A study of the integration of complementary analysis methods
-Analysing qualitative data for distributed tactical operations

Magisteruppsats, 10 poäng, skriven av

Maria Lindström & Lena Ljungwald

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Abstract

Complex socio-technical systems, like command and control work in military operations and rescue operations, are becoming more and more common in the society, and there is a growing urge for more useful and effective systems. Qualitative data from complex socio-technical systems can be challenging to analyse. This thesis probes one way of enhancing existing analysis methods to better suit this task.

Our case study is carried out at FOI (the Swedish Defence Research Agency). One of FOI’s tasks is to analyse complex situations, for example military operations, and they have developed an approach called the Reconstruction – exploration approach (R&E) for analysing distributed tactical operations (DTOs). The R&E approach has a rich contextual approach, but lacks a systematic analytic methodology.

The assignment of this thesis is to investigate how the R&E approach could be enhanced and possibly merged with other existing cognitive analysis methods to better suit the analysis of DTOs. We identified that the R&E approach’s main weaknesses were the lack of structure and insufficient way of handling subjective data, which contributed to difficulties when performing a deeper analysis. The approach also needed a well-defined analysis method for increasing the validity of the identified results.

One way of improvement was to integrate the R&E approach with several cognitive analysis methods based on their respective individual strengths. We started by analysing the R&E approach and then identified qualities in other methods that complemented the weaknesses in the R&E approach. Finally we developed an integrated method.

The Critical Decision Method (CDM) appeared to be the most suitable method for integration with the R&E approach. Nevertheless, the CDM did not have all the qualities asked for so we chose to use functions from other methods included in our initial analysis as well; ETA and Grounded theory.

The integration resulted in a method with a well-defined method for analysis and the possibility to handle subjective data. This can contribute to a deeper analysis of DTOs.
Acknowledgement

This thesis is the last exam before our university degree and we have had the opportunity to carry out this task at FOI during the summer 2005. The work has many times been hard and from the beginning we did not even understand what was expected from us; we thought the task was invincible. But as time went on, we built up an understanding on the subject, and eventually a plan on how to perform the task. Today we are very happy that we accepted the challenge.

We have also had the benefit to have three supervisors that have supported us and helped us when we have lost track. We would like to thank our supervisors at FOI, Pär-Anders Albinsson and Sofie Pilemalm that have shared their great knowledge on the subject as well as helped us with the English language. We also want to thank our supervisor at the University of Linköping, Ulf Melin who has helped us with the outline and the formalities. He had to fight to get an academic perspective on the thesis.

We feel that we have gained great knowledge about cognitive methods and method integration, and we believe that we will benefit from our new knowledge in the future. We have also improved our analytic thinking, which will be a great asset later in the working life.

Linköping, September 2005

Maria Lindström & Lena Ljungwald
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Part I: Introduction, Theoretical background and Methodology

In this part we introduce the subject briefly, explain the study context and the aim of the thesis. We also present the background of the research and explain our scientific approach and the working procedure of the thesis.
1 Introduction

Complex socio-technical systems, like command and control work in military operations and rescue operations, are becoming more and more common in society, and as a consequence, there is a growing urge for more useful and effective systems. As the systems become more complex, many organisations need efficient support to understand and develop their systems.\(^1\) Therefore, substantial research is presently conducted on developing analysis approaches to take on this task. Qualitative data from complex socio-technical systems can be especially challenging to analyse. This thesis investigates ways of enhancing existing analysis approaches to better suit this task.

Examples of complex socio-technical systems can be found in many types of domains, from entertainment and games to professional high-stake work, such as distributed tactical operations (DTOs). In this thesis we shall concentrate on the domain of DTOs: military, rescue or inter-organisational crisis-management operations that involve large geographical areas with many parallel activities. As technology advances, there is a strive to take on new and more complex tasks, often increasing the distribution of cognitive resources through technical support systems. When the technology becomes more advanced, the cognitive demands on the operators often increase which can lead to that system failures become more severe.\(^2\) Due to the complexity, analysing DTOs is a challenging activity as well, most notably because of the problem of gaining overview of a large-scale operation.

As a way to investigate the challenges inherent in the analysis of DTOs, we conducted a case study that serves as an example of an organisation with a need to analyse these types of activities. The study context is the Swedish Defence Research Agency, FOI (see Study context 1.1). FOI uses an approach for analysing DTOs called the Reconstruction – exploration approach (R&E).\(^3\) FOI has given us the assignment to investigate if, and how, it is possible to integrate the R&E approach with other existing methods/approaches for cognitive analysis of complex work.

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\(^1\) Christiansson (2001)

\(^2\) Dekker & Hollnagel (1999)

\(^3\) Albinsson et al. (2005)
1.1 Study context

Military and civil operations in event of war, crises or stress, are by nature complex and demanding. The personnel must often work under hard time pressure, and sometimes in life threatening conditions. It is necessary that the personnel get the opportunity to reflect on their behaviour in the operation and on the type of operation. Unfortunately it is very hard to reconstruct this objectively, and for the involved persons to reflect upon their own actions due to for example memory loss, difficulties to articulate an action, and different perspective. Studying human behaviour in complex situations is extremely difficult.  

When studying a situation, the mental decision process is important. It is the mental process that gives meaning to the observable actions, which is one of the aspects that make it so difficult to study complex situations. The increasing use of technology at work, and the reductions of personnel in many industries have made the role of cognition very important. People’s jobs have become more difficult because they are less involved directly with the process, but when they are, it is in more critical ways. This leads to a desire to develop more powerful techniques of identify workers’ cognitive processes, to reduce the risk of human errors.

FOI works with analysis of complex situations, for example military actions. To facilitate this work, FOI has developed an approach for cognitive analysis of DTOs, the Reconstruction – exploration approach (R&E) for the purpose of exploring mission histories. A mission history is a time-synchronized, event-based, multimedia model of a mission, based on relevant data about the participating units and their activities during an operation. It can be applied to both military operation and in emergency management. The data that build up the mission history come from a variety of sources including communications, unit movements, annotated photos and video, observation protocols, and support system log files.

The R&E approach is divided into two parts, reconstruction and exploration (Figure 1). The reconstruction activity aims to construct a conceptual model of an operational scenario and then fill the model with live data from a real
operation resulting in a mission history. The exploration phase involves the use of the multimedia mission histories for reflection, discovery, and analysis.\(^9\)

![Figure 1 Overview of the steps of the R&E approach.\(^{10}\)](image)

FOI has developed a presentation and analysis multimedia framework, called MIND\(^{11}\), for the purpose of exploring mission histories and which is used in the exploration phase. According to Albinsson et al. MIND uses time as the primary navigation and coordination mechanism and data from different sources collected during operation, for example maps, observation, communication, and log files. These are presented on a timeline. When the user of MIND selects a time point in the mission history, MIND constructs the state of the mission at that point from the data available in the mission history.\(^{12}\) One of FOI’s goals is that the operation personnel should be able to evaluate their own actions with help from objective collected data presented in MIND. The aim with a mission history is to lift the discussion from what happened to why it happened.\(^{13}\)

The researchers at FOI are aware of that the R&E approach currently does not cover all the needs for analysis of DTOs. The R&E approach and MIND lack defined analysis methods and technical support for coding and other fundamental activities in qualitative analysis. The R&E approach has a rich contextual approach, but lacks a systematic analytic methodology.\(^{14}\) These shortcomings constitute the reason for the study presented in this thesis. We will investigate if it is possible to improve the existing R&E approach, for example through a merge with other existing methods for cognitive analysis. Other scientists have also seen the possibility to enhance a method by

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\(^9\) Morin (2002a)
\(^{10}\) Albinsson, Morin, Thorstensson (2004), page 2 (remodelled)
\(^{11}\) MIND is a Swedish name, not an acronym
\(^{12}\) Albinsson et al. (2005)
\(^{13}\) Albinsson (2005-06-28) Interview
\(^{14}\) Albinsson et al. (2005)
merging different methods, with different qualities, to get a better method that suits a special purpose.\textsuperscript{15}

One way of improvement would be to integrate several cognitive analysis methods based on their individual strengths. We will start by analysing the R&E approach, and then look for qualities in other methods that can complement the R&E approach. Finally we will hopefully develop an integrated method. The reasons why we have chosen to look at the alternative to integrate the R&E approach with other existing methods, rather than develop a new method from scratch, is that the R&E approach has many advantages that are desirable to keep. We have also seen that other methods might have qualities that could complement the R&E approach.

Present cognitive analysis methods lack in their ability to reconstruct the context in complex situations. The traditional methods may miss, for instance, critical incidents, multiple perspectives, and communication and coordination activities.\textsuperscript{16} In contrast, the R&E approach and the multimedia framework, MIND, provides possibilities for reconstructing the context of an event. On the other hand, the present MIND framework provides no support for structuring and analysing data, which cognitive analyses methods do.\textsuperscript{17}

1.2 Purpose

The purpose of the study is to explore the possibility to extend the R&E approach to support a more complete way of analysing data, and to gain knowledge about merging different cognitive analysis methods. In the same time we can show how existing cognitive analysis methods can be enhanced to, for example reconstruct entire contexts when analysing distributed tactical operations. In the study, several methods for analysis of qualitative data will be studied on the basis of certain criteria, to investigate integration possibilities, and development requirements concerning the existing R&E approach and MIND framework.

\textsuperscript{15} Moon (2004)
\textsuperscript{16} Woods (1993)
\textsuperscript{17} Albinsson et al. (2005)
1.3 Research questions

In specific the study sets out to answer the following questions:

Main question:

- How can an existing cognitive analysis method be enhanced and possibly merged with other existing cognitive analysis methods to better suit the analysis of distributed tactical operations?

- What knowledge is gained by merging existing cognitive analysis methods?

Sub questions:

- What are the possibilities and challenges for integration between the Reconstruction – exploration approach and other methods for cognitive analysis?

- In the light of a merger, what is the development needs concerning the methods in the Reconstruction – exploration approach?

1.4 Delimitations

We plan to study a selection of the most common methods for cognitive qualitative analysis; we do not intend to map out all existing methods. We also delimit the selection mainly to methods that aim at the analysis of complex socio-technical work.

We will look at FOI’s needs when we study the possibilities for integration between different methods for cognitive analysis, but the results might be generalisable to a larger audience, e.g., in the domain of cognitive analysis of other complex work.

We will concentrate on studying the possibility that involves integration between existing methods. We do not intend to investigate all possible ways to develop an approach for analysing DTOs.
The reason why we only investigate the framework MIND and no other tools for analysis methods is that it is hard to separate the R&E approach from its framework MIND and their developments are dependent on each other.

We choose to use the words method and approach as synonyms for the reason that Albinsson (user of R&E) and Thorstensson (developer of R&E) use the words without difference.\(^\text{18}\)

1.5 Target group

Our immediate target group is FOI, which we aim to provide with an analysis of possible improvements of the R&E approach and directions for further development of MIND.

The second target group is those practically working with or performing research on DTOs that might have an interest to develop better methods for analysing DTOs.

We also believe that people studying information systems analysis at the University of Linköping might be interested in our work, as well as people who have a general interest in the subject.

1.6 Contributions

The purpose of the study is to explore the possibility to extend the R&E approach to support a more complete way of analysing data from DTOs. By mapping different cognitive analysis methods we have developed a special knowledge called, categorised knowledge.\(^\text{19}\) By analysing the R&E approach we identified its needs for development, which leads to “value knowledge”.\(^\text{20}\) This knowledge has then been used when integrating the R&E approach with existing cognitive analysis methods. Before the integration we analysed cognitive analysis methods to investigate their qualities. The results of the analyses lead to a characteristic knowledge.

The most important contribution is normative knowledge. By integrating the R&E approach with three other existing cognitive analysis methods we have created a new method for analysing DTOs.

\(^{18}\) Albinsson (2005-06-28) Interview, Thorstensson (2005-09-07) Interview

\(^{19}\) Goldkuhl (2002)

\(^{20}\) Ibid.
1.7 Outline

Part I: Introduction, Theoretical background & Methodology

Chapter 1: Introduction
Chapter 2: Theoretical background
Chapter 3: Methodology

This part of the thesis consists of an introduction to the subject, which includes a presentation of the study context, the purpose of the thesis etc. This part also presents the background of the subject to make it easier for the reader to understand further research. The last chapter is the methodology, which explains how we, as researchers, have been thinking during working with this thesis.

Part II: Theoretical approach

Chapter 4: Framework for cognitive analysis methods
Chapter 5: Presentation of methods for cognitive analysis

The first chapter, the framework for cognitive analysis methods, consists of an explanation how to perform a cognitive analysis. The second chapter presents the methods for cognitive analysis that later will be analysed in part IV.

Part III: Presentation and Analysis of the R&E approach

Chapter 6: Presentation of the R&E approach
Chapter 7: Analysis of the R&E approach
Chapter 8: Results of the analysis of the R&E approach

Part III begins with a detailed presentation of the R&E approach and MIND, followed by an analysis of the R&E approach. The last chapter presents the result of the analysis, which later will be the base for the analysis of the other cognitive methods.
Part IV: Initial analysis

Chapter 9: Analysis of methods for cognitive analysis
Chapter 10: Choice of methods

Part IV of the thesis consists of the analysis of the methods for cognitive analysis that were presented in the theoretical approach. Part IV ends with a choice of which of the analysed methods that can be a question for a possible integration with the R&E approach.

Part V: Deeper analysis and Integration

Chapter 11: Detailed presentation of the methods of choice
Chapter 12: Analysis of CDM
Chapter 13: Integration
Chapter 14: Result of the integration
Chapter 15: Discussion

Part V begins with a detailed presentation of the methods that we have chosen in chapter 10 followed by a deep analysis of the methods. Chapter 13 presents the integration process between the cognitive methods of choice and the R&E approach. Chapter 14 describes the results of the integration, which later is discussed in chapter 15.

Part VI: Conclusions and Reflections

Chapter 16: Conclusions
Chapter 17: Reflections

The last part begins with the conclusions of the research where the questions of research are being answered. Part VI ends with a chapter were we reflect on the research and the results, as well as on further research. We also provide FOI with recommendations about further developments of MIND.
### 1.8 List of concepts in short

In this section concepts that are used in the thesis are defined and referred to the subject of cognitive analysis methods.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td><strong>CDM</strong></td>
<td>Critical Decision Method</td>
</tr>
<tr>
<td><strong>CIT</strong></td>
<td>Critical Incident Technique</td>
</tr>
<tr>
<td><strong>Cognitive analysis method</strong></td>
<td>To understand performance in complex and critical dynamic work situations.(^{23})</td>
</tr>
<tr>
<td><strong>CTA</strong></td>
<td>Cognitive Task Analysis</td>
</tr>
<tr>
<td><strong>CWA</strong></td>
<td>Cognitive Work Analysis</td>
</tr>
<tr>
<td><strong>DTO</strong></td>
<td>Distributed Tactical Operation</td>
</tr>
</tbody>
</table>

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\(^{21}\) Hoffman et al. (1998), Klein et al. (1989)  
\(^{22}\) Welker (2003)  
\(^{23}\) Woods (1993)  
\(^{24}\) Schraagen, Chipman & Shalin (2000)  
\(^{25}\) Vicente (1999)  
\(^{26}\) Albinsson et al. (2005), Morin & Albinsson (2004)
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA</td>
<td>Emergent Theme Analysis</td>
<td>A method to identify, structure and index voluminous CDM interview data.(^{27})</td>
</tr>
<tr>
<td>GT</td>
<td>Grounded Theory</td>
<td>A method for qualitative analysis that can generate theories in an inductive way.(^{28})</td>
</tr>
<tr>
<td>MIND</td>
<td>A Swedish name, not an acronym</td>
<td>Visualization multimedia framework for presentation of mission histories.(^{29})</td>
</tr>
<tr>
<td>Mission history</td>
<td></td>
<td>A time-synchronized, event-driven multimedia model of a mission.(^{30})</td>
</tr>
<tr>
<td>NDM</td>
<td>Naturalistic Decision Making</td>
<td>NDM specifically addresses high stress, and incomplete knowledge that characterize real-world, complex environments.(^{31})</td>
</tr>
<tr>
<td>Sociotechnical systems</td>
<td></td>
<td>A system composed of technical, psychological, and social elements.(^{32})</td>
</tr>
<tr>
<td>WWM</td>
<td>Wagon Wheel Method</td>
<td>A method to explicate how teams communicate(^{33})</td>
</tr>
</tbody>
</table>

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\(^{27}\) Wong & Blandford (2002)
\(^{28}\) Lundahl & Skärvad (1999)
\(^{29}\) Albinsson et al. (2005)
\(^{30}\) Morin (2002a)
\(^{31}\) Bryant (2002)
\(^{32}\) Vicente (1999)
\(^{33}\) Moon (2004)
2 Theoretical background

In this chapter, the background of relevance to the study is presented, like command and control in distributed settings, decision making, and a general description of analysing of complex work.

2.1 Command and control in distributed tactical operations (DTOs)

Command and control is a fundamental activity in DTOs such as military missions, emergency response and crisis management. Tactical operations are generally used in different organisations to indicate the level of activity. Command and control work is highly dynamic and highly uncertain. It involves countless entangled subcomponents and comes with great risks, time pressure, feedback delays and interdependencies. These elements all contribute to the complexity of a tactical operation.

Morin uses NATO’s definition when he describes command and control: “The exercise of authority and direction by a designated commander over assigned forces in the accomplishment of the force’s mission.” Command and control is further described as a large system of humans and artefacts, operating in a hierarchy. Command and control work is difficult, with units and people scattered over large geographical areas performing multiple sets of parallel activities to achieve common goals. The artefacts can be ranged from simple paper maps to advanced technical devices for communication and computerised information systems. A person at one specific level in the hierarchy uses the artefacts to command and control their sub-ordinate units, to report to and receive orders from, and to cooperate with the side-ordered units. Systems like this, involving humans and artefacts, can be described as joint cognitive systems. The nested structure is typical for traditional command and control where each node will be a part of other joint cognitive systems that are formed by the units’ structure that were mentioned before. This means that all units are connected to each other in varying degrees.

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36 Morin (2002a) sid. 44
37 Albinsson (2003), Morin (2002a)
To study DTOs, it is important to capture events in a relevant and realistic context.\textsuperscript{40} It is difficult to get an overview of distributed activities and to capture the implicit command and control process. To accomplish this task, analysts must use multiple sources of data and find ways of making sense of the large amount of data collected.\textsuperscript{41}

Communication is crucial in the command and control of DTOs. In such environments commanders, team leaders, and specialists must exchange plans, procedures, reports, and orders to organise and synchronise their work.\textsuperscript{42} These messages are essential for a successful result of an operation and they provide an observable trace of how key actors have perceived the emerging situations and what decisions they have made.\textsuperscript{43}

2.2 Decision making in critical situations

Normaly decision making is a process of choosing among alternative courses of action for solving complicated problems where multi-criteria objectives are involved.\textsuperscript{44} But this is not the case when it comes to making decision in critical situations where the decision maker operates under other circumstances than in normal situations, for example time pressure.

Decision making in critical situations is a vital part of command and control activities. There are several theories about decision making, but we have chosen just to present one of them, Naturalistic Decision Making (NDM). The reason of choice is that NDM specifically addresses the sort of conditions, high stress, and incomplete knowledge that characterize real-world, complex environments. These characteristics make NDM a useful theory for studying DTOs.\textsuperscript{45}

Klein presents eight factors that characterize decision making in naturalistic settings and which contribute to the complexity of the decision making process. The first factor is that in a complex situation, there is often no clear, well-defined problem so the decision maker has to begin with forming an opinion of the situation (1). At the same time the information that the

\textsuperscript{40} Woods (1993)
\textsuperscript{41} Morin (2002b)
\textsuperscript{42} Morin & Albinsson (2004)
\textsuperscript{43} Ibid.
\textsuperscript{44} Tran, Jain & Abraham (2004)
\textsuperscript{45} Bryant (2002)
decision maker has to proceed from is often ambiguous and maybe of a very poor quality. The environment may also change quickly, like in a situation where there is a fire (2). It is also rare that there is a single, well defined, goal in a real situation. The decision maker might have access to information that are of different versions and that sometimes even contradicts each other. An example is a fire fighter that wants to save a building, but in the same time he knows that it would imply severe danger to his crew (3). There are also often series of events that the decision maker has to deal with and there are several ways to solve the problem (4).

Decisions are also often made under time pressure, which can lead to personal stress and exhaustion. There is a risk that the user loses vigilance and that he or she use less complicated strategies when under time pressure (5). In critical situations, the high stakes involved affect participants who are likely to feel stressed, but who will take on an active role in arriving at a good outcome (6).

There is often multiple decision makers involved in the same problem. This can be a problem, because it can be hard for the team members to share the same goal and situational status so that relevant information is brought forward when needed in the decision process (7). It can be difficult to incorporate an organisation’s values because they might not correspond to the personal preferences of the individuals involved, and the organisation may respond to the decision maker’s various difficulties by establishing more general goals, rules etc. (8).

There are other factors that influence how persons make decisions beside the eight factors described above. Different individuals can make decisions in different ways, for example depending on how experienced he or she is.47 Experts have an excellent knowledge in their own domain, which makes them able to see information as chunks of information, rather than individual pieces. This enables them to see patterns in the information and to “see the invisible”.48 To “see the invisible” means to see patterns and anomalies. Experts have situation awareness that novices lack. Further more, the experts are aware of their own limitations.49 Experts also try to understand the

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46 Klein et al. (1993)
47 Klein et al. (1993), Klein (1998)
48 Hutton & Klein (1999)
49 Klein (1998)
problem than novices do. The novices often begin to operate on the surface before understanding the problem.\textsuperscript{50}

It is common that people cannot explain what they have noticed in a critical situation, why they made certain decisions etc. This phenomenon is related to the concept of intuition. Intuition concerns recognizing things without knowing how one went about it. Intuition is often based on profound experience that provides the decision maker with a firm set of patterns that he or she matches with the current situation, consciously or unconsciously.\textsuperscript{51}

Another aspect that functions as a base for decision making is a person’s capability of mental simulation. Mental simulation is the ability to imagine people and objects and then transform them through several transitions, and finally picture them in a different way than at the start. Mental simulation helps us to explain the cues and information we have received so that we can figure out how to interpret a situation and diagnose a problem.\textsuperscript{52}

Understanding how people make decisions in actual, operational environments makes it possible to provide developers with useful insight into how systems should be designed to support the users.\textsuperscript{53} Many scientists have struggled with the problem to reconstruct entire contexts in complex situations. An example that tries to capture the whole context is the R&E approach and the framework MIND. The goal of R&E is to lift the discussion about a mission from what happened to why it happened\textsuperscript{54}, and to be able to do this, it is of great advantage to know how people make decisions in critical situations. R&E focuses on objective data to reconstruct a situation and says little about how people make decision in complex situations.

2.3 Analysing complex situations

In parallel with the development of the naturalistic decision theory, analysis methods falling under the name Cognitive Task Analysis techniques (CTA) were developed.\textsuperscript{55} Such methods are used to understand people’s decision making, and to model complex work and systems. Analysing complex

\textsuperscript{50} Hutton & Klein (1999)  
\textsuperscript{51} Klein (1998)  
\textsuperscript{52} Ibid  
\textsuperscript{53} Wong & Blandford (2002)  
\textsuperscript{54} Albinsson el al (2005)  
\textsuperscript{55} Zachary, Ryder & Hicinbothom (1998)
situations involves the analyst developing a dynamic description of a person’s thinking and reasoning in relation to an evolving work situation or incident. In these situations, not only information becomes available, but also changes due to variations in the work environment. Identifying the person’s or the team’s cognitions in these situations is both important and difficult. Also within a complex environment there may be a variety of equally valid work strategies that can be employed to achieve the same work goal. In addition to this qualitative approach, it is often desirable to develop a context about the situation this can be done by selecting measures from objective data, for example observations or records.\textsuperscript{56} Woods believes that there are techniques for examining complex settings that fall between descriptive field observation and narrow laboratory experimentation.\textsuperscript{57} Field observation is a valid, meaningful technique. For example it is necessary to establish the mapping between target and test situation, and to make decisions about what manipulations to use in the test situation to make observable the phenomenon of interest while preserving the basic character of the target situation.\textsuperscript{58}

To handle the difficulties with command and control in DTOs and decision making in critical situations, FOI has developed the R&E approach, which is an example of an approach that analysis DTOs. The R&E approach focuses on making an objective reconstruction of a complex situation for the purpose of exploring mission histories. The R&E approach also focuses on reconstructing the entire field operation and do not present a detailed model of a special situation.\textsuperscript{59} In DTOs, contextual data is very important to effectively interpret communication data in relation to the relating course of events.\textsuperscript{60}

\textsuperscript{56} Patrick & James (2004)  
\textsuperscript{57} Woods (1993)  
\textsuperscript{58} Roth et al. (2003)  
\textsuperscript{59} Morin (2002a)  
\textsuperscript{60} Albinsson et al. (2005)
3 Methodology

In this chapter the scientific approach of this thesis is presented, as well as our way of working. The purpose with this chapter is to give you, as a reader, an understanding of how we have been thinking and working with this thesis.

3.1 Scientific approach

The scientific approach chosen declares our opinions and decisions about the thesis; our opinions about whether it is possible or not to reach the absolute truth, our pre-understanding, and so on.

3.1.1 Positivism and hermeneutics

There are mainly two different scientific approaches, positivism and hermeneutics. Positivism has been a part of science since the beginning of the 19th century when Comte (1844) for the first time introduced the concept.\(^{61}\) Central in positivism is the existence of a true reality, which we can acquire knowledge from by observations.\(^{62}\) The positivists uphold that there is a reality which is free from judgement and which consists of true knowledge, which is objective. According to this idea of the reality, the social sciences should oppose to everything that is not real and observable. This reality is independent of who studies it, and the scientists within positivism should be neutral and impartial. The scientist should not participate in the science, only act as an observer.\(^{63}\)

Hermeneutics is based on the assumption that we always understand things in a special way on the basis of our background and experiences. When we approach a phenomenon we always bring an amount of pre-understanding that affect the process of understanding. We never meet the world unbiased. These prerequisites are more known as comprehension or prejudice. Pre-understanding is necessary for understanding the phenomenon.\(^{64}\)

The word hermeneutics originates from the Greek mythological character Hermes, who was the Gods’ courier. Hermes interpreted the Gods’ indistinct

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\(^{61}\) Alvesson & Sköldberg (1994)
\(^{62}\) Patel & Tebelius (1987)
\(^{63}\) Lundahl & Skärvad (1999)
\(^{64}\) Gilje & Grimen (1992)
messages, to the people so that they become understandable. Later in the history, the concept was used as a method for bible interpretation, a sort of exposition of the contents. Through this understanding, interpretation and searching for a message is a fundamental part in the hermeneutic science viewpoint.

During the 19th-century hermeneutics started form as a scientific theoretical platform in a way of explaining human phenomena. Hermeneutics dissociated with the positivistic thoughts and believed that knowledge about people and knowledge about the nature were two different things. The hermeneutic believe that it is not possible for the scientist to be objective. They also think that the scientist should be engaged and participate in the process of science.

As authors to this thesis we are of the belief that it is not possible to find a truly, generally applicable and objective truth. We do not think it is possible to consider all aspects of a phenomenon in a research study (but we will try), which makes it impossible to find the absolute truth, and therefore we join the hermeneutics ideas. We do not endeavour to find any positivistic truths. We will use our knowledge and pre-understanding as a resource to understand and interpret the area we study. By clarifying our pre-understanding we, as researchers, become more aware of what factors that can affect our interpretations. We also think that it is important that the readers are aware of our pre-understanding to be able to understand and criticise what we write. Under heading 3.1.2 we clarify our pre-understanding and how it can affect the research.

To see the phenomenon in its context is accentuated in hermeneutics. In contrast to natural science, the hermeneutics do not consider accomplishing knowledge by reduction. The meaning of a part of the phenomena can only be understood if it is related to the wholeness. Conversely, the whole consists of parts; hence it can only be understood on the basis of these. This is illustrated in the hermeneutic circle, which shows that parts only can be identified in its entirety and the entirety is identified through the parts. By switching between approaching the whole phenomenon and its parts, a more

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65 Starrin & Svensson (1994)
66 Patel & Tebelius (1987)
68 Lundahl & Skäravad (1999)
69 Alvesson & Sköldberg (2000)
thoroughly understanding for the final phenomenon is given. In our work, it is important that we sometimes take a step back to reflect and change perspective for a deeper analysis of the subject. A simple and effective way of doing that is to discuss issues with each other. We will also design our interview questions by the hermeneutic circle so that they illuminate both the entirety and the parts of qualitative analysis methods.

3.1.2 Our pre-understanding

We believe that our pre-understanding is coloured by the way we are used to think at the university, where we assume that there exist clear and concrete theories to use. During our education we have applied different methods as a way to analyse a particular situation and to come to conclusions. We believe that using a method is a good way to support the analysis that we perform. The methods help us to accomplish a study in a structured way. We also think that using a method for analysis gives the result a higher validity because it is easier for the reader to see how we have reached conclusions. Nevertheless, we believe that one disadvantage with using a method for analysis is that it can be too strict and nonflexible, which can be a hindrance for the research, especially if the methods that we use for analysis not exactly suit the method we analyse.

We do not have much former knowledge in the subject of cognitive analysis methods and analyses of DTOs, but we have experience of working with for example analyses of organisations. These experiences have given us an analytical way of thinking which will be an advantage when analysing cognitive methods.

We have briefly studied the methods that are available for analyses of DTOs, and we think that this field is very complex. Every method has its own advantages and disadvantages and we have identified needs to integrate several methods to help create a more complete method with better qualifications to create a better awareness of the situation.

During the research we will study articles about the subject and even if we do not use all the material we gather and study, we will develop our

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70 Alvesson & Sköldberg (1994)
71 Bell (2000)
understanding during the work, which will help us later in the working process.

We know that our pre-understanding for analysis methods will change over time while working with the subject. Right now we have one pre-understanding but when studying the subject our pre-understanding will probably change. In other words we will change between our pre-understanding and comprehension like the hermeneutic circle.

### 3.1.3 Qualitative and Quantitative methods

There are two different approaches in research for how to gather and analyse data, and these are the qualitative and quantitative approaches. Qualitative research is a study that consists of qualitative data, for example interviews. A qualitative analysis set out to describe, analyse and understand an individual or a group of individuals and the world they live in. Qualitative researches lead to processes of interpretations. The scientist can for example look for similarities and differences between the theory and the empirical data or investigate whether the interpretation can be related to other interpretations of the same phenomenon.

Quantitative research is a way of working that has its roots in natural science. In quantitative research, the scientist collects data and studies the relationship between them. Then he or she uses different methods to achieve results that are quantifiable, for instance statistics. Quantitative researches strive to attain objectivity which leads to that scientist often trust instruments rather than observations or interviews that require interpretations.

We will use a qualitative way of working because we do not have the intention to measure the data. We want to understand the phenomena; cognitive qualitative analyses methods for DTOs, and see how these can be integrated and practiced. We will do some interpretations that most likely will be coloured by our pre-understanding. However, we have described our pre-understanding above, so the reader is aware of how we think when we do the study.

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72 Lundahl & Skärvad (1999)
73 Ibid.
74 Patel & Tabelius (1987)
75 Bell (2000)
76 Patel & Tabelius (1987)
3.1.4 Triangulation

The idea of triangulation is that, with help of different kinds of methods, it is possible to better determine a particular phenomenon. For instance, one can combine qualitative and quantitative methods, which is an example of method triangulation.\(^77\) It gives trustworthiness if the results are similar despite different techniques and analyses approaches.\(^78\) Data triangulation can be achieved by gathering information from many different informants and sources. The data are then compared and the scientists can confirm certain occurrences. Triangulation gives a higher trustworthiness.\(^79\)

In our work with this thesis, we will strive for data triangulation. In our theoretical approach we study different sources to be able to compare different methods and create a trustworthy material. When we collect our empirical data, we will include interviews with experts of methods for qualitative analysis, literature studies and, our own practical experience. This gives us a strong starting point for reaching conclusions with trustworthiness.

Another type of triangulation is the use of more than one author, as we have chosen to do. The learning process can be improved when we support and encourage each other, and if we have an open discussion as well, mistakes can be discovered and corrected which will raise the quality on the finished product.\(^80\)

3.1.5 Relation between theory and empirical studies

A scientist can choose from different approaches to relate theory to empirical studies. There are mainly two different approaches, deduction and induction.

Working deductively means to subject a hypothesis to empirical study. The scientist needs to specify what data can be collected in relation to the concepts that make up the hypothesis. Theories come first and drive the

\(^77\) Alvesson & Sköldberg (2000)
\(^78\) Patel & Tebelius (1987)
\(^79\) Bell (2000)
\(^80\) Ejvegård (2003)
process of gathering data.⁸¹ By working deductively means that you mainly associate with positivism and the quantitative way of working.⁸²

Induction is the opposite of deduction. The researcher concludes his or her findings, the findings are fed back into the stock of theory and the research findings associate with a certain domain of inquiry.⁸³ By working inductively, the scientist follows the way of discovery and do not consider available theories. The survey starts with a study object, which the scientist creates new theories from.⁸⁴

As a summary; when working deductively, the theory rules the data collection, while working inductively; theory is the outcome of the research. It is common to think that research is either deductive or inductive, but that is mostly not the case. It is better to think at deductive and inductive as tendencies rather than as a fast distinction.⁸⁵

In this thesis, we will work in a way where we change between working inductively and deductively. Some of the chapters will tend to be inductive while some chapters will be characterised as more deductive.

In the chapter where we investigate the needs of the R&E approach and MIND by analysing the approach, we will work inductively. We start by interviewing developers and users of MIND and the outcome will be conclusions; in this case requirements for further developments of the R&E approach.

In other chapters, we will work more deductively, for example in the chapter where we study existing theories of different methods for analysis of qualitative data. We will start with the hypothesis that the methods can be integrated with the R&E approach and that they have strengths that can complement the shortcomings of the R&E approach. By studying the theories of the different methods and then analyse them, we will see if the strength of each method can complement the weaknesses of the R&E approach.

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⁸¹ Bryman (2004)  
⁸² Lundahl & Skärvad (1999)  
⁸³ Bryman (2004)  
⁸⁴ Lundahl & Skärvad (1999)  
3.2 Practical approach

Our practical approach is presented below. It includes literature reviews, interviews, evaluations and a presentation of the method we will use when we analyse the cognitive methods.

3.2.1 Case study

A case study is expected to catch the complexity of a single case. In a case study one looks for the details of interaction with its contexts. It is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances. The case study is one of many ways of doing social science research. Each strategy has advantages and disadvantages. In general a case study prefers a strategy posing “how” or “why” questions. A case study is more a way of understanding a context rather than explaining it.

The case study is associated with qualitative research, but such identification is not entirely appropriate. It is true that the qualitative methods are favoured in a case study, however the case study can both employed by quantitative and qualitative research.

The case study is a way of investigating an empirical topic by following a set of pre-specified procedures. The case study is used in many situations to acquire knowledge of individual, group, social, and political phenomena. A case study investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly obvious.

We have chosen to perform a case study at FOI, because FOI is an example of organisation that has a need to merge existing cognitive analysis approaches. They have a need to modify the R&E approach and its units of analysis to improve its ability to support the analysis of DTOs. In specific, our case is to analyse methods for cognitive analysis, including the R&E approach, for a possible integration. The case also includes the integration process between the R&E approach and other methods for cognitive analysis.

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86 Stake (1995)
87 Yin (2003)
89 Yin (2003)
3.2.2 Literature review

We perform our literature research by reading scientific articles, but also by reading books, doctoral and licentiate-theses. It is important that we create an overall picture of the subject and sift the literature that is relevant for our study. This is vital for receiving a good result. Ejvegård describes the difficulties of finding theories of interest. He recommends using the support many books and articles offer; abstracts, contents, glossary and keywords.90

We are aware of that it is impossible for us to read all the scientific articles about the subject, but to be able to do a good selection of the material, we will start reading the articles abstracts for prioritising further reading.

Many of the authors of the literature work, or have worked, at FOI, and we are aware of that this can decrease the credibility of the research. However, we do not think it is possible, or even desirable, to leave out these authors from the research because of their connection to FOI. They have a great knowledge and experience of the area that are invaluable for the research. Since we are aware of the risk of the decreasing credibility of the research, we will after finishing the research process by reflecting on this aspect in chapter 17 in part VI. We will discuss if the conclusions had been different if the literature were written of authors with no connection to FOI etc.

3.2.3 Interviews

We intend to conduct a study where we, among other things, interview experts of the R&E approach and MIND. The interviewees will be developers and users of the R&E approach and MIND. The purpose with the interviews will be to help us enter deeply into the subject and to function as a complement to the literature that we will study.

It is very important that we, as researchers, prepare the interviews carefully. We have to be clear about the research questions, and we have to decide what questions we need to ask. It is very important not to ask leading questions to the interviewee.91 How the questions in the interviews are formulated is very important and has great impact on the study.92

90 Ejvegård (2003)
91 Bell (2000)
92 Wärneryd (1990)
Since the study is of a hermeneutic character, it is important to see both the parts and the entirety of the phenomenon. To make this possible, our interviews will start with very general questions that reflect the wholeness of the area. The interview will then proceed with more detailed questions. In the end of the interview the questions will go back to be more general again. We believe that we, during the interview, will build up an understanding together with the interviewee so that the answers of the general questions in the end of the interview will be of another character than the answers of the general questions in the beginning.

There are different kinds of interviews that suit different purposes and they can be more or less formalised. The extremities are a structured interview where the interviewer asks the questions in a strict order and then registers the answers and the opposite, a non-structured interview where the questions are based on the interviewee’s answers. It is easier for the interviewer to arrange the answers if the interview is structured, but if the interview is too structured you risk to lose information. It is better to use non-structured interviews when the subject is unknown and the purpose with the interview is to get an overview of the area under discussion.

Our interviews will be semi-structured interviews, which are a mix between structured and non-structured interviews. We have some fixed questions but the interviewees will also be encouraged to express themselves freely. In this way we will be allowed to ask questions depending on the interviewee’s answers. The reason why we have chosen to do this kind of interview is that we believe that we will lose important information if the interviews are too structured. Since we are doing qualitative research we are not in need to measure the data from the interviews, we strive to understand the interviewee and how he or she experiences different situations.

If the interviewee allows us to record the interview, we will do that because we believe that it will be hard for us to take notes during the interview that totally covers the interviewee’s answers. It is also an advantage to record the interviews if we later wish to use a quotation from an interview.

In a shorter project there is no time to make more than a few interviews, which can lead to a distorted picture since you rely on very subjective data.

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93 Bell (2000)
94 Larsson & Ekström (2000)
It can also be hard to analyse the answer you get.\textsuperscript{95} If the person doing the interview has a strong opinion about the subject it is easy that the opinions can be reflected in the questions asked. We feel that this is a minor risk in our case, because we have not studied this subject before and therefore we do not have any strong opinions about the subject.

We will do interviews with experts of area, so called expert interviews. These expert interviews are used to generate information about the subject, and are not directly connected to our main question\textsuperscript{96}. Data from the expert interviews will together with literature be the foundation of our analysis of the R&E approach.

3.2.4 Evaluation

To identify strengths and weaknesses with MIND and the R&E approach we will perform interviews with experts that are described in 3.6.2, but we will also perform an evaluation of our own. This means that we will use MIND, and by working with the tool, identify its strengths and weaknesses. The purpose of an evaluation is to see if goals are reached. Before performing the evaluation, criteria are put up that are used during the evaluation.\textsuperscript{97} When we perform the evaluation of MIND we will use criteria that are based on the goals of the R&E approach and MIND. We will try to find problems that contribute to that the goals are not reached. We do not have that much experience of MIND that we are able to identify all the problems, but by combining the evaluation with the interviews, we believe that we will be able to find the primary weaknesses.

3.2.5 MA/SIMM

Methods are used as support for reaching certain goals, and to be successful, it is important to understand the methods. Methods consist of guidelines and definitions regarding; way of working, notation and concepts. Way of working suggest how the work should be done, what questions should be asked etc. The notation describes what kind of descriptions that should be made and rules for interpretations of these. The notation consists of semantics (what is described), form of symbol (how to express the

\textsuperscript{95} Bell (2000)
\textsuperscript{96} Larsson & Ekström (2000)
\textsuperscript{97} Lundahl & Skärvad (1999)
description) and syntax (how different descriptions can be combined). The concepts connect the way of working and the notation by being a part of both of them.\footnote{Goldkuhl & Fristedt (1994)}

To understand how the methods for qualitative analysis work and to help us choose what methods we should use for the integration process, we will use a meta-method called MA/SIMM. MA/SIMM will help us analyse each method so we can compare them and consider how they can be integrated with the R&E approach.

MA/SIMM is flexible for different situations and can be used for evaluation of other methods. MA/SIMM can also be used for further development of an existing method, and this is the reason why we have chosen to use MA/SIMM for our analyses. Göran Goldkuhl and Dan Fristedt at department of Computer and Information Science at University of Linköping, Sweden developed MA/SIMM in 1993.\footnote{Ibid.}

We intend to analyse several existing methods for qualitative analysis, explore possibilities for integration between different methods, and finally make further developments on the R&E approach. MA/SIMM is also contextual and concentrated on the organisation, which means that there is an ambition to see the methods, not only as “components”, but also as tools used by humans in different situations.\footnote{Ibid.}

**The structure of MA/SIMM**

MA/SIMM can be divided into three different areas that the method supports; diagnosis of the method, formulation of the measures and development of the measures. The most important parts of the method are the analysing and mapping. This part of the method is very dependent of the situation. Which parts that should be realised and in which order, depend on the purpose and the delimitations of the diagnosis of the method. Figure 2 gives an overview of the structure of MA/SIMM.\footnote{Ibid.}
Determining conditions: This means to choose the method that should be analysed, to formulate the purpose of analysis and to decide the level of ambition.

Analysis of the weaknesses: Here an inventory is made of the method’s weaknesses and the problems that occur when using the method. First an inventory of the weaknesses is made, followed by an analysis of the causes and effects.

102 Goldkuhl & Fristedt (1994, p. 9) (remodelled)
**Analysis of the strengths:** The purpose of this element is to identify the strengths, and then analyse the relations between the strengths.

**Analysis of the goals and perspectives:** This part of the analysis is divided into four steps. The first step has the purpose to understand the method, which means to study underlying approaches. Here you study important phenomena, such as how the methods are structured. You try to answer the question what should be achieved when using the method. The second step is to perform an analysis of the interests, which means to focus on different groups of actors that are related to the method. The last steps of this part focus on identifying the goals. The goals are then described and valued.

**Analysis of the way of working:** In this part you study the method’s areas and work operations and the relationship between them.

**Analysis of the documentation:** This element is divided into two steps; description of the notation and analysing the relations of the documentation. The description of the notation means to study the different parts of the notation that are mentioned above. The purpose of analysing the relations between the different forms of documentation is to understand the method.

**Analysis of the concepts:** The concepts are the “glue” between the notation and the way of working. A model is made that shows the notions in the method and how they are related.

**Analysis of the tools:** If a method is already implemented in a tool, it might be necessary to study that tool.

**Summarizing valuation:** This element contains a summary of the elements in the analysis and mapping elements. This summary can contain positive and negative aspects of the method, and what you think should be changed.

**Formulation of measures:** This element means for example to formulate suggestions for further developments of the method or combinations of methods etc.

**Design of methods:** This element will be accomplished if you decide to make further developments on a method. Here you perform an analysis of the goals and perspectives, the way of working, the documentation and the concepts.
Design of tools: This element will be accomplished if it is decided to make further developments of a tool for the method.

We will use MA/SIMM different depending on what type of analysis we do. In the initial analysis process, when we only strive for a quick and comprehensive picture of the analysis methods, we will only identify the methods’ strengths and weaknesses. In the deep analysis we will also identify the interest of the methods. In determining of the conditions the purpose of the analysis is declare. The purpose decides what qualities in the method that are strengths and weaknesses; sometimes a quality can be both a strength and a weakness.

The analyses of weaknesses, strengths and goals of a method are all carried out the same way. First they are identified and listed, and then the relationships between them are described in a graph. Figure 3 is an example of a list and a graph that shows the weaknesses in a method and the relations between them. The weakness in the bottom of the graph can be described as the main weakness, which is the result of the weaknesses above.

<table>
<thead>
<tr>
<th>List of weaknesses</th>
<th>Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Weakness</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>2. Weakness</td>
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<tr>
<td>3. Weakness</td>
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<td>4. Weakness</td>
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<tr>
<td>5. Weakness</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3 Example of how to identify the relations between the weaknesses

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103 Developed from Goldkuhl & Fristedt (1994)
3.2.6 Result of the practical approach

In the beginning of the work with this thesis we started out deductively with a literature study of the subject, cognitive analysis methods. We proceeded by studying literature about the relevant background of the subject like command and control work, critical decision-making, and how to analyse a complex situation. This is the foundation for our theoretical approach and also a way to change our pre-understanding for a deeper understanding of the subjects. The literature review also made it possible for us to identify the most common cognitive analysis methods.

We used the MA/SIMM method for the analysis of the R&E approach together with interviews and our own evaluation. The table below (Table 1) presents the interviewees.

Table 1 Presentation of the interviewee

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Position / role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pär-Anders Albinsson</td>
<td>Developer and user of MIND</td>
</tr>
<tr>
<td>Mirko Thorstensson</td>
<td>Developer and user of the R&amp;E approach and MIND</td>
</tr>
</tbody>
</table>

Pär - Anders Albinsson is one of the developers of MIND. He is going to develop a new version of MIND based on a modified version of the R&E approach. He is also one of the users of MIND, which makes him well acquainted with how MIND works as well as its weaknesses and strengths.

Pär - Anders Albinsson is one of our supervisors, which can be a problem when using him as a data source. We will make it clear for him that when we do the interview; his role is not as our supervisor but as developer and user of MIND.

Mirko Thorstensson is one of the developers as well as user of the R&E approach and MIND. He is project manager of a project in Enköping that involves adjusting the R&E approach to a distributed working area. Mirko Thorstensson has been working with the R&E approach and MIND from its origin.
Both interviews were semi-structured where the interviewees had time for reflection and where we as interviewers were able to ask additional questions. The interviews were recorded and later transcribed. The recordings made it easy for us to focus on the interview. The interviews were a complement to our theoretical approach and gave us a deeper understanding about the R&E approach before analysing it. For practical reasons we chose to do our own practical evaluation of the framework MIND, which also complemented the analysis of the R&E approach.

Our own practical evaluation was based on the interviews and articles about MIND. Our own experiences of using computer systems, from our university studies in information system analysis, have given us some knowledge too; for example, to decide what is useful functions and good usability.

The result of the analysis of the R&E approach gave us a clear picture about the qualities of the approach. It also gave us a number of criteria. The criteria together with our theoretical approach made the MA/SIMM analysis of the cognitive analysis methods possible. These initial analyses provided a quick and comprehensive overview of the methods, and enabled our choice of candidates for a possible integration. These candidates were also analysed with MA/SIMM. Our goal was to find a suitable method that covered R&E weaknesses, strengths and goals. This was an iterative process. Hopefully all this work will provide us with a method that can handle both analyses of a deeper character and provide an overview of the context.

Figure 4 illustrates the working procedure in this thesis. The arrows represent the knowledge gained from previous stages.
Figure 4 Working procedure and conditions of the practical approach
Part II: Theoretical approach

The theoretical approach provides a wider picture of what a cognitive analysis method consists of and how a merging between analysis methods can be possible. In this part we present a number of cognitive analysis methods to get a better overview of how they operate, and their strengths and weaknesses. Last we explore the reconstruction and exploration approach with a description of the approach and a MA/SIMM analysis of the approach to find its qualities.
4 Framework for cognitive analysis methods

Studying human behaviour in complex situations is extremely difficult and there are many methods for cognitive analysis. Before presenting some of these methods we will try to explain how a complex situation can be approached and analysed.

4.1 How to analyse a complex situation

To understand and analyse decision-making and problem solving outside psychology laboratory, like human cognition in natural settings in complex rich multifaceted settings, is different from a situation, which is simplified, Spartan and with single factor settings.104 Woods wrote about process tracing which is a way of analysing a person’s cognitive activities during complex work tasks, where the tasks may be real or simulated. Despite this way of working no single methodology has emerged from the literature.105 There are many ways of analysing complex situations and process tracing is just one way to structure the analysis.

In the field of cognitive analysis, there are a huge number of methods for studying socio-technical systems. Most cognitive analyses of an activity during complex tasks can be generated in four different stages.106

1. Collection of data
2. Transcription, integration and segmentation of data into a time-line account
3. Coding
4. Further analysis and representation of data from stage 3.

These stages describe the tasks confronting the analyst (Figure 5). The first three stages occur in order in most cognitive analyses methods for complex situations, whereas the last stage is optional, although it is usually completed. These stages vary among cognitive methods in number of stage and how they are labelled.107

104 Woods (1993)
105 Ibid.
106 Patrick & James (1994)
107 Ibid.
4.1.1 Data collection

The first stage (1) is the process of deciding the collection of data and how this should be accomplished. The most frequent forms of data are records of a person’s general actions and verbal reports, elicited either concurrently or retrospectively, and less frequently, their eye movements.\(^\text{108}\)

A **verbal report** from the task can be collected, either during or after the performance. Either through thinking-aloud protocols, where the participants are instructed to think aloud as they work or through retrospective verbal report or cued retrospective verbal reports.\(^\text{110}\) The interview can be performed after or during a work session. The verbal reports formed of collected data are used in many methods for cognitive analyses. Consequently verbal reports have been used extensively in field studies of work to examine the reasoning skills of operators and technical personnel controlling a complex industrial process. Many studies have been made about the validity of verbal reports, for example humans do not only rationalize about their cognitions, but also tend to be overconfident in the

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\(^{109}\) Patrick & James (1994)  
\(^{110}\) Crandall (1989)
extent to which their verbal reports are accurate reflections of their performance. Despite this some scientists argue that we should treat verbal reports as data and ask under what conditions they are valid.\textsuperscript{111}

**System states** include information about command and data inputs, state transitions of the system and time between keystrokes. System logs are useful because they are not intrusive and they are possible for automatic searches.\textsuperscript{112}

**General behavioural record** is a record of the actions taken by a person during a task such as troubleshooting or controlling. For example a video recording of a screen and keyboard can provide a record that can be evaluated afterwards. Behavioural records can be used for retrospective questioning of the task performer and this can facilitate the creation of verbal reports. The general behaviour record can also provide an important context for interpreting and coding a verbal report.\textsuperscript{113}

**Eye Movements** is growing as a technique to collect data. It is most effective when it is combined with other data. The use of eye movement data has been encouraged by the finding from several studies of a relationship between eye movement and aspects of task performance. More recently, some writers have suggested that eye fixation locations can be used to infer a person’s situation awareness in complex work situations. Despite some potential benefits of eye movement recording, the apparatus is both expensive and technically challenging to operate.\textsuperscript{114}

4.1.2 Transcription, integration and segmentation

The next step (2) in most cognitive analysis methods is transcribing the person’s recorded behaviour. Both physical and verbal behaviour are recorded into a timeline account. This step varies among the cognitive analysis methods, but the aim is to record physical behaviour actions in relation to the state of the work situation. The transcribed, integrated and time-lined account of the raw data provides the basis for further analysis.\textsuperscript{115}

\textsuperscript{111} Woods (1993)
\textsuperscript{112} Woods (1993), Patrick & James (1994)
\textsuperscript{113} Patrick & James (1994)
\textsuperscript{114} Ibid.
\textsuperscript{115} Ibid.
4.1.3 Coding

Stage three (3) in the process of cognitive analysing is encoding the transcribed data from the second step. This step is important because it imposes structure on the data and begins to sharpen the data according to some predetermined theoretical perspective. This stage can be divided into two stages according to how strong the theoretical base is. In more desirable situations the coding categories are imposed in a top-down fashion. In this situation the analyst encodes data of theoretical interest. On other hand, when the theoretical basis is weak, the coding must be a bottom-up fashion through exploration of the data. The two steps that are to be preferred is first a behavioural coding with minimum interference and can be described as some form of task analysis. The second encoding is aimed to identify a person’s cognitions during task performance.\textsuperscript{116}

There is no right or wrong when categorising transcribed data, thus there is a need for data selection and definition to be carefully considered, especially when the analysis is used in an exploratory rather than confirmatory mode.\textsuperscript{117}

4.1.4 Further analyses and representation

There are unlimited ways in which the coded data can be further analysed and represented. During this stage (4) the analyst is involved in filtering or expanding data from the coding stage. A variety type of further analysis and representation has been used. One further analysis is for example to see if the cognition of a worker is correct. It is also useful to quantify operators’ performance for generalizations.\textsuperscript{118}

There is a need to capture and represent a person’s reasoning during a scenario in relation to changes in the task and work situation. Diagrams are being used to illustrate how a situation can be changes by a persons’ action.\textsuperscript{119}

\textsuperscript{116} Patrick & James (2004)
\textsuperscript{117} Ibid.
\textsuperscript{118} Ibid.
\textsuperscript{119} Ibid.
4.2 Integration

Woods sees a problem with methods for studying complex situations like DTOS. Most methods only analyse one piece of a dynamic process and from that understands the whole procedure. If human behaviour is grounded in particular contexts then the phenomenon should be studied in these contexts. Then we need to understand the role of that context in information-process strategies, rather than always eliminate it from the task strategy.\textsuperscript{120} Albinsson et al. identifies the same problem and points out the need for contextual data, and the use of metadata together with an indexing, collating, structuring and distillation process.\textsuperscript{121}

There is a desire to develop more powerful techniques capable of identifying workers’ cognitions, so that the risk of potentially costly and catastrophic human error in industrial and medical contexts can be reduced.\textsuperscript{122}

4.3 Using computers to analyse qualitative data

Even though using computers for handling textual data has been available since the 1960s, it was not until early 1980 that qualitative researchers discovered the advantages in using computers to assist them in their work with qualitative data.\textsuperscript{123} Using computers for analysing qualitative data has many advantages, like speed at handling large volumes of data and by freeing the researcher to explore numerous analytic questions. An advantage is that it can help the researchers to demonstrate their result based on rigorous analysis.\textsuperscript{124}

Several decision support systems have been developed in various fields, like medical diagnosis, business management, control systems and command and control of defence and air traffic control. The need for an intelligent mechanism for decision support comes from the well-known limits of human knowledge processing. It has been noticed that the need for support for human decision makers is due to four kinds of limits; cognitive, economic, time and competitive demands.\textsuperscript{125} To extract human knowledge into a database the knowledge must be analysed and converted into an

\textsuperscript{120} Woods (1993)  
\textsuperscript{121} Albinsson et al. (2005)  
\textsuperscript{122} Woods (1993)  
\textsuperscript{123} Kelle (1997)  
\textsuperscript{124} Silverman (2005)  
\textsuperscript{125} Tran, Jain & Abraham (2004)
information table. People often express knowledge as spoken language or using letters or symbolic terms.\textsuperscript{126} There are several methods to extract human knowledge into an information table; some are explained in chapter 5.

\textsuperscript{126} Tran, Jain & Abraham (2004)
5 Presentation of methods for cognitive analysis

Many techniques for analysing human cognitive processes and decision making have been developed. The methods used must be selected, or developed, to meet the specific needs of the analysis. In this chapter we will present a number of methods for cognitive analysis that could be possible candidates for an integration with the R&E approach.

The picture below (Figure 6) shows the analysis methods we shall present in this chapter. The reason for choosing these methods is because we wanted a range of quite different analysis methods that seemed suitable for a possible integration with the R&E approach for analysis of critical situations, like DTOS. Some of the methods are better known and some are more general than others. The picture also shows how the different methods are related. The x-axis shows the characteristic of each method. To the left are the more subjective methods and approaches, which focus on specific incidents and to the right are more objective methods and approaches, which create an overview of the operations. The vertical line separates the existing cognitive analysis methods from FOI’s R&E approach.

![Figure 6 Mapping of methods for cognitive analysis](image)

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127 Zachary, Ryder & Hicinbothom (1998)
128 Self constructed based on literature
5.1 CTA

Cognitive Task Analysis (CTA) is a collective name of different methods for analysing and modelling the cognitive process that give rise to human task performance in specific domains.\textsuperscript{129} The product of the CTA can be used in the development of training and system design.\textsuperscript{130} CTA is an extension of traditional task analysis techniques to receive information about the knowledge through processes and goal structures that underlie observable task performance.\textsuperscript{131} The CTA is a method to identify cognitive skill and mental demands. CTA can also identify needs for performing task proficiency for extracting the human knowledge.\textsuperscript{132}

CTA is suitable for identifying decision requirements because CTA methods are designed to examine cognitive processes, to understand how people make judgements and decisions, and to uncover strategies the operator might not be able to articulate.\textsuperscript{133}

CTA has been used for eliciting trainee and expert mental models that in turn have been used in attempts to predict performance. Other examples include studies of team decision making, developing training and decision aids, preserving corporate knowledge, and identifying workstation and interface features that facilitates decision making.\textsuperscript{134}

The technique is based on collecting and analysing data from observations and interviews.\textsuperscript{135} In order to conduct a cognitive task analysis, it is necessary to have a set of constructs that are to be identified and described, and a notation with which to describe them.\textsuperscript{136}

5.2 CWA

Cognitive Work Analysis (CWA) is different from cognitive task analysis. CWA is a technique to analyse, design and evaluate human-computer interactions.
interactive systems. Rasmussen, Petjersen and Goodstein outlined CWA when a training system for an advanced aircraft was going to be developed. CWA includes issues unique for training and instruction in contrast to some other methods. A characteristic of CWA is that it focuses on identifying the complexities and constraints of the work domain that serve to shape and constrain the behaviour of domain practitioners. In many cases CWA has been utilized to guide the redesign of the human-system interface for newly automated systems, or to develop information systems or decision aids to support a set of tasks where such support did not previously exist. While the analysis activities of CWA have a broad scope, its primary focus is on the work domain.

CWA can be divided into five phases of analysis; work domain analysis, control task analysis, strategies analysis, social organisation and cooperation analysis, and worker competencies analysis. Work domain analysis (1) is one of the most important phases in CWA. A work-domain representation describes the structure of the controlled system independent of any particular worker, automation, event, task, goal, or interface. Control task analysis (2) focuses on what needs to be done in the work domain. Strategies analysis (3) centres on strategies or processes for carrying out the activity, and social organizational and cooperation analysis (4) focuses on the coordination of workers. Worker competencies analysis (5) identifies the cognitive and perceptual activities the human operator may have to engage in when carrying out control tasks. CWA is capable of identifying problems that workers have to solve in various functions across different stages of the project life cycle.

5.3 Wagon Wheel Method

The Wagon Wheel Method (WWM) makes explicit how teams communicate. The method can be used to extract data for a number of purposes and in a wider variety of settings. It was first developed by Klein Associates Inc. to enable an understanding of how teams communicate, and has been used in a number of domains. WWM provides a quick and easy snapshot of team communications. The goal of the method is to identify the main communication channels existing for each position on the team and the

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137 Vicente (1999), Tran, Jain & Abraham (2004)
139 Bisantz et al (2002)
140 Vicente (1999)
nature of those communications. It is useful for analysing information flow and identifying roles and functions, information requirements, types of information, decision and course of action impacts, criticality of information, and the impact of poor information flow. It can be used with highly experienced and novice subjects in distributed teams, and in both one-on-one and group data collection sessions.\footnote{Moon (2004)}

WWM provides a glance at a team from the perspective of individual team members. Each team member is interviewed about the other members with whom they interact.\footnote{Ibid.}

\section*{5.4 CDM}

To be able to improve the level of human performance in a task it requires an understanding of how individuals perform that task.\footnote{Klein et al. (1989)} The Critical Decision Method (CDM) is a CTA method for investigating decision processes invoked by people during non-routine or significant incidents. The method can best be considered as a framework within which there are variations of tasks and materials. The method has its roots in Flanagan’s critical incident technique and uses systematic probing questions about the incident that an investigator can identify, for example the knowledge requirements, expertise and goal structures involved in performing a decision. The information gained by using CDM has been used to develop better user interfaces for presenting process and situational information.\footnote{Hoffman, Crandall & Shadbolt (1998), Klein et al. (1989)} CDM was developed for research on how decisions were made in actual situations. The model was based on that decision making in “every day” environments differs from situations where there is incomplete information, high stakes, lack of time, and interrelated issues. In these situations decision makers do not practice decision making as prescribed by the classical utilitarian models. Instead, they engage in pattern recognition and storytelling strategies to gain an understanding of the situation. The CDM has led to important insights for designing better decision aids. The CDM is good at exploring and characterising decision needs rather than at hypothesis testing.\footnote{Wong (2004)}
CDM has two broader parts: data collection and data analysis. CDM uses interviews as its main data source and the interviewees think back of special incidents they experienced during work. These incidents are later laid out on a timeline by the interviewer. A weakness with the method is its dependency on the interviewee’s memory and thereby the risk of missing critical information. The data analysis consists of creating a decision chart, an incident summary, a decision analysis table, and then identifying items of interest in each incident and collating and comparing items of interest across incidents studied.\textsuperscript{146}

5.4.1 ETA

The Emergent Themes Analysis (ETA) is based on Grounded theory (see section 5.5) but tailored to take advantage of the exploratory and efficient data collection features of the CDM.\textsuperscript{147}

The ETA approach is an iterative process to reduce and to make sense of voluminous interview data.\textsuperscript{148} ETA does not have any guidelines for collection of data, which means that it only covers the last steps in Woods process tracing.\textsuperscript{149} ETA uses data collected from the CDM method but differs in its way of analysing it. CDM consists of a number of clear steps whereas ETA is not as restricted and has a more iterative process with broad themes and specific themes. The method identifies, indexes and collates similar concepts from the interviews as broad themes. Using a similar distillation procedure sub-themes are identified within each broad group. These specific themes are further structured and reduced into different categories.\textsuperscript{150} Figure 7 shows the basic idea of the ETA analysis from transcripts to broad themes and specific themes.

\textsuperscript{146} Wong (2004)
\textsuperscript{147} Wong & Blandford (2002)
\textsuperscript{148} Ibid.
\textsuperscript{149} Woods (1993)
\textsuperscript{150} Wong & Blandford (2002)
5.5 Grounded theory

Grounded theory is different from the other methods for cognitive analysis because it focuses on everyday actions and not on critical events like the other methods. The reason the method is mentioned is to explore if whether these qualities can be suitable for integration.

Grounded theory is a method that was founded by Glaser and Strauss in 1967. It is a method for qualitative analysis that can generate theories by an inductive way of working. \(^{152}\) Grounded theory aims to create theories derived from data, systematically gathered and analysed through the research process. \(^{153}\) The purpose of the method is to discover factors that are of relevance for the phenomenon of study and to investigate their connections. Grounded theory helps to develop existing methods. \(^{154}\)

Glaser and Strauss believe that the scientist should avoid literature studies in the beginning of the research, because otherwise there is a risk that the scientist will be affected by the literature when interpreting his or her data. \(^{155}\) The scientist should let the theory emerge from the data. In this method, data

\(^{151}\) Wong & Blandford (2002)
\(^{152}\) Lundahl & Skärvad (1999)
\(^{153}\) Strauss & Corbin (1998)
\(^{154}\) Guvå & Hylander (1998)
\(^{155}\) Svensson & Starrin (1996)
collection, analysis and theory have a close relationship. Grounded theory also emphasises that the researcher needs to be very creative.\footnote{156 Strauss & Corbin (1998)}

In practice, the method starts with the data collection and then a description is made from the data.\footnote{157 Ibid.} The data collected are often observations, but also interviews, recordings etc. Interviews must be of qualitative character with open questions.\footnote{158 Guvå & Hylander (1998)} If an interview is too structured, there is a risk to loose information.\footnote{159 Bell (2000)} The descriptions draw on ordinary vocabulary to convey ideas about things, people and places. The next step is the coding. The researcher organises data into categories according to their properties and dimensions and then uses descriptions to clarify those categories.\footnote{160 Strauss & Corbin (1998)} Then, when analysing, the categories are compared. In Grounded theory, collecting of data, coding and analysis are not linear. After the first analysis, a new question emerges that needs additional data collection. In the process the researcher changes between coding and analysing.\footnote{161 Guvå & Hylander (1998)} The theory is the result of a process, which means that the theory is developing constantly.\footnote{162 Svensson & Starrin (1996)}

The coding procedures have the purpose to build rather than to test theories, to provide researchers with analytic tools for handling masses of raw data, to help analysts to consider alternative meanings of phenomena, be systematic and creative simultaneously, and to identify, develop, and relate the concepts that comprise the building blocks of the theories.\footnote{163 Strauss & Corbin (1998)}

5.6 CIT

Critical Incident Technique (CIT) is a technique developed by Flanagan for the US air force during World War II to analyse the reasons why so many pilot candidates were failing flight training. Flanagan defines the technique as a set of procedures for collecting human behaviour in such a way to facilitate their potential usefulness in solving practical problems and developing broad physiological principles.\footnote{164 Callan (1998)} The basic principles of the CIT
are that only behaviours that make a significant contribution to the general aim of the activity should be considered.\textsuperscript{165}

Flanagan describes an “incident” as any observable human activity that is sufficiently complete in itself to permit conclusions and predictions to be made about the person performing the act. For the incident to be “critical” Flanagan declared that it must occur in a situation where the purpose of the act seems clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects.\textsuperscript{166} The methods can be used with a set of flexible guidelines, which modifies and adapts the specific situation.\textsuperscript{167}

CIT has been used in the social sciences to study topics such as group processes, successful job performance and evaluating and analysing program development.\textsuperscript{168}

The data collection can be carried out in several different ways: individual interviews, group interviews, direct observations, questionnaires etc. However, Flanagan thinks that interviews are the best ways because it provides an opportunity for the interviewer to probe and to extract the required information.\textsuperscript{169}

Flanagan identified five stages that are necessary for CIT: (1) Formulating the general aim of the activity, (2) setting plans and specifications, (3) collecting the information, (4) analyzing the information, and (5) reporting and interpreting the findings. The data are based on the participants’ experiences. The analysis procedure summarises or categorises the data without losing comprehensiveness or clarity. The result should then be summarised using self-explanatory titles for the category and subcategory classifications.\textsuperscript{170}

The primary advantage of using CIT as a method is that it provides a complete coverage of the content domain but still requires the researcher to examine the results in a systematic fashion.\textsuperscript{171}

\textsuperscript{165} Norman et al. (1992)  
\textsuperscript{166} Flanagan (1954)  
\textsuperscript{167} Welker (2003)  
\textsuperscript{168} Sautter & Hanna (1994)  
\textsuperscript{169} Callan (1998)  
\textsuperscript{170} Norman et al. (1992)  
\textsuperscript{171} Sautter & Hanna (1994)
Part III: Presentation and analysis of the reconstruction-exploration approach

Part three in the thesis comprises a presentation of the Reconstruction – exploration approach, followed by an analysis if the approach.
6 Presentation of the R&E approach

There are many different methods for analysing DTOs. One of the methods is the Reconstruction – exploration approach (R&E), which is developed by Magnus Morin et al. at FOI. The R&E approach uses a multimedia framework MIND, developed by FOI, to show a reconstruction of an operation for evaluation and analysis. The purpose of the approach is to complement information from local events in a distributed operation with mission histories from activities at multiple locations.\textsuperscript{172}

6.1 The approach

The R&E approach can be divided into two parts, reconstruction and exploration. The reconstruction part aims to plan a conceptual model of an operational scenario and then enrich the model with data from an operation like the scenario. The exploration part consists of a multimedia model for visualisation of the tactical operations used for reflection, discovery, and analysis.\textsuperscript{173}

The picture below (Figure 8) shows an overview of the steps of the R&E approach. The boxes symbolize activities, and the arrows show the artefacts produced by each activity.\textsuperscript{174}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{Overview of the steps of the R&E approach.\textsuperscript{175}}
\end{figure}

\textsuperscript{172} Morin (2002a)
\textsuperscript{173} Ibid.
\textsuperscript{174} Ibid.
\textsuperscript{175} Reproduced from Albinsson, Morin & Thorstensson (2004, p. 2)
The first activity, *domain analysis*, aims to analyse the domain together with subject-matter experts to form important issues in the work situation and look for particular problems of interest. These issues and problems will then be ordered in priority. The information from the first step forms the base of the *modelling* step. In the second step an object-oriented conceptual model is created to define the main actors and activities in the domain. An instrumentation plan outlines the needs for data collection and data presentation. *Instrumentation* means to turn models and plans into procedures, equipment, and software components for data collection and presentation. *Data collection* takes place during an operation, for example by observations and digital photos. The data are then used to create a mission history, which is a time-synchronized model of the operation. All these steps enable a reconstruction of a DTO resulting in a mission history.  

The last part of the R&E approach is the exploration part that consists of an activity called presentation. Presentation means to turn data in the mission history into a form that supports exploratory analysis of the operation. Since practitioners, analysts, and researchers have different needs, additional presentational views can be constructed and added to the presentation framework at any stage of the exploration process for example a casualty-flow view. There is more to data analysis than representation and handling of data. The analysis includes insights, reflections, questions raised and hypotheses. The analysis products are data on a meta-level. These metadata have so far been managed by notes in the framework mind, as personal reflections for each analyst working with the system. The data is separated from the more important overall insights and conclusions that evolve over time.

It is important to point out that the mission history is based on the use of procedures, methodology, and tools to capture selected aspects of a complex situation. The situation is thus interpreted and the mission history necessarily partial, which means that what is presented is not the absolute truth.

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176 Morin (2002a)
177 Ibid
178 Albinsson, Morin & Thorstensson (2004)
179 Morin (2002a)
6.1.1 Data sources

The data used in the reconstruction part or the R&E approach is collected from the field. Sources are managing collections of events from a particular physical or logical source and are the primary mechanism for organising and tracing data from an operation. There are two kinds of sources, inherent sources and non-inherent sources. Inherent sources are for example; archives, records, systems etc. These have the advantage that they are always available unlike for example observers. Examples of sources that are used for MIND are both inherent and non-inherent, such as; audio sources, video sources, digital photographs, observation protocols, system log files etc.

6.1.2 Qualifications

An important strength of the R&E approach is that it focuses on providing very rich contextual data. The approach is supporting a wide system perspective, gathering data on multiple organisational levels, on multiple geographical locations, and from multiple actors. The R&E approach strives for a comprehensive reconstruction of the operations, while some other methods are concentrating on special events and critical circumstances. Some of the weaknesses identified around R&E include that the approach is lacking defined analysis methods and technical support for coding.

6.2 MIND

FOI has developed a multimedia framework called MIND that is based on the R&E approach and which replays mission histories. The goal is to lift discussions from what happened to why it happened. It can be hard for a practitioner to understand a tactical operation because of parallel activities, limited observability, and multiple accounts of overlapping events. One goal with MIND is thus to help practitioners understand the operation in its entirety.

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180 Morin (2002a)
181 Albinsson et al. (2005)
182 Ibid.
183 Morin (2002b)
184 Albinsson et al. (2005)
185 Morin (2002b)
MIND uses time as the primary coordinating mechanism in playback. The user can control the speed of the replayed animation. At any time, the user can stop the clock and freeze the animation. When stopping the clock, the state of the model corresponds to the state of the operation at that time. The user can for example see units’ positions on maps, spoken communication, photos, video recordings etc.\textsuperscript{186}

The picture below (Figure 9) shows a screenshot from MIND. To the left there is a view of the components and down to the left is the mission clock. Up to the left is an overview map and to the right is a more detailed map that shows the location of rescue vehicles. In the middle row are two audio link views showing communication on the fire and police radio networks. The arrows represent messages. At the bottom is a dynamic timeline that provides a graphical representation of communication sequences on multiple networks.\textsuperscript{187}

\textsuperscript{186} Morin (2002a)
\textsuperscript{187} Morin (2002b)
Figure 9 A screenshot from MIND.\textsuperscript{188}

Another example of a view from MIND is figure 10 that shows a military operation. Different maps show the location of the operations and different unit’s points. In the middle and on the left different communication views of the operation is shown with arrows pointing the direction of the communication. Above the communication view, in the middle, an action video is shown.

\textsuperscript{188} Morin (2002b, p. 6)
Figure 10 Overview of a military operation\textsuperscript{189}

\textsuperscript{189} Screenshot from MIND (2005-09-16)
7 Analysis of the R&E approach

The aim of our study is to analyse methods for cognitive analysis to find possibilities for integration with the R&E approach. First an analysis of the R&E approach is made. Since the R&E approach has developed together with the framework MIND we have also chosen to perform our own practical evaluation of the framework for a deeper analysis.

To map the R&E approach’s goals, strengths and weaknesses, the MA/SIMM method is used (see section 3.2.5), and will later assist the decision about what methods are most suitable for a possible integration process. MA/SIMM is a meta-method that is adaptable for a specific situation and can be used as a method to evaluate other methods.

In the analysis of the R&E approach most of the steps in the first area of the MA/SIMM method the diagnosis of the method has been used. We chose this subset of the steps because they best describe the approach and give an overview of what the R&E approach consists of. The analysis is based on interviews with Pär-Anders Albinsson, user of the R&E approach and the framework MIND, and Mirko Thorstensson, developer and user of the R&E approach and MIND shown in appendix 1 (A1). The analysis is also based on literature reviews, and our own practical experience of MIND (for a more detailed presentation of the analysis see appendices 2-4). The analysis of the R&E approach starts with the MA/SIMM step of determining the conditions.

7.1 Determining the conditions

When determining the conditions (Table 2), the method of interest is defined; in this case the R&E approach. The analysis has the purpose of exploring the needs for development of the approach and to define criteria for further analysis. The ambition of the analysis is to follow the steps in MA/SIMM’s diagnosis of the method (Chapter 3).

190 Goldkuhl & Fristedt (1994)
Table 2 Table of determination of the conditions

<table>
<thead>
<tr>
<th>Method:</th>
<th>Reconstruction-exploration approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose:</td>
<td>Analysis of the R&amp;E approach to explore the needs for development of the approach</td>
</tr>
<tr>
<td>Level of ambition:</td>
<td>Method analysis according to MA/SIMM’s diagnosis of the method</td>
</tr>
</tbody>
</table>

7.2 Analysing and mapping

After having determined the conditions of the analysis, the next step is *analysing and mapping* which are the most important parts of the method. Here an inventory is made of the method’s weaknesses, strengths and goals. The characteristics that occur when using the method have been collected from expert interviews made with users of the MIND, literature published by the developers of the approach, and from our own practical experiences.

7.2.1 Analysis of the weaknesses

Analysis of the weaknesses consists of two parts; identification and formulation of the weaknesses and analysis of the relations between the weaknesses. All the problems are listed and plotted in a graph designed to show the relations between the problems. The graph shows the relations between the weaknesses (Figure 11). The graph also shows that the major problems of the R&E approach is its lack of a well defined analysis method, that no object oriented database is used in MIND and that all events must be time stamped and connected to a timeline.191 One major shortcoming we detected in the R&E approach was its lack of structuring data.

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191 Albinsson (2005-06-28) Interview
7.2.2 Analysis of the strengths

Analysis of the strengths consists, like the weakness analysis, of two parts: identification and formulation of the strengths and analysis of the relation between them. The strengths are mapped in a graph to show the relations between the strengths (A3). The R&E approach’s most important strengths is its capability to handle large volumes of data, that the method uses multiple
data sources, the well defined reconstruction part, and the use of a timeline which makes it easy to follow the whole operation.\footnote{Albinsson (2005-06-28) Interview}

7.2.3 Analysis of the goal and perspectives

Analysis of the goals and perspectives have four different parts; understanding and presenting the method, listing interested parties, identifying and formulating the goals, and analysing the relations between the goals.\footnote{Goldkuhl & Fristedt (1994)}

As mentioned before, the R&E approach can be divided into two parts, reconstruction and exploration. The reconstruction part aims to produce a conceptual model of an operational scenario and then understanding the model with data collected from an actual operation like the scenario. The exploration part aims to the use of multimedia models of tactical operations for reflection, discovery, and analysis.\footnote{Morin (2002a)} For a deeper presentation of the method, see chapter 6.

The list of interested parties identifies different groups of actors that are somehow related to the method and their connection to the approach. In the R&E approach four different groups have been discovered, the analyser, the customer, the user, and the developer\footnote{Our own practical experience}. The table below (Table 3) shows the interested parties.

Table 3 Table of interests

<table>
<thead>
<tr>
<th>Interested party</th>
<th>Part / tasks / responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyser</td>
<td>Transcription, coding and analysis</td>
</tr>
<tr>
<td>Customer</td>
<td>Orders services</td>
</tr>
<tr>
<td>User</td>
<td>Analysis and exploration</td>
</tr>
<tr>
<td>Developer</td>
<td>Intermediary methods knowledge</td>
</tr>
</tbody>
</table>

\footnote{192 Albinsson (2005-06-28) Interview}  
\footnote{193 Goldkuhl & Fristedt (1994)}  
\footnote{194 Morin (2002a)}  
\footnote{195 Our own practical experience}
The last step in the analysis of the goals and perspectives is identification and formulation of the goals and the relation between them. The goals are plotted out in a graph (A4). The analysis shows that the primary goals of the R&E approach is to lift the discussion about a mission from *what* happened to *why* it happened\(^{196}\), as well as to get a result that are highly valid (how). Both these goals were mentioned in the interview with Albinsson, user of the framework MIND. Another goal for the R&E approach is to get a better structuring of the data and that data classifies equally. The R&E approach should also be able to manage and connect subjective data into the context of the mission.

### 7.3 Summary of the analysis

To summarise the main weaknesses of the R&E approach, we mention the weakness that all data must be time stamped to be able to fit the system and that no categorisation of data exists. The approach also lacks a well-defined analysis method, which leads to low validity results. A problem with the R&E approach is that it mainly handles objective data and there is limited room for interpretations. The R&E approach only covers the two first steps in Woods explanation about how to analyse a complex situation.\(^{197}\)

The strength with the R&E approach is its many data sources and the timeline. The goal of the method is to get an overview of DTOs and to understand the entirety. Some other goals are to lift the discussion from *what* happened to *why* it happened and to get high validity of the results. The persons involved are the analyser, customer, user, and developers.

\(^{196}\) Albinsson (2005), Morin (2002a)
\(^{197}\) Woods (1993)
8 Result of the analysis of R&E approach

The MA/SIMM analysis of the R&E approach gave a clearer picture of the R&E approach and its qualities. The analysis showed the R&E approach’s weaknesses can be helped by integration with a method that can handle and structure subjective data.

The strengths and the goals with the R&E approach must also be considered. The main goal is to find a method that can handle R&E’s main goal, to lift the discussion about a mission from what happened to why it happened and in the mean time arrive at result that are highly valid. Another goal the approach has is to achieve a well-defined structuring of the data. In order to find a method that can complement the R&E approach a number of criteria is defined. To reconstruct a mission and to lift the discussion from what happened to why it happened has been a goal from the beginning with the R&E approach.

8.1 Criteria

The criteria are identified from the result of the MA/SIMM analysis of the R&E approach and are based on articles, interviews and on our own practical experiences of strengths and weaknesses. The criteria will later support the initial analysis of the cognitive methods and above all facilitate the choice of methods for a possible integration. The criteria are described below.

8.1.1 Structure and categorise data

The need of structure in the R&E approach results in a criterion of a more structured way of handling data, for example the possibility to categorise data. A well-defined structure can help the analyser to find relations between collected data. This criterion is of a more technical characteristic and can perhaps be satisfied by a function in the framework MIND. We as evaluators found the system hard to work with and we lack a good structure.

198 Albinsson et al. (2005)
8.1.2 Well-defined methods for analysing

At present the R&E approach is not using a well-defined method for analysing DTOS, which makes it hard to accomplish a deeper analysis of the mission. This can lead to low validity. A well-defined method for analysis can provide a more uniform way of classifying data. This also facilitates multiple users.

8.1.3 Possibility to handle subjective data

One goal that the R&E approach strives for is to be able to handle subjective data, not only objective data. According to FOI, the R&E approach is focusing on collecting objective data, for example time logs and video records.\textsuperscript{199} Subjective data can for example be data collected from interviews. Being able to handle subjective data is important since the R&E approach wish to raise the discussion from what happened to why it happened. One solution of doing this is to be able to handle data from interviews and other subjective sources that not necessarily are time stamped. A wish is also to connect this material to data providing an overview of the operation.

\textsuperscript{199} Thorstensson (2005-09-07) Interview
Part IV: Initial analysis

In this part of the thesis the initial analyses of the cognitive analysis methods are performed. Depending on the results of the analysis, one or several methods will be chosen as “candidates” for a possible integration with the R&E approach.
9 Analysis of methods for cognitive analysis

By using MA/SIMM to analyse methods for cognitive analysis, a quick and general picture of each method is provided. In the initial analysis, only a small part of the MA/SIMM method is being used, i.e. the analysis of the weaknesses and strengths of each method. The analysis provides a good overview of the methods and is not too time consuming. When analysing the methods, we, as researchers, will have in mind the weaknesses and goals of the R&E approach.

The analyses are based on literature presented in chapter 5. Appendices 5-18 present more details of the analyses.

9.1 Analysis of CTA

The analysis of CTA shows that the method’s main problems are that it is very general and that it does not give an overview of the operation. The problems are listed and then plotted in a graph (A5), which shows that the problem with the CTA method is that it is very general. The generality depends on that CTA consists of a group of different methods and that the method does not provide any strong guidelines. The graph also shows that the problem with that CTA does not give an overview over the mission depends on that there are very few data sources, as well as no strong guidelines.

The analysis of CTA also shows that the greatest strength of this method is its ability to identify cognitive skills among the participants in the mission. The relationship between the strengths is shown in A6. The reasons why CTA has the capability to identify cognitive skills are that the method is based on interviews and observations, which enables identification of needs to perform task proficiency. CTA also extracts human knowledge, which leads to insight into expertise.

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200 Zachary, Ryder & Hicinbothom (1998)
201 Ibid.
202 Tran, Jain & Abraham (2004)
203 Klein, Klinger & Miller (1997)
204 Tran, Jain & Abraham (2004)
9.2 Analysis of CWA

The CWA method is a technique to analyse, design and evaluate human computer interactive systems in their work environment\textsuperscript{205}. A problem with the CWA method is that it focuses on the work environment and the task performance\textsuperscript{206}. The method is mainly developed for evaluating and designing information systems and the method is unique for training and instruction.\textsuperscript{207} The problems are listed and plotted in a graph in A7.

A central strength, and also the main purpose with the CWA, is the possibility to identify complexities on the work domain.\textsuperscript{208} This provides unique issues for training and instructions and together with the power of having clear stages for analyses a good guide to remodel human-system interface. The strengths are listed and plotted in a graph in A8.

9.3 Analysis of the Wagon Wheel Method

The analysis of the Wagon Wheel Method (WWM) shows that there are two main problems with the WWM. The problems are that the method is very specific for the communication area\textsuperscript{209} and that it is subjective. The reason for its subjectivity is that the method lacks data triangulation. The only source of data is interviews with participants in the mission about the information flow. The interviews lead to interpretations, which are subjective. The relationship between the weaknesses is shown in A9.

The WWM is a method that focuses on team communication, which also is one of the greatest strength of the WWM. It gives a quick overview of the team communication.\textsuperscript{210} What makes this possible is that the method is based on user interviews, which leads to an understanding of how teams communicate. This understanding is useful for analysing the information flow and decisions, and finally to get a good picture of how the team communicate. The graph in A10 shows the relationships between the strengths.

\textsuperscript{205} Vicente (1999)
\textsuperscript{206} Bisantz et al. (2002)
\textsuperscript{207} Lintern & Naikar (1998)
\textsuperscript{208} Bisantz et al. (2002)
\textsuperscript{209} Moon (2004)
\textsuperscript{210} Ibid.
9.4 Analysis of CDM

There is one main weakness in CDM, also noted by Wong in his article *Data analysis for the Critical Decision Method*, namely that the method can miss critical data which leads to that the method becomes dependent on the researcher. This is mainly because it is retrospective and that the method uses few data sources. That CDM is retrospective means that the method must rely on the interviewees’ memory. A weakness with CDM is the difficulty for the interviewee to articulate his or her decision making, which means a risk to miss critical data. The relationship between the weaknesses is shown in A11.

The greatest strength of CDM is that it can be used to design better decision aids. CDM uses advanced interviews and places the incidents on a timeline, which makes it possible to handle both collection and analysis of data. The collection and analysis make it possible to investigate how decisions are made in actual situations, which enables exploration and characterising of decision needs, which can be used to design decision aids. The relationship between the strengths is shown in A12.

9.4.1 Analysis of ETA

ETA’s main purpose is to examine and structure data collected by the CDM method. This means that the method does not have a defined technique for data collection of its own. Another weakness is that the analysis is very dependent upon the researcher, which can bring a low level of validity and make the method subjective. The relationship between the weaknesses is shown in A13.

Strength with ETA is that the method is practical and provides a fast result. These strengths are consequences from a structured way of handling large volumes of data from interviews and having insightful themes. The relationship between the strengths is shown in A14.

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211 Wong (2004)
213 Wong (2004)
215 Ibid.
9.5 Analysis of Grounded theory

According to Strauss and Corbin one weakness with Grounded theory is its dependency of the researcher to be creative and avoid being influenced by literature studies\textsuperscript{216}. The method becomes very dependent on the person doing the analyses. This weakness makes the method time consuming and by that expensive. The relationship between the weaknesses is shown in A15.

Grounded theory’s main strength is its capability to discover connections between relevant factors for the incident.\textsuperscript{217} This ability is a consequence of categorised data, which the method supports. Grounded theory also uses many data sources and has clear phases. This together with the possibility to work with empirical data supplies the method with possibilities to identify factors that are of relevance for the incident. The strength with Grounded theory, and also the purpose with the method according to the developers, is its possibility to explore the connection between relevant factors for the incident\textsuperscript{218}. The relationship between the strengths is shown in A16.

9.6 Analysis of CIT

The analysis of CIT’s weaknesses shows that the flexible guidelines can promote interpretations that not always are correct. According to Soutter and Hanna\textsuperscript{219} the method is much dependent upon the researcher, which together with the possibility for false interpretations, make the method subjective. The relationship between the weaknesses is shown in A17.

The analysis shows that CIT have many strengths and the strongest advantage is its possibility to solve practical problems, which also is the intension of the method from the beginning according to Flanagan\textsuperscript{220}. Being able to solve practical problems is a result from its capability to handle subjective data and modifying a specific situation. Handling subjective data and modifying a situation is a consequence of several strengths; the method’s possibility to categorise data, its use of flexible guidelines, its focus on the requirements of the specific situation and a possibility for interpretations. The relationship between the strengths is shown in A18.

\textsuperscript{216} Strauss & Corbin (1998)
\textsuperscript{217} Guvå & Hylander (1998)
\textsuperscript{218} Ibid.
\textsuperscript{219} Soutter and Hanna (1994)
\textsuperscript{220} Flanagan (1954)
10 Choice of methods

In this chapter we choose the methods to for a deeper analysis for a possible integration with the R&E approach.

As a result of the initial analysis of the cognitive methods, we have chosen CDM as the main candidate for a possible integration with the R&E approach. The reason for our choice is based on the belief that CDM’s strengths can complement the weaknesses of the R&E approach. One example is that CDM can handle subjective data from interviews, which is not directly supported in the R&E approach. CDM has a clear and structured way of both collecting and analysing data, which can complement the weaknesses in the R&E approach, which does not have a defined method for analysing the data collected.

As mentioned before, CDM is our main candidate for a possible integration. We intend to use CDM as a base in the integration process, but we will also use parts from the other methods to create a more suitable method for analysing DTOs. The selection is illustrated in the picture below (Figure 12).

![Figure 12 Choice of methods](image)

There are several reasons why we did not choose the other cognitive methods to be main candidates. A problem with CTA is that the method is too general and that it does not give an overview of the operation. Another problem is that CTA does not have any strong guidelines.\(^{221}\) The R&E

\(^{221}\) Zachary, Ryder & Hicinbothom (1998)
approach gives an overview of the mission, but it needs strong guidelines in the analysis phase.

Other methods were too specific to one area, for example CWA focuses on evaluating human computer interactive systems in work environment\textsuperscript{222} and the WWM only concerns communication.\textsuperscript{223} CWA is also very focused on the work environment and the task performance.\textsuperscript{224}

Other methods were too general, for instance Grounded theory. It has many advantages especially when it comes to categorise data.\textsuperscript{225} Yet, the method is very general and do not focus on critical situations, which is essential in this case. This quality makes the method unsuitable as a main candidate for a possible integration, but Grounded theory’s way of focusing on every-day situations could also be a strength because it makes it possible to get a better context of the operation.

Another category of methods that became excluded from being the main candidate for a possible integration with the R&E approach were the methods that were too subjective. This was one of the reasons why we did not chose CIT. The method is very dependent on the researcher and how he or she interprets the collected data. Further, it does not have any strong guidelines, which is needed in the R&E approach.\textsuperscript{226}

One reason why we did not chose ETA as the main candidate is because it does not have a defined technique for data collection\textsuperscript{227}, the method only concentrates on the analysis. The R&E approach needs both a way to collect subjective data, for example interviews, and a defined analysis technique. However, ETA has a structured way of categorising collected data, which is a lack in the R&E approach.

Even if CDM is the main candidate for a possibly integration we will do a deeper analysis of CDM to be sure that its strengths can complement the weaknesses in the R&E approach. If the analysis shows that CDM cannot complement the R&E approach as we desire, there will be a possibility to take influences from other methods.

\textsuperscript{222} Lintern & Naikar (1998)
\textsuperscript{223} Moon (2004)
\textsuperscript{224} Bliantz (2002)
\textsuperscript{225} Strauss & Corbin (1998)
\textsuperscript{226} Soutter and Hanna (1994)
\textsuperscript{227} Wong & Blandford (2002)
Part V: Deeper Analysis and Integration

This part contains a detailed presentation of the method of choice. The presentation underlies the deeper analyses of the method of choice. This part also describes the integration process between the method of choice and the R&E approach.
11 Detailed presentation of the method of choice

Below a detailed presentation of the method of choice, CDM, is made. The presentation of the method will support the deeper analyses.

11.1 CDM

Critical Decision Method (CDM) is a retrospective task analysis technique for investigate the decision processes by people during major or significant incidents. By asking a set of questions about these incidents, an investigator can identify the knowledge requirements, expertise, and goal structures involved in performing a decision maker’s work. There are two phases in the CDM: data collection and data analysis.²²⁸

11.1.1 Data collection

CDM uses interviews as its source of data collection. A CDM interview usually lasts one to two hours where the interviewees are asked to think back to particularly demanding and memorable incidents they experienced during their work. The interviews are semi-structured and used to probe different aspects of the decision-making process. The interviewees describe these incidents as a series of decision points on a timeline.²²⁹ The decision timeline is used as a framework for systematically probing the interviewee about how the decision at each point was made. The interviews are normally recorded so the investigators can concentrate on the interviewee and eliciting what is useful data. The record is then transcribed for subsequent analysis. The result is often voluminous and rich data are also very messy. Consequently, there is a need to identify significant patterns, confirm evidence across different incidents, and find an adequate structure based on the data to communicate the findings. Clear steps and a good structure of the data provide traceability for reader and user of the method. The CDM method is intended to reduce and organise data to make them more manageable for interpretation.²³⁰

²²⁸ Wong (2004)
²³⁰ Wong (2004)
11.1.2 Data analysis

Data analysis (Figure 13) has similarities to a generic stage of cognitive analysis, transcription, integration and segmentation in chapter 4. The analysis can be structured as follows.\footnote{Wong (2004)}

1. Decision charts

A decision chart is a visual representation of the decisions made during an incident, plotted on a timeline. Representing the progressive deepening analysis is helpful in explaining how the decisions were made and for indicating where further analysis in the next stage would be useful.

2. Incident summary

The incident summary provides a description of the incident. It uses the decision chart to organise relevant details from the transcript into stages of the incident. It summarises the key information, making it easier for the researcher to review the incident without having to restudy the whole transcription.

3. Decision analysis table

The decision chart and the incident summary map out the incident and orientate the researcher to decision points during the incident. The decision analysis framework shows how a decision maker is presented with situational cues and information.

4. Identification of items of interest in each incident

Once the decision analysis framework is completed, items of interest can be identified. The next step is to consolidate all the relevant items of interest by grouping similar statements together and give each grouping a label.

5. Collating and comparing items of interest across incidents studied

Once all identifications of each incident have been structured and labelled, an analysis across all cases can be performed. It is through this process that sense can be made of the data.

\footnote{Wong (2004)}
Figure 13 CDM Data Analyses

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12 Deeper analysis of CDM

This chapter consists of a deeper analysis of the CDM and the integration with the R&E approach.

In the deeper analysis of the candidate method, CDM, the MA/SIMM is again used. In the analysis, only a small part of the method of MA/SIMM is used; determining the conditions, analysis of the problems, and strengths of the method. The reasons why we only focus on these steps are because we do not intend to improve the CDM method, we only wish to find its positive and negative sides in order to enhance the R&E approach.

From the analysis of the R&E approach, different criterions were identified. These criterions were a mix of weaknesses, strengths and goals with the approach; characteristics we look for in a cognitive analysis method. The criterions are: ability to structure and categorise data, a well-defined method for analysis, and the possibility to handle subjective data.

12.1 Determining the conditions

In determining the conditions the method of interest is defined, in this case CDM. The analysis has the purpose of exploring the method’s qualities before a possible integration with the R&E approach. The qualities in mind are the criterions from the analysis of the R&E approach. The level of ambition of the analysis is to follow some of the steps in MA/SIMM’s diagnosis of the method. The table below (4) shows conditions of the analysis.

<table>
<thead>
<tr>
<th>Table 4 Table of the conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method:</strong></td>
</tr>
<tr>
<td>Critical Decision Method</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
</tr>
<tr>
<td>Analysis of the CDM to explore the qualities of the method for a possible integration with the R&amp;E approach</td>
</tr>
<tr>
<td><strong>Level of ambition</strong></td>
</tr>
<tr>
<td>Method analysis according to MA/SIMM’s diagnosis of the method</td>
</tr>
</tbody>
</table>
12.2 Analysing and mapping

After having determined the conditions of the analysis, the next step is to analyse and map. Here an inventory is made of the method’s weaknesses and strengths. The goals were not analysed in this deeper analysis of CDM. The characteristics that occur when using the method have been collected from the literature with the criteria from the analysis of R&E as a base.

12.2.1 Analysis of the weakness

The analysis of the weaknesses is divided into two parts; identification and formulation of the weaknesses and analysis of its relations. The weaknesses and the relations are listed and showed in a graph (A19). The analysis shows that CDM’s weaknesses are its dependency on the researcher and the interviewee’s memory, which can lead to the consequence that critical data can be missed. The method has interviews as its only data source, which makes the method retrospective. This limitation is according to Thorstensson dependent on when the interview takes place in time after the incident. You get different answers depending on the time elapsed since the event. You do not get the same result from an interview directly after the incident as after a week. The method also focuses on non-routine events, which makes the result hard to generalise.

12.2.2 Analysis of the strengths

Analysis of the strengths also consists of two parts: identification and formulation of the strengths and analysis of the relation between these. The strengths are listed and then plotted in a graph to show the relations between the strengths (Figure 14). The deeper analysis of the CDM shows the strength in reducing and organising data, which makes the result traceable and more manageable for data interpretations. This strength makes it possible to handle subjective data in an efficient way. The strengths found in the initial analysis are also of relevance. CDM uses advanced interviews and places the incidents on a timeline, which can be used to design better decision aids. The methods qualities to handle both collection and analysis of data make it

\[233\] Wong (2004)
\[234\] Thorstensson (2005-09-07) Interview
\[235\] Wong (2004)
\[236\] Ibid.
\[237\] Ibid.
possible to investigate how decisions are made in actual situations, which enables exploration and characterising of decision needs.

Figure 14 CDM Strength graph
12.2.3 Summary of the analysis

One of the R&E approach’s main weaknesses was the lack of structuring and limited support to code and categorizes data. These weaknesses are one of the main reasons why CDM is our choice of method to complement the R&E approach for a possible integration. The CDM has clear steps how to categorize and structure data into a timeline.

One other weakness with the R&E approach is that it does not have a well-defined analysis method. This weakness makes the analysis harder and the result of lower validity. By integrating the R&E approach with CDM, a more structured way of working is defined which leads to traceability of how the conclusions were reached. The CDM has interviews as the source data and can handle subjective data, which is one of the goals of the R&E approach.

The analysis showed that CDM also had some weaknesses, which could be rectified by influences from other analysis methods, to cover all needs of improvements of the R&E approach.
13 Integration of cognitive analysis methods

This chapter presents the integration between the R&E approach and existing cognitive methods, in this case CDM as a main candidate, but also with influences from other analysis methods.

The purpose with the integration is to complement the R&E approach weaknesses with strengths from other analysis methods. From the deeper analysis of the CDM we found the method appropriate for integration. Nevertheless CDM had some weaknesses that we will try to satisfy with qualities from other methods. The basic ideas will originate from CDM but some functions will also be borrowed from remaining methods. In this case we use CDM with well-defined steps as a base, but we also take influences from ETA and Grounded theory. Figure 15 shows the choice of methods.

13.1 Possibilities for integration between the R&E approach and other methods

Table 5 shows the weaknesses and goals of the R&E approach as a result from the MA/SIMM analysis (Chapter 8). The weaknesses and goals are categorised into different criteria. The weaknesses and goals of the R&E approach are compared with strengths from CDM and other methods where the CDM method is not suitable. The first criterion is to find a well-defined analysis method. These qualities were found as strengths in the analysis of the CDM. CDM has clear steps with a decision chart, decision analysis and
collation of issues across incidents that can be added to the R&E approach to improve the validity and the traceability of the results. CDM’s clear steps cover step three and four in Woods process tracing. A quality of CDM is its focus on non-routine events. This quality is a strength but also a weakness since the R&E approach’s goal is to give a complete reconstruction of the operation. This quality of CDM obstructs the R&E’s goal. To support the goal to make a complete reconstructing of an operation, a quality of the Grounded theory has been selected, its possibility to handle every-day decisions and events.

The next criterion is structuring and categorising data where the R&E approach is weak in handling data that is not time stamped and transformed into events. It is also hard to see connections and consequence of an action. This is mainly a result of the R&E approach’s handling of all data according to a timeline. One of CDM’s biggest strengths is its possibility to organise data with clear steps in a decision chart in CDM, which can support the needs of structure in the R&E approach. We found the steps in CDM to be somewhat rigid with little focus on iteration. This weakness in CDM is the reason why we have chosen to add the ETA’s iterative way of structuring data.

Handling subjective data is a goal with the R&E approach but also an acknowledged weakness. Handling subjective data can be supported by CDM, which is developed to analyse data from interviews.

**Table 5 Possibilities for integration between R&E with CDM and other analyse methods**

<table>
<thead>
<tr>
<th>R&amp;E</th>
<th>CDM</th>
<th>Other analysis methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>A well defined analysis method</td>
<td>- No well defined guidelines for the exploration part</td>
<td>- CDM’s method with clear steps</td>
</tr>
<tr>
<td></td>
<td>- No deeper analysis</td>
<td>- Decision chart, decision analysis table and collation of issues across incidents</td>
</tr>
<tr>
<td></td>
<td>- Gives a complete reconstruction of the operation (goal)</td>
<td>- Traceability with CDM’s well defined steps</td>
</tr>
<tr>
<td></td>
<td>- Low validation of the result</td>
<td>GT- Focus on everyday decisions and not on non-routine events</td>
</tr>
</tbody>
</table>

238 Woods (1993)
<table>
<thead>
<tr>
<th>Structure and categorise data</th>
<th>ETA- Categorising of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Everything according to a timeline</td>
<td>More, say something more on this...</td>
</tr>
<tr>
<td>- Handling data that cannot be time stamped not possible</td>
<td></td>
</tr>
<tr>
<td>- All data must transform into events</td>
<td></td>
</tr>
<tr>
<td>- Difficult to see connections between data?</td>
<td></td>
</tr>
<tr>
<td>- Difficult to see consequences of an action</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hande subjective data</td>
<td></td>
</tr>
<tr>
<td>- Interviews as a collection of data</td>
<td></td>
</tr>
<tr>
<td>- Questionnaires as a collection of data</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13.1.1 How the integration affects the strengths

When developing a method it is very important to consider the strengths of the method so they are not reduced in the process. In the table below (Table 6) we have selected the main strengths of the R&E approach and examined how they will be affected of the integration with the CDM, ETA and Grounded theory. The left column shows the main strengths with the R&E approach and the right column shows if and how the strengths will be affected by the integration. One of the strengths is that the reconstruction part of the R&E approach is well defined. The integration will affect the definition of the reconstruction part since there will be another data source. This change is a positive change that broadens the amount of data sources, which makes it possible to make an even better reconstruction of the mission.

Another important strength is that the R&E approach can handle distributed events, which will not be affected of the integration. The use of a timeline
when structuring the data is a strength that will be developed when the R&E approach integrates with CDM. CDM has a developed interview technique where it uses a timeline when interviewing the participants.

The R&E approach can give an overview of the operation, which will be affected of the integration, but to the better. After the integration there will be possibilities to collect data after the operation from interviews, which will make the reconstruction even better.

A strength that will be obstructed by the integration with other methods is that the R&E approach has been relatively objective when reconstructing and analysing the operations. This is no longer possible when adding interviews as a data source since interviews result in interpretations.

**Table 6 How the integration affects the strengths**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Affects of the integration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The analysis method in general</strong></td>
<td></td>
</tr>
<tr>
<td>- The reconstruction is well defined</td>
<td>- Will be affected by the integration, but not obstructed (one more data source)</td>
</tr>
<tr>
<td><strong>The structuring and categorising of data</strong></td>
<td></td>
</tr>
<tr>
<td>- Can handle distributed events</td>
<td>- Will not be affected by the integration</td>
</tr>
<tr>
<td>- Uses a timeline</td>
<td>- Will be affected by the integration, but not obstructed (the timeline will be developed)</td>
</tr>
<tr>
<td>- Gives an overview reconstruction of the operation</td>
<td>- Will be affected by the integration, but not obstructed (possibilities to collect data after the operation from interviews)</td>
</tr>
<tr>
<td><strong>How to handle the data</strong></td>
<td></td>
</tr>
<tr>
<td>- R&amp;E is objective</td>
<td>- Will be affective and obstructed (it is not possible to improve the analysis if the analysis do not become more subjective)</td>
</tr>
<tr>
<td>- Collects data from different sources</td>
<td>- Will be affected by the integration but do not obstruct the strengths (interviews as an additional data source)</td>
</tr>
</tbody>
</table>
14 Result of the integration

This chapter presents the result of the integration between the R&E approach and CDM, ETA, and Grounded theory. The result is a modified version of the original R&E approach.

The picture below (Figure 16) illustrates the result of the integration process. The original phases of the R&E approach are still there, but with modifications. The dashed lines explain the modifications. There is also an additional phase in the end, the analysis phase, which occurs parallel to the presentation phase. Below the picture every step will be explained in detail.

Figure 16 The modified R&E approach

Domain analysis
The domain analysis is the same as in the original R&E approach. The purpose of the first step is to analyse the domain together with experts of the subject to form important issues in the work situation and look for particular problems of interest. These issues and problems will then be ordered in priority.\(^{239}\)

\(^{239}\) Morin (2002a)
Modelling
The second step is the modelling phase, which is based on information from the domain analysis. In the second step an object-oriented conceptual model is created to define the main actors and activities in the domain.\textsuperscript{240} This is the first phase to be modified. The result of the modelling step is an instrumentation plan outlining the needs for data collection and data presentation.\textsuperscript{241} The instrumentation plan should further on include the needs for handling interviews, a complement from CDM, which will be a new data source in the R&E approach.

Instrumentation
Instrumentation involves turning models and plans into procedures, equipment, and software components for data collection and presentation.\textsuperscript{242} What is new in this step is the planning of interviews; how, to whom and when to do them and the equipment needed.

Data collection
In the original R&E approach the data collection took place during an operation, for example by observations and digital photos. The data were then used to create a mission history, which is a time-synchronized model of the operation. All these steps enabled a reconstruction of a DTO resulting in a mission history.\textsuperscript{243} The difference after the integration is that the data collection also can take place after the operation by interviewing the participants in the mission. During the interviews, key decision points are identified and plotted in a decision chart.

The result of the data-collection step is a mission history. In the modified version of the R&E approach the creation of the mission history is inspired by the categorisation technique of ETA and Grounded theory. ETA has a structured way of handling voluminous data from interviews\textsuperscript{244} that is needed when adding interviews as a data source. The categorisation of data concerns all data sources, not only interviews. Grounded theory is selected because it is not only focusing on critical situations\textsuperscript{245}, which enables a more

\textsuperscript{240} Morin (2002a)
\textsuperscript{241} Ibid.
\textsuperscript{242} Ibid.
\textsuperscript{243} Ibid.
\textsuperscript{244} Wong & Blandford (2002)
\textsuperscript{245} Lundahl & Skärvad (1999)
complete overview of the operation because every decision is noticed, not only the critical.\textsuperscript{246}

**Presentation and analysis**

The biggest challenge of the R&E approach is the last step, the presentation. In the modified R&E approach the presentation step is combined with an analysis step, which is implemented parallel to the presentation step. The presentation step means to turn data in the mission history into a form that support exploratory analysis of the operation.\textsuperscript{247} The new analysis step is based on CDM and ETA with the purpose to automatically analyse the mission history by, for example using a chart. The users will then immediately see the connections between different decisions and events, and its consequences. Depending on the users’ needs, different connections can be shown, for example by a chart or a diagram.

Because of the new data source, interviews, it is possible to return to the data collection step to make additional interviews. To make this possible, it is important that MIND is constructed, technically, in a way that makes it easy to add data afterwards. This is shown with an arrow from the analysis box back to the data collection box.

The integration has resulted in that the R&E approach now agrees more with Woods’s ideas about how to analyse complex situations.\textsuperscript{248} The previous R&E approach only covered the first two steps, whereas the modified version of the R&E approach covers all the steps. The data collection has increased with one more data source, interviews, the coding has been more structured and a step for analysis has been added.

\textsuperscript{246} Strauss & Corbin (1998)  
\textsuperscript{247} Morin (2002a)  
\textsuperscript{248} Woods (1993)
15 Discussion

In the discussion we reflect and discuss the analysis and the integration.

15.1 Choice of methods

The purpose of the integration was to complement the weaknesses in the R&E approach with the strengths from other analysis methods for enhancing the approach to better suit the analysis of DTOS. We chose CDM for the integration because many of its strengths complemented the weaknesses in the R&E approach. An example was CDM’s ability to categorise and structure data. We believe that clear guidelines how to handle data will make the coding much easier and effective, which hopefully will lead to time saving for the analysts. The time saving can in the mean time lead to the possibility to handle more data, which can enable a more complete reconstruction and analysis of the operation. We believe that ETA can contribute with methods for structuring of data as well, why we also chose to involve this method in the integration process. We think that the categorisation could be done in the coding process by connecting an object oriented database directly to MIND. A database would also provide an easier way of handling multiple users.

The choice of a third method for integration was because we thought that there was a possibility to make an even more complete method if we found a method that can focus on every-day decisions and not only critical decisions and events. We believe that this would raise the possibilities to make a complete reconstruction of the operation and facilitate the analysis. The method that fulfilled this need was Grounded theory. The reason for Grounded theory is its ability to consider not only critical events and its categorisation of data.

15.2 The integration

As mentioned in chapter 14, the modified version of the R&E approach now covers more of Woods ideas about how to analyse complex situations\textsuperscript{249}. Still there are things that not agree with Woods ideas, for example the data

\textsuperscript{249} Woods (1993)
source; mentions eye movements. The modified version of the R&E approach does not cover this type of data collection, but it is maybe possible in the future. We think that the development with interviews as a data source will make a big difference for the possibility to analyse an operation, especially the decisions. Decision making in critical situations is a vital part of command and control activities.\textsuperscript{250} We believe that it is hard to analyse decisions without interviewing participants in the operations. It is possible to reconstruct \textit{what} decisions are made and \textit{when} they were made with help of objective data, but we do not think it is possible to analyse \textit{why} the decisions were made without asking the person that made the decisions, the analyst needs to get inside the persons head. This is why interviews as an additional data source will enable a better reconstruction of the operation, and the most important, make the analysis possible.

As is well known, interviews are associated with interpretations. This involves risks because interpretations vary depending on the person who makes them. Despite this risk, we believe that the advantages with interviews exceed the disadvantages. The data collection is complemented with a source, which is more subjective than the others. We believe that a mix between objective and subjective data sources leads to a better analysis of the operation.

We have been considering whether the R&E approach and MIND could be too complex after the modifications since we have not reduced any of the original steps, but we do not believe it will be a problem. We have added one more step, the analysis, and then just made modifications of the others. The only risk is that it can make the method more time consuming because of the additional data source; the interviews. We do believe that the possible increasing of time is outweighing by the advantage of a more complete reconstruction and analysis.

To summarise our opinions about the integration, we believe that a mix of the R&E approach’s present coding and ETA’s and Grounded theory’s way of structuring and categorising data will lead to a more effective coding and a better reconstruction of the operations. This will also facilitate the analysis of DTOs.

\textsuperscript{250} Tran, Jain & Abraham (2004)
Part VI: Conclusions & Reflections

This part of the thesis presents the conclusions drawn from the integration. We, as researchers, also answer the research questions as well as a part where we reflect upon the subject and the work with this thesis.
16 Conclusions

Main question:

- How can an existing cognitive analysis method be enhanced and possibly merged with other existing cognitive analysis methods to better suit the analysis of distributed tactical operations?

- What knowledge is gained by merging existing cognitive analysis methods?

One way of enhancing an existing objective cognitive analysis approach is by integration with other cognitive analysis methods. The enhancement can be accomplished by identifying the method’s weaknesses and goals and find cognitive analysis methods with strengths that reduce these weaknesses. It is also important to discover the strengths with the existing cognitive analysis method and investigate if the strengths are affected in a negative way by a merge.

If the method only uses objective data sources, one improvement can be to enable the method to handle subjective data, which makes it possible to conduct deeper analysis of DTOs. Integration with an analysis method like CDM enables to make visible relations and connections between for example decisions and its consequences.

To investigate the possibilities for a merger we performed a case study on the R&E approach that is developed at FOI. We integrated the R&E approach with other methods for cognitive analysis methods and developed an approach that covers both the need of a rich context and deeper analysis of the operation, to get a cognitive analysis method to better suit the analysis of distributed tactical operations. Figure 17 shows the result of the integration. We have chosen to keep the structure of the original approach but with modifications of some of the phases. These modifications enable a new phase, the analysis. For a more detailed presentation see chapter 13.
The knowledge we gained when merging existing cognitive analysis methods was that integration was a good way of improving an existing analysis method. The work procedure with analysing the methods with a meta-method is an effective way of investigating the development needs. This work procedure gives the possibility to develop a more suitable method for analysing critical situations.

**Sub questions:**

- *What are the possibilities and challenges for integration between the Reconstruction – exploration approach and other methods for cognitive analysis?*

Analysing distributed tactical operations is a challenging activity because of the problem of gaining overview of a large-scale operation. There are possibilities to develop the R&E approach with help from other analysis methods and make the approach better on analysing DTOS, to make visible connections and consequences of events and decisions in the operation. The challenges were to find one or several methods that cover the development needs of the R&E approach. A problem with finding a suitable method for integration is that most analysis methods are either specific on a special domain, for example communication, or very general.

R&E is developed for reconstructing a context over a large-scale operation, which makes integration with other existing cognitive analysis methods difficult because of their qualities to focus on specific events to explain the entirely.
- *In the light of a merger, what are the developments needs concerning the methods in the Reconstruction – exploration approach?*

To investigate the needs for development we chose to analyse the R&E approach with the meta-method MA/SIMM. The analysis resulted in three main areas that needed to be developed. The main problem is that there are no defined methods for analysing, which leads to a low validation of the results.

The analysis of the R&E approach showed that the approach did not have any guidelines for how to structure and categorise data. This problem made it hard to see the connections and consequences of a decision or an action.

The R&E approach has so far only used objective sources for data collections. The analysis showed that there is a need for additional support for a more subjective way of analysing and for subjective data sources like interviews.

These problems have led to three criteria that helped us find suitable methods for integration with the R&E approach. To see all the problems and its relations we refer to chapter 7.
17 Reflections

This chapter contains our reflections over the work with the thesis, recommendations to FOI and suggestions for further research.

17.1 Our work

Before approaching the subject we had little knowledge about cognitive analysis methods and the work at FOI with the R&E approach and MIND. After a while we started to understand the significance of finding a method for analysing cognitive work. The literature about the subject was endless and we had a hard time delimiting the area. This shows that the subject of cognitive analysis methods is well examined. However, articles and literature about merging methods to improve a method were scarce. The purpose with the thesis was to show one way of improving an existing analysis method. We chose to investigate the possibility to improve a method by integration, which we found very suitable. We chose to analyse the R&E approach with the meta-method MA/SIMM to identify the needs for development. The integration was mainly between the R&E approach and CDM. We were also influenced by qualities from ETA and Grounded theory. These methods were selected from a MA/SIMM analysis. Our choice how to use MA/SIMM gave us a wide perception of the methods. If we had used MA/SIMM differently, or used another analysis method, the analyses may have resulted in a more detailed picture of the methods. If we had concentrated on a specific perspective, for example the usability of MIND, we could have made a deeper analysis of the methods.

To prevent a low validation of the result, we used triangulation where we used interviews, literature reviews and evaluations. We were also two researchers that discussed the subject during the whole working procedure. By continuously discussing the subject and trying to reflect upon our work, we reduce the risk to be too subjective.

The R&E approach is developed together with the framework MIND, which makes them closely connected, and which made the work with the approach difficult since they almost always affect each other. We chose to treat them equally with a focus on the R&E approach. This was sometimes hard to handle especially when finding out the qualities of the approach; many
weaknesses we found was a result of a weak technical support of the system. An example is the absence of an objected oriented database connected to the MIND framework, which would simplify data analysis of voluminous data and multiple users. This is a weakness that is not possible to satisfy by integration with another method for cognitive analysis.

17.2 The integration

The “new” R&E approach solves many of the former problems of the R&E approach. We are aware that the new approach may be too complex and time-consuming since we have added more elements to the process without reducing the original approach. Unfortunately we do not have had the opportunity to try the new R&E approach in reality.

The work with this thesis has given us a deeper understanding and knowledge about cognitive methods, but has also given us a possibility to experience the labour environment. During work with the thesis, we noticed that much of the sources to the R&E approach had connections to employees at FOI. We were worried about how this would affect the result and validity of the research, but unfortunately it was not possible to exclude any of the sources. We do not think that the result would have been so much different if there had been other sources, because the situations that the subject concerns are so unique. We think that if it had concerned everyday situations and not DTOS, it would have been difficult because then the theories had been more general.

17.3 Recommendations to FOI and the MIND framework

We have made some recommendations to FOI how to improve the framework MIND.

One of MIND’s main weaknesses, which also are showed in the weaknesses graph (Chapter 7), is its lack of a database connected to the framework. This would solve many problems with the present framework. Categorising of data and being able to see connections and consequences of a decision or an action are some of the problems that a database would solve. Also a connection between the different scenes in the framework would make the analysis easier.
During the evaluation of the framework MIND we thought that the metadata notes were very unorganised and messy. It was hard to see what type of notes it was, or for how long of period the note described.

One goal with the approach is to acquire result that are highly valid and being able to lift the discussion from what happened to why. In the thesis we presented one way of enhancing the R&E approach by integration. This proposal will also affect the MIND framework and can for an example be solved by dividing the screen into two sections (Figure 18). The upper part shows the reconstruction of the history and the lower part shows the analysis. A decision chart or a diagram can for example illustrate the analysis.

![Figure 18 Suggestions for MIND](image-url)
17.4 Further work in the subject

The subject of cognitive analysis methods is extensive and ten weeks is not enough to give a detailed picture of the subject. We see an enormous potential with exploring the subject further and we would have liked to investigate the subject in a deeper level. Since the subject of integrating existing cognitive methods to better suit a specific situation is rather unexplored thus there is great potential for further developments.

Further research may also be to investigate the possibilities to improve the framework and explore other tools for cognitive analysis methods.

Interesting questions:

- Is integration the most suitable way of improving cognitive analysis methods for distributed tactical operations?

- What is the development needs for the framework MIND for better analyses of distributed tactical operations?

- Is integration a good way to enhance methods outside the area of distributed tactical operations?

- How can existing analysis methods be enhanced, in other ways than by integration, to better suit a specific situation?
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Interviews

Albinsson, Pär-Anders, FOI, user of the R&E approach and developer and user of MIND, 2005-06-28

Thorstensson, Mirko FOI, developer and user of the R&E approach and MIND, 2005-09-07
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Appendix 1: Interviews with Pär-Anders Albinsson & Mirko Thorstensson

Interview with Pär-Anders Albinsson, developer and user of the framework MIND and user of the R&E approach

Pär-Anders Albinsson started the interview with explaining the MIND framework and how long FOI have been working with it.

The first version of MIND was developed 1993 for a specific task; to evaluate exercise for the military. After the first version the developers started to examine the possibility to use MIND for a more general purpose and version two was developed. Around 2000 was the third version of MIND developed and was even more general than earlier versions and was no longer concentrated on military work. This is the current version.

FOI is looking for even further developments of the framework and the R&E approach. The purpose with the new version (no 4) is to get a wider target group and perhaps bringing knowledge from other methods for cognitive analysing. FOI have got some critic from people outside FOI; that the analyses from MIND don’t say much, in a scientific way.

- “How can we be sure of the substance of the result? That’s why we want to check how other methods handles the problem with the validity.”

Albinsson also explained his thought about the difference between an approach and a method for us. He said that an approach is on a higher level and can contain several methods and tools; an approach is more like directions. A method is more specific and connected to a specific result. The approach does not have any clear steps like a methodology to follow.

We asked Albinsson what he thought about being subjective in analysis. He answered that you have to play by the rules and you can’t make up things without any grounds for it. But a wish would be to use the R&E approach like a hypotheses generator and test to see if there are any connections. This is important when there are several analysers that work with the same data, and it is very important that they don’t contradict each other.

The data sources that the R&E approach uses today is mostly radio communication, but also system states and behaviour records. There are no limitations of sources of collecting data that Albinsson see.

A weakness with the R&E approach and the MIND framework is that it is not possible to start analysing until all data is transcribed and coded into the system. The system is not working against a database, which makes it difficult when you have more than one person working with the system. Everything must be transformed into events and have to be classified the same way with makes it hard to work with data that for example is collected after the operation and don’t fit into the timeline. Strength with the R&E
approach is that it can handle distributed work and there is no limitations were to put the
recorders. Work these days becomes more and more distributed.

**Interview with Mirko Thorstensson developer and user of the R&E approach and
the framework MIND.**

Our other interview was with Mirko Thorstensson.

Mirko Thorstensson is working at FOI as a project manager responsible for adjusting the
R&E approach to a test environment for the military. Thorstensson has been working at
FOI since 1997.

Thorstensson thinks that the R&E approach is too simple to be called a method but don’t
see a big different among the definitions; approach and method. He said that they might
have called the R&E approach a method in some earlier publications. Thorstensson said
that an approach feels less completed and a method more clear and that the R&E approach
is a composition of different methods.

Thorstensson is very positive towards the R&E approach and don’t see many weaknesses
with the approach except from the quality of the data and that is more of a question of
which data collection is implemented in the system. In the development of the approach it
might be effective to look at other existing analysis methods, but it would be hard to
combine them with the R&E approach, since other methods try to explain the reality by
isolating special dependence variables and explaining them. The flaws with these
methods are many if you have to disregard the context.

The framework MIND is very strongly connected to the R&E approach and it is hard to
reconstruct and explore without a good tool. The tool and the approach do develop the
same time,

-“The more functionality we develop the more we discover that we don’t have in the
approach. In my word is the ways of developing the approach by using it in its operative
environment an effective way.”

We asked about which data sources that are used and if they are in need of another.
Thorstensson answered that they only use data from objective data sources today but
wish to use for example interviews with operators and actors by making deep interviews
afterwards, like them in critical decision methods. It is also important to understand that it
is people they are dealing with. In the framework today they have had to prioritise
objective data and have also received critique that they only measure different positions
and are aware that they have to be better on handling subjective information. One
problem with this kind of data is which interpretations people make, two persons
experience the same thing can make two different interpretations, dependent on what pre-
knowledge they have.
Appendix 2: R&E Weaknesses

R&E: The list of weaknesses

1. No database connected to MIND
2. No analysis before all data is registered in the system
3. Difficult to support multiple user
4. Difficult to change recorded data

5. R&E is very objective
6. No balance between the reconstruction and exploration parts
7. No guidelines for the exploration part
8. All data must transform into events
9. Low validation of the result
10. Everything must be connected into a timeline
11. Can’t handle interviews in the timeline
12. Can’t handle questionnaire in the timeline
13. Indistinct categorizing in MIND

14. No connections between the notations
15. Can’t see the length of the notations
16. Difficult to handle data afterwards

17. Difficult to handle data that can’t be time stamped
18. No connection between communication and the maps
19. Can’t see the consequence of an action
20. No well-defined methods for analyzing
21. Lack of technical support for data coding
22. The notations is insufficient
23. No room for interpretation

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251 Albinsson (2005)
252 Our own practical experience (evaluation)
253 Albinsson (2005)
254 Our own practical experience (evaluation)
255 Albinsson (2005)
256 Our own practical experience (evaluation)
257 Ibid.
258 Morin (2002a)
259 Albinsson (2005)
260 Our own practical experience (evaluation)
261 Ibid.
R&E: Graph of the relations between the weaknesses

1. No database connected to MIND
2. No analysis before all data is registered in the system
3. Difficult to support multiple users
4. Difficult to change recorded data
5. RE is very objective
6. No balance between the reconstruction and exploration parts
7. No guidelines for the exploration part
8. All data must transform into events
9. Low validation of the results
10. Everything must be connected into a timeline
11. Can't handle interviews in the timeline
12. Can't handle questionnaire in the timeline
13. Indistinct categorizing in MIND
14. No connections between the notes
15. Can't see the length of the notes
16. Difficult to handle data afterwards
17. Difficult to handle data that can't be times stamped
18. No connection between communication and the maps
19. Can't see the consequence of an action
20. No well-defined methods for analysing
21. Lack of technical support for data coding
22. The notes is insufficient
23. No room for interpretation

19. No connection between communication and the maps

18. No connection between communication and the maps
Appendix 3: R&E Strengths

R&E: The list of strengths

1. R&E is objective

2. Gives a context over the operation

3. Easy to save large amount of data

4. Collect data from many levels in the organization

5. Collect data from different actors

6. Collect data from different places, geographic

7. Can handle distributed events

8. Gives a overview reconstruction of the operation

9. Reconstruction part is well defined

10. Many data sources

11. R&E use a timeline

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262 Our own practical experience (evaluation)

263 Albinsson (2005), Thorstensson (2005)

264 Ibid.

265 Ibid.

266 Albinsson (2005)

267 Ibid.

268 Albinsson (2005), Morin (2002a)

269 Albinsson (2005), Morin (2002a), Thorstensson (2005)

270 Morin (2002a)

271 Albinsson (2005)

272 Our own practical experience (evaluation), Thorstensson (2005)
R&E: Graph of the relations between the strengths

1. R&E is objective
2. Give a context over the operation
3. Easy to save large amount of data
4. Collect data from many levels in the organization
5. Collect data from different actors
6. Collect data from different places, geographic
7. Can handle distributed events
8. Gives a overview reconstruction of the operation
9. Reconstruction part is well defined
10. Many data sources
11. R&E use a timeline

OCH
Appendix 4: R&E Goals

R&E: List of goals

1. Try to get a complete reconstruction of the operation\(^{273}\)
2. Try to connect a defined method for analysis\(^ {274}\)
3. Handling data collected afterwards better\(^ {275}\)
4. Being able to handle data that is not time stamped\(^ {276}\)
5. High validation on the result\(^ {277}\)
6. Use R&E as hypothetic generator\(^ {278}\)
7. Find support for different stage of subjective and objective\(^ {279}\)
8. Make sure data is classified the same way\(^ {280}\)
9. Being able to answer the question: What happened and why?\(^ {281}\)

\(^{273}\) Albinsson (2005), Morin (2002a), Thorstensson (2005)
\(^{274}\) Albinsson (2005), Albinsson et al (2002a)
\(^{275}\) Albinsson (2005)
\(^{276}\) Ibid.
\(^{277}\) Ibid.
\(^{278}\) Ibid.
\(^{279}\) Albinsson (2005), Thorstensson (2005)
\(^{280}\) Albinsson (2005)
\(^{281}\) Albinsson (2005), Albinsson et al. (2002a)
R&E: Graph of the relations between the goals

1. Try to get a complete reconstruction of the operation

2. To get a defined method for analysis

3. Handling data collected afterwards better

4. Can handle data that is not time stamped

5. High validation on the result

6. Use R&E as hypothetic generating

7. Find support for different stage of subjective and objective

8. Make sure data is classified the same way

9. Being able to answer the question: What happened and why?
Appendix 5: CTA Weaknesses

CTA: Weaknesses

1. A collective name of different methods\textsuperscript{282}
2. Few data sources\textsuperscript{283}
3. No strong guidelines\textsuperscript{284}
4. It is very general\textsuperscript{285}
5. Does not create an overview\textsuperscript{286}

\textsuperscript{282} Zachary, Ryder & Hicinbothom (1998)
\textsuperscript{283} Klein, Klinger & Miller (1997)
\textsuperscript{284} Zachary, Ryder & Hicinbothom (1998)
\textsuperscript{285} Ibid.
\textsuperscript{286} Hoffman, Crandall & Shadbolt (1998)
Appendix 6: CTA Strengths

CTA: Strengths

1. Identifies cognitive skills \(^{287}\)
2. Extracts human knowledge
3. Based on observations \(^{288}\)
4. Based on interviews \(^{289}\)
5. Provides insight into expertise \(^{290}\)
6. Can be used when it is not possible to observe work \(^{291}\)
7. Identifies mental demands \(^{292}\)
8. Identifies needs to perform task proficiency \(^{293}\)

\[^{287}\] Tran, Jain & Abraham (2004)
\[^{288}\] Klein, Klinger & Miller (1997)
\[^{289}\] Ibid.
\[^{290}\] Tran, Jain & Abraham (2004)
\[^{291}\] Hoffman, Crandall & Shadbolt (1998)
\[^{292}\] Schraagen, Chipman & Shalin (2000)
\[^{293}\] Tran, Jain & Abraham (2004)
CWA: Weaknesses

1. Unique method for training and instruction\textsuperscript{294}
2. Focuses on task performance\textsuperscript{295}
3. Focus on evaluation and design of information systems\textsuperscript{296}

\textsuperscript{294} Lintern & Naikar (1998)
\textsuperscript{295} Bliantz (2002)
\textsuperscript{296} Vicente (1999)
Appendix 8: CWA Strengths

CWA: Strengths

1. Unique method for training and instructions 297
2. Identifies complexities on the work domain 298
3. Guide to remodel human system interface 299
4. Focus on the work domain 300
5. Clear phases of analyse 301

297 Lintern & Naikar (1998)
298 Bliantz et al. (2002)
299 Vicente (1999)
300 Bliantz et al. (2002)
301 Vicente (1999)
Appendix 9: WWM Weaknesses

1. Week presentation
2. Subjective
3. Very specific on communication
4. Only interviews about information flows

Moon (2004)
Appendix 10: WWM Strengths

WWM: Strengths

1. Gives a quick show of team communication
2. Understands how teams communicate
3. Identifies main communication channels
4. Can be used with experienced and novice subjects
5. Usefull to analyse information flow and decisions
6. Can be used in both one-on-one and group data collection sessions
7. Uses interviews
8. Subjective

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Moon (2004)
Appendix 11: CDM Weaknesses

CDM: Weaknesses

1. Retrospective

2. Rely on interviewee’s memory

3. The interviewees must have personal experience

4. Hard to articulate decision making

5. Few data collection sources

6. Can miss critical data

7. Rely on the researcher

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304 Hoffman et al. (1998)
305 Wong (2004)
306 Klein et al. (1998)
308 Ibid.
309 Ibid.
310 Ibid.
Appendix 12: CDM Strengths

CDM: Strengths

1. Data quality
2. Places incidents on a timeline\textsuperscript{311}
3. Advanced interviews\textsuperscript{312}
4. Explores and characterise decision needs\textsuperscript{313}
5. Research how decisions are made in actual situations\textsuperscript{314}
6. Used to design better decision aids\textsuperscript{315}
7. Handles both data collection and data analysis\textsuperscript{316}
8. Clear steps\textsuperscript{317}

\textsuperscript{311} Wong (2004)
\textsuperscript{312} Ibid.
\textsuperscript{313} Hoffman, Crandall & Shadbolt (1998)
\textsuperscript{314} Klein et al. (1989)
\textsuperscript{315} Wong (2004)
\textsuperscript{316} Ibid.
\textsuperscript{317} Ibid.
Appendix 13: ETA Weaknesses

ETA: Weaknesses

1. Depend upon the researcher
2. Low valuation

\[318\] Wong & Blandford (2002)
\[319\] Ibid.
Appendix 14: ETA Strengths

ETA: Strengths

1. Promotes insightful themes\textsuperscript{320}
2. Structures data\textsuperscript{321}
3. Fast
4. Practical
5. Make sense of voluminous interviews\textsuperscript{322}

\textsuperscript{320} Wong & Blandford (2002)
\textsuperscript{321} Ibid.
\textsuperscript{322} Ibid.
Appendix 15: GT Weaknesses

GT: Weaknesses

1. Depends on the researcher to be creative\textsuperscript{323}
2. Time consuming
3. Expensive
4. Do not focus on critical events

\textsuperscript{323} Svensson & Starrin (1996)
Appendix 16: GT Strengths

GT: Strengths

1. Research the connection between relevant factors for the phenomenon
2. Identify factors that are of relevance of the phenomenon
3. Can work with empirical data
4. Clear phases
5. Many sources of data
6. Organized data into categories

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See: Guvå & Hylander (1998)
See: Strauss & Corbin (1998)
See: Ibid.
See: Ibid.
Appendix 17: CIT Weaknesses

CIT: Weaknesses

1. Flexible guidelines\textsuperscript{330}
2. Subjective\textsuperscript{331}
3. Interpretations\textsuperscript{332}
4. Depends on the researcher\textsuperscript{333}

\textsuperscript{330} Welker (2003)
\textsuperscript{331} Callan (1998)
\textsuperscript{332} Norman et al. (1991)
\textsuperscript{333} Soutter and Hanna (1993)
Appendix 18: CIT Strengths

CIT: Strengths

1. Solves practical problems
2. Flexible guidelines
3. Can handle subjective data
4. Interpretation
5. Categorises data
6. Modifies the specific situation
7. Focus at the requirements of the specific situation

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334 Flanagan (1954)
335 Welker (2003)
336 Callan (1998)
337 Norman et al (1991)
338 Soutter and Hanna (1994)
340 Ibid.
Appendix 19: CDM Weaknesses, deeper analysis

CDM: Weaknesses

1. Retrospective
2. Rely on the interviewee’s memory
3. The interviewees must have personal memories
4. Hard to articulate decision making
5. Few data collection sources
6. Can miss critical data
7. Rely on the researcher
8. Focus on non-routine events
9. Relies on verbal reports
10. Weak in generalizability
11. The researcher can use leading questions

341 Hoffman et al. (1998)
342 Wong (2004)
344 Wong (2004)
345 Ibid.
346 Ibid.
347 Ibid.
1. Retrospective

3. The interviewees must have personal memories

4. Hard to articulate decision making

5. Few data collection sources

7. Rely on the researcher

8. Focus on non-routine events

9. Relies on verbal reports

10. Weak in generalizability

11. The researcher can use leading questions

6. Can miss critical data
Appendix 20: CDM Strengths, deep analysis

CDM: Strengths, deep analysis

1. Places incidents on a timeline
2. Explores and characterise decision needs
3. Research how decisions are made in critical decisions
4. Used to design better decision aids
5. Handles both collection and analysis of data
6. Shows key decision points
7. Clear steps
8. Focus on non-routine events
9. Uses semi-structured interviews
10. Traceable
11. Reduces and organises data
12. Manageable for data interpretation
13. Reliably
14. Efficient

348 Wong (2004)
349 Hoffman et al. (1998)
351 Wong (2004)
352 Ibid.
357 Wong (2004)
358 Ibid.
359 Ibid.
360 Ibid.
1. Places incidents on a timeline
2. Explores and characterise decision needs
3. Research how decisions are made in critical situations
4. Used to design better decision aids
5. Handles both collection and analysis of data
6. Shows key decision points
7. Clear steps
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9. Reduces and organises data
10. Uses semi-structured interviews
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13. Reliably
14. Efficient
Title
A study of the integration of complementary analysis methods – Analysing qualitative data for distributed tactical operations

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Abstract
Complex socio-technical systems, like command and control work in military operations and rescue operations, are becoming more and more common in the society, and there is a growing urge for more useful and effective systems. Qualitative data from complex socio-technical systems can be challenging to analyse. This thesis probes one way of enhancing existing analysis methods to better suit this task.

Our case study is carried out at FOI (the Swedish Defence Research Agency). One of FOI’s tasks is to analyse complex situations, for example military operations, and they have developed an approach called the Reconstruction – exploration approach (R&E). The R&E approach has a rich contextual approach, but lacks a systematic analytical methodology.

The assignment of this thesis is to investigate how the R&E approach could be enhanced and possibly merged with other existing cognitive analysis methods to better suit the analysis of DTOS. We identified that the R&E approach’s main weaknesses were the lack of structure and insufficient way of handling subjective data, which contributed to difficulties when performing a deeper analysis. The approach also needed a well-defined analysis method for increasing the validity of the identified results.

One way of improvement was to integrate the R&E approach with several cognitive analysis methods based on their respective individual strengths. We started by analysing the R&E approach and then identified qualities in other methods that complemented the weaknesses in the R&E approach. Finally we developed an integrated method.

The Critical Decision Method (CDM) appeared to be the most suitable method for integration with the R&E approach. Nevertheless, the CDM did not have all the qualities asked for so we chose to use functions from other methods included in our initial analysis as well; ETA and Grounded theory.

The integration resulted in a method with a well-defined method for analysis and the possibility to handle subjective data. This can contribute to a deeper analysis of DTOS.

Keywords
Qualitative data, analyse complex situations, analysis method, distributed tactical operations