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TACKLING OCCUPATIONAL HAZARDS AT SOURCE. A SEARCH FOR INNOVATIVE METHODS TO IMPLEMENT SOURCE-DIRECTED STRATEGIES

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Abstract - At the beginning of the millennium, several serious accidents led to increased attention to safety in general and occupational safety and safety management in particular. In addition, there are indications that the number of (serious) occupational accidents in the Netherlands has risen in the past few years. In response to this persistently high incidence of accidents in the workplace, the Dutch ministry of Social Affairs and Employment has initiated a programme carried out by TNO entitled 'Enhancing workplace safety'. The programme consisted of three research lines one of which focused on promoting the tackling of occupational hazards at source. The central questions in this study were: (1) what are the determinants that contribute to or impede combating safety risks at source, and (2) can we, through case studies, develop a successful approach for promoting/-implementing source-directed strategies? The researchers conducted a literature scan, interviews with experts and 13 case studies in search of determinants for successful implementation and best practices. A pilot study was conducted on a prospective maintenance facility for high-speed trains. The case studies in the process industry and the cases involving prospective facilities showed few opportunities and attention for source-directed strategies. The main drivers for companies in source-directed safety management are legislation, drive of the management and societal pressure. The most important impeding factors are commercial considerations like investment in prospective facilities, the many actors in the production chain, and the underlying risk perceptions. The pilot study showed that source-directed strategies can be successful, if planned at the right moment in time and implemented through an interactive approach involving representatives from the work floor.

INTRODUCTION

Both nationally and internationally, a series of dramatic events (the explosion of a fireworks plant in Enschede in 2000, a major fire in a Volendam café in 2001, the explosion of an ammonium-nitrate plant in Toulouse in 2001, and the WTC assault in New York in 2001) has led to an increased focus on safety in general and occupational safety and safety management in particular. Paradoxically, however, there are indications that the number of (serious) accidents in the Netherlands has risen in the past few years (Dutch Lower Chamber 2001-2002a, b, c; Labour Inspectorate, 2002; Labour Inspectorate 2003a, 2003b). Moreover, important safety concepts such as control, safety modelling, prediction and quantification of risks, accepted risk levels, accident causation and safety management systems seem to be losing some of their added value due to increasing uncertainties in and volatility of the situation in which they are used; adaptation may be needed to renew their added value. At the same time, concepts like safety behaviour and safety culture seem to be coming more to the fore as they gain increasing relevance. However, if these concepts are to become more effective in complex situations, they need further development too.

These notions underlay a four-year (2003-2007) 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 relationship between (developments in) the core business of companies and safety management. The underlying idea is that a close relationship between the two may imply that safety gains more strategic added value for companies, and that as a result safety management might be more resilient to changes;

2. the innovative use of information on business, technical and work processes that is available in companies but is currently not utilised to strengthen safety. The underlying idea is that companies often possess a lot of relevant information on possible disturbances in production processes (for business reasons) and this information could be used to gain getting better insight into relevant accident scenarios, for risk quantification and setting priorities for safety prevention;

3. the promotion of tackling occupational hazards at source as well as the feasibility of preventing major accidents through this approach. 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 here 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.

This paper is an account of the projects conducted for the third line of research up to the end of 2005. A more detailed account of the results of the first two years of the project is given in two TNO reports (Popma et al, 2003; Jongen et al., 2005).

Combating the risks at source has been the preferred strategy ever since the Dutch Working Conditions Act came into force in the early 1980s (Van der Poest Clement and Boere, 2002), and is also prescribed by the European Framework Directive of 1989, section 6 of which compels employers to organise their OHS policy on the basis of the following general principles of prevention:

(a) avoiding risks, for example by phasing out or substitution of hazardous substances;

(b) evaluating the risks which cannot be avoided;

(c) combating the risks at source;

(d) adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health;

(e) adapting to technical progress;

(f) replacing the dangerous by the non-dangerous or the less dangerous;

(g) developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors related to the working environment;

(h) giving collective protective measures priority over individual protective measures;

(i) giving workers appropriate instructions.

For this publication we define combating risks at source as the diminishing or complete removal of the source(s) of risks in an existing workplace or in prospective workplaces or processes. *How* to combat risks at source can take many forms:

- simply abolishing dangerous activities;

- substitution of dangerous substances or processes (preferably at the beginning of the production chain), either radically or by phasing out;

- changes in the materials (viz. replacement of powdery materials by grains, paste or liquids, which diminishes the risk of dust explosion);

- bringing a more convenient structure to processes and workplaces (‘user friendly plants’, ‘human factors design’);

- gearing tools and tasks to safety by means of cognitive and physical ergonomics;

- application of ICT as a form of integrated process control, whereby derailments in the production process are detected and corrected promptly by means of automated interventions (integrated safety);

- designing inherent safe processes.

To a large extent this may be considered a technical/material interpretation of the notion of combating risks at source, with a clear focus on technological innovation. Of old, this technological-rational approach to prevention has been dominant among safety specialists. As part of the present research, however, a more organisational type of question is how combating risks at source may best be stimulated. The central questions in this study were:

1. what are the determinants that contribute to or impede combating safety risks at source?

2. can we, through case studies, develop a successful approach for promoting/implementing source-directed strategies?

In order to answer these questions, we deemed it necessary to look beyond the technological-rational paradigm currently dominant in safety science, with the main question being not which (technological) options may be conceived to combat occupational risks at the source but why possible options are applied, or not, in practice. Obvious factors in this respect are economic preconditions, technological feasibility and scientific insight. Also government policy (regulation, enforcement) or pressure from the side of stakeholders (employees, insurance companies, environmentalist groups) may be influential.

METHODS

The study consisted of the following activities:

1. A literature scan, focusing on new approaches for prevention at source. The search was directed at new and innovative approaches to occupational safety, including as inherent safety and the precautionary principle.

2. The development of an analytical model as a basis for conducting case studies. The model assembles determinants of source-directed strategies in companies, and was built on a brainstorm session at the start of the project with safety experts as well as the literature scan. Later on, the authors spoke to representatives from academia (industrial safety), insurance companies (liability), labour unions, and the Netherlands Society for Nature and Environment (Stichting Natuur en Milieu), Friends of the Earth, Netherlands (Milieudefensie).

3. Five case studies in companies that fell under the regime of the so called BRZO (Besluit Risico’s Zware Ongevallen 1999, Major Hazard Control Decree, the Dutch implementation of the Seveso Directive). The idea was that ‘Seveso-companies’ have a good focus on innovative safety management principles, including source-directed strategies, because of the serious risks involved. This implied that the focus in these cases was somewhat more on risks for the environment than occupational safety as such (‘external safety’). The five cases concerned the production of sulphuric acid and sulphur dioxide, of sunflower and cole-seed oil, storage and refining of mineral oil, the production of artificial fertilizer, and paint production. For all cases 16 factors have been scored on a five-point scale (--, -, 0, +, ++) ranging from strongly impeding to strongly promoting source-directed strategies. The case studies consisted of semi-structured interviews with key-actors in the safety management of the companies. In addition a secondary analyses of five cases from previously conducted TNO research, concerning the substitution of hazardous chemicals, has been conducted (Visser et al., 2003). Transition or phasing out of dangerous substances being a fine example of prevention at source, the cases were considered potentially interesting within the scope of the present research as well. The cases were re-analysed with respect to impeding or stimulating factors for starting a substitution project.

4. Three case studies concerning the start of new projects or new production facilities. The basic idea was that in these situations there was, in theory at least, an opportunity to use a source-directed strategy. It concerned interviews with representatives of a steel manufacturer starting new production facilities, with

representatives of the building industry where a project-oriented approach is the standard way of working, and with representatives of a company rebuilding a chemical plant after an accident.

5. A pilot study of a source-directed strategy. In our search for new approaches for source-directed strategies in the first ten case studies we focused on finding examples of source-directed strategies and the factors that impede or stimulate these strategies. In these cases we focused on process safety and the substitution of hazardous chemicals. In order to find new approaches on *how* to tackle labour safety at source we organised a pilot study of a source-directed approach by intervening in the design process of a prospective workplace in the transport sector. The approach consisted of an interactive way of working with the key actors, including representatives of the workers, regarding occupational safety in the new workplace at a moment when it was still possible to change the design of the workplace. The intervention consisted of interviews, observation of the maintenance process in an existing workplace, a document study, three workshops and a final presentation to the project managers of the new facility.

RESULTS

Literature scan

As a starting point of the research, a literature scan was conducted covering the 2000-2003 issues of relevant Dutch and international journals in the field of occupational health and safety. Also, a scan was conducted in databases such as Science Direct as well as the TNO library, which may be considered the main Dutch library on OHS matters. The scan brought to the fore that literature in the field of occupational safety mainly stems from a technological perspective. Within the dominant technological-rational paradigm, the literature scan hardly yielded any novel insights - especially as concerns source-directed strategies. The literature mainly seems to be embroidering existing knowledge, very much inclined towards ‘end-of-pipe’-approaches. Real innovative thoughts tend to arise from policy theories concerning the so-called *precautionary principle* (Renn et al., 2002), the concept of *inherent safety* (Hendershot, 2002), and *discursive risk management* (Klinke and Renn, 2002). Innovative approaches appear to be derived mainly from the *organisation* of processes and of safety management rather than from the further development of technical control.

The analytical model

The literature in the field of policy theory and discursive risk management also contributed to the development of the analytical model with which we approached the topic of tackling occupational safety at source. The illustration below shows the model we developed for the internal and external processes and actors of a company that influence source-directed strategies.

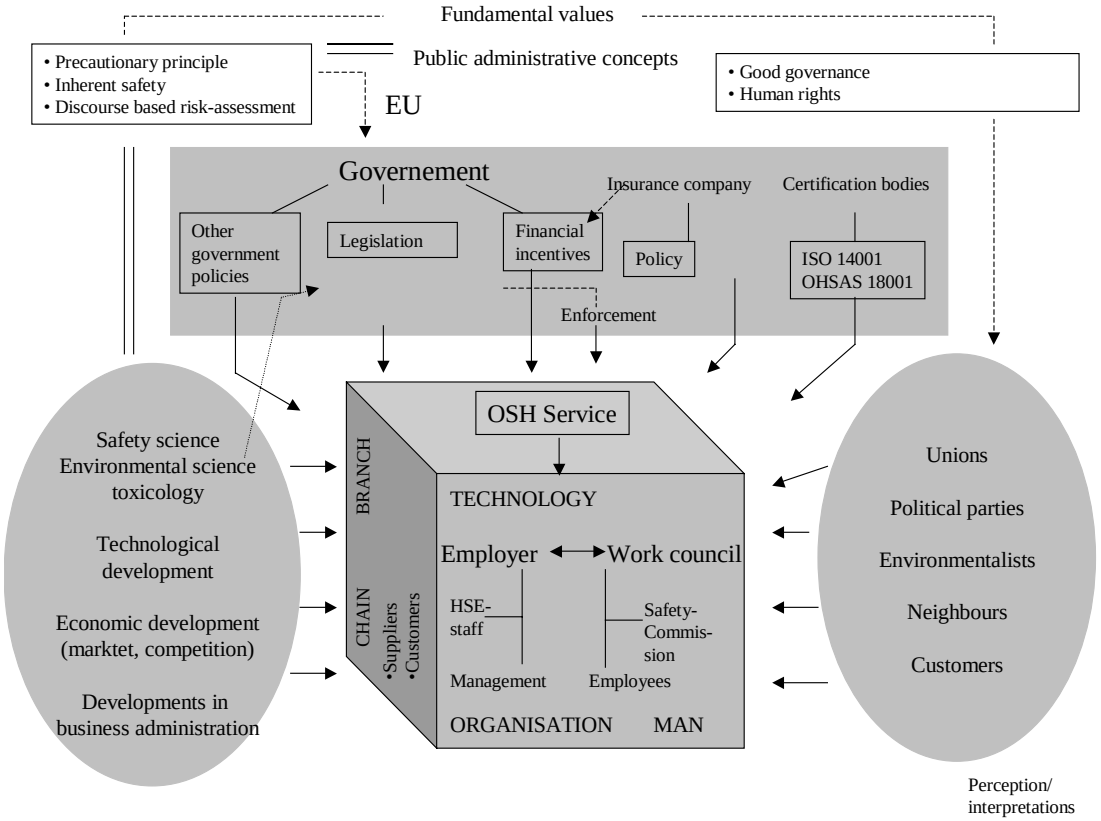

Figure 1: Internal and external determinants that (may) influence source-directed strategies in companies

A list of determinants derived from this theoretical framework was used in the case studies:

- the awareness / perception of the company management regarding safety and source-directed strategies;
- the awareness / perception of the employees regarding safety and source-directed strategies;
- the presence of employees' representatives (in the Netherlands notably the works councils);
- the obligatory risk assessment and evaluation;
- technological developments;
- the organisational structure of the company;
- economic developments (market, competition);
- legislation;
- the authorities that issue a license to operate;
- enforcement policy;
- politics;
- the neighbours of the company;
- the role of NGO's (environmental movements, trade unions, consumers)
- branch organisations.

Case studies

Three groups of case studies were conducted: five cases specifically selected for the current research (described below as the 'Seveso cases'), five earlier cases of substitution of substances were submitted to

secondary analysis, and three cases concerning the start of new projects or new production facilities ('Design and Rebuilding' cases).

Seveso cases

Table 1 contains the scores for the five companies with respect to the determinants derived from the analytical model.

Table 1: Impeding and stimulating factors in the five Seveso-cases

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Process / risks	Storage of sulphur dioxide (release of sulphur dioxide)	Storage of hexane (fire, explosion)	Storage of oil products (fire, explosion)	Storage of ammonia (release of ammonia)	Production and storage of paints (fire, explosion)
Awareness / perception of company management	-	++	+	+	--
Awareness / perception of employees			-		
Employees' representatives/works council	0	0	0	0	0
Risk assessment and evaluation		++	-	+	--
Technological developments	0	0	0	0	0
Organisational structure	-		+/-		
Economy (market, competition)	-	-	-	-	-
Legislation	+	+/-	+/-	++	++
Licensing authorities	+	+	+	++	++
Enforcement of legislation	+	-	+	+	++
Politics	+			++	
The neighbours of the company	+	0	0	+	+
Environmental movements	+	0		+	
Consumers		+	+	+	+
Branch organisations	+	+	+	+	+

(+ = stimulating, - = impeding, 0 = not applicable, empty = unknown)

The companies appeared to be mainly focused on the technical *control* of known risks. If we look at what factors were (or could be) contributing to a more *preventive* strategy in the five companies, some elements strike the eye.

First, the licensing authorities (or government in general) can in fact considerably stimulate the focus on prevention at source - at least in Seveso companies. All five companies indicated that they were keen on complying with all regulations issued by either authority. In one case, the licensing authority had actually imposed the obligation to assess the risks up front. Still, the companies were mainly focused on just complying with current regulations, without further ambitions to anticipate future regulation.

A second driving factor is pressure by internal and external stakeholders, such as corporate OHS policy makers, or pressure from neighbours, consumers or environmentalist groups. At any rate it is clear that this pressure may or indeed does raise awareness of safety matters. Whether this awareness also directs OHS policy towards prevention at source cannot, however, be concluded on the basis of the five case studies.

The main drawback for source-directed strategies in the five cases was the financial constraints at company level, mainly the focus on short-term return on investments in safety, especially when installations are already in use and the (perceived) benefits do not always balance the costs. The five companies saw little or no economic benefit from investments directed at prevention.

Cost-benefit analyses are influenced, as may be concluded from the five case studies, by the perception in companies that they in fact adequately control all safety risks. In various cases, risks were calculated by means of quantitative risk analyses and it was concluded that the risks are acceptable. This risk perception strongly undermines the willingness to invest more in safety.

Table 2: Summary of impeding and stimulating factors for source-directed strategies in Seveso companies

	Process	**Stimulating factors**	**Impeding factors**	**Key actors involved**
Case 1	Storage of sulphur dioxide	Serious accident	Technical problems related to product quality	Fire fighters (?) licensing authority (+)
Case 2	Storage of hexane	Strong company view; Explicit view from top management; Pressure from consumers (food safety); licensing authority	Costs of source-directed approach too high; only feasible when consumers are willing to pay a higher price for decreasing risks	Licensing authority (+/-); OSH-network (+); Head quarters of the company (++)
Case 3	Storage of oil products	Licensing authority	Commerce (competition)	Branch organisation (+); Customer (?); Labour (+) and Environment Inspectorates (+)
Case 4	Storage of ammonia	Licensing authority; Social pressure; Political parties	Commerce (investment will not be profitable)	Province (+); General public (+); Politics (+)
Case 5	Production and storage of paints	Municipal licensing authority; Niche market	Commerce (investment will not be profitable)	Municipality (+); Consumer requirements (+)

(+ = stimulating, - = impeding, ? = unknown)

Substitution cases

The findings of the five substitution cases were analysed from the same theoretical perspective as were the Seveso cases. The comparison corroborated the main finding that companies are very much focused on regulation, albeit that in the substitution cases the management was somewhat more forward-looking. A difference between the two clusters of cases was that in the 'substitution companies' the transition was focused on products, whereas in the Seveso cases the measures were mainly aimed at changes in the production process, notably the storage of large amounts of hazardous substances. The Seveso companies, unlike the substitution companies, did not see any commercial potential for return on investment in prevention at source. A summary of impeding and stimulating factors is given in table 3.

Table 3: Impeding and stimulating factors for source-directed strategies in substitution cases

	Process	Stimulating factors	Impeding factors	Key actors involved
Case 1	Substitution of halogenated hydrocarbons	Customer requirements (commerce); (Upcoming) legislation; Company image; Upcoming ban of compounds	Technical difficulties related to product quality	Branch organisation (+); International law (+); Suppliers
Case 2	Substitution of organic solvents by water	Legislation; Commitment of the management	Vested interests in traditional products; Consumers are unfamiliar with new products	Conservative competitors in the branch (-); Environmental movement (+); Branch organisation (+); Government (++); End user (-); Suppliers (?)
Case 3	Substitution of mineral lubricants by biodegradable alternatives	Legislation; Customer requirements; Stimulation by government	No data available	No data available
Case 4	Substitution of phosphate ore with other sources of phosphates	Management vision on sustainable production; Alternative sources cost less; Competition; Expected future problems with consumers and the general public	Legislation regarding the use of alternative phosphate sources, like waste water treatment	Management and employees (+); Licensing authorities (-)
Case 5	Substitution of organic solvent in paint removers	Possible future ban of the organic solvent; View of the company management; Pressure by environmentalists; Political pressure; Pressure from the branch organisation; External innovative developments	Complexity and contradictory legislation; High price of the alternative product	Branch organisation (+); Government (+); Paint branch (end users) (+); Local initiatives of entrepreneurs (+)

(+ = stimulating, - = impeding, ? = unknown)

Design and rebuilding cases

One of the most promising chances of tackling occupational safety at source is in the phase of designing a process or building. For reasons of comparability, we initially looked for companies subjected to Seveso regulation. However, it appeared quite difficult to find enough Seveso-cases. Therefore, we reverted to three cases of which two were not subject to the Seveso regime: a chemical company rebuilding its production facility, a large steel company building new production facilities on its site, and the building industry where we discussed the opportunities for source-directed strategies in a project-based way of working. In the case of the building industry we interviewed experts on the building process from both industry and university.

CHEMICAL PLANT

In the case of the chemical plant, the company had to totally rebuild its production installation after an explosion some years earlier. This unfortunate event did, in theory, offer the opportunity to apply a source-directed strategy for a safer installation. Although the accident led to increased awareness about safety, the process/facility was to a large extent rebuilt in the same way. In this case, it was not the large investment that

impeded the application of a source-directed strategy, but rather the fear of new, unknown risks resulting from a change in the process. This fear is not only felt within the company but also by the authorities that have to issue the operating permit. In this way, the company and authorities kept one another in deadlock. Whereas in the five Seveso cases it was found that the authorities propelled safety awareness, in this case it kept the company from a source-directed strategy. Still, the urge to start producing again to maintain or recover market share does not leave enough time to develop a safer production process.

STEEL PRODUCTION

In the case concerning a steel producing company with a large site containing dozens of production facilities, pressure of time is so strong in important investments in installations that are directly linked to the production process that the company uses 'turnkey' processes for buying new facilities. New facilities are delivered ready to use on site. This means the use of proven techniques. Modifications to the facility are not even allowed before delivery, which makes a source-directed strategy difficult to implement. For facilities where pressure of time is less, source-directed strategy is applied through the use of quantitative risk assessments like Hazard and Operability Studies (HAZOPs) and Fault Tree Analysis (FTA). This implies that prevention strategies with respect to occupational safety are different for each new installation. The application of source-directed strategies for all installations would require the discussion of safety matters in a very early phase of the tendering process.

The building industry

Construction is one of the industries with a high prevalence of work related accidents. One of the reasons for this, is the complexity of the building process. Generally, the building process consists of seven steps:

1. decision on investment
2. initial draft
3. general design
4. detailed design
5. planning
6. building
7. maintenance

Many of the actors in this process act independently. Co-ordination of all activities is often complex, with a complex demarcation of responsibilities and liabilities. In addition, actors are involved in the process at different moments in time. Also, as the process is divided into various steps with various responsibilities, it may occur that each step in itself is designed optimally but shifts the risks to the next step of the process. This may entail sub-optimisation in the entire chain. Better coordination of the entire chain (or parts of it) offers many opportunities for source directed management of occupational risks. There are some examples of changes in the coordination of these process steps:

- The use of so-called 'design & construct' contracts, where steps 4-6 are controlled by one and the same company. An extreme example is the contract for the Dutch high speed train track where all steps are under supervision of one organisation. This enables the contracting firm to exert better control over the working conditions and to prevent dangerous situations. Not only may the designer anticipate safety risks in the building phase, as the constructor is part of the same firm it is of no avail to shift the risks from one phase to another: the designing firm is confronted with the costs of accidents later on in the building phase.

- Another example is design on the basis of a limited number of standardized building modules. As an edifice is designed (or rather: assembled) on the basis of this limited number of modules, it is easier to produce the respective modules *off site*, in a more controlled and hence safer environment. Also, it is easier to integrate safety measures in the modules itself, such as the incorporation of anchoring for scaffolds in pre-processed walls or the use of completely integrated window frames (that must no longer be fitted on site).

- A third example is standardised planning of the entire building process and very strict agreements among contractors and subcontractors. All steps of the entire building process are accurately defined by the main contractor, where in each step efficiency and safety can be controlled better because the risks are predictable (sometimes, even deviations are standardised). During each auxiliary step there is only one contractor on a

specific site, which decreases occupational risks emanating from unclear responsibilities as well as via a more orderly building site. Also, each sub step prescribes that the subcontractor leave the building site clean and orderly (housekeeping). This prevents common injuries caused by, a.o., stumbling and jolting. The main contractor finally works with a number of selected sub contractors, that are familiar with all OHS aspects of all auxiliary steps and observe the aforementioned prescriptions of good housekeeping. This concept seems to offer considerable advantages for preventing occupational risks in the building process through a chain-approach.

Interviews with experts

The interviews with experts emphasised the role of the company management. A lacking 'sense of urgency', as much as lack of anticipation, on the side of management is a very important drawback for prevention at source. Management awareness of the positive effects of combating risks at source does not appear to be strong. For example, the statutory risk assessment is implemented in much too defensive a way (viz. as an instrument of tracing current problems rather than as a tool to tackle prospective risks, notably in R&D, process design and the building of new production facilities). Another insight reaped from the interviews with the experts was that companies are hardly aware of the fact that the prevention of liability suits for injuries or environmental damage may be considered a potential economic benefit.

Another finding from the interviews was a modification of the claim that regulation must be considered the most potent driver for companies. This may be the case for safety in general, but the influence on prevention at source is ambiguous. On the one hand, it is generally accepted that strict regulations (notably in the field of emissions and of safety contours) force companies to seriously engage in developing a safety policy. On the other hand, it appears that the use of strict standards (such as 10^{-6} contours) is hampering innovation, as companies are not challenged to innovate as long as they are in compliance. This latter attitude was also witnessed in the case studies: focussing on risk calculation entails a perception that if the standards are met the production process may be considered safe. Also some of the interviewees disproved the proposed possibility of enforcing prevention in the process of granting a licence to operate. Some interviewees claimed that most civil servants in this area are too ill equipped to steer companies in this direction.

The significance of stakeholder pressure by neighbours, environmentalist groups and works councils is not unequivocal either. Firstly the involvement of these stakeholders is far from optimal, mainly due to lack of expertise (neighbours, works councils) or manpower (environmentalist movement). Secondly it is not improbable that companies do, in fact, take safety measures due to pressure, but that these measures are not in themselves focused on prevention. Strong internal or external pressures may induce short-term solutions. The effect of a more process oriented approach towards risk management may thus be restricted.

Pilot study NedTrain

Next to the cases described above, we conducted a pilot study in which we reached out more actively in order to actually *create* a situation in which a source-directed strategy could be deployed. The pilot intended to assess the newly developed facility of NedTrain, the workplace 'Watergraafsmeer' in Amsterdam. NedTrain is a wholly-owned subsidiary of the Dutch Railways and is active on the international maintenance market for railway rolling stock. NedTrain has more than 35 locations at strategic points in the Dutch railway network. As a result of the construction of the High Speed Line South, a high speed railway connection between Amsterdam and Brussels, NedTrain will be endowed with the task of maintaining the high speed trains.

Design and maintenance of the new line and the public transport is realised by a public-private partnership, the High Speed Alliance (HSA). HSA, a joint venture between the Royal Dutch Airline (KLM) and the Dutch Railways (Nederlandse Spoorwegen), was granted the concession to operate the high speed line as of 2007 (www.highspeedalliance.nl). The trains have been designed by Pininfarina and are built by the Italian manufacturer AnsaldoBreda. AnsaldoBreda also supplies the maintenance specifications and helps in training the mechanics. The relationship between these partners is shown in figure 2.

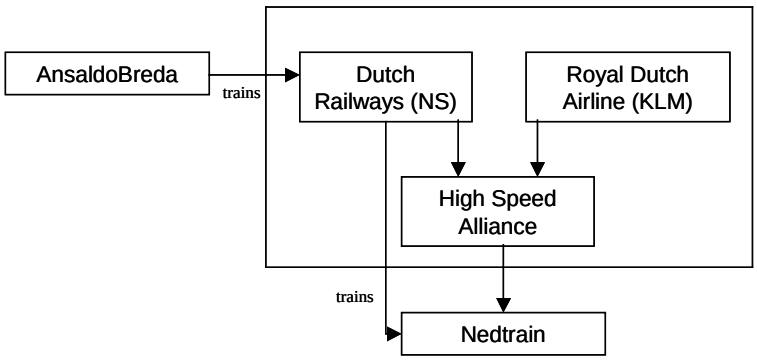

Figure 2: High Speed Alliance organisation

The production chain in the new workplace has been defined as: moving trains into the workplace - maintenance - moving trains out of the workplace. NedTrain cannot influence the design of the trains or their maintenance plans. This implies limited possibilities for reducing labour safety risks earlier in the production chain. The key question of this pilot study was defined as:

'*Which source-directed strategies can be used in the design of the new facility, in comparison to the existing workplaces, in order to reduce safety risks and meanwhile minimise disturbances in the production process?*'

The interviews and the observation of the existing maintenance process gave insight into the labour risks of the prospective maintenance process and the stimulating and impeding factors for source-directed approaches and were used as background information in the workshops/brainstorms with the mechanics.

The first workshop resulted in a shared view of the maintenance process and its most important risks. In the second workshop the mechanics, together with the SHE manager and the project manager of the new facility selected five clusters of risks for further action:

- heavy work;
- exposure to contaminated dust;
- electrocution;
- working at heights;
- improvisation (unsafe behaviour)

The second and last workshop were focused on finding ways to reduce these risks. We used a source-directed strategy as a central concept to find solutions. Creative solutions for all risk clusters could be defined during the workshops. The text below illustrates an example of such a solution:

> The trains have air-conditioning systems These systems contains air filters. The filter cloths contain dust contaminated with metals like copper from the power supply wires. The mechanics have to remove the filter cloth from its frame and then replace it. Not only are the mechanics exposed to dust, but the train also gets contaminated. Two solutions have been proposed:
>
> - instead of changing the filter in the train, store it in a specially built transport-wagon and do the job in a separate room with controlled conditions and proper personal protection;
> - a more source orientated solution is to design disposable filters so that changing of the filter cloth is no longer necessary. This solution has been proposed for further investigation.

Impeding and stimulating factors for source-directed strategies assessed according to the analytical model used for the Seveso case studies are given in table 4.

Table 4: Impeding and stimulating factors for source-directed strategies in the NedTrain pilot

	NedTrain
Process / risks	Maintenance of HSA trains
Awareness / perception of company management	+
Awareness / perception of employees and project managers	+
Employees' representatives/works council	0
Risk assessment and evaluation	0
Technological developments	+
Organisational structure	+
Economy (market, competition)	-
Legislation	0
Licensing authorities	0
Enforcement of legislation	0
Politics	0
The neighbours of the company	0
Environmental movements	0
Consumers (High Speed Alliance org.)	+
Branch organisations	0

HSA focuses on passenger- or consumer safety[1] . We found no explicit attention for occupational safety in the maintenance process. Furthermore, NedTrain could not influence the design process between AnsaldoBreda and the Dutch Railways, which was a major impeding factor for source orientated measures in the maintenance production chain. Therefore, improvements of occupational safety are only possible by changing the design of the workplace or the maintenance process. The safety awareness and personal drive of the project managers appeared to be the most stimulating factor in practising source-directed strategies. They are convinced of the importance of occupational safety for an efficient core business free of disturbances.

The project managers' most important constraints were the fixed budgets. Changes in the basic design, implying higher costs, were only possible when short term returns on investments were possible. Other expensive changes, like a movable platform alongside the train, are only possible if they offer strategic advantages for the management. For example, the movable platform makes it easy to maintain several types of trains which will probably become a standard in the near future. External actors like licensing authorities, environmental movements or consumers had no significant influence on the decision-making process.

We found before that one of the most promising moments for tackling occupational safety at source is during the design of a process or building. In this pilot study we tried to intervene in the design of a workplace. This was partially successful, because the design of the maintenance facility was partly completed. In spite of this, we succeeded in finding solutions for some of the most important risks and also in changing the perceptions of the risks. The discursive process helped to pay attention to more organisational factors like safety culture and leadership. Nevertheless, better solutions may have been found if the intervention could have been done in an earlier phase of the design process , since most design decisions had already been taken.

It was too late for upgrading this discursive approach to a higher level, i.e. influencing the design of the trains further backwards in the chain.

CONCLUSIONS AND DISCUSSION

The purpose of doing these case studies was to find best practices and determining factors for the application of a source-directed strategy for safety problems, especially for chain-oriented strategies that go beyond the company boundaries. Given the difficulty of finding suitable cases, it was difficult to find general

[1] www.highspeedalliance.nl-/static/hsa/en/safety.html

factors that influence the application of source-directed strategies. The case studies in the Seveso companies proved that in the chemical process industry the substantial investments necessary for an effective source-directed strategy appeared to be the main bottleneck. However, the case concerning the rebuilding of a chemical plant and interviews with stake holders and experts revealed that this is not the only bottleneck. The lack of understanding of the risks of new production processes, and the fear of leaving the beaten path are as central as the substantial investments. This applies to the company staff as well as to the relevant authorities.

In the building industry the length of the production chain, with its many independent actors, seems to be the greatest bottleneck. The solution mentioned for alleviating this problem was that one company tried to control several or all of the steps of the building process. The motive for this is to raise efficiency and reduce the costs of the building process. Apparently, the lower risks gained from changing the production process offers opportunities for a source-directed approach.

All case study interviews showed that the idea of source-directed strategies for solving safety problems is not top of mind in the people interviewed. Motives for improving chain management are cost-effectiveness and efficiency of the production process. Safety is not the driving force in chain management but seems to be an unplanned result of these actions. Crossing the company borders for improving safety is still unusual. The handling of risks between chain actors is often managed through 'turnkey' projects, warranty arrangements and contracts dealing with liability.

All in all there seem to be more impeding than stimulating factors for (cross-company) source-directed strategies. In sum, then, the main drivers for companies in safety management are legislation, the drive of the management and societal pressure. Another factor that may stimulate source-directed tackling of safety problems in a production chain is that one party does or wants to control part of or even the whole production chain. The opposite, then, i.e. the complexity of the production chain, may be considered one of the main impediments for tackling occupational hazards at source: along the chain, parties are confronted with the side-effects of decisions earlier in the chain (notably when the independent actors in a production chain do not communicate with one another), and costs and benefits of source-directed action are unevenly distributed among the chain whereas budgeting is carried out for each step in the production chain separately. The most important impeding factors, however, are commercial considerations (like return on investments for new facilities) as much as the underlying perceptions of the risks: as long as a company complies it has no urge to innovate. Also, radical changes in the production process may lead to a sense of uncertainty or a feeling that the risks of these changes are too high.

An important factor in the application of source-directed strategies appears the degrees of freedom one has, or the perceived degrees of freedom. This is closely related to notions about the possibility of influencing other actors in the production chain. Builders, for example, have the idea that they cannot influence architects and the initial design of a building.

One of the main explanations drawn from the research, notably from the Seveso-cases, is that source-directed strategies were not possible because of the high investments involved in changing the production facilities and the complexity of interweaving new solutions in existing high tech facilities. Also, there is the underlying perception of the risks: as long as a company complies it has no urge to innovate.

Still, this applies only to existing situations. It does not explain why source-directed strategies are not employed in the design of new work processes or wholly prospective workplaces. We studied the possibilities of source-directed strategy in the case where a chemical plant was rebuilt after a major explosion. Although the budget for making changes was available, it appeared that time-pressure as well as the fear of unknown risks of thoroughly changing the production process (both with the company management and the relevant authorities), prevented a successful source-directed strategy of safety risks. In the case of the start-up of new facilities on the site of a large steel producer, it appeared that only in certain selected cases there was enough time for incorporating safety issues explicitly in the design and start-up phase. In most cases, turn-key delivery of production facilities prevented the active participation of the steel producer in tackling safety issues of these facilities during the design process. In the building industry, the large number of independent actors in the chain prevents the successful application of source-directed strategies over the company border. There were, however, some examples of successful source-directed strategies by trying to control greater parts or even the whole production chain.

In Dutch occupational practice, it is both statutory and generally accepted that companies carry out a risk assessment and evaluation leading to an action plan to alleviate the most urgent occupational safety and health problems. It is also prescribed that a source-directed strategy for tackling occupational risks is preferred. Still, in practice, this source-directed strategy is seldom pursued. Only as concerns the handling of dangerous substances in the workplace source-directed strategies are more common - even if the use of personal protective equipment is

still very common. In the literature scan and in the case studies we identified three ways of combating risks at source:

1. the substitution or elimination of the use of hazardous chemicals;
2. inherent safer processes in the chemical/process industry;
3. the control of the whole production chain by one party.

Models and methods for substituting hazardous chemicals have been described by several authors/sources: among others, COSHH Essentials of the British Health and Safety Executive[2], a Dutch model for substitution[3] (Van Niftrik et al., 2005), the Toxic Use Reduction Institute[4], a Danish database with examples of substitution projects[5] , German tool from the Bundesanstalt für Arbeitzschutz und Arbeidsmedizin[6].

In the process industry, approaches for source-directed strategies may be directed at the design of new production facilities: inherent safety in the chemical process industry, including methods like process intensification and human factors design (Hendershot, 2002). There is a large amount of literature on these specific topics. Still, most of it is directed at technological solutions for safer installations, although human factors design is an emerging way of thinking in designing installations that are safer to maintain and operate.

Substitution of hazardous substances and inherent safe process facilities are two specific examples of source-directed strategies that apply to specific types of organisations. It is difficult to transfer the knowledge in this field to other, more general forms of workplace safety, whereas for general work place safety we were hardly able to find really new approaches of source-directed strategies.

In the project-oriented building industry there are, at least theoretically, more opportunities for source-directed strategy. Here, the many independent actors within the complex network that makes up the production chain hinder the implementation of prevention at source that crosses company borders. New developments in building techniques seem to offer opportunities for better supervision of the whole or part of the production chain. These developments are, however, still in their infancy. The number of companies practising source-directed strategies is clearly limited.

More generally, the notion of chain dependency is crucial to a source-directed strategy. Many risks originate from decisions or processes earlier in the production chain, and cannot easily be handled within the company. A successful source-directed strategy would therefore often imply involving other companies in the production chain for tackling safety problems. The NedTrain pilot study clearly illustrates the limiting effect of one's position in the production chain.

It may be surmised, though, that in most of the sparse cases of source-directed approaches, these are in greater part confined to the situation within a company. At least this was so in the five Seveso cases. In none of these did we find evidence of an intentionally started source-directed strategy crossing the company's borders. Also, it was clear that the source-directed approach was not at the top of management's mind.

This leads to a general conclusion concerning the possibility of tackling hazards at source. A thorough, source-directed strategy to occupational safety more often than not requires a more *discursive* approach to risk management. First, fighting risks at source entails that parties that experience risks determine the *source* of the hazard and if this source lies outside the direct sphere of influence, communication should be established with the links upstream in the chain of production. Even if it is clear that this would entail a rather complex interactive implementation process, it was found in the NedTrain pilot that (at least within the own company) such processes may indeed be established. The participants in the pilot were quite positive about the method used as well as the results. The participative and bottom-up approach, combined with a 'mind map' of source orientated measures worked well. And even if the possibility of tackling risks at source was to a large extent limited by NedTrain's position in the production chain (notably vis à vis AnsaldoBreda), the discussions did set off a change in safety culture. Our intervention with the design of a new facility for the maintenance of high speed trains showed that an interactive approach, involving the personnel of the company, can result in safer work places.

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[2] www.coshh-essentials.org.uk
[3] www.stoffenmanager.nl (Dutch)
[4] www.turi.org
[5] www.catsub.dk (Danish)
[6] www.baua.de

Upgrading this discursive approach to a higher level, i.e. the production chain, is undoubtedly more complex than within the confines of one own company. It may, however, help to boost safety awareness upstream and more conscious forms of production design.

A, seemingly obvious, but important notion is that source-directed strategies that focus on design processes can only be successful in restricted periods of time. If a source-directed approach is to be successful, management and other actors should be aware of this restriction and seize the chances for improving safety at the right moment.

The findings from this study imply a broadening of the concept of source-directed strategies, from intervention within a organisation to the involvement of all relevant stake holders through a more discursive approach and in many cases the involvement of other partners in the production chain. This applies to the normal daily production chain as well as to the chain of actors responsible for the design of products and processes.

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