SAFETY SCIENCE Monitor

Issue 3 2007

Article 4 VOL 11

SAFETY IN A COMPLEX WORLD AS THE RESULT OF CO-CREATION AND CO-LEARNING BY KEY AGENTS

TOWARDS A VISION ON LIVING SAFETY ORGANISATIONS

ZWETSLOOT G.I.J.M.[1], GORT J., ZWANIKKEN S., STEYGER N., VAN DER VORM J., GALLIS R. AND STARREN A.[2].

Abstract - Many traditional safety approaches seem to have decreasing added value, due to the complexity and continuous change of the world we live in. At the same time, human factors come more to the forefront, as they seem of growing relevance. As part of a four-year research effort (2003-2006) we developed an innovative perspective on the role of people in occupational safety (management). We focussed our analysis around two statements:

(1) Occupational safety and unsafety are man-made and (2) occupational safety and unsafety are the (temporary) result of (continuous) co-creation and co-learning processes from the key actors involved.

The findings presented support the hypothesis formulated, though the evidence is still limited. The implication is a more strategic view on "the human factor in safety": top managers, R&D specialists, safety engineers, line managers, operatives, etc. who jointly decide about the future of the company, the development of the production processes, about technological developments and reorganisations, and hereby often implicitly about safety. This co-creation process has many characteristics of a collective learning process.

The value of safety seen as a social construction is discussed as a natural complement to safety based on objective risk levels. That leads to new insights into the nature of safe and unsafe situations respectively, and clarifies the relevance of two other categories, false safety and false unsafety. From an agent based perspective on safety, the latter two categories seem of great relevance (and need to be clarified further in future research).

1 INTRODUCTION

The EU legislation on health and safety (EU Directive 89/911) is an example of so called "reflexive law". It addresses not only the personal responsibility of the employer and the employees, but presupposes (sometimes implicitly) that these key agents reflect on existing workplaces and work processes, and the associated hazards and risks. In this way the EU legislation attributes a central role to the employer and the employees as responsible key agents in a process of self-regulation and self-reflection. In essence that seems to imply a process of co-creation of occupational safety and health. As researchers and consultants we are very committed to supporting such processes of co-creating of occupational safety and health. However, it seems to us that these processes are not yet fully supported by the usual safety models and approaches.

---

[1] Gerard Zwetsloot is senior researcher and consultant at TNO (Netherlands Organisation for Applied Scientific Research) and professor at Erasmus University Rotterdam. He is manager of the TNO's Research programme on Occupational Safety. E-mail: gerard.zwetsloot@tno.nl

[2] Johan Gort, Sander Zwanikkken, Niek Steyger. Johan van der Vorm, Raphaël Gallis and Annick Starren are all researchers and consultants at TNO and are involved in TNO's research programme on Occupational Safety.

Many traditional safety approaches seem to have decreasing added value, due to the complexity of the world we live in. Companies are increasingly confronted with new competitors worldwide, with mergers and takeovers, new business challenges (e.g. sustainability or corporate social responsibility) and new technologies. Change seems to be the only continuous factor: organisational changes, technological innovations, demographic changes, greater individualisation, changes in human behaviour and perceptions, etc. The complexity of the world we live in has implications for the success of safety approaches.

Important safety concepts such as: control, safety modelling, prediction and quantification of risks, accepted risk levels, accident causation, and safety management systems seem to loose part of their added value due to increasing uncertainties in and fluidity of the situation where they are used. At the same time, concepts like safety behaviour, safety culture seem to come more to the forefront, as they seem of growing relevance. However, these concepts need further development too, for becoming more effective in complex situations.

In the dominant safety paradigm, people are usually seen as either leaders who should be committed and should drive the safety culture through exemplary behaviour, or people are seen as a kind of human machines that are supposed to carry out mainly routine work, while they – even for the work that requires no real thinking, are still sources of human errors. Human factors have a rather negative connotation with respect to safety.

In our opinion, from a systems perspective, safety (management) systems should not only be regarded as "functional systems" (in which people play a limited positive role – at best they behave fully rationally). Instead we feel safety systems should also be regarded as "social systems", were people can play a positive role, and contribute to the liveliness of safety systems (Visser & Zwetsloot 2004 p 35-37).

The notions mentioned above were mostly implicitly underlying a four-year research effort on Occupational Safety, carried out by TNO (the Netherlands Organisation for Applied Scientific Research) in close co-operation with the Dutch Ministry of Social Affairs and Employment. The research programme consisted of three programme-lines:

1. The first line focussed on the relationship between (developments in) the core business of companies and safety management. The underlying idea was that a close relationship between the two might imply that safety gets more strategic added value for companies, and that as a result safety management might be more resilient to changes.

2. The second research line focussed on innovative uses of information on business processes, technical processes and work processes that is available in companies but is currently not utilised for safety reasons. The underlying idea is that in companies often a lot of relevant information on possible disturbances in production processes is available (for business reasons). We wanted to use that information for getting better insight in relevant accident scenarios, for the (semi-) quantification of risk, and setting of priorities for safety prevention.

3. The third research line focussed on the promotion of taking "measures at source". Taking measures at source is often proclaimed as the first priority in safety, but in the real world it usually isn't that important. The underlying assumption of this research line is that the operational and technical definition of sources of hazards and risks may be a limiting factor. Many decisions can be actually regarded as "the source" for creating hazards and risks, and that shifts the focus on decision-making by key actors, both in the company and in production chains.

When these three research lines were determined in co-operation with the Dutch Ministry of

Social Affairs and Employment (mid 2002), we were aware of several of the limitations of many current safety models and approaches. We sometimes felt uncomfortable with them, without having clear alternatives. Several findings in our research programme strengthened our feelings, and this was also the result of some related research or consultancy activities outside this programme. Also the Dutch Ministry of Social Affairs and Employment, challenged us several times to develop a convincing vision on "the human factors – in its broadest sense- in occupational safety (commitment, awareness, behaviour, communication, competence, culture, learning, etc.). Therefore in the fourth year of our research programme, we made a dedicated effort to develop an innovative perspective on the role of people in occupational safety (management).

We focussed our analysis around two statements, which functioned as hypotheses in our discourse. These are:

1. Occupational safety and unsafety are *man-made*.

2. Occupational safety and unsafety are the (temporary) result of (continuous) co-creation and co-learning processes from the key actors involved.

The second statement can be regarded as a more specific version of the first.

2 LIMITATIONS OF CURRENT APPROACHES AND PARADIGMS

Firstly, we want to give a concise overview of observations –both from literature and safety practice- that contributed to our "uneasy feelings" about the limitations of the currently dominant safety paradigms. These observations are clustered around three issues: (1) change and complexity is limiting the value of safety models and practices, (2) human factors often underlie technological hazards and risks (but are usually not taken into account), and (3) difficulties in dealing with human hazards and human factors that enhance risks. For each of these three issues we limit ourselves to a few relevant observations.

Change and complexity is limiting the value of safety models and practices,

Ulrich Beck (1992) introduced the concept of the risk society. In his view, risks are a dominant feature in our society. The control of risks is increasingly depending on experts and expertise that are uncontrollable by the general public. As it is often the case that the experts have contradicting points of view (an implication of complexity, change and inherent uncertainties) people have a decreasing trust in the expert based control systems. It is increasingly becoming apparent, that the expert knowledge about risk control is not an "objective science" but often an example of social or societal constructions. This also implies a threat to our society, as critical events may trigger mistrust and societal unrest. The question arises what are the implications of the risk society for managing occupational safety?

Risk Assessments, mandatory for all companies in the EU, are formally meant to assess the risks in existing situations and are intended to lead to improvement by triggering preventive measures. What we actually see all to often, is that risk assessments (and many other safety models and tools) take the existing *status quo,* the designed situation, more or less for granted. The underlying idea is that in any situation, control of risks can lead to acceptable safety. As a result risk assessments usually trigger *corrective action* (reactive measures). Risk assessments often fail to trigger "doing things right the first time" via safer redesign of workplaces and work processes, i.e. by triggering dedicated innovation. The implicit acceptance of the *status quo* is a very useful approach for a world that is more or less static, implying a lot of time for system optimization. However, in the "changing world of work", economic, technological, organisational, demographic changes are increasing in pace and impact on work and safety. Also in the era of the *knowledge society* were innovations are taking place continuously, the traditional perspective on safety is no longer sufficient. Complexity and continuous change mean that cause and effect are not close in time and space (Senge 1988). Decisions have to be taken, even when there are uncertainties about their implications. So there is a need for a safety paradigm that is better suited for an era of continuous change, complexity and uncertainty.

The impact of organisational change (often a response to changes in the organisation's business environment) on safety seems to be a major blank spot in safety management. Change management is usually limited to technological change, at best including assurance of the safety qualifications of key people. The safety implications of drastic organisational changes (merges, take-overs, downsizing, off-shoring, outsourcing, etc) are usually only addressed after the change (i.e. the new situation is then regarded as static again, and so as useful for safety control), see Zwetsloot et al, submitted.

In the safety literature the impact of change on safety is not completely new. The well-known book of Hale and Hovden (1998) is about safety and change. In a well-known article in Safety Science, Rasmussen (1997) addresses safety modelling problems (a result of complexity), and introduces a model of safety performance drifting continuously to the acceptable limits due to pressure from cost reductions. In Rasmussen's rather pessimistic vision, safety culture campaigns are regularly needed to counter balance this drift to the safety limits, and are not able to achieve sustainable safety improvements. In fact, safety culture campaigns are then leading to temporary improvements only, not to lasting results. A number of issues with respect to safety in the changing world of work, are addressed in the European Agency's publication on that topic (Op den Beeck & Heuverswyn, 2002). As a general perspective, it can be stated that in a continuously changing world, safety is increasingly becoming a matter of timely anticipation on such changes, while the strategy of optimising the status quo is loosing part of its value.

Human factors often underlie technological hazards and risks

Qualitative Risk Analysis (QRA) seems one of the masterpieces of what safety science can accomplish. Mainly applied in major hazards industries, it is very much focussing on the risk of technological production processes, usually associated with chemical processes or nuclear power. The risks for people working in the installation, or living nearby, can then be expressed via complicated, software supported analyses, and can be expressed in the chance for a serious accident, i.e. a likelihood of 10^{-8}. However, there are serious problems with the reproducibility of such figures. In the band assay of QRAs, carried out by the best experts from several EU countries, it became apparent that the uncertainties in these assessment techniques are quite substantial (Lauridsen et al 2001). These uncertainties are almost never made explicit or communicated to a wider audience. When the best experts of several EU countries reproduced QRAs for the same installation, the standard deviation between the outcomes (except for breaking pipelines), is no less than two orders of magnitude. That means that if bureau A assesses the risk as 10^{-8}, there is a chance of no more than 66% that the result of the next assessment of the same installation by another bureau will be somewhere between 10^{-6} and 10^{-10}. This was a rather dramatic finding, as it implies that the QRA technique is not able to distinguish with sufficient certainty between an unsafe installation (10^{-6}), an installation that is functioning around acceptable safety limits (10^{-8}) and an installation that is fairly safe (10^{-10}).

Of course, the researchers tried to reduce the problems with reproducibility. An obvious source of variation could be the use of different sets of accident scenarios (implying that the identification of scenario's – mainly based on human judgements is a main factor in the technique), and also the use of different (their own) databases in the interpretation of the accident scenarios. That is why in a second stage of the project, a renewed QRA effort was made, in which every bureau used a standardised set of accident scenarios and used the same data bases as reference. The rather disappointing result was that his made no significant difference: the standard deviation remained two orders of magnitude. Within the research team it was then concluded that the *interpretations of the consultants or researchers (*i.e. human factors!) involved must be the cause of the (so far hidden) uncertainties. The research team was unable to develop procedures or other solutions, to reduce these uncertainties significantly (Lauridsen et al 2001).

Well, if the QRA technique is not able to give absolute data, one could hope that it is still useful for comparative analyses. For instance, for comparing the safety of an installation design X with a modified design Y. Unfortunately, also in this respect the outcomes of QRAs are not reproducible. The outcomes (i.e. design Y is safer than design X) are reproducible only, when one and the same consultant makes the assessments. When different consultants or bureaus make the assessments, the result can be just as good that the second consultant concludes that design X is safer than design Y (Lauridsen 2001). We conclude that QRAs have many characteristics of a technologically complex social construction.

Another technologically oriented methodology for evaluating risks and safety is the Layers of Protection Analysis (LOPA) introduced in 1993 by the American Centre for Process Safety (CCPS 1993). The central idea is that a production process, with its inherent hazards and risks, is controlled by a number of added-on "protection layers"; each contributing to a further reduction of (external) risk. In the CCPS model, operator supervision is mentioned as being part of two protection layers that are the only human factors taken into account. Indeed, human factors seem to play a very limited role in this model. While companies are trying to increase safety by better training of their personnel, by creating a safety culture in the organisation, by integrating safety requirements in the contracts of their suppliers and contractors, all these efforts have practically no impact on the outcomes of a Layers of Protection Analysis (and also of QRAs). In this respect there is a large gap between theoretical safety models and company practices.

Inherent safety is a very promising approach for reducing hazards and risks. However, the impact of the body of knowledge on inherent safety remains rather limited, because it is seen only as an issue for engineers. As was stated in Zwetsloot & Ashford 2003, "inherent safety is too important to leave it to the engineers".

In 2005 we organised a workshop on inherent safety with representatives from the Dutch chemical industry (from the sector organisation and individual industries), the ministry of the environment, etc. The aim was to identify opportunities for making better use of the body of knowledge on inherent safety. A main conclusion was that there are many unused opportunities for inherently safer technologies in most of the companies that were represented. The principal one being lack of commitment from the CEO to inherent safety principles (except a few frontrunner companies like Dow). As a result engineers are not encouraged to come up with inherently safer solutions.

Prevention is supposed to primarily focus on taking measures "at the source". Sources are technologies, materials or tools, associated with (technological) hazards. Other approaches focus on the underlying causes of

accidents and incidents, or on some basic risk factors in the organisation for dealing positively with safety (e.g. TRIPOD). These two approaches for prevention seem not to match very well. The first sees technological sources as the main factors to be controlled, while in the second organisational factors are regarded most important. Both do not seem to take fully into account that - in the end - people decide about technologies and organisation.

Current safety approaches are of limited value for dealing with human hazards and human behaviours that enhance risks

Risk Assessments (and policies based on them) focus on (technological) hazards and the risks associated with them. Categories like *management commitment, safety leadership, worker supervision,* or *operating discipline*, that are known to have a very significant impact on safety are regularly neglected or treated only as "underlying factors" or as boundary conditions, not as the heart of the matter.

Scenarios are regularly used to analyse accidents and to improve safety. However, scenarios usually focus on technical hazards and the effects of various factors and events on their (potential) impact. The scenario techniques can also be used, at least in principle, to focus on human decision-making, from the stages of planning, design and investment, to construction and realisation, operation, maintenance and demolition of production systems – and their impact on safety. Then the chain of events analysed would focus on human decisions and acts throughout the production chain. Why is this not a regular approach?

Safety theories seem to have problems in dealing with *aggression and violence at work*. Like in traditional occupational safety, in these cases the challenge is to prevent undesirable and unacceptable events. However, the hazards are not technological but are of human nature. Theories and models about e.g. limiting the transfer of energy that is released in an event are not very useful in such cases. To us, it seems there must be opportunities for more general safety models and theories that are also useful for dealing with hazards and risks of a human nature.

The proliferation of terrorism is another factor that challenges the current safety paradigms. An implicit assumption of safety theories seems to be that human beings have a clear interest to protect themselves, and that safety is a common interest of all people potentially affected. Terrorists regularly challenge that axiom, by deliberately committing suicide and purposely causing disasters.

All together it seems that the dominant safety thinking is focussing on protecting people against technological hazards, and is now challenged by several phenomenoms that require a broader or a complementary approach. There is a need for approaches with greater added-value in dealing with the uncertainties stemming from complexity and change, that take the human decision-making that underlies technological hazards and risks fully into account, and that gives meaningful clues for dealing with human hazards and human factors that create or enhance risks.

3 MATERIALS AND METHODS

The methodology we used, is mainly based on the work of Morgan (1986, 1993) and De Geus (1997). Morgan describes several alternative "lenses" for looking at "organisation" (not organisations), each one generating its own perspective, with its associated strengths and weaknesses. Morgan describes six perspectives on organisation: as machines, as (living) organisms, as brains, as culture, as a political system (were power games and conflicts dominate), and as mental prison. Two of these perspectives are regularly used with respect to safety: safety organisation as a machine, and as a cultural phenomenon. We were aware that other perspectives introduced by Morgan might be relevant for safety as well and could lead to new insights. Note that Morgans approach implies that safety organisation, like any other type of organisation, is ambiguous and can be seen and interpreted in various ways.

As we strived to develop a "strategic vision on human factors in safety", one in which people are actually not regarded as human factors, but as human beings with a unique personality, the perspective we put central in this paper, is the metaphor of safety organisation as a living organism".

Morgans metaphor of living organisation is well elaborated upon by Arie de Geus, the former head of the Shell scenario development unit and one of the founders of the Society for Organisational Learning, in his book The Living Company (de Geus 1997). According to De Geus, companies should be regarded as living organisms, which often die too early because their managers dominantly treat them as machines. The differences between seeing a company as a machine and seeing it as a living being, are summarised in the foreword of De Geus' book by Peter Senge (Senge 1997):

Seeing a company as a machine implies that it is fixed, static. It can change only if somebody changes it. Seeing a company as a living being means that it evolves naturally.

Seeing a company as a machine implies that its only sense of identity is that given to it by its builders. Seeing a company as a living being means that it has its own goals and its own capacity for autonomous action.

Seeing a company as a machine implies that it will run down, unless it is rebuilt by management. Seeing a company as a living being means that is capable of regenerating itself, of continuity as an identifiable entity beyond its present members.

Seeing a company as a machine implies that its members are employees, or worse, "human resources", humans standing in reserve, waiting to be used. Seeing a company as a living being leads to seeing its members as human work communities.

Finally, seeing a company as a machine implies that it learns only as the sum of learning by individual employees. Seeing it as a living being means that it can learn as an entity, just as a theatre troop, jazz ensemble, or championship sports team can actually learn as an entity.

In the book of de Geus, it is argued that *only* living beings can learn – implying that any form of organisation that is supposed to learn, should be organised as a living organism.

Translated to safety organisation, the metaphor of the living safety organisation, thus implies a safety organisation that:

- Evolves naturally, also in response to change
- Has its own goals and capacity for autonomous action
- Is capable of regenerating itself, beyond its present members
- Sees its members as human work communities
- Can learn as an entity

For us, this is a very challenging perspective on safety organisation. How did we use this "lense" in our project?

Firstly, we started to make our implicit assumptions about the human impact on safety in our research programme and the individual projects, as explicit as possible. This made it possible to scrutinise and critically evaluate them.

Secondly, we scrutinised and discussed each of the projects and its main findings to share a deep understanding of their implications, and to explore clues for the new perspective we wanted to develop. In a systematic way we organised reflections on the strategic meaning of "the human factor" for occupational safety. The discussions among the researchers were instrumental in giving new meaning to some of the findings, and in developing a joint understanding of the new perspective.

Thirdly, the findings from the research programme were complemented by findings in a few related research and development projects we were involved.

Altogether, we were following to a high degree Peter Senge et al's "U model" for developing a shared understanding of new paradigms and new perspectives for the future (Senge et al, 2004, p. 88) . According to Senge et al there are three stages relevant:

- *Sensing* i.e. a stage for developing a shared better understanding of the present situation and its limitations – by joint introspection and reflection with heart and mind, and trying to eliminate the internal "voices of judgement" that always lead back to the existing paradigm and its associated values (this new idea is not feasible).
- *Presencing*, i.e. developing in interaction a shared image of the future; the idea of presencing is that several characteristics of the future are already present today, but they are usually not recognised as such. We were especially interested in the future of the human roles in safety.
- *Realising*, i.e. once the hard job of sensing and presencing is accomplished, and a shared vision of developments for the future is developed, it is relatively easy to start working on the realisation of the new

perspective. In our case, this was limited to clarifying the new perspective and its consequences for our future research programme.

4 MAIN FINDINGS

In this section we present the main findings of our reflections on the three research lines of our programme, and also of some related activities.

Research line: safety and core business

In the research line "safety and core business" the central model that was developed and tested combined three perspectives on both the management of core business and safety: *structure, culture, and learning* (Gort et al 2006). In this model, culture and learning are two complementary perspectives on "the human factor".

We had several discussions on the added value of this three perspective model. The structure perspective, when used in a proficient way, implicitly also addresses culture and learning (a good safety system will have an impact on safety culture, also via some of its main elements, e.g. through management commitment and safety education, and will trigger learning through elements such as registration and analysis of accidents and incidents). However, we clearly saw an added value in having equal and explicit attention for all three aspects. Explicitly addressing culture and learning triggers explicit attention for and conclusions about safety culture and learning. That conscious awareness makes it possible to identify opportunities for safety improvement that would otherwise not have been recognised. The explicit attention is also valuable for managing these "human aspects" consciously.

A key finding in the case studies on safety and core business, is that the way organisational learning with respect to safety is organised in companies, is often the limiting factor that achieving adequate safety performances. The impact of learning seems greater than those of the structure and culture (the other two in-company perspectives in this study) See Gort et al 2006.

Though the evidence for this conclusion is limited to the few cases we were able to research, this strongly suggests that the organisational learning perspective is very significant, both for company safety practice, and for safety research. Clearly this finding strongly supports the second hypothesis that we have formulated: occupational safety and unsafety are the (temporary) result of (continuous) co-creation and co-learning processes from the key actors involved.

Another significant finding from the *safety and core business* research projects is that safety management seems more robust on the longer run, especially in periods of organisational change when safety management is closely linked to the core activities of the organisation. That does *not* imply that a close relationship between safety and core business guarantees a better safety performance at all times. Excellent safety performances can be realised in several ways, also by having a safety organisation that is an added-on organisation to a company's business. However, in times of great turbulence (economic problems and associated cost –reduction programmes, mergers and takeovers, business process re-engineering, downsizing, outsourcing and off-shoring, new corporate strategies, and rapid technological innovations, etc.) the main focus of companies is to continue its existence by changing its core business, and to realise the associated strategic company goals. Safety is then, understandably but unfortunately, usually not the prime concern of management. If safety is organised as part of the core business, or closely related to the core business, this implies a much better chance that it will be considered as an important factor *in* the change process and not *after* the change process (i.e. when key decisions – that may affect safety are already taken).

Research line: quantification of occupational safety risks

In the research line quantification of occupational safety risks, a key finding was, that risk assessments tend to focus on the hazards and their effects. The work processes, and the people who perform the work are together forming the socio-technical system were these hazards and risk are actually occurring. However, in the overwhelming majority of risk assessments, the work processes, and the individuals or teams that perform them, are usually *not* systematically considered. The behaviour of operatives, e.g. working according to procedures, the way tools are used, the use of personal protective equipment, etc., and also the supervision of the shift leader are all clearly relevant for the actual risk level. Systematic analysis of these factors would certainly lead to much better risk assessments. In a case study in a brick factory it proved very useful to systematically map all relevant work processes, and then relate them to the company's accident and incident data set. In this way it was relatively easy to identify the work processes that were not well in control, and therefore contributed most to the actual safety risks.

Another finding was that in many industries, the complexity of the organisation and all its processes, leads to "separated subsystems" inside the production organisation. For example, safety systems were sometimes completely separated from maintenance systems, both in terms of procedures, data bases with relevant data (functioning to a large degree as the organisation's memory) and people or disciplines involved.

In a case study carried out in the process industry (a company known as a frontrunner in safety), a maintenance database on "deviations from normal" was analysed on its safety relevance. It was shown that some of the data were indeed safety relevant. But they were usually not recognised as such, even though the company had very high standards for safety. For the people involved (maintenance people, safety engineers) usually take the separated organisational subsystems for granted: the system separation has become a routine aspect in their mindset. That is why the safety engineers do not even consider analysing data from "data bases designed for maintenance purposes", while maintenance people are not expected to think about relevant safety scenario's that could be associated with the maintenance problems they are fixing. As a result, in the mental models of the experts involved, it was quite natural to regard the databases as irrelevant for the other discipline. Clearly Morgan's perspective of *organisation as a mental prison* is nicely illustrated here.

Research line: promotion of risk reduction at the source

The third line of research focussed on opportunities and strategies to foster prevention and risk reduction by taking measures "at source".

While carrying out the research on opportunities for stimulating prevention at source, it became increasingly apparent that the technological fix on "sources" in terms of technology related hazards and risks, was not most productive for stimulating prevention. It seems at least equally relevant to regard the (human) *decisions* about the technologies, workplace designs, tools, etc. as the source of potential safety problems or solutions. That is why attention was paid to decision-making by key actors, both in the company that formed the case for the analysis, but also in relation to up-stream decision-making from suppliers or customers, and from other key stakeholders (Zwanikken et al 2006).

The classic idea of taking measures at source (technological sources of hazards) is still relevant, but the research line showed that it is much more productive to stimulate thinking about these technological solutions in the decision-making processes, especially by anticipating on safety impacts already as early as the stages of research and development, planning, design and procurement both within the own organisation, but also in a joint effort with suppliers to intervene earlier in the production chain.

Supporting evidence from two other research projects

The findings mentioned above are complemented by some relevant findings in two related research projects.

In a study for the European Agency on Corporate social Responsibility and Safety and Health at Work (Zwetsloot & Starren 2004), it was clearly shown that in Corporate Social Responsibility policies, an impact on strategic company decisions is much more common than in occupational safety and health. For giving occupational safety more strategic meaning for companies it was shown to be useful to integrate occupational safety with other safety disciplines that were relevant for the companies, e.g. product safety. This is especially relevant when the *human value aspect* of safety is emphasized. In the end, safety as a strong human value in a company (ideally speaking as one of its core values) cannot be limited to only one sub discipline of safety (e.g. occupational safety).

In a study on safety and downsizing processes, six cases of downsizing and reorganisation processes in the chemical industry were analysed via a survey among all employees and managers involved (Gort et al 2005). The analysis showed that the most significant influence on safety performance was the quality of leadership (this was also the most significant factor on team performance).

The findings from the three research lines and two additional projects presented above, clearly support the two hypotheses formulated at the start of our analysis:

- Occupational safety and unsafety are *man-made*.
- Occupational safety and unsafety are the (temporary) result of (continuous) co-creation and co-learning processes (in a changing environment) from the key actors involved.

This does not imply that this research is sufficient evidence to fully prove these hypotheses. In this respect, further research is certainly desirable, especially to better understand the limitations of the hypotheses formulated. Nevertheless both hypotheses are supported by our findings and are shown to be interesting and meaningful. Further research is therefore certainly recommended.

5 DISCUSSION

In the sections above we focussed on evidence in our research projects for the two hypotheses that safety and unsafety are man-made and result from co-creation and co-learning from key actors. In the following section, we discuss some of the wider implications of these statements. We pay attention to (1) the wider and strategic meaning of human factors in occupational safety, (2) the actor perspective on occupational safety, and (3) on occupational safety as also the result of a social construction.

5.1 The wider and strategic meaning of human factors in occupational safety

If we see safety and unsafety as man-made, it is obviously implying a wider and more strategic impact of "humans factors" (if this is still the right terminology) on occupational safety. So how do we regard this human involvement with the creation, reduction and control of hazards and risks? We explain both the *key processes* were these human factors are relevant, and the *contents* of these human factors.

Basically we distinguish between four *key processes* in which human involvement creates safety or unsafety, i.e. through:

1. Research and development, design and planning of work processes and social-technical work systems and the associated hazards and risks;
2. Realisation of work processes (often planned and routine based tasks as part of work processes) that are (implicitly) considered safe (also when hazards and risk are obviously associated with that work);
3. Dealing with unplanned and unforeseen events, such as deviations from normal, incidents, emergencies and accidents;
4. Individual and collective reflection on the three above mentioned levels, potentially leading to innovations in the work processes or work systems, and associated with individual and collective learning processes (i.e. individual and collective learning).

The *contents* of strategic human factors refer to three types of human factors: personal, inter personal factors and man-system interactions.

In one of our projects that preceded this research we worked in close co-operation with three organisations (two of them chemical process industries) on the difficulties in realising complex changes in organisations. In that study (Moonen et al 2002 and Zwetsloot & Moonen 2003) it proved very useful to distinguish between three types of factors, objective factors, personal factors and interpersonal factors. Here our focus is on the human factors only, and that means the category of objective factors is replaced by interactions of people (individually and collectively) with the system (the technical and organisational system they work in, including relevant characteristics of the wider organisational environment). Personal are those factors that are always bound to a certain person; typically they vary from individual to individual (e.g. personal ambitions, emotions, or risk perceptions). Interpersonal factors are those factors related to the interaction between people. The latter category is often ambiguous: the various individuals involved often experience it differently, and sometimes these factors are even associated with conflicts of interest.

The three categories are illustrated in table 1.

Table 1 - Three categories of human factors, and typical examples thereof		
Personal factors, i.e. items related to the individual, e.g.:	**Interpersonal factors**, i.e. interactions between people and/or characteristics of the social system, e.g.:	**MAN-SYSTEM DYNAMICS**[3] i.e. interactions between people and the technical-organisational system they work in, e.g.:
Ambitions Authenticity Awareness Competencies Feelings and emotions Fitness for the job Habits Individual learning Involvement Mental models Motivation Perceptions Personal development-potential Personal values	Co-operation Collective and organisational learning Communication (vertical and horizontal) Conflicts (open and hidden) Corporate culture and safety culture Group and organisational-learning Inspiration Leadership Roles Shared values Shared mental models Team spirit	People influencing the socio-technical work system (e.g. via R&D, design, development, change, etc.) The socio-technical work system influencing individuals and teams, e.g. via job content, ergonomic characteristics of workplaces and tools, working time arrangements, etc. Interactions of people with the broader system (societal values, legislation, the Occupational Safety and Health Knowledge Infrastructure[4], etc.).

In different settings, people have usually different roles and behave differently. This raises the question in what role people should be addressed to create optimum safety results. Of course, there is not one best answer to this question as it will depend on the situation. It is quite clear that different roles can be relevant. An employer can be addressed, for instance, in his or her role as responsible entrepreneur, as good employer, as team leader, as the person responsible for his own family (see Zwetsloot & Starren 2004).

The four key processes and the three dimensions of the contents of strategic human factors, give the concept a much broader meaning and greater potential impact, than in the way human factors are normally addressed.

5.2 The actor perspective for occupational safety

If occupational safety and unsafety are the (temporary) result of (continuous) co-creation and co-learning processes (in a changing environment), from the key actors involved, it is important to better understand safety from the perspective of the people involved: the actors or agents.

If the people are seen as potential part of the solution and the problem, it is clearly important to take the people, i.e. each individual and the groups or teams they work in, seriously.

---

[3] Interestingly, developments in technology and changes in behaviour (associated with changes in complex social systems) may mutually enhance each other, see De Vulpain 2005.

[4] The OSH Knowledge Infrastructure represents how national (or international) OSH Knowledge Management functions. It determines what OSH knowledge is available, is developed (demand or supply driven?), is transferred (to whom?), is used (e.g. by SMEs?) and is evaluated (e.g. on its user friendliness and effectiveness). Various institutions (e.g. national government, social partners, research institutes, OHS Services, companies) play a role in this infrastructure.

For improvements in safety, it seems that the consequence is that already in the earliest stages of a possible intervention, it is important to identify the key actors (i.e. those individuals that are likely to be part of the problem or of the potential solution. To further organise an effective collective learning and co-creation process the following steps seem a logical general format.

Table 2 - Steps for effective involvement of key agents in the collective learning and creation process to improve safety

1. Identification of the key agents (= individuals or groups that are likely to be part of the problem or of the potential solution).
2. Involve all key agents from the beginning in the process.
3. Identify a shared aim, a common goal.
4. Analyse with the key agents how the existing situation (e.g. safety problems) are created (probably unconsciously) by the key agents. Identify the main factors that played a role in creating this situation. Be keen on different perspectives (ambiguities) and discuss them all. Conflicting perspectives may lead to complementary insights into the problem and its potential solution.
5. Be sure to organise a process in which all key agents communicate in an open way also about objective personal and interpersonal aspects, without hidden agendas. This may require the support of a neutral facilitator.
6. Organise a process of joint "sensing"[5], of letting go the existing paradigms. Eliminate the internal voices of judgement.
7. Organise a process of presencing, of jointly developing a deeper understanding of opportunities for the future.
8. Organise the process of realising. Answer the question: What actions are possible today that generate (co-create) possibilities that contribute to improved and sustainable safety?

Of course, the eight recommended steps are not implying at all a standardised process. Every situation, and each individual involved is unique.

The approach described above, contrasts in terminology and process with more traditional approaches. Several regularly used terms that have negative connotations. The terms *human error* and *human failure* only address the negative side of human behaviour in respect to safety. In these concepts, the connotation is that people are imperfect machines, that even make mistakes in routine activities. People are part of the problem, not the solution. Of course, the concepts can have added value in analysing a problem, but for creating the solution jointly with the key agents, more is needed.

The same is true for the term *risk perception*. That term is often used for explaining why people behave non-rationally. The main issue is here that people have feelings and emotions, which partly drive their behaviour. When the term risk perception is used, it usually implies that "people are stupid" or "the experience of people is inferior to scientific and objective analysis". Again, people as part of the problem, and not the solution. It seems that the above mentioned concepts are mainly associated with the mechanistic view on organisations, do not fully acknowledge the human potential, and are not fully adequate for creating living safety organisations.

For the actor perspective, it is important that people are approached and treated as valuable individuals, as human beings that are important and are taken seriously. Then people are not reduced to the "homo economicus" that is only acting rationally and selfish. Employers and employees are valuable professionals that are able to integrate safety into respectively their entrepreneurship and their craftsmanship, and that are able to learn. People are individuals each with their unique personal qualities.

[5] See Senge et al 2004.

5.3 Safety as *also* a social construction

In all former sections, we looked at safety solely with the lense focussed on strategic human factors. We referred to Morgan (1984, 1993), who introduced the idea of different metaphors and different "lenses" to get a more complete understanding of organisation. The consequence is that the various lenses are – at least to a certain degree- complementary. Therefore, in this section we discuss the complementary value of regarding safety as a social construction (= *man-made*), and the more regular objective scientific approach.

When people in a given situation are asked about safety or unsafety, they may experience it in various ways. In their experience safety (or unsafety) refers to more than risk alone. Safety is often associated with feelings and emotions. *Confidence* and *trust* seem mostly associated with safety, while *fear* and *anxiety* are often associated with unsafety. At first it seems not very rational to take these feelings and emotions into account, because they complicate the issue, and it is not vital for analysing the risks. But if we see safety and unsafety as the result of a co-creation and co-learning process, the motivation of the key agents is essential for the success to improve safety. From that perspective, these subjective or inter-subjective factors are quite significant. Their motivation to take action, will be greatly influenced by their feelings and emotions. From this point of view, it is very rational to keep in mind that people do have feelings and emotions, and that they matter – as a form of "extended rationality" **(**Railton 2001). The implication is to take seriously into account that safety is – at least partly – a social construction.

So what are the consequences of taking these subjective or inter-subjective aspects of safety seriously? To clarify the impact we developed a two by two matrix, consisting of four quadrants combining the traditional merely rational dimension of safety, with the human, social construction dimension. See the table below.

Table 3 Two dimensions of safety combined: as objective and as social construction	*Objectively the situation is safe* *(low risk levels)*	*Objectively the situation is unsafe* *(high risk levels)*
The situation is experienced by key agents as safe	Safe	Situation appears safe, but isn't i.e. *false safety*
The situation is experienced by key agents as unsafe	Situation appears unsafe, but actually isn't i.e. *false unsafety*	Unsafe

The matrix clarifies that instead of the traditional dichotomy *safe* versus *unsafe*, four situations are relevant. The traditional labels "safe" and "unsafe" are still important, but they have now an additional meaning:

- A situation is *safe* when the level of risk is objectively low (below generally accepted levels) *and* the situation is experienced (and understood) as safe by the key agents. This nicely underlines the well-known statement, that *safety is more than merely the absence of accidents and incidents.*
- A situation is *unsafe* when the level of risk is objectively high (above generally accepted standards) *and* the situation is experienced (and understood) as unsafe by the key agents.

When an unsafe situation is identified, the matrix shows that two different aspects have to be changed in order to transform it into what we now define as a safe situation. The risks have to be reduced *and* the awareness and experience has to change. This raises a dilemma for the strategy to follow: is it better to firstly reduce risks (making the shift to false unsafety) or is it better to first start working with the people involved, by improving their awareness and motivation, and so create the conditions for the co-creation of real safety. It seems there is no best solution for all circumstances here, as the best strategy will also depend on the urgency of the situation. However, when the situation is not very urgent, we recommend investing firstly in the awareness and motivation of the key agents, initiating the process of co-creation of greater safety.

Besides a new perspective on the old concepts safe and unsafe, the matrix also shows two new quadrants. These are:

- *False safety*: situations that are characterised by a high level of risk (above generally accepted standards), but are experienced as safe by the key agents.
- *False unsafety:* situations that are characterised by low levels of risk (below generally accepted standards), but are experienced as unsafe by the key agents.

Below we give a few illustrations of these two categories and discuss some of their consequences.

False safety

In the safety and core business projects, the metal and plastic producing company A, was eager to profile itself to be technologically on the edge. But this was seen as relevant for production and for quality reasons. It was recognised that unsafety was a potential disturbance of production, but safety was *not* regarded as relevant for quality improvements. As a result, safety was not optimally integrated into technological innovations, opportunities for improvement were not recognised because "technological innovations" were without systematic safety assessment implicitly assumed to be safe (while this was not made certain).

In several other case studies (both in the safety and core business and the quantification of risk line of research) we saw examples of "separated (sub)systems" (databases, information flows, experts and/or expert departments) for safety on the one hand, and production, quality and maintenance on the other. These separated subsystems were also internalised in the mental models of the people involved. These leads to situations were potentials for safety improvement were not recognised, were some situations are experienced as safer than they actually are, so as – at least to a certain extend - as false safety.

Certified safety management systems may also lead to the general perception in the company that all safety issues are already adequately addressed. This does not encourage people to reflect on further improvements. In reality, safety management systems are perhaps a necessary, but not a sufficient condition for safety, and there is no direct relationship between the functioning of a certified Safety Management System (SMS) and safety performance.

Consequences of false safety are: wrong awareness, lack of motivation for safety improvement, neglecting relevant risks. No adequate action taken. In this respect false safety is already mentioned in some literatures as a problematic situation.

False unsafety

A national example that goes beyond occupational safety was the Dutch policy with respect to hazardous substances and dangerous situations. During the nineties and the early years of the 21st century, due to sustained pressure of NGO's, the chlorine transport by train (over about 200 Km passing several city centres) became increasingly a political problem in the Netherlands. Finally the ministry of the environment made a deal with the company involved: for a compensation of about 200 million euros the company involved was willing to move production capacity, eliminating the need for chlorine transport; the net safety result is difficult to assess, certainly not tangible, and in some respects questionable. In the same period, the same ministry also considered measures to reduce the problems associated with the exposure to radon gas in houses. This would have cost the ministry about 30 million euros and would lead to about 1000 victims less per annum. However, radon gas is a silent killer, the victims are usually not identified as such, and there is no societal awareness of that problem let alone societal pressure to solve it. As a result, it is politically not sexy to invest in its solution and this overruled the rationality of the ministry (Interdepartementale Werkgroep NOR 2004): that measure with significant impact got no political support at all, and so that policy option was cancelled.

In some companies a somewhat overwhelming effort is made for a specific type of measures for controlling well-known safety issues (e.g. with specific technological solutions, or with behavioural programmes focussing on routines) were it is questionable whether this has evolved into an irrational habit that overemphasises some safety issues (false safety), associated with too little attention for less well known (new emerging) risks. In several cases in the *safety and core business projects*, we saw an overemphasis of "structure" approaches for safety, and too little attention of culture and/or learning aspects of safety improvements.

False unsafety may, from a traditional safety perspective, be regarded as a rather innocent situation (because it is objectively safe). Probably that is the reason that explains that false unsafety is hardly discussed at all in the safety literature. However, such a situation will be objectively safe only for the moment X or Y: in an era

of continuous change and turbulence, the safe situation will only be temporary. It may easily lead to activities that are meant to improve safety, but that are actually non relevant for safety. It is likely that his will be counterproductive in the end: these activities cost time and money, but will not contribute to safety. As a result the general trust in safety measures will gradually decrease, and the same for the willingness to invest in safety measures. This will reduce the likelihood that adequate action will be taken, when a new risk is introduced by change or innovation. To be short: in a situation of false unsafety, the situation is temporarily safe, but by no means sustainably safe.

These two categories (false safety and false unsafety) are, from an actor perspective, very relevant to better understand, because in both situations, the motivations and actions of the actors involved will not be suited to the objective situation.

5.4 Further perspectives….

We have seen that complexity and change imply important limitation of the perspective were safety is mainly seen as a result of "control" of "technological hazards". Control is aiming at the prevention and suppression of deviations in regular and planned activities. However, to improve or to innovate, - especially for out-of-the-box solutions - it is also vital to go *beyond* the regular activities. In this way, control and innovation seem to mutually exclude each other. To overcome this paradox, it is vital to think in terms of (dynamic) processes, not static measures. It is then important to anticipate and respond adequately to changes in the organisation's environment (which has all the characteristics from an organisational learning process). In responding and anticipating change, people are usually superior to machines and automate. This strongly supports the re-valuation of the human factor.

Of course, responding and anticipating adequately to complex changes is not an easy task. It requires a collective learning process of the people most involved. However, when safety and unsafety are the temporary results of a continuous co-creation and co-learning process that is precisely the heart of the matter for creating safer workplaces and a safer world.

New challenges for research are to better understand, and systematically research (requiring involvement of the key agents) the characteristics and causes of situations that are false safe or false unsafe.

The challenge for practitioners will be to fully acknowledge the dynamics and processes of collectively creating and learning to generate safety, and to better understand the pitfalls of false safety and false unsafety.

ACKNOWLEDGEMENTS

The research project described here was part of the four-year research programme on occupational safety 2003-2006, subsidised by the Dutch Ministry of Social Affairs and Employment. We thank the Ministry for their interest in and support for this programme. We would also like to thank the people from the various companies for taking part in this programme.

REFERENCES

Beck U, 1986. Risikogesellschaft: Auf dem Weg in eine andere Moderne, Suhrkamp, Frankfurt.

De Geus, A., 1997. The living company – Habits for the survival in a turbulent business environment, Harvard Business School Press, Boston MA.

De Vulpain A., 2005. Listening to ordinary people- how technical progresses synergise with changes in people and in the social fabric, keynote paper, presented at the 2nd Global Forum of the Sociaety for Organisational Learning, Vienna, 13.-16 September 2005.

Gort A.J., Keus B.M., Moonen C., van Dijk M., de Vroome E., & Zwetsloot G.I.J.M., 2005. Safety during organizational change in the chemical process industry. Paper for ESREL conference 27-30 June, Gdynia, Gdansk, Sopot, Poland, 2005.

Gort J., Starren A., Zwetsloot G.I.J.M., 2006. Embedding safety in the company's core business – case studies, Paper to be presented at the 3rth Working on Safety Conference, September 2006, Delft.

Hale, A., Baram, M., Hovden, J., 1998. Perspectives on Safety Management and Change, in Hale & Baram (eds), Safety Management: The challenge of change (1998), Elsevier Science, Oxford.

Interdepartementale Werkgroep NOR -Nuchter Omgaan met Risico's, 2005. Werkdocument ter voorbereiding van de Workshop Robuustheid NOR, September 2005, Den Haag.

Lauridsen K, Amendola A., Christou M., Market F. & Kozine I., 2001. Uncertainties of risk analysis of chemical esthablishments – the ASSURANCE project, presentation at the CEC Conference, Antwerp, 10 October 2001.

Lauridsen K, 2001. Personal communication, Antwerp 10 October 2001.

Morgan, G., 1986. Images of organization, SAGE Publications, Beverly Hills.

Morgan G., 1993. Imaginisation, the art of creative management, SAGE Publications, Beverly Hills.

Moonen C, van der Drift D., Voskuilen G., van Dijk M.D., Zwetsloot G. & Brouwers A., 2002. Op weg naar een nieuwe generatie management systemen; het managen van diversiteit in belangen en werkelijkheden (On the journey towards a new generation of management systems; the management of diversity in interests and realities), Hoofddorp, TNO Arbeid.

Op de Beeck R. & van Heuverswyn K., 2002. New trends in accident prevention due to the changing world of work, in co-operation with André J.C., Kuhn K., Lemkowitz S.A., Saari S., Sundström-Frisk C., Tannenhauer J., Tejedor M, Zwetsloot G.), European Agency for Safety and Health at Work, Bilbao, 36 pp.

Railton P., 2001. Emotion and rationality, Paper for the Erasmus Summerschool of Social Onthology of Emotions and the Limits and Extensions of Rationality, June 2001, Rotterdam.

Rasmussen J., 1997. Risk management in a dynamic society: a modelling problem, Safety Science 27 (2/3) p 183-213.

Senge P., 1997. Foreword in: de Geus A., The Living Company, pp VII-XI, Harvard Business School Press, Boston MA.

Senge P. Scharmer C.O., Jaworksi J., Flowers B.S., 2004. Presence – Human purpose and the field of the future, Society for Organisational Learning, Cambridge MA.

Visser R, and Zwetsloot G.I.J.M., 2004. Arbomanagement in bedrijven (OSH management in companies), Kluwer, Deventer.

Zwanikken S. Jongen M.J.M., Popma J.R., Gallis H.R., and Zwetsloot, G.I.J.M. 2006. Tackling occupational hazards at the source. A strategy fro innovative methods to implement source-directed strategies, paper to be presented at the 3rth Working on Safety Conference, September 2006, Delft.

Zwetsloot G.I.J.M. and Askounes-Ashford N., 2003. The Feasibility of Encouraging Inherently Safer Production in Industrial Firms, Safety Science, 41, Vol. 2, Special Issue on Safety and Design (E. Fadier editor), p 219-240.

Zwetsloot G.I.J.M., Gort J., Steijger N., and Moonen C., revised version submitted July 2005. Management of change: lessons learnt from optimising manning staff reductions in the chemical process industry, Safety Science.

Zwetsloot G.I.J.M., Lemkowitz S.A., and Hale A., 2002. Safety and Change: managing safety during change, Proceedings of XVIth World Congress on Safety and Health at Work, Innovation & Prevention, 26-31 May 2002, Vienna.

Zwetsloot G. and Moonen C., 2003. Organisaties vernieuwen is mensenwerk (Organisational renewal, a human effort): In: S. de Vries, E. Wortel and A Nauta editors, Excelleren voor en door mensen (to excel for and by peope), pp210-227, Kluwer & INK, Deventer & Zaltbommel.

Zwetsloot G.I.J.M. & Starren A., 2004. Corporate Social Responsibility and Safety and Health at Work, Research Report from the European Agency for Safety and Health at Work, Issue 210, Bilbao, 131 pages.

Also available as a web feature via: http://agency.osha.eu.int/publications/reports/210/en/CSR_Report_EN.pdf.

Zwetsloot G.I.J.M. , 2003. From Management Systems to Corporate Social Responsibility, Journal of Business Ethics 44: 201-207, special issue on Corporate Social Responsibility.