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Erik Hollnagel,
François Pieri,
Eric Rigaud

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Preface

In the two years since the Second Resilience Engineering Symposium, 8-10 November 2006, the interest for resilience engineering has not just continued but increased. This can be seen from a growing number of papers and presentations in journals and at conferences throughout the world that refer to resilience engineering. (In august 2008, Google, the poor man's substitute for an *amanuensis*, produced almost 7.000 hits for 'resilience engineering', while Goggle Scholar produced 252 hits.) It can be seen from a number of local conferences, sessions, and seminars on resilience engineering. And more importantly, it can be seen from efforts to turn the resilience engineering principles into practice, both as research & development projects in Europe and the US, and as direct industry focused, and industry sponsored, efforts.

On the publication front, there is now a second book on resilience engineering (Hollnagel, Nemeth & Dekker, 2008), which includes selected presentations from the Symposium in 2006. This is also the first book in a series called *Ashgate Studies in Resilience Engineering,* managed by Ashgate Publishing Ltd., UK. This series promulgates new methods, principles and experiences that can complement established safety management approaches, thereby providing invaluable insights and guidance for practitioners and researchers alike in all safety-critical domains. Examples of domains are aviation, ground transportation, the military, energy production and distribution, finance, and healthcare. The series welcomes ideas and suggestions for books that can help bring the discipline of resilience engineering forward.

Another indicator of the growing interest is that the call for submissions to this Symposium resulted in sixty-eight abstracts, 50% more than in 2006. While this definitely has been very encouraging for the organising committee, it also presents a practical problem for the organisation of the Symposium. The 'easy' solution would have been to allow all qualified papers to be presented, either by extending the duration of the symposium, by shortening the time allowed for each paper, or by introducing parallel sessions. The first option was not considered feasible for practical reasons. The second and third options were not acceptable for 'scientific' reasons and because they both defied the purpose of organising a symposium in the fist place, namely to provide interested people an opportunity to listen, to debate, and to learn. The organising committee therefore chose the 'hard' solution, namely to limit the number of presentations to the benefit of discussions and debates. The Third Symposium therefore has the same basic structure as the Second Symposium. This means 30-minute presentations, two separate discussion periods each day, two relaxed visual presentation sessions, and ample breaks in between. It also means that the threshold for acceptance was raised, but this will hopefully be to the benefit of all participants, not least the many who have chosen to attend because the Symposium offers an opportunity to sample the state-of-the-art.

The symposium owes a great deal of gratitude to the people who provided the reviews of the many abstracts submitted, always under time pressure an in many cases with detailed comments. Here are their names: Rene Amalberti, Richard Cook, Sidney Dekker, Arthur Dijkstra, Steve Epstein, Rhona Flin, Christopher Nemeth,

Yushi Fujita, Gudela Grote, Andrew Hale, Erik Hollnagel, Jan Hovden, Nick McDonald, Jean Paries, Gunilla Sundström, Ron Westrum, John Wreathall, and Erica Seville.

The following pages contain the papers that were selected for presentation at the Symposium, either as verbal presentations or as visual presentations. Even though they are in the nature of pre-proceedings, it is hoped that they may be useful for people who are interested in resilience engineering but who, for one reason or another, were unable to attend. The papers will also be posted on www.resilience-engineering.org, which serves as the common resource for the resilience engineering network.

This symposium would not have been possible without the sponsorship and support of the industrial partners of the Industrial Safety Chair at Ecole des Mines de Paris (AGF, APAVE, ARCELOR, FIMMM, GDF, INERIS, Ecole des Mines de Paris Alumni Association, SNCF, TOTAL). Their contribution is gratefully acknowledged, as is the enthusiastic support from the people at the Crisis and Risk Research Centre.

Sophia Antipolis, 19 September 2008

Erik Hollnagel

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Safety, Culture and the failure of foresight

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How, if at all, is it possible to assess and monitor aspects of organizational culture and the way culture influences safety? This is a question that lies at the heart of the recent interest in safety culture and resilience engineering but which, nevertheless, has been largely neglected by safety research.

Descriptions of an organization's safety culture are considered to provide grounds for proactive safety management, by yielding 'predictive measures (…) which may reduce the need to wait for the system to fail in order to identify weaknesses and to take remedial actions' (Flin et al., 2000: 178). The hope is that such 'predictive measures' will constitute leading (as opposed to lagging) indicators for the management of safety. All of this depends on the ability to assess and monitor reliably the relevant cultural factors that cause accidents. However, whether we are in fact able to do this remains an open question.

The paper presents an empirical analysis of this question by comparing the results of a safety culture assessment on the Norwegian oil and gas platform Snorre Alpha, with the results of an investigation after a potentially catastrophic gas blowout on the same platform. The culture survey was conducted only one year prior to the incident, which makes Snorre Alpha a unique case for analysing the links between proactive assessments of safety culture and assessment of the same culture done with the wisdom of hindsight.

The analysis shows that the description of the safety culture made prior to the incident was dramatically different to the situation described in the incident investigation. The lack of concurrence between the two descriptions of the same culture suggests that safety culture surveys may have little or no predictive value. The paper suggests other principles for culture assessments which rely more on qualitative methods than the existing assessment tools.

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Supporting Decisions on Change: Balancing Safety Issues with Operational and Commercial Decisions in an Airline Company

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Abstract. Our on-going study in the airline company underlines some issues which confirm that transport systems such as aviation have become safe without having an explicit model of how they achieve this. However, without a clear model of who does what and which measures control which scenarios, change can remove vital safety functions in the system without us realising it (Hale, 2001). This is especially important to remember when changes are introduced. Not only technological change but also organizational change needs to be subject to safety assessment and control. In order to tackle the issue of balance between safety performance measures and operations performance measures in a complete way there is a need to analyse simultaneously all threats and factors influencing in-flight safety in all activities across the organisation, as well as stakeholders` objectives and the ways they manage the risks within their areas of competence.

1 A DISJOINTED AND IMBALANCED DECISION MAKING PROCESS AS A CONTRIBUTOR TO A DRIFT INTO FAILURE

A company in a networked and changing environment strives to reconcile two objectives: i) to ensure the stability of successful business results through enhancing adaptive organisational capacity, and ii) to anticipate and to shape the future through continuous improvement and innovation. This reconciliation is to be seen as strategic adaptive planning and thus as a process of learning and development. One of the factors in this process is the safety, both in the short and long term, of all employees, customers and third parties. Since we are looking primarily at the prevention of major accident safety implications we focus on long-term organisational objectives, and, therefore, on strategic decision making.

NASA's approach to decision-making shows that a failure to balance safety risks with intense production pressures results in accidents because of the drift towards failure while defenses erode in the face of production pressure (Woods, 2003). When this imbalance or failure to trade-off safety and productivity is combined with a fragmented problem-solving process which misses cross checks and is unable to see the big picture, the result is an organization that cannot see its own blind spots about risks.

All organizations can unbalance safety risks with the pressure for efficiency. It is difficult to sacrifice today's real production goals in considering uncertain evidence of possible future risks. Thus, among the multiple goals of a company there are short-term (productivity) and long-term (safety) organisational goals. Imbalance occurs gradually as pressure leads to a narrowing focus on some goals while obscuring the tradeoff with other goals. This process usually happens when short-term goals like production/efficiency take precedence over long-term goals like safety (Woods, 2003).

We argue that supporting strategic decisions triggered by the desire for competitive advantage from new technology, or triggered by safety incidents, raises the question whether a mechanism exists for measuring explicitly both the impact of safety on the quality of service to passengers, on operations quality, on 'company-wide quality', and the effects of such 'quality' actions on safety.

It seems that there is no formal methodology for evaluating and supporting strategic decisions and that the overall decision-making process does not necessarily guarantee the resolution of conflicts in order to establish what should be changed between relevant stakeholders/ departments, and in what way. The relevant problems are:

- Operational, environmental or commercial threats are all considered separately and are not included in the overall evaluation of safety implications, although they may be important in terms of safety.
- There is a lack of information on threats and the impact on safety performance in the case of organisational or commercial policy change. An integrated analysis bridging all the processes (if it exists at all in the airline) is only partial and is not shared with the safety department or pilots.
- Management of change(s) is very top-down. There is a lack of communication between groups/ departments. Communication flows are limited; information sharing is often blocked at the senior/director level and does not circulate to lower/ sub-divisional levels.
- Decision-makers for innovation or change often have neither the means nor sufficient operational knowledge to assess all potential benefits and risks for all sub-divisions in a holistic manner.

2 REQUIREMENTS FOR ENHANCING THE EVALUATION OF DECISIONS ON CHANGE

In order to resolve these problems, a special methodology needs to be introduced to bridge both the sharing of information on risks and capacities across the organization and the inclusion of them in the decision-making process.

This methodology needs to meet a number of requirements, such as:

- The willingness of a company's management to invest in safety and to allocate resources to safety improvement in a timely, proactive manner, despite pressures on production and efficiency, is the key factor in ensuring a resilient organization.
- Creating an ability continuously to re-evaluate the assessments of risks (in terms of opportunities as well as of potential failures) in time;
- Creating an ability to re-examine management options/ objectives in response to changing risks;
- Creating an ability to interact between diverse groups with diverse knowledge;
- Creating visualisations which capture the integral (system) picture and allow re-organising individual/ group assessments in order to envisage multiple perspectives.

Risk-based decision-making, coupled with organisational learning, requires i) a shared understanding of the need for change in a company or industry, and ii) the capacity and analytical skill for transforming existing experiences and solutions for new customer services in order to respond to challenges.

In the continuous process of creating and maintaining Organizational Memory (OM), decision-making can stimulate the learning mechanism and improve the detection of potential conflicts as well as their resolution. A decision-making process needs to be a pro-active, considering both the positive and negative implications of risk-induced change. Mechanisms for learning and the trade-offs between various stakeholders leading to appropriate action(s) need to be provided.

The decision process might then be seen as an evaluation of consequences for different alternatives, given the plurality of individual and group goals. On the other hand, the decision process should also generate answers on how to modify the system and how to provide dynamic stability at the same time. Understanding how different stakeholders judge the possible negative consequences of risks and their costs, as against the potential benefits from the associated opportunities arising from change, will allow us to visualise the diversity of judgments about safety and other criteria and to learn how to balance them.

In the continuous process of re-evaluation of risks assessments and creating a shared and integrated picture on system risks, decision-making can improve the detection of potential conflicts as well as their resolution. Re-negotiations achieved through an integrated decision-making process will in fact contribute to balancing safety issues with production/ efficiency issues.

3 A CASE INVOLVING AN AIRLINE COMPANY

Our on-going interviews and observations at an airline company are focused on evaluating change with respect to the balance between commercial decisions and operational consequences. Since we are looking primarily at major safety implications it focuses on long-term organisational objectives, and therefore strategic decisions.

The airline company can be seen as a networking organisation, where different functional groups are affiliated to multiple organisations and where communication is complex due to diverse and often conflicting interests (Hauptman & Hirji, 1999). These multiple organisations include for example production management, planning unit, maintenance, cabin crews and pilots, unions, cargo and handling, operational control, navigation and routes, airport security, quality audit, training unit, manufacturer, procedures & aircraft safety, strategic planning, human resource development and management, commercial unit, customer relationship management, fuel, environmental affairs etc.

Another typical feature of such a company is that safety is defined as a priority incorporated into the services which the company delivers. Therefore, by definition, safety has to be included in the evaluation of quality or business results.

Our research shows that in a real organisational model, as practised, safety and an operations/airline quality system are neither dependent on each other nor subordinate one to the other. There is ‘understanding’ among safety staff that there is a relationship, but there seems to be no mechanism for measuring the impact of safety on the quality of service to passengers, on operations quality, or on ‘company-wide quality’. Nor are the effects of quality actions on safety explicitly measured. In fact, in practice quality is divorced from safety.

One of the decision processes we are studying as a case is the process of adding a new destination to the airline’s network. When a new destination is introduced ‘threats analysis’ will be conducted. Threats are considered as all situations/events external to the flight deck which must be managed by the cockpit crew during normal flight. Such events increase the operational complexity of flight and pose a safety risk to the flight. A number of threats are considered such as adverse weather, missed approaches, heavy traffic, similar call signals, maintenance error, unfamiliar airport, etc. Such threats analysis results in notes/briefings to the pilot, and a safety report is sent to the operations department and also to the flight line manager. Security, environmental or commercial threats are all considered separately and not included in the evaluation of safety implications, although they may be important in terms of safety.

Another issue is that in practice there is no formal mechanism implemented for translating those threats into risk and cost assessments. While information on threats is shareable within the company as well as with other airlines, information on bad design or serious maintenance problems, which are revealed in similar implementation processes due to incidents occurred is strictly confidential within the one airline; therefore the opportunities to use those lessons are limited. Even within the airline there is another ‘separation’ in reporting on potential safety implications between two feedback loops: maintenance – safety department – manufacturer, and safety department - flight operations.

To address these problems (of separation, of translating threats into risk assessment, and of confidentiality) we need a Risk and Decision Analysis methodology which allows for:

(I) an evaluation of the effectiveness of decisions about change (e.g. introducing a new destination) in providing a minimum, or higher, level of required Safety as well as in increasing Quality of Service and Profitability;

(II) an evaluation of the effectiveness of existing organisational models (communication flows on threats and the processes of managing them) in the mitigation of aircraft accident risk;

(III) support for decisions during 'active flight operations' by providing access to relevant commercial information for process improvements which might have a significant effect overall on a company's performance and safety record.

Our approach is based on recognising that decisions about change produce various types of consequences associated with performing complex tasks in a new operational environment - both positive (business and safety benefits) and negative (risks to safety and increasing costs).

Our interviews show that there is a lack of information on threats and the impact on safety performance in the case of organisational or commercial policy changes, such as the new destination decision we analyse in this case study.

From our interviews we also can see that the company, in making new decisions, aims at a balance between the following criteria:

- Profitability: revenue management + network development
- Feasibility: capacity and availability including maintenance, slot, crews, airport bases.
- Good quality of service to passengers: regularity, number of cancellations, punctuality, good connections etc.
- Environmental dimension (corporate level, Environmental Affairs & Innovation Department): planning to avoid inappropriate locations of new runways, or use of existing ones; noise at night, etc.

Safety is not taken into account explicitly here. All stakeholders can be seen as also risk proprietors, who have responsibility for managing the risks within their area of competence, and for developing action plans to control those risks. However, not all of them make these risks explicit, especially risks affecting operational safety or safety performance.

4 PROVISIONAL FINDINGS

Conducted interviews show that there is a lack of information on threats and the impact on safety performance in the case of organisational or commercial policy changes, such as the new destination decision we analyse in this case study. Our view is that the safety dimension does not seem to rate as a primary objective in evaluations prior to such a decision, although we could conclude that safety considerations do arise indirectly through the participation of the Production Management Department and consultations with the pilots in special cases.

The feedback from Flight Operations to the Production Management Department helps to calculate the operational consequences of decisions made by commercial department in terms of crews' availability. However, there are no visible inputs or calculations in terms of implications for human factors, safety or quality. Planning is aiming at resource re-allocation, not at re-design. The synthesis of information between departments takes place on the basis of informal contacts or inter-departmental meetings. Currently decision making process on change is not structured and based on subjective judgments from a personal expertise. The whole process is not resilient since knowledge may be easily lost when people leave a company.

Non-structured decision making process generates mainly safety issues list, not a discussion and solutions on how to treat those risks and safety issues. This process is missing a pro-active evaluation of unknown/ unseen risks. Also it leaves no room for developing shared picture on each others criteria. Criteria on cost of risks to safety are not present in financial considerations.

In order to tackle the issue of balance between safety performance measures and operations performance measures in a complete way there is a need to analyse simultaneously all threats and factors influencing in-flight safety in all activities across the organisation, as well as stakeholders` objectives and the ways they manage the risks within their areas of competence.

5 TOWARDS AN INTEGRATED ANALYSIS

In order to achieve an integrated and balanced strategic decisions process we refer to structured decision making (Failing et al., 2007). Structured decision making is an organized process for engaging multiple parties in a productive decision-oriented dialogue that considers both facts and values. It relies on the principles and tools of decision analysis, the core elements of which include defining objectives and measures of performance, identifying and evaluating alternatives, and making choices based on a clear understanding of uncertainties and trade-offs (Hammond et al., 1999).

In order to overcome poor system risk and multi-objective trade-offs analysis related to a changing environment and to added risks due to innovation, special attention is drawn to Multi Criteria (multi objective) Decision Analysis (MCDA). In the absence of a formal methodology for Integrated Decision Support when envisaging and implementing innovation, MCDA methodology can be useful in overcoming the fragmentation in risk assessments perceived by Risk, Budget, Quality or Schedule Managements, in order to resolve potential conflicts between safety, efficiency and well-being.

This work will apply a particular technique for multi-criteria decision analysis - Analytic Network Process (ANP) - in a new area (system integrated risk assessment), usable for a company in its strategic decision making (Beauchamp, 2007). ANP (Saaty, 2001; 2004) allows for complex interactions between sub-models and between criteria inside a cluster. Thus, for our study we present here an example of generic framework (see figures 1).

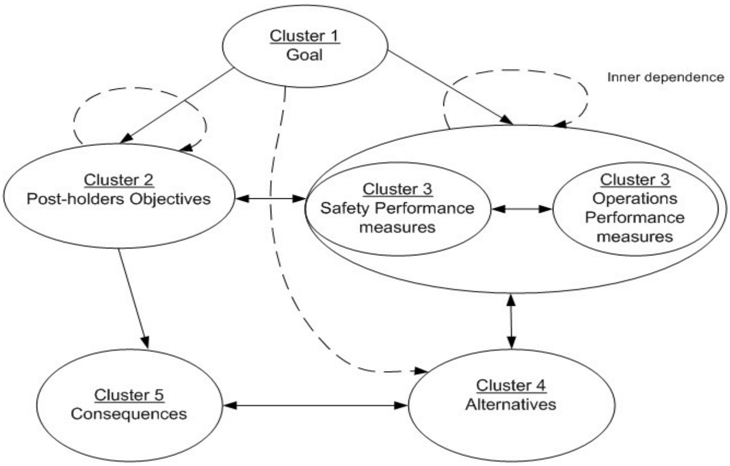

Fig. 1. An example of ANP model/ framework for supporting a decision making process

ANP can help in conducting an integrated analysis of explicit objectives expressed by different stakeholders as well as ideal criteria for long-term airline company development. Subsequently it would be possible to build further models in order to define and select the best strategies with a view to avoiding undesirable changes in safety or quality levels while making commercial decisions.

While applying ANP methodology for a synthesis of information on stakeholders' understanding of a specific decision-making problem, as well as their preferences, we need to evaluate the relative importance of the merits - such as benefits, opportunities, risks and costs (BOCR). They are rated under the company strategic objectives

The results of this study will contribute to the development and implementation of a usable version of MCDA at senior management level, using techniques for weighting risk factors within safety parameters when conducting Integrated Risk Assessments. As such they are relevant both to the strategic loop of Organisational Learning, and to Decision- Making.

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Securing Organizational Resilience in Escalating Situations
Development of skills for crisis and disaster management

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Abstract. Over-reliance in high-risk industries on prescriptive emergency procedures and the capacity of high-fidelity simulation has initiated the search for new steps for training in handling complex and escalating events. A theoretical framework for generic, non-domain specific competencies in proactive crisis management has been developed. The framework contains the following four categories: 1. Information Management, 2. Communication and Coordination, 3. Decision and Implementation, and finally 4. Effect Control. The ability to train the generic competencies has been studied using a crisis management training program in the context of a simulation exercise. A group of Fire Safety Engineers went through the non-domain specific training program and their performance was compared with a control group when doing crisis management exercises in their own domain. This experiment indicates that non-domain specific training improves the participants' ability to manage crises in their own domain and to evaluate their actions and shortcomings when handling complex and dynamic situations.

1 INTRODUCTION

The overall aim with this research has been to increase the understanding of resilient organizations and their characteristics. It has been suggested that in creating resilient flight-crews, increasing focus needs to be placed on awareness of, and language for, the need for generic, rather than specific or procedural competencies, for managing low-probability/high consequence events [Dekker, Dahlström, van Winsen & Nyce, 2008]. The specific aim has been to study if such generic competencies also can be applicable to manage escalating situations in other, less operator-oriented, industries and if it is possible to practice the generic competencies in such a way that the training improves peoples' handling of escalating situations in their own domain. To answer the questions a theoretical framework was needed to explain the basic concepts underlying the generic competencies. Experiments were then performed where the effects of training, focusing on the generic competencies, were studied.

2 DEVELOPING A THEORETICAL FRAMEWORK

The development of a theoretical framework aims at isolate generic, non-domain specific competencies, that can help explaining and evaluating how teams from various industries handle unexpected and escalating events.

Theory elaboration is described as: “a method for developing general theories of particular phenomena through qualitative case analysis” [Vaughan, 1992]. Using theory elaboration a theoretical framework for generic competencies has been established. A theory base considering peoples’ handling of complex and dynamic systems [Janis, 1982; Dörner, 1996; Flin, O'Connor & Crichton, 2008], and decision making [Brehmer, 1992; Hutton & Klein, 1999; Mathieu, Heffner, Goodwin, Salas & et al., 2000] guided the research through five case studies from various industries. Vaughan [1992] explained how case comparison can generate contrasts that demand us to discover, reinterpret and transform our theoretical constructs.

The cases presented below represent crises from five different industries that generated considerable challenges for the organizations which had to manage the crises during their escalating phases. The first case involves the challenges of understanding signals and revising strategies. The second case highlights the use of emergency procedures. The third, and fifth, cases cover coordination at a strategic level and the fourth case coordination at an operational level.

When the main feedwater pumps at Three Mile Island tripped on March 28 1979 the increasing pressure in the reactor made a pressurized relief valve open. The valve should have closed, but did not. A control lamp in the control room that was intended to indicate that the valve had closed instead indicated that the signal had been sent to the valve to close [Kemeny, 1979]. For several hours the operators were unable to make sense of the incoming information, in hindsight showing that the valve was open and that the reactor was loosing its coolant water through the valve [Perrow, 1984]. Their main goal was probably to avoid filling the reactor with water which was known as an unwanted state. With no revision of their initial mind-set the operators were unable to establish a proactive management of the situation.

Swissair 111 crashed into the sea outside the Canadian coast on September 2 1998. When the pilots noticed smoke in the cockpit they first concluded that it was coming from the air conditioning system. The pilots initially decided to divert to Boston, but after a call from the air traffic controller whether they would rather go to Halifax, which was closer, they revised the plan and turned towards Halifax. However, what became the main goal during the entire approach towards Halifax was not the diversion itself but rather the completion of the emergency procedure for smoke into the cockpit. The procedure consisted of two checklists that were designed to help the pilots figure out the source of the smoke rather than making proactive assessments of how to get the passengers and crew on solid ground or put out a possible fire. At several times the approach was delayed in order to get more time to complete the procedure. Instead the fire spread until it reached vital systems and made the aircraft uncontrollable [National Transportation Safety Board of Canada 2003].

When the tsunami struck south-east Asia on December 26 2004 the information of a large-scale crisis, possibly involving thousands of Swedish citizens, reached the Swedish authorities. However the managers rather waited for more information to come in than to act based on the available information, a phenomenon that Moats, Chermack and Dooley [2008] calls “paralysis by analysis”. Even when the information had reached all decision makers, the involved authorities were not coordinated with shared goals to guide their response operations making the Swedish authorities unable to establish any proactive strategies for several weeks. The commission that investigated the Swedish authorities' handling of the tsunami disaster criticized the authorities for not having a central crisis management function within the government offices.[The Swedish Tsunami Commission, 2005]

After a tank rupture at the company Kemira in Helsingborg, Sweden, 16 300 tons of sulfuric acid leaked out. This triggered the largest operation ever by the local rescue services. The operation came to involve ten different crisis management teams responsible for supplying different kinds of information and support to the rescue crews on site. Also eight different people had the role as incident commanders, causing confusion regarding who was the highest decision maker in the operation. Lacking communication and coordination between the management teams and commanders led to unclear goals, the same tasks made by several teams and lacking follow-ups of the situation. [Danielsson & Winnberg, 2005]

On October 2 2002 a major breakdown of the telecom system occurred in Uppsala County, Sweden. 230 000 subscribers were affected, 40 000 of which were completely cut off from the telecom network without the ability to make any phone calls, not even to the emergency services. Not having any predefined procedures for a situation where the telecom system was down, the personnel at the rescue station soon realized the severity of the situation and started to act. The crisis management team for the county was brought in by letting horns in the population centers sound (indicating important message for the public as well as a call for the staff). The team was soon gathered and without any information about the severity of the breakdown, or how long it would remain, goals for the coming 24 hours was set up and prioritized. The early formulation of explicit goals helped the management team to guide the decision-making processes in a proactive manner. The county was well prepared for the breakdown to last a lot longer when the telecommunication was back later in the evening. [Hedin Ekström, 2004]

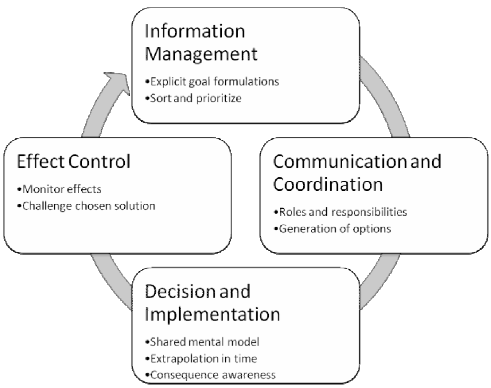

Fig. 1. A theoretical framework of generic competencies for proactive crisis management

In terms of the competencies needed for a team handling an escalating scenario, some parts of the theoretical base were able to explain key aspects of all the cases. These generic, non domain specific, competencies are shown in figure 1.

The first competence category is *Information Management*. In an escalating situation the team managing the situation is often in a situation of information overflow. To establish proactive strategies, analyses of possible developments of the situation has to be based on explicit goals [Dörner, 1996]. The ability to sort out relevant pieces of information in an information overflow may also have decisive importance for the outcome of the crisis management [Orasanu & Connolly, 1993].

In the *Communication and Coordination*-processes the roles, and their areas of responsibilities, in the team have to be robust and clear. But the roles also have to be flexible to the need of assistance for some responsibilities and call on for others [Heath, 1998].

The third competence category is named *Decision and Implementation*. In a situation of high information flow the decision-making process has to take place within every area of responsibility. To make all decisions in consensus would cost too much time. It is therefore necessary that the various ongoing decision-making processes are based on the shared goals. This is described by Fredholm & Åström [2006] as distributed decision-making based on a shared mental model.

The importance of updating the initial thesis and goals of the crisis management, based on additional incoming information, is expressed as the final competence category: *Effect Control*. The category also contains the importance of avoiding mind-sets that makes people see and interpret information that confirms the initial thesis rather than information that does not.

3 TRAINING THE COMPETENCIES USING A CRISIS MANAGEMENT SIMULATION

To evaluate the possibility to train the generic competencies, and use the theoretical framework as an evaluation tool, an experiment was made at the Swedish Rescue Service Agency's school in Revinge, Sweden. A crisis simulation exercise was used to train the generic competencies in two experiment groups.

The simulation used allows five to seven participants to assume different roles on the bridge of a vessel caught in a stormy night on the Atlantic Ocean [Strohschneider & Gerdes, 2004]. During the simulation different events occur that increasingly demand that the participants establish strategies to apply generic competencies to prevent the situation from escalating beyond their control. The simulation provides information to the participants in the form of computer printouts. Beyond blueprints and maps there is no visualization of the simulation and the participants are not equipped with any predefined strategies for managing upcoming situations. The simulation is part of a two-day training program which also includes lectures, discussions and debriefing sessions.

From a course with 23 Fire Safety Engineers, on a year-long training program to become incident commanders in rescue services, half received the two-day program before scheduled emergency management team training on their course. During the simulation data collections were made in regards to the students' abilities to use generic competencies. Data collections were also made during the emergency management training, i.e. where they were performing within the boundaries of their own domain. Differences in the use of generic competencies between those engineers who had received the two-day program and those who had not were observed and analyzed.

The two experiment groups were not successful in handling the simulated vessel during the crisis management simulation exercises. None of the groups established any strategies to handle the information overflow, did not state any explicit goals, did not establish any successful strategies for distributed decision making and were not flexible in their roles. Shortly into the simulation the teams' performance could be described as normal operations-behavior, focusing on what to do to solve current problems based on their urgency rather than trying to refocus on how to create structures and strategies to solve problems based on an assessment of their importance. However both teams did improve their performances at the second day's exercise and expressed that the exercise had been useful for their training.

During the following emergency management team training an increased ability to apply generic competencies was demonstrated by the experimental groups compared to the control groups. The experimental groups established shared mental models based on clearer formulations of roles and with a mandate for decision making within the different roles. The control groups were hardly aware of roles in any sense beyond labeling group members and their decision making processes were characterized by gathering the groups for briefing sessions as soon as any new information was received, instead of sort and distribute the incoming information to the team members based on their roles. The experimental groups followed up on how ordered tasks were performed while the control groups ordered work to be performed and then took no action to ensure that the orders were carried out. The use of the generic competencies made the experimental groups able to establish more proactive processes than the control groups which rather were stuck in the inability to sort, prioritize and distribute information and tasks. A summary of the observations made during the staff exercises is shown in table 1.

Table 1. A comparison between the groups that had received the simulation training program and the control group's performances at the staff exercises

The experimental groups	**The control groups**
Indistinct roles at high information flow	Hardly any roles
Showed proactive tendencies	No proactive tendencies
Not all decisions taken in consensus	Briefing sessions as soon as any new information was coming in
Clear team-leader and team-moderator	Who answers the phone is selected by chance
Tasks were performed	Thematic vagabonding
Some explicit goals	No explicit goals

The most significant difference between the groups was however observed during the debriefing sessions. During these the control groups commented their own performance with "In real life one has predefined procedures and roles for situations like this" and "I don't know if more sharply defined roles would have made us more effective". The experimental groups performed far more qualified analyses of their performance and their shortcomings. Their statements showed understanding of the need for generic competencies and the difficulties in establishing strategies for applying them. A summary of the observations made during the debriefing sessions is shown in table 2.

Table 2. Differences in reasoning at the debriefing sessions after the staff exercises.

The experimental groups	**The control groups**
Identifies the problems in doing other peoples' work	No understanding for the importance of roles
Discusses the difficulties in formulating explicit goals and the benefits from doing so	Believes implicit goals are capable of guiding the management
Discusses the difficulties in being proactive	Wrongly believes that some actions were proactive
Generally good in evaluating their own actions	Express believes that in real life there are predetermined roles and procedures for all situations

4 DISCUSSION

This experiment indicates that non-domain specific training of escalating situations improves the participants' ability to manage crises in their own domain and to evaluate their actions and shortcomings when handling complex and dynamic situations. The potential to apply this sort of training in various industries, that demand rapid and well structured response to escalating situations, is great although more research and further testing is needed. However, as a part of the overall aim to increase the understanding of resilient organizations and their characteristics non-domain specific simulation have already proved to be an effective tool.

The theoretical framework explaining generic competencies for proactive crisis management was a useful tool for contextualizing statements made, and strategies chosen, by the observed teams in their managing of the escalating situations. The framework could also be a useful tool for development of new programs and methods for managing and training of escalating situations in numerous industries like aviation, ship management, health care and the nuclear industry.

The framework is an early model based on five cases. Further case studies are needed to study whether the same framework could be useful in describing the competences needed to maintain organizational resilience in operations where various management teams and organizations are not predefined, but rather an emergent phenomenon, rooted in the complexity and dynamics of the situation. Triangulation using additional case studies and training experiments could reveal additional competencies that need to be considered and added to the framework.

In future development of training programs in handling complex and dynamic systems the need for the development and training of generic competencies, in contrast to drilling prescriptive plans and procedures, needs to be emphasized. The theoretical framework for generic competencies could help guiding such processes.

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Cognitive Resilience in Emergency Room Operations, a Theoretical Framework

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Abstract. System resilience implies practitioners' capacity to cope with unexpected events, i.e. cognitive resilience. To address it, we outline a framework based on the Skill-Rule-Knowledge model grounding it in the operators' sensitivity to the variety that normally occurs in complex systems activities. This variety can hide information enabling the organization to be proactive and to manage unexpected events. Each situation can be described with a SRK profile, according to the cognitive processes necessary to control it. Operators' reliability can therefore be analyzed by evaluating the match between their cognitive SRK profile and that demanded by the current situation. System resilience is ensured by the capacity of operators to: (i) choose the most suitable cognitive level; (ii) freely move along these levels according to the situation; (iii) be mindful towards variety; (iv) transfer their personal mindfulness into group dynamic adaptation. The outcome of these behaviors is a balance of mindfulness (constant attention to anomalous signals) and dynamic adaptation (organizational adjustment of existing rules according to the new information). This continuous equilibrium between chaos and order is the strategy followed by adaptive complex systems in order to evolve and can be successfully applied to high-risk organizations to enhance the emergence of resilient behaviors.

1 INTRODUCTION

According to recent views about safety and error, the major challenge for current theories, models and frameworks is to handle what Weick and Sutcliffe (2001) defined as "dynamic non-events" where human performance has a role that goes beyond the mere trade-off of correct and wrong actions (Hollnagel, 2004). Thinking about safety in terms of preventing human error is reductionist and simplistic and current approaches to system safety and human factors try to overcome these limitations (Hollnagel, 1998, Dekker, 2004).

In line with these new directions, in this paper we will develop a framework to account for a cognitive approach to system safety, assuming that safety is a system property which comes from thoughts and actions arisen in practitioners' mind. We will apply the framework to ER operations, since they are characterized by their interesting balance between different cognitive processing demands, from automatic and skilled responses, to rule-based reasoning, up to the management of unknown and unpredicted situations.

2 A COMPLEX APPROACH TO COMPLEX SYSTEMS

High-risk organizations are characterized by several factors that make it necessary to change traditional attitudes towards safety, and to move towards an approach inspired by modern theories of complexity (Gell-Mann, 1994). These properties are: multiple hierarchical levels of organization, dynamic self-organization, concurrent interaction of several factors, unpredictability of some internal and external events, balance between order and chaos, development of schemes in order to manage complexity, optimization of variety to enhance system fitness.

Variety is the key concept of the framework we are proposing, since it can be understood as both a property of human performance variability (Hollnagel, 2004) and the source of unpredictability the system has to cope with. Variety is the positive side of chaos, since, if it's optimized by the system, it can bring new order and, most of all, new complexity and better organization. Optimizing variety, for a practitioner, means not relying on the mere application of rules and procedures whenever the situation seems usual, but rather to be sensitive to the mismatch between the current circumstances and the abstract situation to which the rule applies. In fact, every rule is a generalization aimed at managing a simplified version of the countless contingencies that an operator will cope with. Moreover, human behaviour is a local optimization of abstract rules to the specific situation, this implies a gap between *normative* behaviours defined by rules and *normal* performances stemming from local adaptation. Sometimes this difference could leave room for anomalies to grow and proliferate, that is why it is important to be sensitive to variance and to make explicit the gap separating normative and normal behaviours. This gap could contain useful information to help the system prevent future accidents, therefore it is important to facilitate practitioners in developing such a sensitivity. Seen from this point of view, the classical notion of error is useless, since every variability in system performance will be a source of variety, and therefore, a source of information. This anomalous variety may improve system fitness also in the case of dangerous outcomes, because this new experience could help the system to learn more about the nature of accidents (Hollnagel, 2004).

3 RESILIENCE ENGINEERING, COMPLEXITY AND SAFETY

Recently, Resilience Engineering (Hollnagel, Woods and Leveson, 2006) has been proposed as a new way to think about system safety, characterized by a more proactive attitude which has the capacity to anticipate future events. However, in many publications and debates we notice emphasis placed on organizational issues concerning safety, whilst far less attention is given to cognitive implications

(Hollnagel and Rigaud, 2007). Resilience is an emergent property of a complex system and, just like fitness for an organism, it comes from the joint interaction of a structure, its functions and an environment where they take place. Emergent properties arise at a specific level (e.g. organizational), but they can be formed only if precise conditions are satisfied at the lower levels (e.g., cognitive). If resilience concerns the ability to manage the unexpected, we know that very often, in high risk systems, there are hundreds of weak and anomalous signals preceding the accident that could be appositely sensed by frontline operators.

3.1 The SRK Framework

Every action could be the result of three general kinds of cognitive processing: at the lower stage we have the *skill-based level* (S level), whose behavior is fast but rigid, it doesn't require a lot of attentive resources to be accomplished since it involves only procedures and actions which have been over-learned. If we have to take a decision in applying a known rule, we are at the second stage, the *rule-based level* (R level), it is slower than S level, but more flexible and resource demanding. If we have not learned procedures because the situation is unknown we are at the *knowledge-based level* (K level), which is slow and time consuming, it implies a lot of cognitive effort and is very flexible and creative.

Within this framework, what defines a correct performance or a mistake is not only the resulting action - e.g. a skill/rule/knowledge-based error (Reason, 1990) - but how cognitive work demands are faced by the cognitive setting of the operator's mind. Actually, each situation can be represented according to its cognitive demands profile, for instance, it could require a lot of skills, many rules, and little knowledge-based reasoning. On the other hand, if it is a pioneering domain, it's management would need few skills, many rules, and a lot of K-based processing. A bureaucratic system should entail some skills, a large amount of rules and very few K-based tasks. The cognitive fitness of the operator can be described by how it matches with the set of cognitive demands of the situation. If an operator faces an unpredicted and novel emergency reasoning at the S and R level, she will probably undergo a maladaptive approach and bad performance will be the outcome.

In addition, the SRK framework can offer a visual model to help practitioners acquire a resilient cognitive attitude. We can represent the operator's cognitive setting with the SRK ladder: her thoughts and actions will climb or descend the three steps according to the situation (Fig. 1).