

8.2.2.3 Attempts of counteracting the new approaches?

The fact that the hierarchical and risk based approaches did not have the expected impact upon the modification processes and their results raises the question whether there were mechanisms in the cases where the approaches were counteracted.

Outsmarting of the new requirements?

The theories of Baumard (1999) can provide one possible explanation for limited influence of the new approaches. The early experience with elements of the hierarchical approach and the development of risk analytic competency can be seen to parallel his description of lateral transfer of both tacit and explicit knowledge from the collective to the individuals participating in the work. In this process the actors might have appropriated and assimilated the knowledge of the two approaches. According to Baumard, this provides the participants of the cases with the ability to use this knowledge to outsmart rules for the work, argue against the new approaches and to adapt them to what they find appropriate or suited them the most. In the terminology of March (1994), one could say that the cases could bend the new approaches from the original intention.

There were also differences between the cases in the influence of the new approaches. The internal control principle that can be associated with both the hierarchical and risk-based approaches has been discussed in the Norwegian railway system for a long time (Gulowsen & Ryggvik, 2004; Justis- og politidepartementet, 2000b; Justis- og politidepartementet, 2001; Ryggvik, 2004). Baumard (1999) explains that when a rule is laid down without systematically provoking revolution, it is because there has already

been a tacit absorption of them before their institution is made explicit. The reason why the cases accepted being influenced by the hierarchical and risk-based approaches might therefore be that the system had already accepted them as useful. Another reason might be that parts of the organizational learning necessary to apply them, had happened before the cases started their work. Differences in the implementation might also be related to different forms of acceptance, different social practices and different ways to get around the practices.

The results reveal no proof of mechanisms of outsmarting such as discussed by Baumard (1999). Furthermore, my impression is that the participants of the work were devoted to the issue of safety. This is based on the explanations that the cases gave for their solutions to the new approaches. As discussed, their argumentation for their limited trust in the conclusions of the hierarchical and risk-based approaches resembles that of LaPorte, & Consolini (1991) against experimenting when the consequences of the experiments might be dangerous situations. Their argumentation was anchored in their rich knowledge of the existing technical solutions and the functions of the Norwegian railway system.

Also, if mechanisms of outsmarting were operating, the strong commitment to safety discussed above, does not make me suspect that the participants did this out of evil or private motives, but rather out of concerns for safety.

Hypocrisy?

The limited influence from the new approaches can also be explained by organizational hypocrisy such as described by Brunsson (1989). With reference to bureaucratic public organizations he associates this phenomenon with weak or nonexistent links between talk, decisions and actions. He argues that organizational hypocrisy might develop in organizations that have to deal with conflicting demands. A division between words and action in organizational hypocrisy might be very damaging for organizational learning (Argyris & Schön 1996).

Put to the edge, the solutions that the cases found for the introduction of the new approaches and that gave them limited influence in the practical modification work, can be understood as organizational hypocrisy. They can be seen to represent a way to solve the conflicting demands to control risk and to apply the new approaches that were not considered capable of sufficient risk control. The solutions gave the illusion that the new rationalistic approaches were introduced while the work was dominated by intuitively-contextual knowledge of how risk had to be controlled. However, the chosen solutions for the approaches were thoroughly discussed before decisions were made, i.e. there were links between talk, decisions and actions. Therefore I find it difficult to accuse the cases for hypocrisy.

What could be questioned is the fact that the ambitions of the new approaches were not followed with preparation of conditions that could have made their implementation compatible with safe performance. In the Traffic-rule case this problem was particularly

evident regarding suggested rule solutions compared to technology and the conditions of the implementation phase. In the Maintenance-rule cases this was evident regarding the decision to apply risk analyses compared to the limited resources to perform the risk analyses and the timing of decisions.

This discussion also directs the attention towards the close relationship between rule modification and access to resources. Access to resources is closely related to power (Clegg, 1989; Hindess, 1996; Shrader-Frechette, 1991). However, power is a huge theoretical field that is not within the scope of this study.

8.2.2.4 Attempts to find good solutions?

The conclusions above that there was no evidence of attempts to outsmart the new approaches and the refusal organizational hypocrisy implies that there must be alternative explanations for their limited influence.

Confidence in railway knowledge revisited

The most obvious explanation is already thoroughly discussed. This is that the participants of the work of the cases trusted the existing railway knowledge so much that they found it very unwise to abandon this knowledge base.

This cautious approach of the cases made them look for solutions where it was possible to include the new approaches in the existing tradition. By doing so they demonstrated a willingness to enrich the existing tradition dominated by rule- and identity based rationality and intuitively-contextual knowledge with elements belonging to the rationalistic rationality and knowledge tradition.

The solutions for the new approaches also provided examples of how this could be done. This is particularly evident in three findings. One is the inductive bottom-up approach to rule development that can be seen as a supplement to the rationalistic deductive top-down approach. Another is the iterative processes between risk analyses and rule development shown in the Traffic rule case and the Power supply case. As revealed the other two cases also preferred an iterative development. The third is the solution of the Maintenance rule cases that combined different types of rules; the triggering requirements that can be associated with rationalistic decision making and the prescriptive rules that can be associated with rule- and identity based decision making. Also, the Traffic rule case wanted a solution that included an increased emphasis upon the intended outcomes of the rules. The argumentation here was educational purposes.

A move towards discursive strategies?

The current conditions of the Norwegian railway system contain elements of complexity, uncertainty and ambiguity. The theory discussed in Section 3.5, favored combined perspectives of rationality and knowledge when uncertainty and ambiguity exist (Jaeger et al., 2001; Klinke & Renn, 2001; Perrow, 1999; Schrader-Frechette, 1991). This gives support to the preference that the cases revealed for strategies that combine perspectives.

Furthermore, under such conditions these theorists argue for discursive strategies (Jaeger et al., 2001; Klinke & Renn, 2001; Perrow, 1999; Shrader-Frechette, 1991). Also, the introduction of hierarchical and risk-based approaches to the rule modification and solutions of the cases can be seen as a move towards more discursive strategies in the modification work. There are three major reasons for this.

First, the introduction of new approaches created a new situation for rule modifications that functioned as an incitement for inquiries and discussions involving different actors. The cases also demonstrated that inclusion of different perspectives created a challenge of diverging conclusions that had to be solved.

The cases did not have any preset procedures for the discussions and handling conflicts and diverging conclusions such as Hale & Swuste (1998) suggested. By drawing upon their network and available resource groups, the decision-makeres tried to involve actors that were considered to be capable of positive contributions to the purpose of safe solutions. Furthermore, they tried to build consensus around their decisions. Accordingly a good decision was the one found to be good for safety under the current conditions among those involved. Etzioni (1967) suggests that the measure of a good decision might be the decision-makers' agreement about it.

However, Etzioni (1997) also discuss that the measure of poor decisions is those that exclude actors capable of affecting the projected course of action. Some interviewees made reflections about how people were involved in the work. Because many of the involved actors had much of the same background, belonged to much of the same network and applied a consensus building strategy, there might be a danger of bias in the decisions. Hoffman & Maier (1961) have demonstrated that group discussions made the participants more satisfied with consensus decisions even though the discussions did not increase the probability for better conclusions. There might also be a risk that the motivation of participants to reach consensus extended the motivation for evaluating risk and benefit of alternative solutions (Janis, 1982a; Janis, 1982b). Therefore, there might be weaknesses in the decisions that the participants are not aware of. The cases also made steps to counteract this danger. The Traffic rule case involved new actors in their change analyses of the rules. The Maintenance rule cases had a hearing process for the rules in the regions.

The second reason that can be associated with a move towards more discursive strategies, is that a hierarchical approach, with more use of outcome-oriented rules and the internal control principle, requires more engagement from the rule-followers' side. The

Maintenance-rule cases that implemented an outcome-oriented rule solution were also prepared for more dialogue about the rules.

However, the mentioned experiences from the oil industry indicate that the dominance of academic thinking in this development might be a problem for this democratic element (Hovden, 2002). This might make it difficult for the rule followers to influence the decision processes with their more rule- and identity based rationality and intuitively-contextual knowledge in a democratic sense. Another problem is the distributed nature of the system, both geographically and organizationally. With reference to the Dutch railway system Hale et al. (2003) argue that the distributed nature of that system and the constant traveling of the majority of staff cause that there is no such thing as a cohesive work group. They find that the limitations imposed on communications between the main protagonists, make it difficult for any cohesive relationship to develop between them. The recent development where they are now working for different companies rather than the old monopoly strengthens the difficulties. This description has parallels to the regulated area of the Maintenance rule cases.

As discussed, for the Traffic-rule case there were no concrete plans for direct dialogue between the main rule-followers and the Inspectorate.

The third reason is that even tough risk analyses are originating in a tradition where rationalistic perspectives dominate, the work processes can be made more or less discursive. The results of the risk-based approach showed that the cases varied with respect to the involvement and interaction of actors. One important reason for this was the different organization of the cases.

In the descriptions of discursive strategies the inclusion of potential victims is also an element (Jaeger et al., 2001; Klinke & Renn, 2001; Perrow, 1999; Schrader-Frechette, 1991). This was not an issue at stake in the cases.

Perspectives from other branches?

The discussion about the conditions of complexity, uncertainty and ambiguity in the Norwegian railway system directs the attention towards the ability of the cases to reveal potential risk. Furthermore, some interviewees raised the question of the ability of railway personnel with a strong experience base in the former NSB to foresee the consequences of the ongoing changes in the system. Accordingly there might be a danger of disaster incubation in the system, i.e. a discrepancy between the state of affaires and the culturally taken for granted (Turner & Pidgeon, 1997). Etzioni (1967) argues that under conditions like the Norwegian railway system, it might be required to increase investments in encompassing high coverage scanning of the situation. In this case the purpose of such scanning can be to check for dangers that can not be easily discovered by the help of the knowledge of the tradition of the former NSB and risk analyses derived from this knowledge. In this work it might be useful to search for the inclusion of alternative approaches to the traditional railway knowledge. In the framework for safety

rule development that is applied for the SAMRAIL research (European Commission. 2004b), this might imply to increase investments in the first step covering the activities *"Define processes, scenarios & controls for the activity"*.

In this connection it is worth mentioning that many interviewees unasked expressed that the railway system had much to learn from aviation but not so much from the oil industry. Their arguments were that aviation had many of the common features as the railway system for example the geographical distribution and a long history. In addition, this field had already faced the challenges associated with many actors and cross national traffic operation. Many also mentioned that the strong impact from the oil industry in Norway had made them rather familiar with the perspective and knowledge of this field.

8.2.3 Concluding remarks

The introduction of rationalistic hierarchical and risk-based approaches influenced the direction of attention in the modification processes. Furthermore, the new approaches increased the diversity of represented perspectives upon rationality and knowledge. This development is supported by theory (Jaeger et al. 2001; Klinke & Renn, 2001; Perrow, 1999; Shrader-Frechette 1991). However, the preexisting rule- and identity based rationality and predominantly intuitively-contextual railway knowledge dominated the work.

The main elements in the development towards the combination of perspectives upon rationality and knowledge were as follows:

- The new approaches created a situation where the modification work mobilized both rationalistic rationality and knowledge and rule- and identity based rationality building upon intuitively-contextual knowledge.

- In the modification processes and the rule solutions, the cases favored to combine perspectives of rationality and knowledge. This can be seen to represent a development towards more discursive strategies.

- The modification processes selected knowledge and transformed included knowledge, that fitted into or could be changed into the forms of the chosen rule solutions and the rationalistic form of the risk analytic methods.

- When conflicts occurred between perspectives, consensus-building processes developed. Here predominantly intuitively-contextual railway knowledge had a function as reference for appropriateness, i.e. as reference for good solutions.

- The use of predominantly intuitively-contextual railway knowledge as reference for good solutions gave this knowledge perspective the dominating role in the modification work.

- Furthermore, the modification processes contained mechanisms where the introduction of the approaches increased the trust in this railway knowledge. This happened both when the new approaches gave support to this knowledge and when it came in conflict with it.

The way people with railway knowledge were included in the work might be a source of bias in favor of perspectives and knowledge of skilled and centrally positioned railway professionals from the former NSB.

8.3 Railway knowledge was revived and changed

The second problem of this Chapter concerns the influence from the rationalistic hierarchical and risk-based approaches upon the predominantly intuitively-contextual railway knowledge.

Below, it will be further elaborated that the new approaches raised questions and provoked inquiries into the predominantly intuitively-contextual railway knowledge. The modification processes also contained different feedback loops that initiated even more inquiries. These processes revived railway knowledge. It remains a question whether the new approaches contributed with really new railway knowledge.

8.3.1 Changes in railway knowledge

The findings of changes in railway knowledge are presented according to the two major themes of knowledge and organizational learning discussed in Chapter 3, i.e. changes in knowledge forms and learning cycles. Finally, the evidences of changes in railway knowledge are presented.

8.3.1.1 Changes in knowledge forms

The introduction of the hierarchical and risk-based approaches created a new situation for the modification work. The cases met these approaches with processes of reverse invention. The explorations and evaluations of the new approaches provoked inquiries into the predominantly intuitively-contextual railway knowledge. For example, one member of the Board of the branch of the Traffic-rule case explained how one of the railway professionals of the work group always expressed his worries for safety. He did this even when he was not able to express why he was worried. These expressed worries led to inquiries and discussions that revealed the foundations for these worries. This contributed to better solutions.

The work of the risk analyses also initiated inquiries. As one of the interviewees of the Maintenance-rule cases related:

"But I do believe that we have had much to learn from the RCM. There (in the RCM analyses, my comment) were systematically asked questions about consequences of failures etc. And it is clear that we have this in the back of our mind for anything we do but we have not always followed the thinking to the end. And sometimes one experiences some surprises."

The inquiries of the cases revealed that railway knowledge was spread around the organization. It was sometimes difficult to retrieve because some of it had a more or less individual and tacit form, just as the quotation above demonstrates.

The knowledge retrieved from the inquiries were combined and sorted out, discussed, systematized and to some extent documented. These processes were governed by a combination of the incitements to the rule solutions, the frameworks that the risk analytic methods provided and the risk perception of the participants. For instance, the final report of the Traffic-rule case comments that the risk analyses did not contribute with any particular unknown conditions. However, it had a systematizing function, contributed with an overview and drew attention to conditions known from before[40]. An interviewee of the Maintenance-rule cases made some of the same reflections: *"At least the systematizing of it (the risk analyses, my comment) forces one to evaluate and document what one does."* And he continues: *" …before it was very based on individuals - the experience one had within the areas."*

Therefore the inquiries and the following work with the achieved knowledge implied an articulation of this knowledge and that more people had access to it. Furthermore, this implied a direction of attention where some knowledge became more in focus than others and therefore included in the work.

However, there were differences between the cases. The interviewees were asked who the core contributors to the work were. This revealed that those performing the rule development and the risk analyses were the main contributors. Their networks contributed as important supplements. The organizing of the cases and the tasks differed and influenced how much the knowledge of these actors became articulated, made collective and combined. There were also differences between the cases regarding time for reflection.

As revealed, the Traffic-rule case had the best conditions of the cases for interaction and access to knowledge resources. The work group was located together and had specific time for the work. It worked as an interactive team where also the different task interacted in iterative processes. Furthermore, this case had a formalized organization that included many actors, required communication and written reports and agenda papers. This implies that knowledge from different sources became articulated and combined and to a great extent transferred into a written form.

Among the Maintenance-rule cases, only the work group of the Superstructure case was located together and had continuity in their work. This case also had a formalized Board

[40] Logg 1208, p 20

of the branch that it included. The Signal case that had the role as a pilot had more available economical resources and specific time to organize meetings about the risk analyses. The Maintenance-rule cases were also less formalized than the Traffic-rule case. Therefore they did not communicate with others and did not produce written documentation to the same extent.

However, when it came to the rule solutions, the Traffic-rule case only expressed knowledge in prescriptive rules while the Maintenance-rule cases expressed it in three ways: In triggering requirements, their explanatory texts and in prescriptive rules.

There were also other factors influencing the articulation of knowledge during the work. The rule-responsible of the Signal cases found that the homogeneity of participants in the work also influenced the expression of tacit knowledge: *"… as the participants of the work were so competent and posited so much tacit knowledge, it is very likely that this knowledge was used in the analyses but not documented or made visible."* And he adds: *"So there is much tacit knowledge in the existing (set of rules, my comment) that is still tacit in the new set of rules."*

Another interviewee from the Board of the branch of the Traffic-rule case revealed that because he considered the railway knowledge of the work group to be very good, he found it unnecessary engage himself in the work.

8.3.1.2 Feedback loops of the work

The work of the cases included different and more or less formalized feedback loops. First, the cases had feedback about the efficiency of the existing rules. Second, the cases took steps to achieve feedback upon the evolving rule solutions, methods to include risk analyses in the modification work and risk analysis results. In the Traffic-rule case the members of the work group took advantage of their good organizational conditions for using each other and their network for feedback. This was mostly done through informal inquiries and discussions when the work raised questions. The work group also involved their resource groups. Statistical material and reports of unwanted events and accidents were also used.

The Maintenance-rule cases also took steps to get feedback upon their work. Again, the network of the core participants became involved to achieve feedback. However, differences in the organization of the Maintenance-rule cases and their tasks created different conditions for using those people directly involved in the different tasks for feedback. The cases participated in a joint hearing process of the modified rules and the risk analyses. Also these cases looked into statistics and accident reports. At the end, the Maintenance-rule project organized a joint two-step hearing process.

No evidence was found of consciously withheld information in the studied modification processes. However, examples of this were provided from other processes within the Railway system. These were associated with the competitive advantage of knowledge.

For example, one interviewee had experienced that staff performing outsourced maintenance activities had told him that they knew what maintenance activities the Rail Administration should ask for, but now that the activity was outsourced, he would not tell representatives of that organization what they were.

8.3.1.3 Evidence of changes in railway knowledge?

Many of the participants in the modification processes described how they had learned from the work.

Changes in railway knowledge due to the risk-based approach?

Most of the examples were associated with the competence building of risk analytic methods and their application in the modification work. For instance the interviewees described how they felt more confident with the methods and the analytic results when they had practiced them on their areas of regulation. Furthermore, even though the risk analyses were applied differently in the work of the cases, the fact that all cases performed analyses implies that learning about risk analytic methods had taken place among the participants. This also demonstrates that the participants of the work have learned something about combining rule development and risk analyses. However, as they found different solutions and functions for the analyses, they have learned different lessons.

The question at stake is whether the risk analyses caused any changes in the railway knowledge. Above it is argued that the inquiries of the processes made railway knowledge more explicit and collective and that knowledge from different sources was combined. Also, the risk analyses functioned as a validation of selected railway knowledge. Accordingly, the risk-based approach has caused changes in railway knowledge; the processes of articulation, sharing, combining and validating railway knowledge have revived it.

The study revealed different attitudes towards the contribution of the risk analyses to the development of railway knowledge. For instance the Safety director of the Rail Administration found that the risk analyses of the Traffic-rule case had increased the consciousness about which unwanted events the rules were supposed to prevent. He also found that the analyses had demonstrated both missing barriers and unnecessary barriers against accidents. On the other hand, the final report of this project commented that: "*the risk analyses did not contribute with any particular unknown conditions*"[41]. The report went on and commented that because "…*existing rules build upon long time experiences where one in practice has tried to build in barriers when found necessarily this is not strange. Where one has not managed to build in barriers there have been good, real reasons for not managing this.*" At first glance these quotations appear to contradict each

[41] Logg 1208, p 20

other. However, as the report explains, missing barriers does not necessarily mean that this fact was not known. It might mean that no practicable solution had been found to solve the problem.

Regarding the Maintenance-rule cases, the project leader of the Overarching Maintenance project found that the risk analyses had contributed to clarify where prescriptive rules were necessary. One of the participants in the work of these cases described: *"… I think that by working with the RCM-process I have a strengthened picture of what are safety related requirements and what are not because I have recognized what top events they prevent."*

However, one of the rule-responsible of the Maintenance-rule cases found that:

> *"I do not feel that the (the RCM-analyses, my comment) has contributed so much to the field until now, but it is obvious to me that it will contribute a lot. The challenge will be to combine, one has to find a way to get a practical approach to the inspections of the tracks."*

Changes in railway knowledge due to the hierarchical approach?

Regarding the hierarchical approach, it is also argued above that this initiated inquiries that made railway knowledge more explicit and collective and that knowledge from different sources was combined. Also, the previous section revealed an increased trust in railway knowledge associated with the prescriptive rules that survived the modification process. Accordingly, also the hierarchical approach has caused changes that revived the railway knowledge.

Even though the Traffic-rule case and the Maintenance-rule cases ended up with different rule solutions, all cases made attempts to develop higher order rules in the outcome-oriented form. This implies that learning about outcome-oriented rules has taken place. However, as mentioned in the previous subsection, the cases were not unfamiliar with outcome-oriented rules from before. It is therefore difficult to judge if the introduction of the hierarchical approach was a direct source for learning that contributed with new knowledge. There are some indications of this: For instance one interviewee of the Maintenance-rule cases explained: *"One faces some questions that one has not been thinking about before. When following rules it was like this, but when developing rules one has to argue for the solution one prefers."*

How collective and explicit did knowledge become?

Even though the results demonstrated that the risk-based and hierarchical approaches revived railway knowledge, a common feature from the findings is that it is difficult to judge exactly how collective the knowledge became. The descriptions of the work processes, the conditions for interaction and access to knowledge resources indicate that

the more involved actors and the more cooperation between them, the more collective the knowledge became.

The study does not include studies of the distribution of revived knowledge outside this group of people. One participant of the Board of the branch from the Traffic-rule case expressed that he was hesitant to distribute information from the processes before it became clearer what the results of the process would be. Furthermore, the study has had its focus upon the modification processes and not upon the consequences of the processes and resulting rules for the areas of regulation. Therefore it did not inquire into changes in practice of the rule-followers.

8.3.2 The revival and change of railway knowledge

The results revealed that the new approaches initiated processes where the predominantly intuitively-contextual railway knowledge became inquired into. Furthermore, the cases made arrangements to achieve feedback upon the efficiency of existing rules in their current context and their evolving work. Through these processes the railway knowledge became articulated, shared, combined and validated, i.e. it became revived. These issues will be discussed below. Finally, it will be discussed if the railway knowledge really developed.

8.3.2.1 Revival of knowledge and knowledge transitions

The railway knowledge was revived and transformed by different mechanisms.

Recalling knowledge

In accordance with the discussions of organizational memory of Stein (1995), the inquiries into railway knowledge that the new approaches stimulated can be understood as if organizational memory of the Norwegian railway system was recalled. This also demonstrates that the participants found this knowledge important enough to mobilize motivation for retrieving it. Accordingly, even though the system was undergoing significant change they valued what was done in previous contexts.

As revealed, the cases also faced problems to retrieve some of the wanted knowledge. To be aware of information and knowledge that exists such as Stein (1995) discusses, requires an overview of what information there is. The participants of the work used each other, their network and if available, their resource group(s) to locate and decode knowledge that was seen as important for safety. Accordingly, the task to gather relevant knowledge for the work was very dependent upon those who became included in the modification activities.

The cases showed that the participants' own knowledge and network were important for the retrieval of knowledge. Many of the networks built upon relations developed in the former NSB. The networks were included because they were considered as positive contributors to the modification processes. As they were "about something" they held an important feature of "communities of practice" such as discussed by Wenger (1998). Furthermore, they seemed to be active because they provided something that the participants valued.

When modification processes are so much dependent upon knowledge from such communities of practice as those studied here, the future modification work is very vulnerable; it is a vital question whether these communities will be kept alive. According to Wenger (1998) this will depend on the experience of them as valuable for the new context of the Norwegian railway system.

The new context of the Norwegian railway system with a more divided and competitive environment might be a challenge for the dependency that the cases revealed upon individual knowledge, their network and communities of practice. For future modification processes it might therefore be necessary to look for alternative solutions for collection of important knowledge. For instance, the new context might represent a potential for development of new communities of practice.

The strong position in the work of skilled and centrally positioned railway professionals from the former NSB might have been a source of bias in the cases. As Stein (1995) warns, this might represent a potential for retrieval of dysfunctional methods, values or prejudices. Accordingly, there is a danger that the work has been based on lessons learned from conditions in the former NSB instead of the features of the current Norwegian railway system. The results also revealed a concern that they were biased in favor of the needs of centrally positioned, skilled railway professionals.

The use of experience-based statistics and accident reports in the work might strengthen this danger. These sources for information also represent a potential source of biased in favor of former features of the system. As discussed in the SAMRAIL report upon organizational learning from accidents and incidents, such information also contain very little information about the context of these happenings (European Commission, 2004a). Accordingly, it is difficult to judge their relevance for the current situation.

However, all cases established direct communication with the practical fields of the rule-followers and made active steps to counteract such dangers of bias. Anyway, the fact that one representative asked for risk analyses of the dangers associated with no changes in the rules can be seen as a warning.

Furthermore, both Stein (1995) and Baumard (1999) point to the fact that not all forms of knowledge maintained by the organizations are voluntarily retrievable. They discuss the fact that knowledge might be consciously withheld. However, I did not find any evidence of this. As discussed, my impression is that the participants in the work were seriously devoted to safety.

There are also some suggestions for solutions to solve the challenges of knowledge retrieval in the future. First of all, Wenger (1998) discusses that there are possibilities to stimulate both the survival and establishment of communities of practice. Furthermore, the new context might create new communities of practice such as revealed in the Dutch railways where motivated railway people from different companies set up informal networks in order to foster learning from each other (European Commission, 2004a). The planned system for future rule management of the Maintenance-rules might be another possible strategy for developing alternative solutions for knowledge collection.

Furthermore, as discussed in Chapter 3, SAMRAIL suggests establishing learning agencies at different levels in the railway system (European Commission, 2004a). They explain that such agencies consist of people with the assigned task to look into matters of concern and generate lessons-to-learn and a learning products. Updated knowledge of rules context and efficiency and modified rules can be seen to be such learning products.

Feedback upon current rule context and efficiency of existing and evolving rules

The results also revealed that the cases held different conditions for feedback such as discussed by Argyris & Schön (1996). The issues that got most attention in the cases were feedback upon the development of the current context of the rules, the experiences of the rules' efficiency and feedback upon the evolving rules

The Traffic-rule case with the different resource groups, funds to pay for investigations and a rich network had better conditions for feedback upon existing rules and the evolving work than the Maintenance-rule cases. Furthermore, the Traffic-rule case had generally more time for reflection and better conditions for dialogues between participants than the Maintenance-rule cases. These are conditions that are seen as important conditions for organizational learning, i.e. the conditions for learning of the Traffic-rule case seemed better than those of the Maintenance-rule cases (Ellström, 2002).

Regarding feedback upon the efficiency of existing rules and the development in their context, there were differences between the cases. The Traffic rule case initiated a small study among the rule followers while this plan was dropped by the Maintenance rule cases[42]. Furthermore, the Traffic rule case involved more actors in the work. On the other hand, the Maintenance rule cases could draw upon the system for communication with rule-followers that were established for the annual rule revisions.

However, these feedback mechanisms were rather unsystematic and limited. The study of the Traffic rule case involved very few people (11 persons and one group discussion[43]) and was also not an element in a more continuous system for feedback upon the efficiency of existing rules and the development of their context. Furthermore, the communication system of the Maintenance-rule cases was mainly based on the

[42] SINTEF report for the Traffic rule project, no STF38 F03408
[43] SINTEF report for the Traffic rule project, no STF38 F03408

motivation of the rule followers to inform the rule responsible people at the Head office about problems with the rules. As discussed by SAMRAIL, such a system is very dependent upon the ability of rule followers to recognize the importance of their discoveries and their motivation to report them (European Commission, 2004a). Unsystematic and limited feedback upon the efficiency of existing rules and dependency upon the participants' own knowledge, initiative and network in the modification work is not only a problem for the Norwegian railway system. It is in line with studies of rule modifications in the Dutch railways provided by Hale et al. (2003).

Regarding feedback upon the evolving rules during the work of the cases, the cases built in feedback processes. Again, these were rather dependent upon participants' own knowledge, initiative and network. As discussed, the Traffic-rule case appeared to possess the strongest railway knowledge and networks. Furthermore, through the use of resource groups, the Traffic-rule case had a more organized structure for feedback than the Maintenance-rule cases. However, the discussions above about the possible danger of bias from the strong position in the work of centrally positioned railway professionals from the former NSB are also relevant here.

All together, these discussions reveal that the modification processes had a function that resembles learning agencies even though this was not an assigned task for those modifying the rules. Those involved in the modification work gathered knowledge about rules' context and efficiency from rule followers and translated these messages into lessons-to-learn in the form of modified rules.

However, the system for transfer of observations of changes in the rules' context and weaknesses in their efficiency were not systematized in a way that makes it possible to claim that learning loops were well developed in the cases. The implementation phase of the modified rules that is important for the closing of the loops is also not included in this study.

The SAMRAIL report upon accident and incident reporting argues that the increased organizational complexity of railways in Europe has created barriers for organizational learning (European Commission, 2004a). The report underlines the importance of finding solutions that counteract the negative impact of the reorganizing of the railway systems upon former learning arrangements.

The plans for future management of the Maintenance rule cases might improve the learning conditions associated with these rules. However, theory upon knowledge implies that to fill this function, this system must not become reduced to communication of mere written information through a data system (Baumard, 1999; European Commission, 2004a). The challenge to manage the important step of communication between the rule-followers and the rule-imposer of the Traffic rules, i.e. the Inspectorate, about changes in the rules' context and discovered weaknesses in the rules is very complicated. This communication has to bridge the long distance between the rule-follower and the rule-imposer in the organizational hierarchy of the Norwegian railway system. Furthermore, as Kirwan & al. (2002) discuss, the nature of the regulatory relationship is difficult with

respect trust. According to Argyris & Schön (1996) this is an important condition for organizational learning.

An additional challenge associated with feedback is its retroactive character (Baumard, 1999; Ellström, 2001b). As revealed, Ellström discuss the paradoxical function of feedback in learning; it impedes the more development forms of learning necessary under changing conditions. In addition, changing conditions create different opportunities to relate the work to the actual context for their application, to apply mental maps in the work and to correctly formulate problems for inquiry.

In particular, three theorists underline the importance of finding solutions to these challenges. First, Bourrier (1998) has revealed that rule-followers might develop different strategies to manage situations where rules do not match the actual context. Second, Vaughan (1998) has illustrated that safety might be negotiated. Third, Rasmussen (1997) has demonstrated how the combined pressure towards efficiency and least effort can cause migrations towards boundaries of safe performance.

Knowledge transitions

These recalling- and feedback processes revived railway knowledge. However, the conditions for articulation, sharing, combining and validating of knowledge varied between the cases. Accordingly, the cases varied regarding conditions for knowledge transitions that might create organizational learning such as discussed by Nonaka & Takeuchi (1995) and Baumard (1999). The results showed that the Traffic-rule case had better conditions for knowledge transitions and articulation than the Maintenance-rule cases.

These processes, that led to a revival of railway knowledge, can be associated with two out of four transitions between different knowledge forms discussed by Nonaka & Takeuchi (1995). First, the descriptions of the inquiries and feedback processes in the work and the treatment of their results demonstrated that tacit knowledge became converted into explicit by articulation. Furthermore, the inquiries and discussions imply that railway knowledge was shared between people. Accordingly, railway knowledge has been transformed into a more explicit and collective form.

Second, the inquiries and the discussions of the cases caused conversion of explicit knowledge into another form of explicit knowledge by the combination of knowledge from different sources. The combination of knowledge was based on the understanding that the participants of the modification work had of safe performance. In the terminology of Nonaka & Takeuchi (1995) a logic of compatibility or “fitting together” dominates. Further, the logic of compatibility was applied when the suggested rule solutions and the risk analysis results were compared with and adapted to railway knowledge.

Selections of this knowledge became transferred into the written texts. In the terminology of Stein (1995) the knowledge became encoded into the written form of the chosen rule

solution and the framework of the applied risk analytic methods. Some knowledge was also encoded into agenda papers, minutes from meeting and written explanations for the changes in the rules

The knowledge that the inquiries retrieved was treated differently depending on how it fitted in with the discussions of the new approaches and the frameworks of the rule solutions and the risk analyses. Accordingly, some knowledge had more attention while others got little or no attention. Knowledge that was seen as irrelevant became excluded from the rule texts, from the risk analyses and the other written texts. This opens the possibility that the processes also contain elements of the third conversion of knowledge that Nonaka & Takeuchi (1995) discuss. Here explicit knowledge is converted into tacit by internalization. Knowledge that received little attention or that became excluded might have been internalized by the participants of the work. One example of knowledge that might be subject to such a process is knowledge associated with the attempt to develop goal-oriented rules in the Traffic rule case. However, the cases did not provide any clear examples of internalization and the study has not included follow up studies to see whether this happened or not, for instance to by checking later use of knowledge about the rules' intentions. The differences in the organization of the cases and the interaction between the actors and the tasks might influence the potential for internalization.

The comment of one interviewee that a homogenous group articulated less of their knowledge might mean that this group shared the same knowledge from the beginning. However, it might also be that their homogeneity gave the participants a platform that made it possible for them to share and circulate tacit knowledge within the group through socialization. If that was the case, it fits in with the description of Nonaka & Takeuchi (1995) of the fourth conversion of knowledge; from tacit knowledge into another form of tacit knowledge.

The new constellation with the hierarchical and risk-based approaches in the modification work created a situation of ambiguity that revived railway knowledge. This gives associations to Baumard (1999). He argues that under conditions of ambiguity articulation might make knowledge visible to some and invisible to others more visible. This increase in visibility of knowledge might solve ambiguities. This theory might also provide one explanation why there were different experiences of learning among the interviewees. Those for whom the knowledge was visible, might not have experienced any learning while those who had it demonstrated by its revival, experienced learning.

8.3.2.2 Did railway knowledge develop?

Above is concluded that the modification processes contained elements of inquiries, feedback loops and knowledge transitions that represent potential for organizational learning (Argyris & Schön, 1996; Baumard, 1999; Ellström, 2001a; Nonaka & Takeuchi, 1995). However, the results revealed that learning loops associated with the modification work were not fully developed.

Also, the study is limited to the modification processes themselves and their products. Therefore the study only includes evidence of organizational learning within processes. The results associated with the hierarchical and risk-based approaches revealed that the introduction of the new approaches to the modification processes did not create any fundamental change that demonstrates dramatic changes in knowledge. The new approaches became adapted to the existing railway knowledge. This is particularly evident in the consensus building processes when conflicts between railway knowledge and conclusions of the new approaches occurred. To apply the terminology of Ellström (2001b), the learning that took place had the characteristics of adaptive learning. Accordingly the new approaches did not cause higher order developmental learning as described by Ellström or "turnaround learning" that require unlearning as described by Hedberg (1981).

However, the introduction of hierarchical and risk-based approaches revived existing knowledge. Through this process knowledge was transformed into more collective and explicit forms and combined into other explicit forms as discussed by Nonaka & Takeuchi (1995) and Baumard (1999). Furthermore, railway knowledge that became validated through the processes achieved increased trust. The cases did not provide clear evidence of knowledge transformation from explicit to tacit and from tacit to tacit.

There is a question how collective or distributed this revived knowledge became. There is also a question whether the transformation and combination of knowledge developed new railway knowledge. The discussions of Baumard (1999) about knowledge that can be visible for some and invisible for others demonstrates that the experience of learning among some interviewees does not necessarily mean that entirely new knowledge is added or developed in the processes. However, it might mean that individual knowledge has become more collective or organizational.

The transformation of predominantly intuitively-contextual railway knowledge into a more explicit and collective knowledge implies that it was transformed into a more rationalistic form. Furthermore, selections of retrieved knowledge that fit into the framework of the chosen rule solutions and the risk analyses became encoded into written texts. The same happened with some of the knowledge that was emphasized in discussions, particularly in the Traffic-rule case. Through these processes the revived knowledge became reduced into thin written descriptions (Perrow, 1999; Stein, 1995)

8.3.3 Concluding remarks

The hierarchical and risk-based approaches created processes where predominantly intuitively-contextual railway knowledge became revived, i.e. it was inquired into and made more explicit and collective, combined and validated. Accordingly, the modification work had elements where those involved functioned as a learning agency such as discussed by SAMRAIL (European Commission, 2004a). However, this function was not formalized. Furthermore, the retrieval of knowledge was much dependent on the competency of those directly involved in the modification work and their network. Also,

the modification processes did not include fully developed learning loops that are seen as important for organizational learning (Argyris & Schön, 1996; European Commission, 2004a).

It remains a question how collective the revived knowledge became. It also remains a question whether the new approaches led to actually new railway knowledge.

The transfer of railway knowledge into the more explicit and collective form implies that it was changed into a more rationalistic form, i.e. a form dominated by thinner descriptions where the contextual elements of knowledge becomes less visible. Parts of the revived knowledge became encoded into written texts.

8.4 Revived, but saved?

The third problem of this Chapter concerns how railway knowledge became stored in organizational memory.

Below, it will be elaborated that even though the hierarchical and risk-based approaches contributed to a revival of the predominantly intuitively-contextual railway knowledge, only the most rationalistic elements of railway knowledge is systematically stored in organizational memory.

8.4.1 Written texts systematically stored, weak or no systems for the rest

In the following, results revealing that the hierarchical and risk-based approaches influenced the direction of action will be presented. Furthermore it will be revealed that some knowledge became encoded into written texts and that there are indications that the organizing of the work influenced storing of knowledge in organizational memory.

8.4.1.1 The hierarchical and risk-based approaches and direction of attention

The previous results and discussions have demonstrated that the rationalistic hierarchical and risk-based approaches led to a revival of the predominantly intuitively-contextual railway knowledge. Knowledge that fits in with the rationalistic perspectives of these approaches got attention in the modification processes. The railway knowledge served as a reference for good solutions and as a corrective to the conclusions and solutions of the new approaches. Therefore, also knowledge that conflicted with the new approaches got attention. Through the rule development and the risk analyses, the included railway knowledge became articulated, combined, systematized and encoded into the thin written descriptions of the chosen rule solutions and the risk analytic frameworks. Some knowledge also became encoded into agenda papers and minutes from meetings.

The direction of attention and selection of knowledge that the hierarchical and risk-based approaches caused, implies that knowledge that did not get attention or became excluded was less discussed and articulated. As one interviewee of the Maintenance-rule project expressed it:

> *" The issue of tacit knowledge was very much emphasized. And there was rather a lot of "aha" experiences for the most. However, I feel that much of this tacit knowledge fell out of the process. That there is not so much space for this competency that is not on the paper but that exists within the heads, the experiences and such things, in such a theorized system as we have here."*

8.4.1.2 Encoded knowledge into written texts

Regarding encoding of railway knowledge into written rules, the rule solution of the Traffic-rule case became limited to expressing knowledge about what to do to perform safely. The rule solutions of the Maintenance-rule case expressed both expected outcomes and required activities. When found necessary, it was also prescribed how the required activities should be done.

Also, both the Traffic-rule case and the Maintenance-rule cases removed some of their former prescriptive rules. In particular, the Traffic-rule case removed rules that were seldom used due to a development in the technical solutions for traffic control and rules for educational purposes. The Maintenance-rule case removed rules that were seen to represent unnecessary restrictions upon rule-followers. This implies that rule specific knowledge of removed rules became less visible.

Many interviewees, and in particular those who were or had been involved in educational activities, were concerned about the function of rules as knowledge communicators. Their concerns were about both rule specific knowledge and knowledge about rules' context and intended function. This knowledge was also experienced as being important for judging the quality and relevance of rules under the changing conditions of the regulated areas.

However, none of these interviewees considered the rules themselves to be sufficient as knowledge communicators. One interviewee of the Maintenance-rule cases expressed it this way: *"The regulations can be incomprehensible if one does not know their platform. So then the challenge is to bring forward the tacit knowledge"*

Many interviewees discussed the importance of textbooks and explanatory texts for the rules. This was particularly evident among the interviewees of the Traffic-rule case that did not have any textbook previously. One teacher expressed the need for such a book like this: *"What is most difficult is what we do not have, the textbook about why things are as they are."* And she continues: *"Because the regulation is very short, or the rule set are short. We miss a description about why it is as it is (the rule set, my comment), in other words, an explanation."*

As revealed, it seems that the textbook will not be developed in the near future. Two of the interviewees of the Inspectorate were also concerned about the need for a textbook, but were uncertain whether it was the task of the Inspectorate to develop it. Regardless of this, the Director of the Inspectorate found it to be the responsibility of the Inspectorate and also an important task for the organization to store knowledge about the background of the rules and their changes. He also found that it was the risk analyses that had become most visible in this documentation.

The situation of the Maintenance-rules was different. The rules were supplemented with explanatory texts placed in direct connection to the rules. In addition, this area already had textbooks from before.

Rule specific knowledge expressed in rules that survived the modification processes of the cases and that got support from risk analysis results, achieved increased legitimacy and hence increased status. Also, when rules received the status as 'safety relevant' their status increased with respect to requirement to comply. This was particularly evident in the Maintenance-rule cases where safety relevant rules were tagged. The Traffic-rules have traditionally been considered as safety relevant and had a high status.

When it came to encoding of railway knowledge into the frameworks of the risk analyses, it was the Traffic-rule case that transformed most knowledge into written texts. The reason was that this case had wide scope for the analyses and this caused the analyses to become very extensive, i.e. they encoded a lot of knowledge into the schemas of the analyses. The scopes of the Maintenance-rule cases were more narrowly defined. Therefore they included less knowledge than was included in their schemas.

Through the cases' striving for consensus, the knowledge of the chosen rule solutions and of the risk analyses became validated by the railway knowledge and thus achieved higher status. Many interviewees argued that the risk analyses had an important function as underlying documentation for the rules. One lawyer involved in the work of the Traffic-rule case said that the risk analyses were an important source of background information for the rules. Another interviewee found it important for the judgments of later rule revisions:

> *"Before one was also thinking in terms of risk assessment, but this has not been documented in a good way. And this is the most extensive change when we make changes in the rules this time. Today it is – everything that is done in the Traffic-rule project is very well documented. …this makes a very good foundation for later revisions and for judgments about where changes are needed."*

He underlines the importance of this documentation in the current situation of the Norwegian railway system like this:

> *"Then (in earlier times, my comment) this has been documented in the head of each individual. This has not been a problem because they have had a lifelong*

course within the system. Before people left, newcomers started learning. In this way there has been a continuous follow-up. But now as people are changing their jobs more often and one turn around quite a bit (change the organization, my comment), it has become important that this is very well documented."

The function of the risk analyses in the planned system for future rule management of the Maintenance-rules, also gives the risk analyses of these cases the function as the formal foundation of the rules.

Accordingly, in all cases the rationalistic risk analyses had the function as the formal legitimating of the rules. The revived intuitively-contextual elements of railway knowledge remained undocumented and with an informal status. This happened in spite of the fact that this knowledge had such an important role in the judgments of the suitability of suggested rule solutions and for the judgments of the quality of evolving rules and risk analyses

Both projects developed databases. The database of the Traffic-rule project contained the old and the new rules, the links between these and comments. Furthermore, the risk analyses and the links to the rules and arguments for changes in the rules are stored here. As revealed, one of the interviewees pointed out that this does not provide information of the rationale for not changing pre-existing rules. Another pointed out that the context and function of the rules that former rule-developers had was still missing. At the end of the project the database was transferred to the Inspectorate together with the rules. The future management of this database was not settled when the data collection of this study came to its end. One interviewee commented that the transfer of the rules and the database to the Inspectorate made it difficult to use the database for the purpose of communicating feedback to the risk analyses.

The Maintenance-rule project developed two databases for future management of the Maintenance-rules. The plan was to use these in future rule modification and as a means to communicate feedback to the rule management processes. The included elements were the old and the new rules, the reasons for change, the risk analyses and their link to both the triggering requirements and the work instruction. The databases were not operative by the time of implementation of the rules.

Both the Traffic-rule project and the Maintenance-rule project developed agenda papers and minutes from formal meetings. These enlighten questions of principle interest related to the hierarchical and risk-based approaches. The Traffic-rule case had a more complicated and formalized organizational structure for the work than the Maintenance-rule cases. Therefore the Traffic-rule case produced a huge amount of agenda papers and minutes. The production of such written statements was rather limited for the Maintenance-rule cases. This documentation became stored in electronic archives.

8.4.1.3 Organizing of the work and organizational memory

The previous section discussed the differences between the cases in their organizing regarding participation, communication and interaction. This revealed that they differed regarding degree of social interaction and relation to the rules' context. Furthermore, this created differences regarding articulation of knowledge and how this knowledge was distributed among the involved actors.

The Traffic-rule case involved most people in the work and in the discussions. Also, the work group itself included people who had recently worked in the operative field and cooperated closely. Accordingly, in this case knowledge was a part of a social interaction, it became context related and distributed among many people. When the work was transferred to the Inspectorate and the project closed down, the explicit and tacit knowledge that was not encoded into written texts or transferred through the cooperation between the project and the Inspectorate became scattered around in the Norwegian railway system. Some of it left the system with the hired participants. Therefore, the structure for social interaction changed and was continued by the personnel of the Inspectorate. At the end of the data collection of the study there were no concrete plans for systematic communication between the Inspectorate and the core rule-followers.

The situation of the Maintenance-rule cases was different. The cases included far less people and only the Superstructure case had close interaction between those directly performing the modification work. Also personnel operating in the rules' contexts were less systematically involved in the work. Accordingly, in these cases the knowledge was not a part of a social interaction, coupled with the rules' contexts and distributed among people to the same extent as the Traffic-rule case. On the other hand, the participation of the permanent rule-responsible people, made the work more linked to continuity than the project organizing of the Traffic-rule case did. The plans for communication between the rule-imposers and the rule-followers of the Maintenance-rule cases might contribute to make knowledge contextual and relational in the future. The project leader of the Overarching Maintenance project explained that one intention with the transition to risk-based management was to create a more dynamic view of knowledge. The idea was that this would develop knowledge and make the enterprise able to take more advantage of tacit knowledge. The tacit knowledge should be attended to by making the work with the data-program for management of maintenance activities and the prescriptive work instructions more alive. However, this will depend upon the implementation of the plans.

8.4.2 Written texts systematically stored – what about the rest?

The introduction of the new approaches has caused a development where railway knowledge is now stored better in organizational memory than before. However, the rationalistic elements of this knowledge, and in particular the written texts are better stored than the intuitively-contextual railway knowledge that is seen as important for decoding rationalistic knowledge and in particular written texts. In the following these

issues will be elaborated. Finally, the process of reverse invention will be linked to the process of revival and reduction of railway knowledge.

8.4.2.1 Knowledge stored in organizational memory

The two main reasons for the better storing of knowledge in organizational memory are the revival of railway knowledge and the transfer of railway knowledge into written texts.

Revival of railway knowledge

The modification processes with the interplay between the rationalistic hierarchical and risk-based approaches and the predominantly intuitively-contextual railway knowledge revived and activated the latter. Social interactions between the participants of the work and their network were also an important contributor to this revival. This implied that existing railway knowledge became more articulated and distributed within the Norwegian railway system and hence less vulnerable, for instance by departure of employees.

It also appeared that this railway knowledge had a high status and played an important role in the modification processes, in particular as reference for what were considered to be good conclusions and solutions. Also, the experiences that this knowledge became validated through the modification processes improved its status.

According to theory, the safety work of the Norwegian railway system can benefit from the revival of the intuitively-contextual elements of the railway knowledge. Chapter 2 revealed that there is a development towards increased complexity, ambiguity and uncertainty in the Norwegian railway system. The organizations that Baumard (1999) has studied escaped ambiguity when they directed their efforts towards understanding the ambiguity instead of concentrating on the reduction of complexity into rationalistic knowledge. Furthermore, theory upon risk and accident prevention does not find rationalistic knowledge sufficient for accident preventive work under such conditions (Perrow, 1984/1999; Shrader-Frechette, 1991; Jaeger et al., 2001; Klinke & Renn, 2001). Furthermore, such knowledge is important for decoding the written rule texts (Stein, 1995).

Encoding of railway knowledge into written texts

Selections of revived railway knowledge became encoded into written texts such as the rule texts, the risk analyses, agenda papers and minutes from meetings, i.e. it became transformed into a more rationalistic form.

Regarding encoding knowledge into rule texts, the choice of rule solutions naturally influenced what elements of the revived knowledge that became encoded, i.e. the

solutions favors some knowledge and not other. As revealed, the cases both wanted and had the possibility to take advantage of both prescriptive and outcome-oriented rule formulations. As discussed in Chapter 6, this might have been positive for the safety work. However, in the resulting rule solutions only the Maintenance rule cases increased the emphasis upon outcome-oriented formulations.

The prescriptive rule solution of the Traffic rule case and the work instructions of the Maintenance rule cases contains rather thick practice related descriptions or rules about what were considered to be the appropriate actions when certain conditions occurred, i.e. the IF-THEN knowledge as Hale describes it (Hale, 1990). Accordingly, the content of these solutions favor rule- and identity based railway knowledge. They do not contain the rationalistic elements of outcome oriented rules or the BECAUSE element for motivational purposes such as Hale discuss.

Also, the triggering requirements of the Maintenance rule cases contain elements of IF-THEN knowledge. However, here the IF-THEN conditions became reduced into shorter descriptions of the conditions that the maintenance activities are supposed to maintain, i.e. the intended outcomes of the maintenance activities, and the required action to achieve this outcome. Accordingly, the rule-followers are supposed to elaborate the best way to perform the required activity for maintaining the required condition. Furthermore, with the emphasis upon outcomes in the IF-condition, the BECAUSE element as described by Hale (1990) becomes more evident.

If the Traffic rule case had followed up their intention of goal oriented formulations either as higher order rules or in a textbook for educational and motivational purposes, the BECAUSE element would have become more evident also in this case.

On the other hand, if the cases had based their rule solutions entirely solely upon outcome oriented rules, this would also have implied a reduction or removal of the encoded knowledge of the prescriptive rules. This might result in a weakened position of rule- and identity based rationality and the associated intuitively-contextual knowledge. The lower status of this rationality and knowledge might have strengthened this tendency (Perby, 1995; Schön, 1991). As revealed, the cases found this strategy to be to dangerous.

Regarding transformation of revived railway knowledge into the framework of the risk analyses, these processes consisted of two stages. First, the knowledge became selected and transformed in accordance with the chosen risk analytic method. Second, the selected and transformed knowledge became encoded into written texts in the schemas of the analyses. In other words, the written texts of the risk analyses contain the encoded elements of the knowledge that was considered relevant for the frameworks of the chosen risk analytic method.

As the risk analytic methods are derived from a rationalistic knowledge tradition, these frameworks and schemas are influenced by its knowledge perspective. Accordingly, the content of these texts emphasize the rationalistic elements of the revived railway knowledge. However, also the chosen scope for the analyses influenced to what extent

the revived knowledge became included in the written texts; wide scopes resulted in inclusion of more knowledge than narrow scopes.

As already discussed, the written texts of the risk analyses together with some written explanations for the changes in the rules achieved an important role in the formal legitimacy of the modified rules, i.e. the rationalistic risk analyses became the major formal written statements of the rationale behind the rules. Accordingly, they will most probably play an important role in future rule modification processes.

Regarding the other types of written texts, the study revealed that the cases produced agenda papers and minutes from meetings. In particular, these covered matters of principle interest. As revealed, the new approaches raised questions that led to inquiries into railway knowledge. This implies that these written texts are influenced by the questions that the introduction of the new rationalistic perspectives stimulated.

In the current situation of the Norwegian railway system with ongoing changes both generally and in the regulated areas, theory gives support to this transfer of railway knowledge into the more rationalistic written form. Baumard (1999) argues that when organizations begin to move, it appears essential that they learn to move their knowledge. He argues when renewing knowledge it is usually necessary to use codified knowledge, i.e. knowledge encoded into written texts. According to him, this implies to reduce the complexity of the rich mental maps in the practice related knowledge. When discussing organizational learning from accidents and incidents, SAMRAIL also directs the attention towards the necessity to filter data to enhance fast dissemination of important knowledge (European Commission, 2004a). However, here it is also underlined that to add value to the data it is important to code knowledge about the actual context of the knowledge. Furthermore, as Perby (1995), Zuboff (1988) and Ellström (2001b) discuss theoretical knowledge and concepts might help the understanding of information from production processes and their interactions. Therefore, this transfer of knowledge into more rationalistic explicit collective forms seems to be a positive contribution to the safety work.

Is written texts in databases the same as stored knowledge?

The fact that some of the revived railway knowledge is transferred into the written form and stored in databases does not mean that the knowledge is stored in organizational memory. As knowledge is relational and context specific, data and information that is transferred into written form is not the same as knowledge for the reader of the written documentation (Baumard, 1999; Nonaka & Takeuchi, 1995; Stein, 1995). Written documentation cannot communicate the rich mental maps that might be necessary to decode written texts and to understand the complex dynamics of reality. Written texts stored in databases require that its storing can be located and that access is given to it when it is necessary or useful to retrieve it (Stein, 1995). In addition, mental maps are also often important to foresee consequences of different actions and choices that are

necessary for accident prevention (Perrow, 1984 /1999; Rasmussen, 1997; Rasmussen & Svedung, 2000).

Accordingly, to keep the revived railway knowledge alive for the future, the written text has to be possible to retrieve. Furthermore, it has to be supplemented with elements of social interaction and context. The results of the study also revealed that such knowledge was experienced as being important for the understanding of the rules and their intended function, for judging their relevance and for rule-followers' motivation for compliance. Therefore, it is essential that intuitively-contextual railway knowledge is stored in organizational memory.

8.4.2.2 Intuitively-contextual elements of railway knowledge at risk?

In spite of the discussions above about the important functions of the intuitively-contextual elements of railway knowledge, there are indications that this very knowledge might be endangered in the future. The most important reason is that the transfer of this knowledge into the more explicit and rationalistic form might have weakened its position compared to rationalistic knowledge. The major explanations are as follows:

First, even though this knowledge served as fundament for the work, it is not systematically stored in the encoded written form to the same extent as the rationalistic knowledge.

Second, the written risk analyses have the function as documentation of the rules' legitimacy and serves as the main official argumentation for rule changes. The original intuitively-contextual railway knowledge of the context and function of the surviving rules remained undocumented and has lost its status as their formal fundament, a status it had before.

Third, the strong emphasis that the Inspectorate has put upon the internal control principle, risk analyses and increased use of outcome-oriented rules, see Chapter 2, is a rather rationalistic strategy for the safety work. This implies that rationalistic knowledge will, most probably, have a higher status in Norwegian railway system in the future. In addition, rationalistic knowledge already generally holds a higher status than intuitively-contextual knowledge (Perby, 1995; Schön, 1991). The status of knowledge might influence the motivation to retrieve information (Stein, 1995).

Fourth, Baumard (1999) warns against the danger that the need to renew knowledge might lead the firm to remove the representatives of the old knowledge. By doing this, they remove the tacit knowledge of the firm. As revealed, the Norwegian railway system is already deep into this problem, particularly because of workforce reductions and organizational changes.

Fifth, the ongoing division of the Norwegian railway system seems to weaken the conditions for developing railway knowledge that holds an extensive overview of the

complex interactions of the system. They also weaken the system's traditional conditions for socialization and existing communities of practice that were considered particularly important for transfer of tacit knowledge (Baumard, 1999; Lave & Wenger, 1991; Nonaka & Takeuchi, 1995; Wenger, 1998).

In addition, the study revealed that the organizing of the cases influenced the distribution of revived railway knowledge within the Norwegian railway system. Stein (1995) argues that this might again influence how difficult it will be to retrieve this knowledge for later use.

If the strengthening of rationalistic knowledge in organizational memory is followed by a weakening of intuitively-contextual knowledge, it is not only the theory that indicates that this might be negative for the safety. Also results presented in earlier chapters imply that it might be negative for the safety of the Norwegian railway system.

One reason for this is that the results revealed that this knowledge is an important element in the knowledge of rules' context and function. Without it, it appeared difficult to judge their relevance and efficiency for current conditions and expected development. This knowledge was also seen as important for educational and motivational purposes.

Another reason is that without its contribution to the understanding of the system's functioning it might be difficult to anticipate the consequences of ongoing changes.

A third reason is that the results revealed how this knowledge was crucial in the judgments of new incitements to rule modifications such as the hierarchical and risk-based approaches.

8.4.2.3 Possible solutions for storing intuitively-contextual knowledge in organizational memory

The discussions above mean that to enhance the storing of intuitively-contextual railway knowledge and in particular knowledge of rules' context and functions appears to be very important in the future. In the following I will outline a few possible solutions that can be derived from the study and theory.

First of all, the results revealed that the organizing of the cases influenced the possibility to retrieve available knowledge and the contribution of the work to the distribution of both retrieved and evolving knowledge. With respect to participation, the inclusion of people directly involved in the work and the organizing for communication between these and others influenced both what knowledge became included in the work and how it became distributed. Strong links to the rules' context made it easier to include intuitively-contextual railway knowledge in the work. Furthermore, the interaction and continuity of the work both within a particular modification process and between different rule modification processes influenced the possibility to transfer such knowledge from one task to another and between different modification processes.

Second, the discussions of SAMRAIL revealed that there are already ongoing discussions in European railways about establishing learning agencies to further the development of organizational knowledge and it's storing in organizational memory (European Commission, 2004a). The organization of rule modifications can either be given the status as a learning agency or be linked to such agencies.

Third, the results revealed that there are existing communities of practice within the Norwegian railway system that can be stimulated such as Wenger (1998) has discussed. Furthermore, there might also be a potential for establishing useful communities of practice within the system, such as revealed in the Dutch railways ((European Commission, 2004a).

8.4.3 Reverse invention revisited

The discussions of this section and the previous one gives associations to the processes of reverse invention discussed in the previous two Chapters. First, the two stages of exploration and evaluation of the rationalistic ideals of the hierarchical and risk based approaches initiated inquiries into railway knowledge. Retrieved knowledge was discussed. Through these activities the predominantly intuitively-contextual railway knowledge became more explicit and collective, and knowledge from different sources became combined, i.e. the knowledge was revived.

Second, the stage where the rationalistic ideals were left and conclusions were adapted to railway knowledge, functioned as a validation of the railway knowledge. Through the validation this knowledge achieved increased trust.

Third, in the stage where the work built upon validated railway knowledge; this knowledge became reduced to knowledge that fitted into the frameworks of the chosen rule solutions and risk analyses. Selections of knowledge became decoded into the written texts of the rules and the risk analyses. Accordingly, railway knowledge became reduced into more rationalistic forms. This process might endanger the revived intuitively-contextual railway knowledge in the future.

The development is illustrated in Figure 8.1 below.

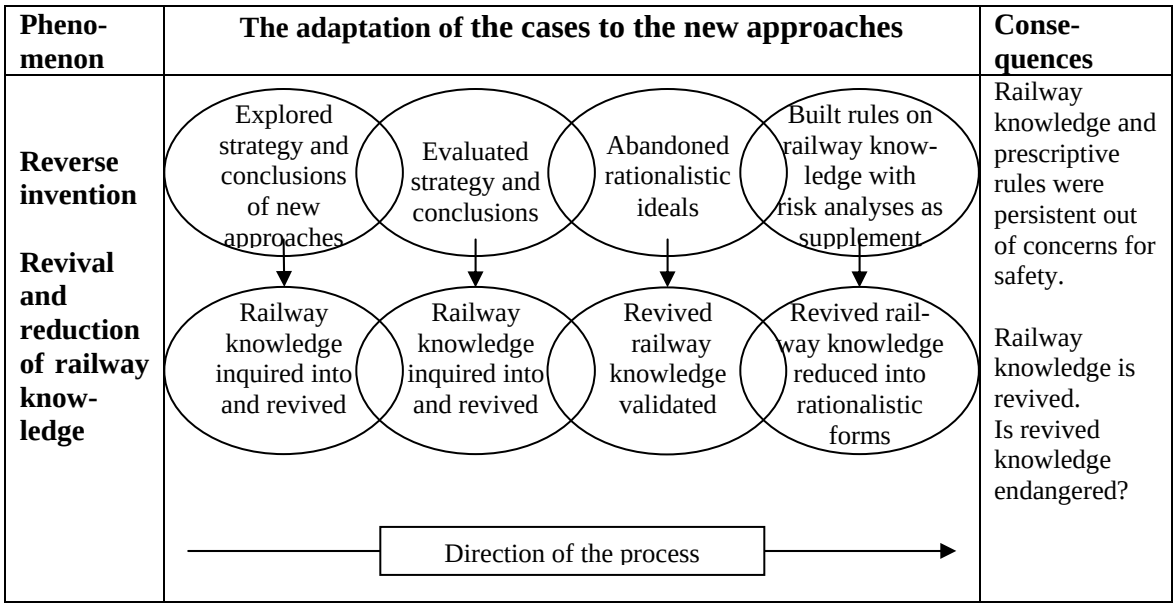


Figure 8.1 The influence from the process of reverse invention upon railway knowledge.

In Figure 8.1 the circles demonstrate the stages of the process. Their overlap illustrates that there were overlap between the stages. The arrows from the stages of reverse invention towards the process of revival and reduction of knowledge indicate the direction of influence. The arrow from left to right demonstrates the direction of development for the two processes.

8.4.4 Concluding remarks

The revival of the predominantly intuitively contextual railway knowledge that the cases demonstrated made this knowledge more explicit and distributed. Accordingly it became better stored in the organizational memory of the Norwegian railway system.

Knowledge that fit into the frameworks of chosen rule solutions and the risk analytic methods and selections of knowledge of principle interest became encoded into written texts. The written texts became systematically stored in databases and electronic archives. This development strengthens the position of rationalistic knowledge. Theory gives support to a strengthening of rationalistic knowledge elements when an organizational system undergoes changes (Baumard, 1999; Ellström, 2001b; Perby, 1995; Zuboff, 1988).

However, the organizational structures for storing unwritten revived knowledge and in particular the intuitively-contextual dimensions of this knowledge are unsystematic and vulnerable. Due to the organization of the cases, much of the revived knowledge became spread around in the Norwegian railway system when the work was finished in a way that might make it difficult to keep track of it for later retrieval. This was particularly evident

in the cases where engaged people did the majority of the work. Accordingly, revived intuitively knowledge is endangered. Ongoing changes of the Norway railway system and increased emphasis upon rationalistic knowledge strengthen the vulnerability of this knowledge.

According to theory, intuitively-contextual knowledge is necessary for decoding written texts (Stein, 1995; Nonaka & Takeuchi, 1995; Baumard, 1999). This knowledge is also considered to be important for safety work (Perrow, 1984/1999; Shrader-Frechette, 1991; Jaeger et al., 2001; Klinke & Renn, 2001; Rasmussen, 1997; Rasmussen & Svedung, 2000). This implies that if this knowledge is not stored in organizational memory by means other than written texts, it might be negative for the ability to decode rules and to retrieve revived knowledge for later use. The chapter provides some examples of how such a negative development can be counteracted. These are first to carefully organize future rule modification processes with emphasis upon knowledge retrieval, transfer and distribution, second, to give the organizations for rule modifications a status as learning agencies or to link them to such one(s) and third, to stimulate existing and potential communities of practice.

8.5 Conclusions to influence upon railway knowledge

8.5.1 Main conclusions

The introduction of the hierarchical and risk-based approaches created a new situation for rule modifications in the Norwegian railway system. This activated different perspectives of rationality and knowledge and revived railway knowledge.

This happened because the new approaches functioned as an incitement to inquiries into the predominantly intuitively-contextual railway knowledge. This knowledge was distributed in the system in a more or less explicit and collective form. Through the inquiries and following discussions the railway knowledge that received attention was articulated and made more collective. Furthermore, knowledge from different sources was combined. When railway knowledge got support from the new approaches or survived a conflict with them, it was seen as a validation. Hence the trust in this knowledge increased. The cases provided contradictory information about whether these processes produced knowledge that was really new for the system.

However, the richness of this revived knowledge became reduced through the processes. Its relevance for safety and for the new approaches was discussed and knowledge sorted out. Knowledge that became included was systematized according to disagreements between conclusions of the new approaches and railway knowledge, the frameworks of chosen rule solutions and the chosen risk analytic methods. Some knowledge was encoded into the written texts of rules, risk analyses and agenda papers and minutes from meetings. This means that the knowledge became removed from human action, i.e. contextual and relational elements of the knowledge were removed. Accordingly, the

predominantly intuitively-contextual railway knowledge was reduced into a more rationalistic theoretical form.

The organizational structures for storing unwritten revived knowledge and in particular the intuitively-contextual dimensions of this knowledge are unsystematic and vulnerable. Accordingly, revived knowledge is endangered. According to theory, intuitively-contextual knowledge is necessary for decoding written texts (Baumard, 1999; Nonaka & Takeuchi, 1995; Stein, 1995). This knowledge is also considered to be important for safety work (Jaeger et al., 2001; Klinke & Renn, 2001; Perrow, 1999; Rasmussen, 1997; Rasmussen & Svedung, 2000; Shrader-Frechette, 1991). This implies that if this knowledge is not stored in the organizational memory by other means than written texts, it might be negative for the ability to decode rules and to retrieve revived knowledge for later use.

Referring to the framework for the study demonstrated in Figure 3.1 of Chapter 3, these consequences of the new approaches upon railway knowledge are visualized in Figure 8.2.

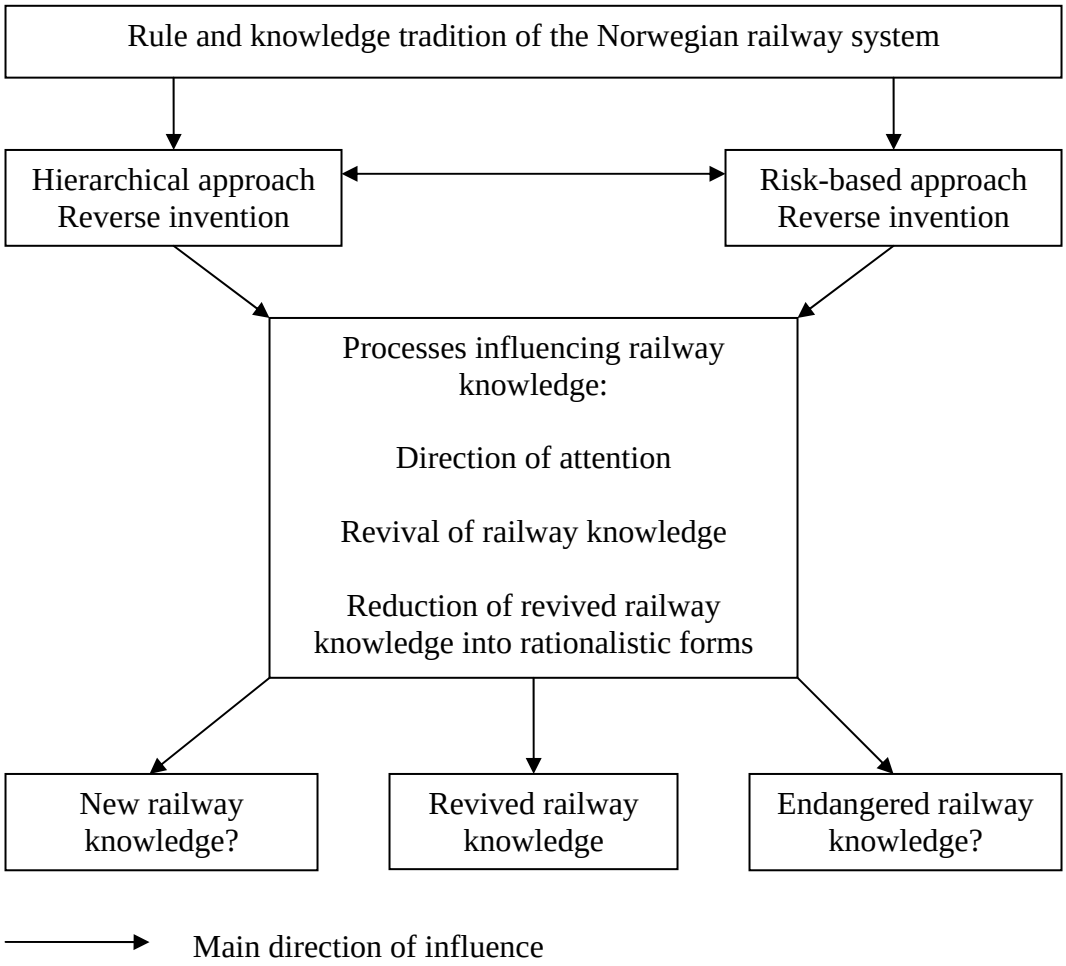


Figure 8.2 The influence of new requirements upon railway knowledge

The boxes in Figure 8.2 demonstrate the main concepts discussed in the study. The arrows of the figure illustrate the directions of influences and interactions between the concepts in the studied modification processes. The arrows from the rule- and knowledge tradition towards the hierarchical and risk based approaches demonstrate that the hypothesis that this fundament would influence the implementation of the two approaches was supported. The two-ways directed arrow between the hierarchical and risk based approaches illustrated that the hypothesis that these approaches interacted was supported. The arrows from the two approaches towards the box of processes influencing railway knowledge illustrates that also the hypothesis that these approaches influenced railway knowledge was supported. The arrows from the box of the processes to the boxes of the impacts upon railway knowledge illustrate that the processes gave different results for the railway knowledge. However, the figure is a simplification of the real processes. As the results and discussions demonstrated, the influence upon railway knowledge had a more iterative character.

Finally, the chapter provides some examples of how the problem of endangered knowledge can be counteracted. One example is to carefully organize future rule modification processes, another to give the organizations for rule modifications a status as learning agencies or to link them to one or some and a third is to stimulate existing and potential communities of practice. However, these examples are outlines that need to be elaborated.

8.5.2 The theoretical problems

The conclusions of the revealed problems are:

1. *What knowledge base to apply as decision support?*

The introduction of rationalistic hierarchical and risk-based approaches influenced the direction of attention in the modification processes. Furthermore, they increased the diversity of represented perspectives upon rationality and knowledge. The pre-existing rule- and identity based rationality and predominantly intuitively-contextual railway knowledge dominated the work. This gave continuity to the rule development and made it possible to build upon existing railway knowledge. To combine perspectives of rationality and knowledge is supported by theory upon risk and safety (See for instance Jaeger et al. 2001; Perrow, 1999; Schrader-Frechette, 1991).

2. *Did increased emphasis upon the rationalistic knowledge perspective change the predominantly intuitively-contextual railway knowledge?*

The hierarchical and risk-based approaches created processes where predominantly intuitively-contextual railway knowledge became revived, combined and transformed into more collective and explicit forms. Retrieval of knowledge was greatly dependent

upon the competency of those directly involved in the modification work and their network(s). It remains a question how collective the revived knowledge became. It also remains a question whether the new approaches led to actually new railway knowledge.

The transfer of railway knowledge into the more explicit and collective form implies that it was changed into a more rationalistic form. Parts of the revived knowledge became encoded into written texts.

3. How did railway knowledge become stored in organizational memory?

Encoded written information derived from railway knowledge and that fits into the frameworks of chosen rule solutions and risk analyses or were of principle interest is most systematically stored in organizational memory. The existing structures for storing intuitively-contextual knowledge are unsystematic. Unwritten knowledge and in particular the intuitively-contextual railway knowledge is therefore very vulnerable. However all cases saw the need for improving this. Theory underlines the importance of intuitively-contextual knowledge for decoding written information (Baumard, 1999; Nonaka & Takeuchi, 1995; Stein, 1995). This knowledge is also seen as important for safety (Jaeger et al., 2001; Klinke & Renn, 2001; Perrow, 1999; Rasmussen, 1997; Rasmussen & Svedung, 2000; Shrader-Frechette, 1991).

8.5.3 Needs for further research

The overview reveals that the study leaves some questions for further research:

First, the processes both included and excluded knowledge. The importance of excluded knowledge for the safety work remains a question. If important, it is vital to study what happens with excluded knowledge.

Second, the study demonstrates that the intuitively-contextual railway knowledge that played an important role in the modification processes, and that theory finds important for decoding of stored written information, is endangered. It is therefore interesting to study if this knowledge becomes stored in the organizational memory and if it is possible to retrieve it in future modification processes.

Third, a few solutions for storing intuitively-contextual railway knowledge in organizational memory are outlined. These should be elaborated.

PART III: MAIN CONCLUSION AND IMPLICATIONS FOR PRACTICE AND RESEARCH

The three previous Chapters have answered the sub-questions of this study. In this Part of the study the main conclusion is drawn and implications of the results for safety rule modifications are discussed. Finally, the results are linked to theory and suggestions for further research are provided.

9 Main conclusion and implications

9.1 Main conclusion: Reverse invention and revival of knowledge

The four studied modification processes abandoned the intentions of hierarchical and risk-based approaches; they did not develop outcome-oriented rules on the background of risk analyses and did not derive prescriptive rules from such rules. Furthermore, the hierarchy of rule solutions were not linked to the positions of rule-imposers in the organizational hierarchy such as expected.

The main reason was that the new approaches did not take existing railway knowledge, that had been found to be important for safe performance, sufficiently into account. Instead, the modification work of all cases turned into processes that are given the name "reverse invention" in the study. Here existing railway knowledge and prescriptive rules were used as a fundament for the work. Accordingly, existing knowledge was brought forth.

The risk analyses supplemented railway knowledge. The four cases integrated the risk analyses in the modification processes in four different ways (See Figures 7.1, 7.2, 7.3, 7.4 in Chapter 7). This gave the analyses different functions in the rule development. The evolving work was evaluated with railway knowledge as a reference and brought in accordance with this knowledge.

The cases favored solutions that took advantage of different perspectives upon rationality and knowledge. However, existing railway knowledge, including existing prescriptive rules, appeared remarkably persistent compared to the expectations for the work. Furthermore, the modification processes contained mechanisms that validated this knowledge.

The new approaches and the processes of reverse invention raised questions that initiated inquiries into railway knowledge. These inquiries revived this knowledge. It remained uncertain whether the potential of inquires for organizational learning resulted in actual new knowledge.

However, the rationalistic ideals of new approaches stimulated a reduction of the revived railway knowledge into more rationalistic theoretical forms, i.e. relational and contextual elements were removed. Theory argues that the latter knowledge is important for the ability to decode theoretical knowledge for future use and to judge its relevance (Stein, 1995; Baumard, 1999; Nonaka & Takeuchi, 1995). The benefit of revived knowledge might therefore be lost in the future. The study outlines some solutions for counteracting such a negative development.

9.2 Implications for rule modifications

The purpose of the thesis has been to contribute to better safety rules through the development of new insights into rule modification processes. It is therefore natural to follow up the conclusions of the different parts of the study with reflections upon their practical implications. However, due to limitations of the study, the relevance of the lessons learned must be carefully judged before applying them to other contexts.

9.2.1 A bottom-up strategy for rule development

The projects revealed that requirements of higher order, outcome-oriented rules in a system with a prescriptive rule tradition can be met with an inductive bottom-up approach to rule development. In this strategy the existing railway knowledge and prescriptive rules are used as fundament for the rule development, both when the chosen rule solution is outcome-oriented and when it is prescriptive. This strategy contradicts the deductive top-down strategy that was the major incitement to the work.

The bottom-up strategy in a prescriptive rule tradition gives an opportunity to transfer the existing tradition and rules with associated knowledge into new rule modifications and higher order, outcome-oriented rules. This prevents that the old tradition and knowledge is abandoned, as it would have been if the rationalistic principles of the top-down approach had been followed, i.e. the work does not have to start from scratch.

However, when the knowledge is transferred into higher order, outcome-oriented rules, this changes the attention from what to do towards what to achieve. The study revealed that knowledge of both might be important for safe performance. Hence, when outcome-oriented rules are introduced, steps should be taken to ensure that knowledge of what to do is also safeguarded. An example of possible means might be context related training with social interaction supported by written guidelines for the rule-followers.

Furthermore, the study revealed that to be able to judge the relevance of railway knowledge including the safety rules, it is important to have access to knowledge of the rules' context. In other words, it is important that such knowledge is stored in organizational memory and that the development of the context is followed closely. The framework of outcome-oriented rules reduces the attention to such knowledge in the rule texts compared to prescriptive rules.

9.2.2 Risk analyses as supplement: Risk informed rule modifications

The projects revealed that the risk analyses could be applied very differently in modification processes. In the four different applications that the cases demonstrated, the risk analyses had a function as supplement to existing railway knowledge instead of a function that replaced this knowledge. In other words, the requirement to apply risk

analyses in safety rule modifications were given the content of “risk informed” and that is applied elsewhere (Apostolakis & Vesely, 1999; Chapman & Dimitrijevic, 1999)

The different applications of the risk analyses revealed that risk analyses could serve different functions: First, they can contribute as decision support. That is to say to provide information for use in decision processes. In the studied processes the analyses had this function when they were carried out before or during the rule development. One case developed a method for the interaction between risk analyses and rule development as an iterative process. Here the risk analyses gave information to the rule development and vice versa. Second, they can be used to raise questions and explore issues of concern, in other words as a means to ensure the quality of evolving rules and in particular to reveal whether the rule changes generate new risks. Third, they can be used to validate existing or new rules and railway knowledge.

The risk analyses selected, systematized and reduced railway knowledge into the written texts in the schema of the chosen analytic method. This demonstrates how risk analyses can contribute to a documentation of selected railway knowledge. However, this process also implied that contextual and relational elements of the selected knowledge were reduced. Theory underlines the importance of such knowledge to be able to decode written texts for application in later situations (Stein, 1995; Nonaka & Takeuchi, 1995; Baumard, 1999).

The use of top events as the starting point for the analyses makes the risk analyses rather experience-based. When such methods are applied under changing conditions the relevance of the top events for the actual situation should be questioned. Again, updated contextual knowledge is required. It is also important to anticipate if the changes have created conditions for new top events.

9.2.3 The importance of confidence for the impact of the new approaches

The projects demonstrated that the impact of the new approaches was dependent upon the participants’ confidence in their ability to cover risks that they considered important on the basis of railway knowledge.

With respect to the outcome-oriented rule solutions, the confidence was dependent upon the expected ability of the rules to control risk under the actual conditions, i.e. their ability to serve their major function. Major concerns appeared to be conditions for feedback and requirements for coordination associated with a tightly coupled system, severity of potential accidents, characteristics of rule-followers and context for implementation of modified rules. When the outcome-oriented rules were not considered capable enough to control known risk, they were either replaced or supplemented with the traditional prescriptive rule solution. This is supported in theory; experimentation with different solutions should be performed under conditions where erroneous decisions will not cause accidents (LaPorte & Consolini, 1991).

The projects provided examples where detailed prescriptive rules were preferred to compensate for reduced trust in rule-followers' railway competency and weakened conditions for peer review. However, even though rules can have a function in organizational memory, theory discusses that this knowledge form has its limitations because the rules represent codified knowledge (Stein, 1995; Nonaka & Takeuchi, 1995; Baumard, 1999). To be useful, the same theory argue that such knowledge must be decoded, i.e. a process that requires knowledge of the rules' context and social interaction.

With respect to the risk analysis results, the projects demonstrated that the confidence in these were dependent upon a judgment of their ability to cover known risks, including complex underlying mechanisms for potential accidents. Weaknesses in the risk analytic methods are widely recognized in the scientific literature (see for instance Schrader-Frechette, 1991; Klinke & Renn, 2001; Aven, 2003; Rausand & Øien, 2004). It is therefore reasonable and recommended to critically judge the risk analysis results.

Three factors appeared to be particularly important for the confidence in the risk analysis results: First the competency of the risk analyzers, second the experienced suitability of scope and preconditions for the analyses and third, the experience of the appropriateness of the chosen risk analytic method for the actual risk problems and conditions. These factors underline the importance of the initial phase when risk analyses are introduced to modification processes.

9.2.4 The cautious strategy in a dynamic context

One can say that the importance of trust discussed above created a cautious pattern in the cases and with good reason.

However, there is a danger that the strong influence from the participants' railway knowledge might bias the work. The projects were aware of this and took steps to counteract this danger. These steps provide examples of how bias can be prevented. Most of the steps were based upon feedback processes that either included people considered to be up-to-date railway experts or experienced rule-followers who had not been involved in the processes. However, one problem might be that because these trusted people held much of the same background, this might result in "group think" as they did not represent completely "fresh eyes" (Janis, 1982a; Janis, 1982b).

As already touched upon, the relevance of old knowledge and rules based on this knowledge must be judged when a system undergoes rapid change. In particular the study demonstrated two important issues. First, the cases provided examples where the knowledge of the context and the intended function of existing rules are no longer available or even lost. This makes it difficult to judge their relevance. This underlines the importance of taking good care of such knowledge in organizational memory.

Second, to make sure that the rules are on pace with the development of the rules' context when conditions are changing, the question of their relevance requires concerns and

organizing. Theory suggests that special attention should be given to the possibilities for the closing of the learning loops and the conditions for both single and double loop learning (European Commission, 2004a and 2004b; Argyris & Schön, 1996; Kjellén, 2000). This implies that there must be communication between the rule-imposer and the rule-follower and the rule-imposer must have access to knowledge about the development of the rules' context. The need for regularity and systematizing of judgments of relevance should be considered, especially when the situation is very dynamic.

9.2.5 Ambitions of change and dependency of other processes

The projects demonstrated how the potential for wanted changes in safety rules or alternative preventive means might be dependent upon other developmental processes in the system. Special attention was given to the development of technology and rule-followers' knowledge base. In addition, inherent requirements of the new solutions to changes in rule-followers' competency, combined with constraints upon the implementation processes were taken into consideration.

Therefore the ambitions of changes in safety rules should take other ongoing processes into consideration. In particular, the study underlines the importance of processes associated with the opportunities and constraints related to the actual conditions, the rule-followers' characteristics and the implementation phase.

If changes in rule principles are really requested and the actual rule solutions do not suit the actual conditions, steps should first be taken to change these conditions. Hence, to achieve a requested rule development, modification work should be coordinated with other ongoing processes that influence the potential for safe changes. If not, the chosen rule solution might be incompatible with safe performance.

9.2.6 The potential for reviving, developing and endangering knowledge

The projects revealed that the introduction of hierarchical and risk-based approaches represent a potential for interactions between knowledge traditions dominated by different knowledge forms. Interaction between different knowledge forms can create organizational knowledge (Nonaka & Takeuchi, 1995; Baumard, 1999). Furthermore, the meeting between traditions triggered off inquiries into railway knowledge that led to a revival of railway knowledge and combinations of knowledge from different sources. This demonstrates that the introduction of new approaches can create arenas for organizational learning and serve a function in organizational memory.

However, the projects also showed that the new approaches influenced the attention of the modification work, the status of the former safety rules and associated knowledge. The contextual and relational elements of the knowledge and that are important for the ability to decode the content of the abstract formulations in the written texts of the rules were weakened. This might endanger the ability of rule-followers to use the rules as

intended. Therefore, implementation of new approaches requires attention to the potential for such negative consequences. In particular, the theories of Nonaka & Takeuchi (1995) and Baumard (1999) underline the importance of attention to tacit knowledge.

In addition, the projects demonstrated the importance of organizing and participation in modification processes for knowledge. The reason was that the organizing of the work created the conditions for involvement of participants, their interactions and the interaction between different tasks. Accordingly, the organizing influences the inclusion of knowledge in the modification processes, the opportunities for feedback during the processes and how much the knowledge becomes articulated and exchanged and hence shared.

Due to the limited generic knowledge about how to perform safety rule modifications and to prepare for future rule modification process, the experience and knowledge acquired from rule modifications should be taken care of in a systematic way. This is also important to ensure continuity in the management of safety rules.

9.3 Links to theory and needs for further research

The study has just followed the rule modification processes of two projects within the Norwegian railway system. Hence, the study has only managed to look into some aspects of safety rule modifications and only in one particular context. Accordingly, there is still a need for more research upon safety rule modification.

9.3.1 Reverse invention

First of all, the cases revealed the strategy of reverse invention as solution to the hierarchical and risk-based approaches. It would be interesting to follow up this finding. One reason is that this strategy contradicts the rationalistic ideals of the new approaches. Another reason is that the new approaches are increasingly required. A third reason is that almost no organizations start their rule development from scratch. Therefore, it is interesting to make comparative studies to find out how widely this strategy is used. Furthermore, it is also interesting to perform evaluative studies to find advantages and disadvantages of the strategy. In addition, it is interesting to make comparative studies to see if there exist alternative strategies to the reverse invention.

In spite of a common strategy of reverse invention, the cases revealed that the inclusion of risk analyses in the modification processes could be done in different ways that give different roles and functions to the analyses. One case even wrote their method, see Appendix F. To improve knowledge about risk informed safety rule modifications, the contributions and efficiency of the different applications and functions of the risk analyses for the quality of the rules should be explored and evaluated. Furthermore, a follow-up study to see how the experiences with the methods are incorporated in later

modification practices might give useful information about their usability for other contexts.

9.3.2 Appropriateness of rule solutions

The cases demonstrated concerns for the appropriateness for the rule solutions for the actual situation and the rule-followers. This finding calls for more research. One issue of interest is the importance that these concerns were given compared to concerns for appropriateness for the rule-imposer. There should be comparative studies performed to elaborate whether the dominance of the concerns for the actual situation and the rule-followers represents a more general pattern. Furthermore, the importance of the appropriateness for the rule-imposer for safety should be elaborated upon. This will require explorative and evaluative studies.

Another and associated issue is that the concerns for the suitability of rule solutions for the actual situation imply that to decide upon rule solutions, the rule-imposer must possess a rather extensive knowledge of the actual activities and the rule-followers. Furthermore, some interviewees explained that they had to go into details to understand what the outcome-oriented rule had to be. This contradicts the argument that higher order rule solutions reduce the requirement to rule-imposers' knowledge of the rules' context (Hale, 1990). Hence, further research is required to nuance the requirements to rule-imposers' competency. This also raises the question of possible means for the rule-imposer to achieve knowledge of rules' context as discussed by Reason (1997).

A third issue is whether the arguments that the participants gave for appropriateness of different solutions functions in practice. The theory regarding which rule solutions fit in with which conditions is not completely clear. Therefore, when implemented for some time, it would be useful to follow-up the efficiency of the rule solutions to fulfill their intentions with evaluative studies.

A fourth issue that has links to the one above is the interaction between rule development and other developmental processes in the actual situation. As one case pointed out, a common strategy for technical development and rule development, instead of performing rule development as isolated phenomena, could have opened for alternative rule solutions or reduced the need for rules. Furthermore, as both theory and the cases demonstrated, the need for rules and if needed, the suitability of different types of rules, are also associated with the rule-followers' competency (Reason, 1997; Rasmussen, 1997). Concerns for the amount of rules found both in theory (see for instance Hale, 1990; Reason, 1997; Rasmussen, 1997) and in the railway system (see Chapter 2) make it interesting to explore possible solutions for more coordinated developmental strategies, i.e. strategies that change the situation or the competency of the rule-followers so that rules, and in particular detailed prescriptive rules become less necessary.

Fifth, both theory and the study demonstrated the importance of evaluating the relevance of rules in dynamic context (Rasmussen, 1997; Hale et al, 2003; European Commission,

2004b). This makes it important to explore methods for such evaluations. The study revealed that to be able to evaluate the relevance of rules in such contexts it is necessary to know the context that the rules were associated with when they were developed and their intended function. This also demonstrates that it is important to explore means to store knowledge of the rules' context and intended function.

9.3.3 Railway knowledge and knowledge of safety rule modifications

The new approaches initiated inquiries and directed attention that revived railway knowledge. However, the study has revealed two issues that need to be elaborated. First, there were dangers of bias in the modification processes. Together this points to the danger that possible risks might be overlooked. With reference to Reason's theory of latent conditions or pathogens and Turner's discussions of incubation of disasters it is therefore of interest to follow the implementation of the rules and evaluate their efficiency (Reason, 1997; Turner & Pidgeon, 1997). The efficiency should be evaluated with the purpose to reveal if potential risks are overlooked.

Second, the study has concluded that the modification work should take advantage of both rationalistic and intuitively-contextual knowledge, but that the latter might be endangered. One important reason was that this knowledge was not systematically incorporated in organizational memory. This reveals different topics that should be explored. First, it is important to explore methods for safety rule modifications that include both intuitively-contextual and rationalistic knowledge in the work. Second, an associated topic is to evaluate what really happens with this knowledge in the long run and how available does it become for future modification processes. Third, it is important to explore methods for storing knowledge in organizational memory.

In particular, theory directs attention towards challenges associated with storing of intuitively-contextual knowledge and in particular the tacit elements (Baumard, 1999; Stein, 1995). Therefore, there is an urgent need to elaborate practical means to safeguard such knowledge in modification processes. The development of learning agencies and communities of practice, as discussed by SAMRAIL (European Commission, 2004a), might be of interest to explore. The ongoing changes within the Norwegian railway system discussed in Chapter 2 imply that methods to be explored should not be as dependent upon personal networks as the methods of the projects were. They must also be able to cope with the development of the system towards a more dynamic context.

9.3.4 Rule-imposer's position

In the cases the question raised by Hale & Swuste (1998) and followed up by Hale & al. (2003) in their discussions about railways about who it best suited to have the role as rule-imposer was not an issue for the cases except for in two situations. One was when it was discussed if the rule solution fitted with the position of the rule-imposer in the organizational hierarchy of the Norwegian railway system. The other was when it was

discussed if the actual risk required that decisions about how to proceed safely, i.e. to translate goals about safe performance into action/state rules, could not be left to the rule-followers themselves. These decisions were also linked up with the positions of the rule-imposer in the system's organizational hierarchy.

Hale & Swuste (1998) discuss the position of the rule-imposer. However, in their discussion the position is linked to their position and function in an organization's safety management system. They underlines that this position often, but not necessarily parallel the positions in the organizational hierarchies.

As the study does not go deeply into the discussion about who the most suitable rule-imposer is, the question of Hale & Swuste (1998) and Hale & al. (2003) calls for further research.

REFERENCES

Apostolakis, G.E., Vesely, W.E.. 1999. Developments in risk-informed decision-making for nuclear power plants. Reliability Engineering and System Safety 63, 223-224.

Arbeids- og inkluderingsdepartementet. 1996. Regulations relating to Systematic Health, Environmental and Safety Activities in Enterprises (Internal Control Regulations). http://www.arbeidstilsynet.no/regelverk/forskrifter/pdf/544.pdf

Argyris, C., Schön, D.A. 1996. Organizational Learning II. Addison-Wesley Publishing Company Inc. Massachusetts.

Aven, T. 2003. Foundations of Risk Analyses. A Knowledge and Decision-Oriented Perspective. John Wiley & Sons Ltd. Chichester.

Baumard, P. 1999. Tacit Knowledge in Organizations. Sage Publications Ltd. London.

Becker, G. 2002. Towards Goal-Directed Regulation in a Competitive World: Do We Underestimate the Risk of Changes in the Regulatory System? In: Kirwan, B., Hale, A. & Hopkins, A. (Eds.). Changing regulation: controlling risks in society. Pergamon. Oxford.

Berg, T. 2004. Jernbanen i Norge 1854-1940. Nye spor og nye muligheter. Vigmostad og Bjørke AS. Bergen. (In Norwegian)

Bourrier, M. 1998. Elements of designing a self-correcting organization: examples from nuclear plants. In: Hale A.R. & Baram M. (Eds.). Safety management: the challenge of change. Pergamon. Oxford.

Brown, J.S., Duguid, P. 1991. Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. Organization Science. Vol 2, No 1, 40-57.

Brunsson, N. 1989. The Organization of Hypocrisy. Talk, decisions and actions in organizations. John Wiley & Sons Ltd. Chichester

CEN. 1991. Safety of Machinery – Basic Concepts, General principles for Design – Part 1: Basic Terminology, Methodology. European Standard EN 292-1:1991. Brussels

CENELEC. 1999. Railway applications – The specification and demonstration of Reliability, Availability, Maintainability, and Safety (RAMS). European Standard EN 50126. September 1999.

CENELEC. 1997. Railway Application: Software for Railway Control and Protection Systems. European Standard EN 50128. June 1997.

CENELEC. 2003. Railway Application: Safety related electronic systems for signalling. European Standard EN 50129. February 2003.

Chapman, J.R., Dimitrijevic, V.B. 1999. Challenges in using a probalistic safety assessment in a risk informed process (illustrated using risk informed inservice inspection). Reliability Engineering and System Safety 63, 251-255.

Clegg, S.R. 1989. Frameworks of power. Sage Publications. London.

DG Energy and Transport. 2000. Final report: Safety Regulations and Standards for European Railways. NERA, Sedgwick Wharf, CERNA, FFE/TIFSA, IVE, Nomisma, RAND Europe/Kindunos, VTI, VTT, Marsh UK, UCL and LSE. n/e/r/a, London

Directive 96/48/EC on interoperability of trans-European high-speed rail system. Commission of the European Communities. Brussels. 26 February 2001

Directive 2001/16/EC on the interoperability of the trans-European conventional railway system. Official Journal of the European Union, L110, pp 1-27, 19 March 2001

Directive 2004/49/EC of the European Parliament and the Council of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying charges for the use of railway infrastructure and safety certification (Railway Safety Directive), Official Journal of the European Union, L164, pp 44-172, 30 April 2004.

Douglas, M. 1986. How Institutions Think. Syracuse University Press. Syracuse. New York.

Ellström, P.E. 1996. Report: Operatörkompetans – vad den er och hur den kan utvecklas. DUP-resultat. NUTEK. Stockholm. (In Swedish)

Ellström, P.E.. 2001a. Läreande ock innovation I organisationer. In: Backlund, T., Hansson, H. & Thunborg, C. (Eds). Lärdilemman i arbetslivet. Studentlitteratur. Lund. (In Swedish)

Ellström, P.E. 2001b. Integrating Learning and Work: Problems and Prospects. Human Resource Development Quarterly v12 n4, 421-435.

Ellström, P.E. 2002. Time and the Logics of Learning. Lifelong Learning in Europe, v7 n2, 86-93.

European Commission. 1996. A Strategy for Revitalising the Community's Railways. White Paper COM (96) 421 final. July 30, 1996.

European Commission. 2003a. SAMNET Glossary. Fifth Framework Program SAMNET thematic Network. April 09, 2003

European Commission. 2003b. Safety culture in nuclear and process control. Fifth Framework Program SAMRAIL. Appendix 10: WP 2.1.9. August 5, 2003

European Commission. 2004a. Accident and incident reporting system for the EU railways. Fifth Framework Program SAMRAIL. WP 2.6. July 4, 2004

European Commission. 2004b. Regulations, roles of rules and their unification. Fifth Framework Program SAMRAIL. WP 2.8 Volume I. June 21, 2004

European Commission. 2004c. Synthesis of SAMRAIL findings. Fifth Framework Program SAMRAIL. WP 2.9. December 6, 2004

European Commission. 2004d. Guidelines for the safety Management System. Fifth Framework Program SAMRAIL. WP 2.2. May 20, 2004

Etzioni, A. 1967. Mixed-Scanning: A ”Third” Approach To Decision-Making. Public Administration Review 385-392. December 1967.

Flagstad, K. E. 1995. The Functioning of the Internal Control Reform. Ph.D. thesis. University of Trondheim, NTH. Trondheim.

Friberg, O. 1995. Arbeidsmiljøloven (The Working Environment Act).Kommentarer til lov av 4. februar 1977 om arbeidervern og arbeidsmiljø m.v. med endringer, sist ved endringslov av 6. januar 1995 nr 2. Tano, Oslo. (In Norwegian)

Guba, E.G., Lincoln, Y.S. 1981. Effective evaluation: Improving the Usefulness of Evaluation Results Through Responsive and Naturalistic Approaches. Jossey-Bass. San Francisco.

Gullowsen & Ryggvik, 2004. Jernbanen i Norge 1854-2004. Nye tider og gamle spor. Vigmostad og Bjørke AS. Bergen. (In Norwegian)

Hale, A.R. 1990. Safety rules O.K.? Journal of Occupational Accidents 12, 3-20.

Hale, A.R., Heming, B.H.J., Carthey, J. & Kirwan, B. 1997. Modelling of safety management systems. Safety Science 26(1/2), 121-140.

Hale, A.R. & Swuste, P. 1998. Safety rules: procedural freedom or action constraint? Safety Science 29, 163-177.

Hale, A.R., Heijer, F. & Koornneef, F. 2003. Management of safety rules: The case of railways. Safety Science Monitor 7, Article III-2, 1-11.

Harms-Ringdahl, L. 2004. Analysing Safety Functions and Barriers – Experiences from Different Industrial Sectors. In: Conference proceeding for PSAM 7 – ESREL ’04. Berlin. June 14 – 18, 2004.

Harms-Ringdahl, L., Kecklund, L. 2004. Safety Functions in Railways – a Structural Analysis of Safety Rules. In: Conference proceeding for PSAM 7 – ESREL ’04. Berlin. June 14 – 18, 2004.

Hedberg, B. 1981. How organizations learn and unlearn. In: Starbuck, N. (Ed.). Handbook of Organizational Design. Oxford University Press. New York. pp 3-27.

Hellevik. O. 1991. Forskningsmetode i sosiologi og statsvitenskap. Universitetsforlaget AS. Oslo. (In Norwegian)

Hindess, B. 1996. Discourses of Power: From Hobbes to Foucault. Blackwell Publishers Ltd. Oxford.

Hoffman, L.R., Maier, N.R.F. 1961. Quality and acceptance of problem solutions by members of homogeneous and heterogeneous groups. Journal of Abnormal and Social Psycholgy Vol. 62, No 2, 401-407.

Hood, R., Rothstein, H., Baldwin, R. 2001. The Government of Risk. Understanding Risk Regulation regimes. Oxford University Press, Oxford.

Hopkins, A. 2000. Lessons from Longford. The Esso Gas Plan Explosion. CCH Australia Limited. Sydney.

Hopkins, A., Hale, A. 2002. Issues in the Regulation of Safety: Setting the Scene. In: Kirwan, B., Hale, A., Hopkins, A. (Eds.). Changing regulation: controlling risks in society. Pergamon. Oxford.

Hovden, J. 1998a. Models of Organizations versus Safety Management Approaches: A Discussion Based on Studies of the ”Internal control of SHE” Reform in Norway. In: Hale, A.R. & Baram, M. (Eds.). Safety management: the challenge of change. Pergamon. Oxford.

Hovden, J. 1998b. Ethics and Safety: “Mortal” Questions for Safety Management. Proceedings presented at Safety in Action, Melbourne, 25-28 February, 1998.

Hovden, J. 2002. The Development of New Safety Regulations in the Norwegian Oil and Gas Industry. In: Kirwan, B., Hale, A. & Hopkins, A. (Eds.). Changing regulation: controlling risks in society. Pergamon. Oxford.

Hovden, J. 2004. Public policy and administration in a vulnerable society: regulatory reforms initiated by a Norwegian commission. Journal of Risk Research 7, 629-641.

Høyland, A. & Rausand, M. 1994. System Reliability Theory: Models and Statistical Methods. John Wiley & Sons, Inc. New York.

Jaeger, C.C., Renn, O., Rosa E.A., Webler, T., 2001. Risk, Uncertainty and Rational Action. Earthscan Publications Ltd. London.

Janis, I.L. 1982a. Groupthink. Houghton Mifflin Company. Boston.

Janis, I.L. (1982b). Counteracting the Adverse Effects of Concurrence - seeking in Policy- planning Groups: Theory and Research Perspectives. In: Brandstätter, I H., Davis, J.H. & Stocker-Kreichgauer, G. (Eds.) Group Decision Making. Academic Press Inc. (London) LTD, London.

Jernbaneverket, 2004. Overbygging. Regler for vedlikehold. Generiske arbeidsrutiner. Generelle tekniske krav. Jernbaneverket hovedkontoret. Oslo. (In Norwegian)

Justis- og politidepartementet, 2000a. Report: NOU 2000: 24. Et sårbart samfunn. Akademika AS. Oslo. (In Norwegian)

Justis- og politidepartementet, 2000b. Report: NOU 2000: 30. Åstaulykken, 4. januar 2000. Akademika AS. Oslo. (In Norwegian)

Justis- og politidepartementet, 2001. Report: NOU 2001: 9. Lillestrøm-ulykken 5. april 2000. Akademika AS. Oslo. (In Norwegian)

Kahneman, D., Slovic, P., Tversky, A. (ed.). 1982. Judgement under Uncertainty; Heuristics and Biases.. Cambridge University Press. New York.

Kirwan, B., Hale, A. & Hopkins, A. 2002. Insights into Safety Regulation. In: Kirwan, B., Hale, A. & Hopkins, A. (Eds.). Changing regulation: Controlling risks in society. Pergamon. Oxford.

Kjellén, U. 2000. Prevention of Accidents Through Experience Feedback. Taylor & Francis. London.

Klinke, A. & Renn, O. 2001. Precautionary principle and discursive strategies: classifying and managing risks. Journal of Risk Research 4, 159-173.

Krippendorff, K. 1975. Some principles of information storage and retrieval in society. General systems 20, 15-35.

Kvale, S. 1996. InterViews. Sage Publications, Inc, California.

Kørte, J., Aven, T., Rosness, R. 2002. On the use of risk analyses in different decision settings. Paper presented at ESREL 2002. Lyon. March 19 – 21, 2002

LaPorte, T.R., Consolini, P.M. 1991. Working in Practice But Not in Theory: Theoretical Challenges of "High-Reliability Organizations". Journal of Public Administration Research and Theory J-PART 1, 19-47.

Latour, B. 1987. Science in action. Harvard University Press. Cambridge.

Lave, J., Wenger, E. 1991. Situated Learning. Legitimate peripheral participation. Cambridge University Press. Cambridge

Leiulfsrud, H., Hvinden, B. 1996. Analyse av kvalitative data: Fiksérbilde eller puslespill? In: Holter, H. Kalleberg, R. (Eds). Kvalitative metoder i samfunnsforskning. Universitetsforlaget. Oslo. (In Norwegian)

Lincoln Y.S., Guba, E.G. 1985. Naturalistic inquiry. Sage Publications, Inc. Newbury Park.

Lindblom, C. 1959. The Science of "Muddling Through". Public Administration Review 19, 79-88

Lupton, D. 1999. Risk. Routledge. London.

Maidment, D. 1998. Privatization and Division into Competing Units as a Challenge for Safety Management. In: Hale, A.R. & Baram, M. (Eds.). Safety management: the challenge of change. Pergamon. Oxford.

Maidment, D. 2002. The development of Safety Regulation in the Rail Industry. In: Kirwan, B., Hale, A. & Hopkins, A. (Eds.) Changing regulation: Controlling risks in society. Pergamon. Oxford.

March, J.G. 1994. A Primer on Decision Making. The Free Press. New York.

Melia, K.M. 1997. Producing 'Plausible Stories':Interviewing Student Nurses. In: Miller, G., Dingwall, R. (Eds.). Context and Method in Qualitative research, Sage, London, pp. 26-36

Miles, M.B., Huberman, A.M. 1994. Qualitative Data Analysis. Sage Publications Ltd. London.

Minzberg, H. 1979. The structuring of organizations. Prentice-Hall International. New Jersey.

Nonaka, I., Takeuchi, H. 1995. The Knowledge-Creating Company. Oxford University Press. New York.

NSB BA. 1998. Jernbanen i Norge 1840 – 1998. NSB konsernet. Oslo. (In Norwegian)

Perby, M.L. 1995. Konsten att bemästra en process. Om att förvalta yrkeskunnande. Gidlunds Förlag, Hedemora. (In Swedish)

Perrow, C. 1999. Normal Accidents. Living with High-Risk Technologies. Princeton University Press, Chinchester, (First issued in 1984)

Polanyi, M. 1966a. Personal Knowledge: Toward a Post-critical Philosophy. University of Chicago Press. Chicago

Polanyi, M. 1966b. The tacit dimension. Routledge & Kegan Paul.London

Rasmussen, J. 1983. Skills, rules and knowledge: Signals, signs and symbols and other distinctions in human performance models. IEEE Transactions of Systems, Man and Cybernetics, Vol. SMC – 13, No 3, 257-267.

Rasmussen, J. 1997. Risk management in a dynamic society: A modelling problem. Safety Science 27(2/3), 183-213.

Rasmussen, J., Svedung, I. 2000. Proactive Risk Management in a Dynamic Society. Räddningsverket. Karlstad.

Rausand, M., Øien, K. 2004. Risikoanalyse. Tilbakeblikk og utfordringer. In: Lydersen, S (Ed.). Fra flis I fingeren til ragnarok. Tapir Akademisk Forlag. Trondheim. (In Norwegian)

Reason, J. 1997. Managing the risks of organizational accidents. Ashgate Publishing Limited. Aldershot.

Reason, J., Parker, D., Lawton, R. 1998. Organizational controls and safety: The varieties of rule-related behaviour. Journal of Occupational and Organizational Psychology 71, 189-304.

Rosness, R. 2000. Slank og sårbar? Om verdien av organisatorisk redundans. SINTEF Industrial Management, Safety and reliability. Trondheim. (In Norwegian)

Rosness, R. 2003. Addicted to Rules? Users' views on Railway Traffic Safety Regulations. Paper presented at the workshop "New Challenges to Understanding System Safety". Fredensborg Conference Centre, 6-7 October, 2003.

Rosness, R. 2004a. Alt flyter – og hva så? Paper presented at "Sikkerhetsdagene" Trondheim. 2 – 3 November 2004. (In Norwegian)

Rosness, R. 2004b. Memo: Deregulation and Safety in Transportation Outline for a research framework. SINTEF Technology and Society. Trondheim. (In Norwegian)

Rouhiainen. V. 1993. Importance of the quality management of safety analysis. Reliability Engineering and System Safety 40, 5-16.

Ryggvik, H. 2004. Jernbanen, oljen, sikkerheten og historien. In: Lydersen, S (Ed.). Fra flis I fingeren til ragnarok. Tapir Akademisk Forlag. Trondheim. (In Norwegian)

Samferdselsdepartementet (Ministry of Transport and Communication). 1993. Lov om anlegg og drift av jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (jernbaneloven). http://w.w.w. lovdata.no/all/hl-19930611-100html (In Norwegian)

Samferdselsdepartementet (Ministry of Transport and Communication). 1999. Forskrift om krav til styring og oppfølging av forhold relevant for sikker trafikkavvikling på jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (Sikkerhetsforskriften). Statens forvaltningstjeneste. Oslo. (In Norwegian)

Samferdselsdepartementet (Ministry of Transport and Communication). 2001a. Forskrift om krav til jernbane, herunder sporvei, tunnelbane og fortstadsbane m.m. (Kravforskriften). http://w.w.w. lovdata.no/for/sf/sd/hd-20011204-1334.html (In Norwegian)

Samferdselsdepartementet (Ministry of Transport and Communication). 2001b. Forskrift om trafikkstyring og togframføring på statens jernbanenett og tilknyttede private spor (togframføringsforskriften). http://www.sjt.no/Hva_styrer/Togframforingsforskriften.html (In Norwegian)

Samferdselsdepartementet (Ministry of Transport and Communication). 2002. Forskrift om opplæring av personell med arbeidsoppgaver av betydning for trafikksikkerheten ved jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (opplæringsforskriften).http://lovdata.no/for/sf/sd/xd-20021218-1679.html (In Norwegian)

Savage, I. 2003. Deregulation and Safety: Experiences from the United States. Paper for the “Deregulation and Transport Safety in Rail – What is Best Practice in the European Union?” Workshop – Brussels, Belgium, October 2003.

Schäbe, H. 2002. The Safety Philosphy Behind the CENELEC Railway Standards. Paper presented at ESREL 2002, Lyon. March 19-21, 2002

Schön, D.1991. The Reflective Practitioner. Arena, Ashgate Publishing Limited. Aldershot. (First issued in 1983)

Shrader-Frechette, K.S. 1991. Risk & Rationality. University of California Press. Berkeley and Los Angeles.

Simon, H.A.1966. The new Science of Management Decision. Harper. New York.

Starbuck, W.H. 1992. Learning by knowledge intensive firms. Journal of Management studies, 29 (6), 713-740

Stein, E.W. 1995. Organizational Memory: Review of Concepts and Recommendations for Management. International Journal of Information Management. Vol. 15, No. 2, 17-32.

Strauss, A., Corbin, J. 1998. Basics of Qualitative Research. Sage Publications, Inc. California.

The Research Council of Norway. 2003. Report: Risk and safety in the transport sector. RISIT. A-state-of-the-art review of current knowledge

Turner, B. A., Pidgeon, N. F. 1997. Man-made disasters. Butterworth-Heinemann, Oxford.

Vaughan, D. 1996. The Challenger Launch Decision. Risky technology, Culture, and Deviance at NASA. The University of Chicago Press, Chicago. USA

Vesely, W.E.. 1999. Principles of resource-effectiveness and regulatory-effectiveness for risk-informed applications: Reducing burdens by improving effectiveness. Reliability Engineering and System Safety 63, 223-224.

Weber, M. 2000. Makt og byråkrati. Gyldendahl Norsk Forlag ASA. Trondheim. (First issued in 1922) (In Norwegian)

Weill- Fassina, A., De La Garza, C., Kaplan, M., Schmidt, A. 2003. Report: Freight Interoperability Safety Recommendations and Tools for the Planning. UIC, EPHE, Paris 5, TU Berlin.

Wenger, E.1998. Communities of Practice: Learning as a Social System. Systems Thinker. Vol. 9, No 5, 1-5.

Whyte, W.F., Whyte, K.K. 1984. Learning from the field. A guide from experience. Sage Publications. Beverly Hills.

Wolmar, C. 2001. Broken Rails. How privatization wrecked Britain's railways. Second revised edition. Aurum Press. London.

Wormnæs, O. 1987. Vitenskapsfilosofi. Gyldendal Norsk Forlag. Oslo. (In Norwegian)

Wulff, I.A. 1997. Implementing ergonomics in large-scale engineering design. Ph.D. thesis. Department of Industrial Economics and Technology Management. Norwegian University of Science and Technology. Trondheim.

Yin, R.K. 1994. Case Study Research. Sage Publications, Inc. California.

Zuboff, S. 1988. In the Age of the Smart Machine. Basic Books, Inc. USA

Appendix A: List of acronyms

ATC	Automatic Train Control
DG	Directorate-General
EEA	European Economic Agreement
EU	European Union
FMECA	Failure Mode, Effect and Criticality Analysis
HAZOP	Hazard an Operability Study
HRO	High Reliability Organizations
HUL analyses	Analyses judging if rule-changes had caused higher, unchanged or lower risk (HUL refers to the first letters of high, unchanged and lower.)
Inspectorate	Norwegian Railway Inspectorate
ISO	International Organization for Standardization
NCR	The United States Nuclear Regulatory Commission
NSB	Norges Statsbaner (The former state owned Norwegian State Railways)
NSB BA/ NSB AS	The new commercialized traffic operator originating from the former Norwegian State Railways called NSB BA and later NSB AS
PDCA	Plan-Do-Check-Act
PHA	Preliminary Hazard Analyses
Rail Administration	Norwegian National Railway Administration
RAMS	Reliability, Availability, Maintainability and Safety
RCM	Reliability Centered Maintenance
RISIT	Risk and Safety in the Transport Sector
SAMRAIL	A project directed at Safety Management in Railways under the Fifth Framework Programme. Financed by the European Commission
TRJ 2003	Trafikk Regler for Jernbanen 2003 (In English: Traffic-rules for Railways 2003).
TSI	Technical Specifications for Interoperability

Appendix B: Presentation of author's background

My professional background and practice have links to safety rule management, educational systems and the Norwegian railway system.

I am educated as a physiotherapist with a Master degree in preventive health care. Furthermore I have attended several courses in different aspects of safety management. These were mainly courses for chartered engineers and for the Ph.D. degree in engineering.

My most important professional experiences are from occupational health services in companies with a variety of characteristics, the Norwegian Directorate of Labor Inspection and from the Physiotherapy education, teaching in the field of occupational health care.

From 1998 until 2001 I worked in the Occupational health service of NSB BA. The department where I worked served all railway activities of both NSB BA and the Rail Administration in one geographical region. Furthermore, we cooperated with departments serving other geographical regions.

This work gave me an extensive knowledge of the different activities of the Norwegian railway system and in particular those that were associated with ergonomic problems. Furthermore, it gave me a network of railway professionals at different levels in the system's organizational hierarchy. It also functioned as an introduction to the different methods of communicating and cooperation within the system.

In the Ph.D work I took advantage of my prior knowledge of the Norwegian railway system. First, it made me aware of the ongoing rule modification projects, how to approach them and achieve the necessary permissions for the study. Second, the knowledge of the different activities helped the communication with the railway professionals. I was familiar with the terminology and the subjects they were talking about. Third, as a former employee of the system I found that I was considered an insider by the interviewees. I also got the impression that the role I had had as a health worker meant that I was considered to be a person with a certain degree of integrity.

However, there might also be some dangers associated with the prior knowledge. First, there might easily occur a misunderstanding that I had understood more than I had because the interviewee and I built upon unconscious assumptions that we did not check out. This is why I found it particularly important to verify my preliminary analyses with the two project leaders.

Second, an associated problem might be that both the interviewees and I were socialized into the railway culture. Therefore, I might have adopted many of the same attitudes as the interviewees. This might have made it difficult to be sufficiently critical of the information I received.

Third, because the interviewees knew I had a background as a health worker in the system, I sometimes realized that the interviewees had certain expectations about what I wanted them to tell me. When this happened, I repeated the purposes of the study and discussed my new role as a researcher of safety management more thoroughly.

Fourth, as I had worked in one region of the Norwegian railway system, the use of my network and knowledge of the system to approach the field and potential sources for information might have influenced the data collection. However, many of the interviewees held central positions in the system and I only previously knew 5 of the 41 people interviewed from before.

Fifth, there are some geographical differences in the Norwegian railway system. As I had worked in one region I was most familiar with the characteristics and culture of this region. The region I knew was the most geographically distributed one. Furthermore, it did not include the lines with the highest traffic density.

Appendix C: Interview guide, a translated example

1. **Introduction:**
    a. Thank you for participating in the study. I hope it will give something back, ref. the information about the purpose of the study.
    b. Any questions to the information about my work?
    What is the available time? I suggest starting with the questions I have prepared. They do not have to be followed strictly, I will be happy about comments, points of views, associations.
    c. I might ask questions that might appear obvious or that you expect me to know or where you expect me to have opinions. The reason is that I am interested in your points of view.
    d. The information that you give during the interview will be used in the study. However, direct quotations that can easily be linked to individuals will be clarified with the actual people. I will also be careful about referring to what you say in my communication with others in the system.
    e. You still agree with the use of tape recorder?
    f. Do you want the transcription of the interview?

2. Background information
    a. Name?
    b. Age?
    c. Profession?
    d. For how long have you been working in NSB/the Rail Administration/the Inspectorate/the Educational system?
    e. Which functions have you had in NSB/the Rail Administration/the Inspectorate/the Educational system?
    f. Do you have other background/work experience that you think might have affected your work with rules?
    g. What was your organizational position when you were involved in the modification work?

3. Own role and perspectives
    a. What is your role in the work groups where you have participated?
        i. What have you considered to be your main task?
    b. How has it been to possess that role?
        i. Have you experienced conflicts between roles?
        ii. Have you had sufficient resources at your disposal to fill the role?
    c. What have been your major concerns during the work?
    d. How have you found working with safety issues in the organization?
    e. How do you define risk?
    f. How do you define safety?

4. **The process of developing rules**
    a. What do you think is the major reason for the decision to make rule modifications?
    b. Where did the most important inputs to the work come from?
    c. What role have the risk analyses had in the rule development?
        i. Who and how many people participated in the risk analytic work?
        ii. What have been the roles of the different participants?
    d. How would you describe the development of the work to change the rules?
    e. What do you think has served as important fundament for the work?
    f. What do you think has been important for the development of the work?
        i. For the process?
        ii. Other important aspects?
    g. What is you opinion about the results of the development?
    h. How have you found the work?
    i. What challenges have you met?
    j. How do you consider your own impact?
    k. How is the project developing compared to your expectations?

5. **The choice of rules as solution**
    a. Why did you decide upon rules as a solution?
        i. Do you think that it is necessary to have written rules for safety in the regulated area?
        ii. Have you discussed if there should have been other means than rules to achieve the purposes of safe traffic performance? If yes, which means?
        iii. Have you found that rules have had to compensate for lack of other means that would have been better for safety?
    b. How do you think rules can contribute to accident prevention?
        i. How do you think that the rules will work?
    c. What challenges do you associate with them?
    d. Do you think that the rule-followers will find the rules necessary and efficient for the purpose of safety?
    e. Do you think that the line management will consider the rules as necessary and efficient for the purpose of safety?
    f. How do you think the rules will function for the future development of the regulated area?
        i. Are there conditions in the development you think will influence the rules and their application?
        ii. Which ones?
    g. How would you describe a good rule?

6. **Chosen rule solution**
    a. Why did you decide upon the rule solution?
    b. What is your opinion about the chosen rule solution?

c. What have been the main arguments for removing some of the existing rules?
d. Have there been discussions of level of detail in the rules?
    i. If yes, what has been their content?
e. Have there been discussions about user-friendliness?
    i. If yes, what has been their content?
f. Have there been discussions about the form and the content of the rules compared to competency and understanding of risk and safety in the organization?
    i. If yes, what has been their content?
g. Do you think the form of the rules can influence the ability of the organization to learn?
h. Have there been discussions about geographical differences of geographical environment, climate and the railway system?

7. The relationship to old rules

a. What do you consider to be the most important changes in the rules?
b. Why were these changes made?
c. Who/What has provided the most important input for these changes?
d. Has there been input to changes that has not been emphasized?
e. Have there been discussions about how extensive the changes can be?

8. The relationship to other participants

a. Who do you think have been the main contributors to the rule development?
    i. What has been their contribution?
b. Are there actors you think should have been/have been more included in the developmental work?
    i. If yes, what do you think their contribution would have been?
c. In general, who do you think are the most important contributors of knowledge to the accident preventive work?
    i. What were their contributions?
    ii. Are there other groups that should participate in this work?

9. Rule-followers

a. Who do you consider to be the most important rule-followers and users of the rules?
b. What knowledge do you find important that the rule-followers possess?
c. What do you find are the rules' contribution to them?
d. Do you think that the rules are directed at the right group of rule-followers?
e. What opportunities do you think the rule-followers have to influence the rule development?
    i. Do you think it is important that the rule-followers have influence?
f. What possibilities do you think the rule-followers will have to influence the work in later phases?

10. Hearings

a. Do you think that the hearings have involving the right people? (If there have been any hearings or approval processes)
b. What do you think of the plans for later hearings?
c. Are there other processes that have influenced the rule development?

11. Education

a. How would you describe the education of the rule-followers?
b. How is the interaction between theory and practice organized?
c. How do you think future education should be?
d. Do you think that the chosen rule solution should influence future educational programs?
e. Do you think the rule changes should be followed by educational means?
    i. If yes, do you see any problems associated with these means?

12. Control of compliance

a. Are there any plans for future control of compliance with the rules?
b. How do you think compliance with the rules should be followed up?
c. Do you think that the chosen rule solution will influence how control of compliance with the rules should be done?
d. Do you think the choice of means for control will influence organizational learning?
e. How do you think deviation from rules should be handled?
f. Do you think there will be situations where the rules are not appropriate?
g. If weaknesses of rules are revealed, where to give this information?
h. How will you describe good rules?

13. Preparation for future modifications

a. Has future needs for rule modifications been discussed?

14. Closure

a. Thank you
b. May I come back later and ask more questions?
c. To you have any feedbak to give me?
    i. About the interview?
    ii. About the project?

Appendix D: Reflections behind each group of questions

The front page
The front page did not contain questions; it was developed as a memo. It contained elements to be covered in the introduction to the interview. It was an aid to myself to ensure that the interviewees were taken well care of and all formalities were clarified.

Background information of the interviewee
The interviewees were asked about their age, educational background and work experience, current position in the organization and other information that they thought might influence their work and points of view. These questions were prepared from the expectation that this might influence their answers to the following questions.

Role and perspectives related to the rule modification and/or the safety work
The research questions had a very open form. This was done in the belief that different roles and perspectives might increase the understanding of the modification process and its outcome. To get a better understanding of the interviewee's answers and the rationales behind them, it was necessary to ask about their perspectives on risk, safety and safety rules and their role in rule modification. It appeared that the questions of perspectives had to be asked in an indirect way, because many of the interviewees found it difficult to answer the questions directly and some felt as if it was an examination.

Knowledge about the actual or former rule modification processes
In this section the interviewees were asked about their knowledge about the background for the actual rule modification process, its development and influencing factors and their own experience as participants. This section was very important for the development of a picture of the whole modification process. The questions were therefore asked to all the interviewees that had been directly involved in the process. Because some had been involved in former rule modification processes, they were also asked about these. This was done because I thought that their experiences might have influenced their attitudes to the ongoing rule modification.

Attitudes towards the choice of rules as solution for the actual safety issues
Here the interviewees were asked about their knowledge of the rationales behind the choice of rules as means for control of the actual risk and their expected role in the preventive work. They were also asked about their own and others' attitudes towards rules in the preventive work. These questions were developed to get an impression of the role of the rules and the attitudes towards other possible solutions for risk control. I thought that different actors might have different points of view according to their different roles and that these points of view might influence the process and the choice of rule approach. The interviewees were also asked about potential challenges to the rules. This was partly done to reveal issues at stake for the future implementation, control and possible need for modification of the rules. At the end they were asked to describe "good" rules to see if there were many diverging attitudes. The questions of this section were used a lot in the interviews.

Chosen rule solution
The section invited the interviewees to talk about the rationale behind the chosen rule solutions and eventually the removal of former rules, their attitudes towards the new rules, the usability of the rules regarding the needs of the rule-followers, their detail level, different geographical conditions and their relation to the knowledge tradition and the organization's ability to learn. These issues were of interest to get information for the research questions related to the rationales behind the rules and how the new rules would be met and function.

The relationship between the new and the former rule solutions
This section was meant as a follow-up question for the former section. The purpose was to clarify what the interviewee considered as the most important changes of the rules. I hoped that this would show both what the system considered as the most important breaks with the former rule tradition and also indicate where the projects might face challenges and needs for education in the implementation phase. These questions were considered to indicate follow-up questions related to the rationale behind the changes.

Evaluation of the contribution of others in the rule modification processes
Here the interviewees were asked about who they considered to be the main contributors of the projects and what their contribution was. They were also asked about who they considered to be the most important contributors with knowledge to the general safety work. This was done to get input to the research questions both related to the development of the processes and the chosen rule solutions. These questions were used a lot.

The relationship between the target group and the rules
This section directed attention towards the potential rule-followers. What interested me was who they were considered to be and how their needs for rules were considered. Whether the interviewee considered the potential rule-followers to be the right target group for the control of potential risk related to the activities at stake was of interest. The opportunities for the rule-followers to influence the process were also covered. I thought that the definition of the rule-followers and their needs was an important issue for the content and form of the rules and who were invited to influence the process. Further I thought it might be an important issue for the understanding of the role of the rules in the safety work. The questions of this section were frequently asked.

Hearing of the rules
Since the projects were ongoing, the interviewees were asked both about what involvement and hearing processes had been in the project and what plans there were. I though that the involvement in the development and approval of the rules might influence the process, the chosen rule approach and the future implementation and use of the rules. This section was frequently used as most of the interviewees had been in touch with the rule modification. However, the formal approval of the Traffic-rules was not carried out by the end of the data collection of this study.

Education and training related to the activities of the rules and expected challenges to the implementation phase

This section focused on the educational background that the rule-followers had and the way this was organized. Furthermore, the interviewees were asked about the expected needs for education or training when the rules were about to be implemented and the practical possibilities for this. None of the projects had developed plans for this when the data collection finished. The intention was both to see if there was any relationship between the background of the rule-followers and the chosen rule solution and considered needs for education or training in the implementation phase. I also wanted to see how such education could be carried out. These questions were mainly used for the Traffic-rule project since the professions involved in the regulated activities were educated within the railway system.

Control of compliance with the existing rules, their quality and eventual plans for the future

Even though the rule modifications were not finished, I wanted to know if there were any plans for future control of compliance with the rules or if the interviewees had any experience with former controls which could be useful to take into consideration. Further information about where knowledge about the efficiency of rules could be channeled was wanted. I thought that there might be a relationship between ideas of control, the development of the process and the chosen rule solution. I also thought that there might be some interesting ideas on the relationship between the control of rules, learning and rule modification. This question was frequently used, but with most response related to experience with the former rules.

Expectations for and preparations of future rule modifications

The interviewees were asked about their ideas about the needs for future modifications of the actual rules, eventually whether this was taken into consideration in the work and if so, how. This was done because it would be interesting to see if there were any planned-for dynamics in the rule management and how this could be done.

At the end I had another memo to be covered when rounding off the interview.

In addition to thanking the interviewees, they were asked for the opportunity for further questions if needed and feedback on the interview. The purpose of the latter was to give a debriefing opportunity, to see if they had any more information related to the issues that was not covered in the interview and to learn about the guide and my performance as an interviewer. How deeply we went into these issues varied with their response.

Appendix E: Analytic schema

	Intentions for the cases	**What happened in the cases?**	**Why and with what conse-quences? Comments**	**Conse-quences for knowledge**
1.Introduction Presentation of the rule projects				
1.1.The Norwegian Railway system and its rule tradition				
1.2.Area of regulation				
1.3.Purpose and background for the projects				
1.4.Organizing and organizational position of the rule projects				
2. How are the processes of developing the rules run and why?				
2.1.The activities and sequences				
2.1.1.Information that are grounding the work:				
2.1.1.1.The existing learning and training programs/ Knowledge				
2.1.1.2.Input from evaluation and information about the existing situation and rules of the area				
2.1.1.3.Input from risk analyses				
2.1.1.4.Input from international development				
2.1.1.5.Input from other sources or groups				
2.1.2.Defining the process, scenarios				
2.1.3.Defining control principle				
2.1.4.Simplifying the rules				
2.1.5.Writing the rules where rules are considered necessary				
2.1.6.Combining the risk analyses and the rule writing				

	Intentions for the cases	**What happened in the cases?**	**Why and with what conse-quences? Comments**	**Conse-quences for knowledge**
2.1.7.Developing the database of the rules				
2.1.8.Testing the rule suggestions				
2.1.9.Transfer from the projects to the “owners” of the rules				
2.1.10.Approving the rules - The hearing processes				
2.1.11.Plans for promotion and training of the rules				
2.1.12.Plans for monitoring the use of the rules				
2.2. Progression and status of the work				
3. What are the underlying perspectives dominating the ongoing modification of safety rules?				
3.1.The main contributors to the development of the rules				
3.2.Underlying perspectives				
3.2.1.Risk and safety				
3.2.2.Rules and their role				
3.2.3.The rule-followers				
3.2.4.Other influencing perspectives				
3.2.5. Summary				
4. What are the chosen rule solutions?				
4.1.Rules or no rules?				
4.2.Type of rules				
4.2.1.Operative versus technical				
4.2.2.Goal-oriented versus prescriptive				
4.2.3.Structure of the rules				
4.3.Formalizaton of the rules (Organizational position of the rules)				
4.4.Developed systems to build on for future learning and adaptation of the rules				

	Intentions for the cases	**What happened in the cases?**	**Why and with what conse-quences? Comments**	**Conse-quences for knowledge**
4.4.1.Inherent in the projects				
4.4.2.Inherent in the chosen solution				
4.5.Knowledge modes of the safety rules				
4.6.Built- in features of the system that represents opportunities for org. learning of the quality of the rules				
5. Unclassified issues				

Appendix F: The method of the Traffic rule case

When the Traffic rule case, i.e. the TRJ 2003 project of the Norwegian National Railway Administration, were run for a couple of years, the work group described what became seen as the method of the case[44]. This was a summary of the experiences that had evolved until then and the plans for the further progression of the work. In this method the risk analyses and the rule development were organized as two parallel processes; risk analyses and rule development. These processes were divided into stages where the rule development interacted with the risk analyses.

The main steps in the two parallel processes are as follows:

The process for the development of the risk analyses:

- Develop a risk analysis of the activities with top events as an outset, version 1
- Hearing of the version 1 analysis and discussions with the involved professional groups
- Correct the analysis, i.e. develop version 2
- Based on version 2, develop risk analyses and analyses of the safety condition for sub-top events. These serve as foundation for changes from Draft A to Draft B of the rules (see below)
- Perform change analyses for each sub-top events of the new rules
- Upgrade the risk analyses version 2 to version 3 on the background of changes found during the analyses of the safety condition

The process for rule development in combination with the risk analyses:

- With the 1997 rules as an outset develop draft A based on the input of the general knowledge of the project group and the impressions from the work of the version 1 risk analyzes. This version A keeps the same format and structure as the 1997 rules.
- Develop draft B based on draft A and the analyzes of the safety conditions of each sub top event, also in the same format as the 1997 rules
- Hearing of draft B and a subsequent update of this draft
- Based on the wishes from those involved and the requirement as to form for regulations, develop version C in the final format and organizing from the revised version B.
- Develop plans for education of the new rules and related education material.

The case also provided thorough descriptions of each step

As the work proceeded it became more iterative than expected. The main explanation for this was the time pressure of the work. However, the work contained the elements of the described method.

[44] Project log 689