The vulnerable robustness of High Reliability Organisations: A case study report from an offshore oil production platform

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Abstract

This paper discusses relationships between staffing level, organisational redundancy and risk. Researchers studying High Reliability Organisations have argued that some organisations achieved highly reliable operations through organisational redundancy. We argue that organisational redundancy depends on structural/instrumental as well as cultural factors. Results from an exploratory study on a Norwegian offshore oil production platform indicate that operators and maintenance personnel may have established extensive organisational redundancy. Downsizing processes and low staffing levels might threaten organisational redundancy, and thus lead to increased risk.

Introduction

Organisational change presents opportunities as well as threats with regard to safety. Staff reductions are among the most common ways for companies to cut costs and increase profitability (Perron and Friedlander, 1996). The effects of downsizing are not simply equal to the effect of a reduced work force. The *process* of downsizing incurs its own costs and benefits, for instance in terms of insecurity. Moreover, downsizing is usually associated with deeper changes in the philosophy or organising, such as Business Process Reengineering (BPR) or Total Productive Management (TPM), as well as technological change (e.g. automation). The impacts of downsizing on accident risks are thus complex and ambiguous. Previous research on the effects of major reorganisations on health and safety does not allow firm conclusions, except that reorganisation can be stressful and that health and safety standards can be affected in both positive and negative ways (Wright, 1998: 209). Developing a better understanding of how staffing level and downsizing processes may affect the accident risk is thus an urgent task in safety science.

Given the complexity of the effects of staffing level and downsizing processes, one is not likely to find a general and simple relationship between staffing level and risk. The most promising research strategy may thus be to identify and explore a few important mechanisms by which staffing level and downsizing processes influence the risk level. Mechanisms that can provide "early warnings" that the downsizing process may lead to increased risks are particularly interesting. Knowledge of such mechanisms may allow enterprises and authorities to meet adverse effects of downsizing in a proactive manner.

Loss of organisational redundancy may be one of the first mechanisms leading to increased risk if an organisation with good safety performance goes through a drastic down-sizing. By "organisational redundancy" we refer to *co-operation patterns that allow the organisation as a whole to perform more reliably than each individual operator*. Organisational redundancy may be created when individuals ask for advice and second opinions from knowledgeable colleagues, when an operator challenges the judgement of her colleague, or when she intervenes to recover an erroneous action by a colleague. We will argue that a downsizing process may lead to loss of organisational redundancy, even if the staffing level is still sufficient to perform the requisite

operational, maintenance and contingency tasks. The paper thus discusses the cause-effect-relations shown by contiguous arrows in Figure 1.

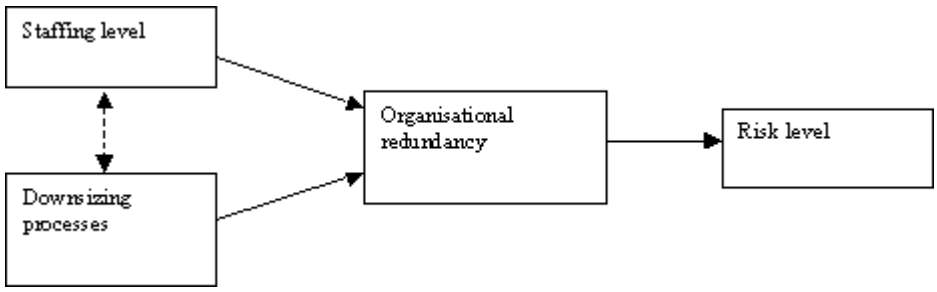

Figure 1. Proposed relationships between staffing level, downsizing processes, organizational redundancy and risk level.

In the following section, we will discuss the preconditions for organisational redundancy. We will then present research findings which suggest that organisational redundancy may contribute significantly to the safety performance of Norwegian oil production platforms. Finally, we will discuss implications for safety management and needs for further research.

High Reliability Organisations and the notion of organisational redundancy

Lessons from High Reliability Organisations

LaPorte and Consolini (1991; see also Rochlin et al., 1987; Roberts, 1989) drew attention to a class of organisations that display outstanding safety records in extremely hazardous operations, such as aircraft carrier flight operations at sea. Such High Reliability Organisations (HROs) are required to handle complex, demanding technologies under hazardous conditions without causing major accidents. At the same time, some HROs need to mobilise the capacity to handle periods of extreme production demands.

LaPorte and Consolini (1991) suggested that HROs achieve reliable performance by building organisational redundancy. Organisational redundancy could be achieved when persons with overlapping competence had the opportunity to monitor each other's performance and intervene in the case of inadequate performance, and such intervention was encouraged by the culture.

According to LaPorte and Consolini (1991), HROs also display a remarkable ability to change their structure and interaction style in periods of high production demands or crisis (capability for reconfiguration). During normal operations, the interaction style is formal, and people complied with formal authority relations and lines of communication. Under periods of peak demand, an informal structure emerges. Decisions are taken on the basis of functional competence rather than formal authority, communication patterns are adapted to the immediate demands of the task, and

interaction style is informal and professional. Crisis situations elicit programmed responses that have been drilled in advance.

Preconditions for organisational redundancy

Based on the work of LaPorte and Consolini (1991), we have outlined a framework that relates organisational redundancy (1) structural/instrumental preconditions, and (2) cultural preconditions (Steiro et. al., 1999; see Figure 2).

<table>
<tr><td rowspan="3">Cultural dimension:

Capability and willingness to exchange information, provide feedback, and reconsider decisions made by oneself and colleagues.</td><td>High</td><td>Structural Vulnerability</td><td>High Reliability Organisations</td></tr>
<tr><td>Low</td><td>Low Reliability Organisations</td><td>Cultural Vulnerability</td></tr>
<tr><td></td><td>Low</td><td>High</td></tr>
<tr><td></td><td></td><td colspan="2">Structural dimension:

Possibility of direct observation, overlapping competence, tasks or responsibility</td></tr>
</table>

Figure 2. Two dimensions of organisational vulnerability.

The *structural/instrumental dimension* of organisational redundancy concerns the personnel's possibility of direct observation of each other's work, overlapping competence, and overlapping tasks or responsibilities. Roberts (1989) and Bierly and Spender (1995) noted that HROs devote much attention to the development and maintenance of individual and collective competence. Some organisations build structural robustness by distributing veto powers, particularly in situations where inaction is a safer state than action (Schulman, 1993). Another important aspect of this dimension is the diversity and quality of communication channels. Weick (1987) argued that rich communication, for instance face-to-face discussion, is in general more powerful in promoting reliability in a complex system than sparse communication such as formal written messages.

Technology has an impact on the possibility for building structural redundancy as well as the appropriate means. For instance, technologies that are at the same time complex and tightly coupled may be inherently vulnerable (Perrow, 1984; Sagan, 1993). One should therefore view organisational redundancy as an attribute of the socio-technical system, not of the organisation viewed in isolation from the technology it employs.

The *cultural dimension* of organisational redundancy concerns the capability and willingness to exchange information, provide feedback, reconsider decisions made by oneself and colleagues, and intervene to recover erroneous actions. LaPorte and Consolini (1991: 29) observed apparently

contradictory production-enhancing and error-reducing activities in HROs. People reported errors without encouraging a lax attitude toward the commission of errors. They took initiatives to identify and improve flaws in Standard Operating Procedures. Error avoidance was achieved without stifling initiative or operator rigidity. People monitored each other's performance without counterproductive loss of operator confidence, autonomy and trust.

The cultural aspects of organisational redundancy also include diversity and trust (Weick, 1987; Schulman, 1993). Organisational redundancy is not simply a matter of duplication. A diversity of operator perspectives may be needed to match the variety of situations occurring in a complex system. However, such diversity can only contribute to reliability if a requisite level of trust has been built between operators.

The combined effect of the two dimensions on the risk level is likely to be multiplicative rather then additive. Overlap in possibilities for observation, competence and tasks are only likely to create redundancy if the culture supports error-reducing activities such as the provisions of feedback. This point is illustrated by the plane crash at Tenerife on March 27 1977. Because of limited visibility and communications difficulties between air traffic control and a KLM 747 aircraft, the KLM 747 started its takeoff while a Pan Am 747 aircraft was on the same runway. All 234 passengers and 14 crew were killed in the KLM 747. Nine of the 16 crew and 321 of the 380 passengers on the Pan Am flight were killed. The Spanish investigation report gives the following analysis of the communication in the KLM 747 cockpit immediately after the plane had started takeoff:

> The communication from the tower to the PAA aeroplane requested the latter to report when it left the runway clear. In the cockpit of the KLM aeroplane which was taking off, nobody at first confirmed receiving these communications (Appendix 5) until the Pan Am aeroplane responded to the tower's request that it should report leaving the runway with an "O.K., we'll report when we're clear." On hearing this, the KLM flight engineer asked: "Is he not clear then?" The captain didn't understand him and he repeated: "Is he not clear that Pan American?" The captain replied with an emphatic "Yes" and, perhaps influenced by his great prestige, making it difficult to imagine an error of this magnitude on the part of such an expert pilot, both the co-pilot and the flight engineer made no further objections. The impact took place about thirteen seconds later.

The presence of three competent persons in the cockpit provided the structural and instrumental preconditions for organisational redundancy. However, according to this analysis, the cultural preconditions left the system vulnerable.

Organisational redundancy on a Norwegian oil production platform

Method

We will now report results from an exploratory study at a Norwegian offshore oil production platform. The platform was of moderate complexity, and all drilling operations had been completed about a year before our visit. The platform had achieved an excellent LTI record for several years.

The results are based on open-ended individual interviews, a group discussion, informal discussions and observation of work performance, operations meetings and a safety meeting as well as incident reports. Incident reports were employed as input to the group discussion. Our informants included control room operators, field operators, maintenance personnel (mechanical and electrical), operations and maintenance managers, shift supervisor, Offshore Installation Manager and safety co-ordinator.

Data collection and analysis were focused on three research issues:

1. What perspectives and mental models do the various groups on the platform use to detect and judge potential for major accidents?
2. To what extent do the patterns of co-operation on the platform correspond to those observed in High Reliability Organisations?
3. How do platform personnel handle conflicting goals related to the potential for major accidents?

Only results related to organisational redundancy will be presented here.

Organisational redundancy

The interviewees described several ways in which they may have established organisational redundancy through the way they co-operate. For instance, before a mechanic starts opening a flange connection, he may ask several critical questions to the process operators to make sure that the connection is indeed adequately isolated and depressurised. Two control room operators may discuss symptoms of process instability, and in difficult cases discuss with the shift supervisor who works in an adjacent room.

We also observed patterns of co-operation that seemed likely to create organisational redundancy. Experienced maintenance personnel would ask young operators critical questions or ask them to demonstrate that there were no power voltages present. Everyone could ask for a Job Safety Analyse (JSA) if they were not satisfied that they knew how to perform a job or they perceived the job as hazardous. However, one operational manager requested a Job Safety Analysis more often than others did. In this way he created a forum for proactive exchange of information and judgements on possible hazards and problems related to the job.

The platform had many highly skilled and experienced operators. When asked about potential consequences of staff reductions, the personnel emphasised the importance of operator competence. For instance, there should always be at least one experienced control room operator present. It was considered an early warning sign if an inexperienced operator had to teach a new operator how to do the job.

The platform was sometimes referred to as a training platform. A lot of personnel was sent to the platform and then moved to other platforms. Especially significant was this for Offshore Installation Managers. *"We hardly get to know them before they move on".*

The operators also emphasised the importance of learning something new. Challenges in the daily work were believed to increase attention and ensure safety on board. The argument was that if you do the thing over and over again, you may get "blind" to hazardous situations.

The platform had recently experienced staff reductions. This was partly because the drilling activities had been completed, but there had also been a reduction of process personnel due to new technology and a production that was stable. This downsizing was perceived as a fair process. The organisation had closely co-operated with the trade union. As the Offshore Installation Manager expressed it: *"We remove functions rather than positions".* The downsizing had happened in parallel with development of new oil and gas fields so that redundant personnel could be offered jobs on other installations. At the moment, facing new rounds of downsizing, there was more uncertainty of what would happen. Some operators claimed that there had recently been more stress and more sick leaves. This issue had been discussed on a management meeting offshore, and the management had decided to focus more on psycho-social issues.

Impact of organisational redundancy on safety – an example

Most often organisational redundancy causes nothing to happen. The effects of organisational

redundancy on risk are therefore rarely recorded. However, we did identify an incident on the platform where organisational redundancy probably made the difference between a minor and a major uncontrolled hydrocarbon release:

> One group of operators were preparing for an inspection of the kill mud system, which is part of the platform's blow-out protection. They opened a valve toward the flare system, in order to vent off gas released from a minor leak. Due to difficulties in achieving adequate drainage from the valve to be replaced, the valve toward the flare system was left open for an extended period.
>
> At a different place in the same module, another group of workers started preparations for testing a Down Hole Safety Valve (another barrier against blow-outs). As part of these preparations they initiated a pressure release, thus blowing gas into another section of the flare system.
>
> One of the operators working on the kill mud system, an experienced mechanic, noticed that the pressure release had started. He immediately shouted to the person performing the pressure release that he should close the valve towards the flare system at once. The valve was closed and the pressure release terminated. A moderate amount of gas was released from the flare system at the place where the first group of operators had started work on kill mud system. A single gas alarm was activated.

Two parallel jobs, both involving the flare system, came into conflict due to inadequate co-ordination. The prompt intervention by the experienced mechanic probably prevented major gas release, which might have led to a costly shutdown and a period of increased fire and explosion risk. In discussions with other operators, we learned that this mechanic was well known for his ability to attend to activities outside his formal area of responsibility and for his willingness to intervene when he perceived a potential for problems.

However, this incident also pointed to a possible cultural vulnerability of the organisation at the time the event occurred. The decision to perform the two jobs in parallel was made at an operational meeting, in spite of a recommendation from one manager that the second job be postponed until the first job was completed.

Discussion

Does organisational redundancy contribute to the safety performance of high-risk production systems?

Our results suggest that the level of staffing, the competence level and the organisational structure at the platform provided the structural/instrumental preconditions for considerable organisational redundancy. Moreover, the culture at the platform supported patterns of co-operation associated with organisational redundancy. We were able to trace the impact of organisational redundancy in a critical incident, but we also found indications of cultural vulnerability at the time the incident occurred. The platform had achieved an excellent LTI record for several years.

These results are compatible with a negative relationship between the level of organisational redundancy and the risk level. They are also compatible with the hypothesis that the staffing levels and the organisational structures and cultures on Norwegian production platforms during the nineties allowed for a considerable degree of organisational redundancy.

The empirical results presented here are not sufficient to *prove* that organisational redundancy makes a significant contribution to safety performance on the Norwegian shelf or in other industries

coping with major hazards. To test such an assertion, we need more extensive evidence concerning the current degree of organisational redundancy. Moreover, to support the claim regarding a significant relationship between organisational redundancy and risk, one needs to compare otherwise similar organisations with different degrees of organisational redundancy.

The role of operators in handling crisis situations may become more demanding when recent concepts such as production ships (FPSOs - floating production, storage and offloading units) become more common. Some crisis scenarios with FPSOs require quick and complex operator intervention, whereas technical safety systems and passive barriers with limited operator intervention can handle most scenarios on conventional installations. At the same time, the role of operators may become more critical on existing conventional platforms due to modifications. The influence of organisational reliability on the risk level may thus become stronger in the future.

Is organisational redundancy vulnerable to downsizing processes and low staffing levels?

At present, we base the hypothesis that organisational redundancy is vulnerable to downsizing processes and low staffing levels on theoretical arguments:

1. Too extensive staff reductions or changes in organisational structure may affect the structural/instrumental preconditions for organisational redundancy. For instance, having only one control room operator would remove the instrumental preconditions for redundancy in the control room.
2. Outsourcing might threaten the cultural preconditions for organisational redundancy, even if mutual consultations and checking are physically feasible, since personnel from different organisations might lack the mutual trust and openness necessary to exploit such opportunities.
3. The process of downsizing may, if inadequately managed, lead to loss of operator commitment and reduced willingness to take action beyond the tasks for which one is strictly responsible.

Based on the title of this paper, some readers may have expected us to present a case where staffing reductions are followed by a disaster, which can be attributed to loss of organisational redundancy. On the contrary, the platform studied could present excellent LTI-records *and* considerable organisational redundancy in spite of moderate staff reductions. This suggests that the relationships between staffing level, organisational redundancy and risk are not linear, and sometimes possibly not even monotonous. It is, for instance, conceivable that well managed downsizing processes under some circumstances may lead to more effective and task-oriented communication patterns and thus enhance organisational redundancy.

Implications for safety management

How can organisational redundancy be maintained and promoted in periods of organisational change? The first task is probably to *make organisational redundancy visible*. Weick (1987) pointed out that reliable systems and subsystems do not attract attention because they to not create disturbances. Outsiders, and even the operators themselves, may not be aware of the complex, dynamic pattern of corrections that produces error-free system performance. The mechanisms that create organisational redundancy may thus be ignored during the planning of organisational change. One way to make organisational redundancy visible is to focus more on recovery in the analysis of unwanted events. Making organisational redundancy visible also implies pointing out its contribution to quality and regularity of the production processes.

Another challenge is to find ways to monitor organisational redundancy during periods of change. This may require development of new indicators, since conventional safety performance indicators

may give only weak and indirect evidence on organisational redundancy.

There is also a need to promote openness and humility regarding the targets of downsizing processes (Hvalgård, 1999), since the targets are often set by high level management far removed from the challenges and dangers of day to day operations.

The quantitative models currently used in Safety and Emergency Preparedness Analyses in the Norwegian oil industry capture the effect of staff reductions on number of people exposed to hazards, but not the effect on organisational redundancy. This practice implies a hidden assumption that organisational redundancy is either stable or that it has little impact on the risk level. Such assumptions may prove increasingly invalid as staffing levels are further reduced and installations requiring more complex operator intervention in critical situations proliferate.

Research needs

The theoretical framework outlined in this paper needs further elaboration. The delimitation between cultural and structural/instrumental factors needs to be clarified. For instance, informal structures of authority and communication may be viewed as an aspect of organisational structure as well as culture. Moreover, the notion of culture as an explanatory factor may be problematic if a characterisation of the culture is derived from the behaviours it is supposed to explain.

Most of the published HRO studies derive from a limited range of systems, such as aircraft carriers (Rochlin et al., 1987; LaPorte and Consolini, 1991; Weick and Roberts, 1993), nuclear submarines (Bierly and Spender, 1995), and the nuclear industry (Schulman, 1993; Weick, 1987). This research is typically based on investigation of one or more organisations with impressive records of safety and/or reliability. The specific organisational attributes that contribute to safety and reliability seem to be identified on the basis of intuition and theoretical argument. We perceive a need for similar studies covering a broader range of organisations, as well as a need for research designs that allow more powerful empirical analysis of causal relationships (e.g. hypothesis testing case studies; Yin, 1994). For instance, Schulman’s (1993:370) claim that "too much clarity in organizational authority might well increase the potential for "authoritative error"" is sufficiently well-argued and controversial to merit further empirical investigation.

We also need to investigate empirically the impact of staffing level and downsizing processes on organisational redundancy. At a practical level, we have already noted the need for approaches to make organisational redundancy and its significance visible in an organisation, and the need to develop valid indicators of organisational redundancy.

Conclusions

We have identified structural/instrumental as well as cultural preconditions for organisational redundancy. Based on results from a case study, we suggest that organisational redundancy may have contributed significantly to the safety record of the North Sea oil production. We have argued that downsizing processes and low staffing levels might threaten some of the mechanisms that create organisational redundancy. Conventional procedures for Safety and Emergency Preparedness Analysis are not likely to capture the impact of staffing level on organisational redundancy.

The implications for safety management are significant. It is not enough to set up systems to identify deviations and follow up their correction. Safety management also needs to promote an understanding of the mechanisms that create redundancy and support line management in building, maintaining and monitoring these mechanisms.

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