Co-operative Nordic Research

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CO-OPERATIVE NORDIC RESEARCH
Nordic Industial Fund Project P98087

LUCRAM

Lund University Centre of Risk Analysis and Management

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Nordic Industrial Fund, project P98087
"Co-operative Nordic Risk Research"

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Project report
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Abstract:
This report has a two-fold objective.

- To identify the changing risk management needs in the private and public sectors and the corresponding needs for development of risk analysis methods and related practices.
- To list examples of projects where Nordic co-operation between industry, authorities and universities can be effective for increasing the contribution of risk management to industrial growth and a sustainable society.

A Nordic expert group, funded by the Nordic Industrial Fund, identified the urgent need for co-operative Nordic risk management research and suggested a structure for co-operation and cross-disciplinary research and for dissemination of knowledge and implementation. The group also specified research areas and project ideas for future development into actual research projects. A workshop with participants from the Nordic countries was one source of ideas.

The expert group in addition identified a number of basic resource areas necessary for the development of more efficient risk management industry and which would benefit from Nordic co-operation.

A Nordic risk management academy and a Nordic risk management network should be formed. Also a Nordic graduate school on safety and risk management for PhD-students should be organized on a Nordic basis in order to ensure competence at all Institutes of Technology, all Business Schools and other education bodies of importance for risk management.

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Summary

CO-OPERATIVE NORDIC RISK RESEARCH
Nordic Industrial Fund Project P98087

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A Nordic expert group, funded by the Nordic Industrial Fund, has identified the urgent need for co-operative Nordic risk management research and suggested a structure for co-operation and cross-disciplinary research and for dissemination of knowledge and implementation. The group has also suggested some research areas and project ideas to further develop and co-operate on. A workshop with participants from the Nordic countries was one source of ideas. (No representatives from Iceland took part in this project, but Icelandic participation in suggested activities is very much welcomed.)

Risk analysis and risk management are growing more important. Reasons are the rapid changes in society and social life, economic forces, technology development, and new types of production systems and organisational structures. Information technology ties units together in large complex systems with short time constants giving little or no time for corrections of mistakes or for counteracting effects due to unforeseen circumstances. Limits between responsible bodies are often vague. This is often the case in company subsystems all the way up to the global scale. Concentrations of people, of dangerous chemicals, of energy, of information and of other values are increasing which may considerably increase effects of

accidents. There are strong forces driving the humanity and nature as well as organisations and individuals towards a world of "produced uncertainty and organised irresponsibility". Counter-forces have to be found and used as soon as possible.

Large accidents get much publicity and wake up different responsible actors, but we learn too little and soon we are asleep again. This is very worrying because of the increased potential for disasters with ever increasing consequences due the rapid changes mentioned above.

Minor accidents are much more frequent. They are of major importance for environment, for health and wellbeing, and for competitiveness. For organisations there are not only possibilities to decrease negative effects, but there are also opportunities to get competitive advantages by cost-effective risk management. However risk management is not effectively used today. Existing methods and knowledge are not in common use. Also existing methods and knowledge have to be improved. In a climate of increasing international competition the Nordic countries can not afford not to fully exploit the possibilities with risk management well integrated into companies from top management to all employees.

Traditional risk research focus at reasons why accidents happen and at methods to quantify risks. This kind of research needs to be strengthened but it is also of outmost importance to integrate this research with research on how to decrease risks - preferentially already in the design phase, and on how to get risk management as a part of corporate management as well as of all other activities in organisations. Here co-operation with research areas focusing at topics such as TQM, continuous improvements, leadership/management, organisational design, empowerment, participation and human factors is important.

To disseminate adequate knowledge in risk management and awareness of risks and possibilities it is important to have adequate curricula for students at Institutes of technology and at Business schools.

There are islands of very good competence in the risk area in the Nordic countries but the total amount of risk research in the Nordic countries is too little. Furthermore, most of the islands are too small for integration between different disciplines in a way as pointed out above.

To be cost effective co-operation is necessary. For many reasons (culture, history, size, ..) the Nordic countries constitute a good base for such a co-operation. However European and global co-operations should also be strengthened.

Cross-disciplinary centres are suggested for efficient integration between disciplines and between academia and practice. For dissemination of knowledge and for diversity it is essential to have several centres in the Nordic countries.

However each of the centres can not cover the whole spectrum of important and necessary disciplines, thus a close co-operation between them is essential.

Some suggested important research areas which are necessary to carry out for a broader use of efficient risk management, require co-operation and are suitable for Nordic common efforts. A Nordic risk management academy and a Nordic risk management network should be formed. Also a Nordic graduate school on safety and risk management for PhD-students should be driven on a Nordic basis in order to ensure competence at all Institutes of Technology, all Business Schools and other education bodies of importance for risk management. The Nordic graduate school on safety and risk management should also supply

experts in risk management to organisations/companies in both the private and the public sector.

Urgent research areas or research projects suitable for co-operative Nordic research have been identified and discussed in the expert group and in the Workshop. Ten of them are presented below. The projects have to be further developed by interested parties to fit their expertise and considering other research going on in our dynamic world. The expert group urge interested researchers/research groups to contact the project leader or any other member of the expert group (for addresses, see above) for further information.

The projects are:

1. *Organisational aspects of corporate safety management*
   There is a growing concern about the key roles of organisational aspects to safety. Co-operative research is needed to learn about safe organisations - how do they look like and how to develop such organisations?

2. *Efficient risk management based on the Balanced Score Card concept*
   Balanced Score Card is a management tool which could show for all involved the vision in a company broken down to measurable factors. By including 'safety' as a perspective an efficient risk management policy could be implemented including participation and empowerment of all employee involved. To develop these ideas and to show their strengths a co-ordinated project is needed in which networks of companies or other organisations take part.

3. *Risk Management under pressure from rapid organisational and technological changes*
   During rapid changes such as downsizing, safety aspects are often ignored. A very important task is to find routines to keep safety during such circumstances. Thus suitable methods to analyse, manage and improve safety are needed.

4. V*ulnerability related to infrastructure and information technology*
   Infrastructure systems as telecommunication, electrical power systems, transportation etc, have due to advancement in information technology become increasingly automated and interlinked. New sources of vulnerability have emerged due to e.g. equipment failures, human error and situational factors. The proposal is to organise a Nordic project where alternative vulnerability assessment methods are analysed, compared and, maybe in a longer perspective, developed.

5. *Development of tools to support decision-making in risk management*
   Problems in risk management could be categorised as information flow, decision process, participation and method problems. There is a need for Nordic co-operation to develop tools supporting decision-making considering these problem areas. The project includes studies to further enlighten the problem areas listed above.

6. *Quality standards for quantitative risk analysis (QRA)*
   Governmental rules and the need for companies to identify cost-effective means to prevent accidents will increase the use of QRA (quantitative risk analysis). A suitable Nordic co-operative project is to produce background material exemplifying and specifying how the requirements in the IEC standard could be met in practical risk analysis cases.

7. *Tools for HSE-management of small and medium-sized enterprises (SME*
   Risk management in small and medium sized companies needs special concern. Major and very interesting projects have been undertaken in Norway and Finland. And in e.g. Sweden special centres have focussed on change processes within organisations. A pilot study is suggested to find out what could be learnt from the different approaches and how they complement each other. The pilot study could be a base for continued project aiming at developing methodology for efficient risk management in SMEs with a great potential for a widespread use.

8. *A Nordic Graduate School on Safety and Risk Management*
   The need for knowledge on Safety and Risk Management will increase due to development of technology and organisations. Knowledge in this are is thought to be an important factor for competitiveness. To develop and disseminate knowledge in this area a Nordic graduate school would be very efficient, also because it would be a generator for Nordic co-operation and co-operation between academia and industry.

9. *A Nordic Risk Management Academy (NORIMA)*
   It was felt that a Nordic risk management academy is very urgent and important. Safety is such an important issue for the society and the area is so complex involving aspects from so many disciplines. Available experts in the Nordic countries have to be shared amongst them. Therefore a Nordic Academy should be formed promptly.

10. *A Nordic Risk Management Network*
    The Academy should be complemented with a risk management network with the task to promote the development and use of risk management in both the private and the public sector for a sustainable society and environment, for competitiveness and life quality.

1. Introduction, background

1.1 The project

In June 1998 the Lund University Centre for Risk Analysis and Risk Management (LUCRAM) was given a pilot project "Co-operative Nordic risk research" by the Nordic Industrial Fund. The aim of the project was to outline and specify future co-operative Nordic risk research. The recommendation in the final report was to include suitable risk research projects for such a co-operation, co-operative partners and practical forms, structures and procedures for such a co-operation. Action plans, budgets and financial plans were to be provided. The projects were to be selected with the final objective of maximising the contribution of risk management to industrial growth and a sustainable society.

1.2 Project work plan

An expert group with specialists from the Nordic countries was established. Participating from Denmark was Kurt Petersen, from Finland Yngve Malmén, from Norway Jan Hovden and from Sweden Lars Harms-Ringdahl and Sven Erik Magnusson and Roland Akselsson. Project secretary was Peter Göransson. The work process of the project has been divided into the following parts

- a survey of national Nordic developments and trends regarding new regulation with impact on risk management
- a survey of Nordic risk management research
- discussion with representatives from industry and regulatory bodies
- identification of those research areas and projects where a Nordic co-operation would seem to be optimally beneficial
- production of a preliminary report
- open discussion of and debate on the preliminary report at a Nordic seminar
- production of a final report

1.3 Prioritisation of research area

After some initial discussion, the expert group decided to concentrate its effort to the area of risk analysis of technological systems and the need for the development and improvement of current risk analysis methods and practice. Special emphasis was to be put on the use of risk analysis in practical decision-making. A tentative title of the project is "Technological systems, risk analysis and decision-making in the 21st century" (alternative "The increasing role of risk analysis of technological systems in decision-making").

The sheer volume and diversity of the risk research area necessitates a limitation and a restriction of subjects to be discussed in the project. The expert group choose to concentrate its efforts to areas where it was felt that the group expertise could be most usefully employed; areas that at the same time are at the centre for the current risk research debate and development.

The decision to concentrate on environment and safety issues linked to industrial activities and risks generated by technological systems implies that specific aspects of major risk areas such as food risks, social risks, consumer product risks are excluded as well as risks due to natural hazards.

The objectives of this report are at least two-fold

- To identify the changing risk management needs in the private and public sectors and the corresponding needs for development of risk analysis methods and related practices.
- To list examples of projects where Nordic co-operation between industry, authorities and universities can be effective for increasing the contribution of risk management to industrial growth and a sustainable society.

In addition a draft version of this report was used

- To serve as a basis for a Nordic workshop, April 15-16, 1999, where issues were debated and a list of urgent projects was produced.

1.4 The problem context: the main stakeholders in risk control and safety management

What is at stake is a balanced and effective control of risks to people's lives and health, economic assets and the environment, and to the social and political stability. The stakeholders can be defined in relation to risk arena, activity and industrial domain, type of risk and the way society is divided into sectors for administrative and control purposes.

Main stakeholders are enterprises and authorities from strategic and policy making levels to control and execution management levels, including their internal and external (consultants) experts. The challenges for effective safety management and practises differ enormously between companies. Two main dimensions are the companies' size (number of employees) and the hazards and risk potential involved in the activity, i.e. general design criteria for safety management systems based on the contingencies of the organisation and the hazards and parties involved in the activity.

The context for safety management in companies is not just regulations and control by government, but insurance and certification institutions, inter-organisational networks, including industrial branch organisations. This institutional context is encompassed in the political and public spheres, and includes pressure groups and parties affected by the risk and/or the risk handling, plus mass media.

The political and scientific implications of the fragmented picture of risk handling by society and industry given above are enormous. We do not know any country with an overall co-ordination and prioritisation of safety. The result is sub-optimisation of resources and an uneven distribution of risk between individuals, groups and sectors. The industry has to relate to a huge and inconsistent number of laws and regulations of risk problems which may hinder an effective and holistic approach to safety management by the industry, and/or serve as an excuse for being ignorant and lacking motivation for safety improvements. Accident risks seem to need disasters to get a focus on the political agenda that may result in overreactions and a bad overall prioritisation. *There is a need for major changes in the political role and institutional patterns of societal risk management.*

The risk science and research community in many ways reflects the disorganisation of societal safety management. It is decomposed in specialised disciplines and sectors with little knowledge transfer and collective learning. For safety science and risk research, the consequence is that each of the levels involved in risk management is studied by a different discipline (engineering, psychology and human-machine interaction, management and industrial engineering, organisational sociology, economics, and law). As most researchers have little or no competence with respect to the functionality of particular work systems, safety research will have a 'horizontal' orientation across work systems and hazard sources.

From this it follows, that a predictive model of accident causation cannot be created by aggregating models developed separately by different academic disciplines. The integration is on the premises of the disciplines, i.e. multi-disciplinary and not cross-disciplinary as it is not driven by a united problem-definition and understanding of the primary hazardous processes. Therefore, the mainstream approaches to risk research will not be able to solve the problem of proactive risk management in a dynamic society. However, the "risk society" we are facing on the turn to a new millennium has stimulated some creative debates in traditional academic arenas, especially among philosophers, sociologists and anthropologists, which are promising for new lines of thinking and paradigm shifts in academic risk research.[1]

On this background it is a need to emphasis a more cross-disciplinary, problem oriented and integrated risk research programme. *This Nordic initiative may play an important role in the development of such alternative paradigms for risk research.* Most risk research units are small and mainly occupied with earning money on short term applied science and consultant tasks. They need to join efforts and share experiences and ideas in an innovation friendly setting.

2. A perspective on co-operative Nordic Risk research

There is a long tradition of research co-operation within the field of risk analysis in the Nordic countries. Appendix B gives an account of some of the experiences and examples on projects. There has been co-operation in projects focusing on limited aims and application issues. There are also a number of projects or programmes, which have had a rather broad scope.

A number of common Nordic activities and projects have addressed particular issues. For example, one project was related to safety reports required in the Directive on major-accident hazards ("Seveso directive"). The project was sponsored by the Nordic Council of Ministers, and it involved researchers and representatives from industry and authorities from four Nordic countries. The report (Malmén et al, 1992) sums up experiences, and it gives good advice for the preparation of safety reports.

SCRATCH

A co-operative programme called SCRATCH (1984), attempted to collect and analyse experiences from projects within a broad spectrum of applications. SCRATCH stands for Scandinavian Risk Analysis Technology Co-operation. The programme was run over the period 1979 to 1982. One aim was to establish a good praxis for the procedures for risk analysis of industrial systems. Other goals were to sum up experiences of different analysis methods and of the use of information and databases to be used in an analysis. The approach was to associate national projects in the area of risk analysis, and 35 projects from Denmark, Finland, Norway and Sweden were connected.

In the programme, guidelines were developed concerning terminology, data, methods, and planning of a risk analysis. The results have been of large importance in the views on risk analysis in the Nordic, and e.g. the Danish and Norwegian standards for risk analysis have utilised the experiences.

Survey of safety management research

In a recent study, an overview of Nordic research in industrial safety management and adjacent areas has been made (Harms-Ringdahl et al, 1997). The project was a co-operation

[1] This paragraph is based on Rasmussen (1998).

between research organisations in five Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. The emphasis was on "integrated safety management", which, for instance, means that the same approaches are used to control accident hazards, health and environmental risks, and quality problems.

Experiences and conclusions from research in the Nordic countries during the past decade were asked for. The enquiry has given 108 descriptions of research topics from 47 organisations. Although, the material is incomplete it gives a fairly good map of on-going research. This material has been analysed and summarised from different perspectives and has also served as a basis for this report.

Conclusions concerned some areas with an apparent need for more research. They were based on the fact that little or no research was reported and that the area could be regarded as essential. Some areas included are:

- general evaluation of safety management approaches,
- evaluation of different approaches based on real results, e.g. accidents, environmental damage, costs and benefits,
- evaluation of environment management schemes,
- studies and evaluation of integrated approaches,
- studies on certain parts of safety management

The results of the study pointed at a need to utilise research results in a much more efficient and systematic manner. It was recommended that the research councils and other organisations initiate and maintain activities to identify, evaluate, and support the utilisation of research results. The responsibility for this should not be thrown upon the individual researchers. It is a societal responsibility. One proposed activity was to set up Nordic ad hoc committees for reviewing certain areas within the field of integrated safety management.

3. Trends affecting risk analysis work

During the last three decades the risk analysis approach has been applied in a number of areas. The first applications were within the military and nuclear areas. The "Rasmussen Report" on assessment of risk of a nuclear installation was a major step forward in presenting a comprehensive and systematic safety analysis by the use of a probabilistic approach. This has been further developed since and its use broadened to other areas like aviation, telecommunication, control engineering and space technology. The focus of the analysis was on identification of failure causes and relationship between failure of single components and overall system performance. The scientific background was reliability theory and advanced statistical methods for treatment of failure data, dependencies and uncertainties.

In other areas like the process and the chemical industry parts of this technique was used and supplemented by a much bigger effort on the description of system performance under unwanted system conditions and possibly consequences to the public and the environment. These risk analysis methods were either semi-quantitative or quantitative. The emphasis was on the substances and impact of any deviation in the process conditions. The scientific bases was chemistry and physics to describe the performance of the substances under various conditions and in particular chemistry, physics and toxicology to describe types of events, fires, explosions and releases, and the effects of exposure to people and the environment.

In the last 15 years the consequences to the environment have been of increasing concern; in particular through the implementation of the Environmental Impact Assessment.

Further, the principles or the ideas have been used in a number of areas without explicitly referring to the methodology.

In recent years this approach has been used in quite different areas as construction - to describe uncertainty in completing a major construction within a given budget and time schedule, economy - to describe the risk of a deficit by a given investment, and food industry - to describe the uncertainty in using new food products and their possible health effects.

The process outlined above may be characterised in terms describing the general development of scientific and technological ideas. In general, a mechanism seems to exist, where single ideas – subject to social selection – first become more generally accepted, then form the general opinion, and finally form norms, which control society as unwritten laws. Supporting structures prepare motives for bringing the idea to practice. Legislation cause mandatory motives, a changed customer behaviour gives rise to market based motives, social pressure to societal motives, and efficiency and quality thinking to operational voluntary motives. Although not all ideas develop in the same direction and at the same pace all over our society and in all industrial sectors, some trends that affect risk analysis work can be noted.

Systematic risk analyses were originally developed to serve internal purposes of high-risk companies representing, for instance, nuclear and aviation industries. These methods later became tools for studying safety, health or environmental risks of different kinds of hazardous installations. Process industry has been a predecessor in the application of risk analysis among the conventional industry. An increasing number of process industry companies have found risk analysis and risk management a necessary tool to increase effectiveness and competitiveness. Transportation of dangerous goods has been another area where risk analysis quite often has been applied. The aim has typically been to consider the risks of alternative transport means and routes.

Recently the use of risk analyses of hazardous installations has quite widely become mandatory in the industrialised world.

In addition, machine constructors and producers of consumer products are clearly becoming more and more interested in using risk analysis in the development and design of new products. Here too, EU directives are requiring risk assessments to be carried out.

During the last two decades, many new risk analysis methods have been developed in order to meet their ever increasing use in decision making, and to meet the challenges of the changes in the business world and in society in general. With these methods, the safety, health and environmental risks of everything from the smallest components and computer software to large industrial complexes and natural catastrophes can be studied systematically. An increasing emphasis is put on integrating human errors, organisational and cultural problems into the risk analysis procedure.

In the following, a brief summary of trends affecting the need for risk analyses will be presented. Firstly, the use within only one plant or department will be considered. The viewpoint will then be gradually broadened, and finally trends on an international level will be discussed. After this the viewpoint is changed, and the trends in different industrial sectors are described separately. The effects of these trends on the development and use of risk analysis are also briefly described.

3.1 Trends influencing the use of risk analysis within a work team

In the nuclear, process and aviation industries, qualitative, semi-quantitative and/or quantitative risk analysis methods have been used for years to serve the needs of the engineers. Methods like HazOp have been used by thousands of companies all over the world. The emphasis has been on identifying those problems in the design of the installation or in the operational procedures that may cause accidents. This must be done in order to be able to take the steps needed to remove or reduce the risk.

3.1.1 Shorter time to market

Hazard studies in process development and in the early stages of equipment or plant design have usually been based on relatively simple procedures, such as the use of different kinds of checklists. In large projects conceptual risk analysis methods have been used to limit the workload. Only in the late stages of design – and often only for the most hazardous parts of the design – have the more resource intensive methods, such as HazOp or Fault-trees, been considered.

The general trend in industry has been that the time from idea to market has been reduced considerably. If a risk is now identified at the later stages of design, very little can be done to solve the underlying causes of the problem without dramatic changes to the whole schedule of the project. This means that add-on safety equipment must be used to reach the desired risk level.

In practise, the use of risk analyses in parallel with early development and design work means that more and *more analyses are carried out without the involvement of safety professionals.*

3.1.2 Inherently safer processes and designs

In the process industry, there is also a trend towards inherently safer and environmentally friendlier solutions. The advantage of these is, that expensive end-of-pipe or add-on equipment are not needed to the same extent as before. "What you don't have can't leak" (Prof. Trevor Kletz). In order to achieve these targets, there is, however, an increasing need to address safety and environmental issues systematically at a much earlier stage of process and product development and of the design of equipment and plants than what has been the custom in the past. Some risk analysis methods have already been developed expressly to address these early needs. Again, these methods should give useful results without the involvement of safety experts.

3.1.3 Concurrent design and teamwork

The need for rapid progress has led, for instance, to concurrent design and team-work. This in turn means that safety related information must be documented and distributed without delay amongst all those involved in the different parts of the project. Tools for documenting range from standardised forms to computerised risk analysis documentation systems. The growing use of internal computer networks gives increasing opportunities to meet these new demands within the project or the plant. This trend also means that more non-experts in safety are involved in assessing the risks. Therefore, *risk analysis training must be given to a larger amount of engineers and chemists* than used to be the case when risk analysis experts were available for all risk studies.

3.1.4 Decision making

Internal decision making is more than before based on systematic risk analyses. This means that the quality of these analyses must be sufficient for the intended purpose. For instance, if unsuitable methods have been used or if the knowledge has been insufficient or false, the result of the risk analyses will probably be incomplete. As a consequence, the decisions made may be wrong, leading to an undesired outcome.

3.2 Trends influencing the use of risk analysis within companies

Originally risk analysis methods were used mainly to serve the engineers involved in the project in questions. Today risk analysis results are used within the company, for instance, when planning operational, maintenance, and emergency procedures.

3.2.1 Economical considerations

Many decisions taken in companies today are based on economical grounds. Risks are very difficult to express in economical terms. High consequence events having a low probability are more often than not neglected in the decision making process due to this. Other aspects than safety influencing decisions taken during process or product development are putting increasing demands on the development process. These are, for instance, the decrease of daily emissions, increasing automation, and the strive for higher throughput.
The financial aspects are also increasing in importance as there seems to be a trend towards an increasing distance between the (often international) owners of the company and the employees. This makes the risk communication between the owners and the workers more difficult than before, when the owner was present at the workplace. It also makes it easier for the "faceless" owners to take difficult managerial decisions that affect the workforce and the safety culture at the plant but are financially sound.

3.2.2 Closed processes

The demand to decrease daily emissions has in some cases led to closed systems. This in turn might mean more concentrated streams in the plant, putting new requirements on the materials used and the ways leaks are controlled. Otherwise the more concentrated solution – often at a higher pressure than before – may cause a more serious accident than before closing the process. Processes previously considered harmless must now be analysed.

3.2.3 Automation

Installed automation means that the production process can be better controlled, which allows the company to operate closer to the safety limits than before, when manual control was used. A failure in the automation system may under these circumstances instantly lead to an accident – well before anything can be done to prevent it from happening. Consequently, the risk for failure of the automation system must be assessed carefully and the consequences of such a failure must be assessed.

3.2.4 Higher throughput

The strive for higher throughput might mean bigger and faster machines with faster movements or processes with higher temperatures and pressures and more reactive substances. These are all aspects that increase the potential for serious accidents and the need for detailed risk analyses to be carried out.

3.2.5 Trade-offs

In all cases mentioned above, trade-offs between the different benefits and disadvantages must be made. Risk analyses form one tool assisting the decision makers in their task to chose the best option from the candidate processes, products, designs, procedures, components, etc.

3.2.6 Extended studies

In many companies economical reasons have also led to the reduction of the amount of staff to a minimum. The move towards lean organisations has been a typical trend. One can assume that this process has reached its peak in many sectors. It is, however, believed that the need for experts from outside the company to carry out different kind of safety studies will remain. In addition, the needs of the companies will extend from risk analyses of technical systems towards risk studies related to man-machine interface, human factors, organisational and cultural questions, and computer software and hardware problems.

3.2.7 Lean organisations and team work

Lean organisations have in some cases got rid of supervisors and managers, leaving, amongst others, the safety issues to teams. A change to a lean organisation may increase the risks – and the need for risk analysis – if nobody is especially nominated to address safety. Team work can, however, also reduce the risks, provided that all collectively take care of safety, and not only the manager, which is often the case in more traditional organisations.

3.3 Trends increasing the need to transfer risk analysis results between companies

3.3.1 Core business and networking

A clear trend towards specialised companies can be identified: companies have concentrated on their core business buying all other activities they need from outside the company. For instance, a piece of equipment for power generation is bought only if the provider of the equipment takes care of the operation and/or maintenance of the unit. This hardware company may not have the experience needed and gives the operation to one subcontractor and the maintenance to another, and so on. Quality assurance systems have been developed in order to cope with the problems of the ever growing delivery chains. Safety information is not always included in this system unless the quality of the project is affected. Recently safety and environmental management systems have appeared on the scene, but still a lot of work in this field remains. Systematic risk analysis methods should play an important role in securing the transfer of information between the companies involved.

Another example of an increased need for dissemination of risk analysis results between companies, is the recent trend that an increasing amount of independent companies are operating on the same industrial site. This is result of the original company selling parts of its earlier businesses to other companies. An increased need exists to inform not only the own staff, but also the persons from the maintenance company carrying out the maintenance at the plant, the truck drivers from the transport firms now in charge of transporting raw-materials, products and wastes, and the persons employed by the catering company but working at the plant canteen, and also those working in the installation next door about the risks caused by your own activities. The external people are not receiving this information as might have been the case earlier when all worked for the same company. Now, a more active dissemination of the risks and what should be done in order to prepare for an accident is needed than before.

3.3.2 Consultant companies

Consultant companies will find that an increasing amount of data is needed to carry out risk analyses that fulfil the requirements of their future customers. This information lies to a great extent within the companies, that have to share the information between themselves and with the consultants and research organisations. A trend towards a better collection and dissemination of data has been visible lately. Developments of, for instance, computer technology, sensors, and mathematical models, have made this process easier than before. Luckily enough, safety is traditionally seen as a field where shared information has its benefits: an accident in one company normally affects the operations of the competitors as well, for instance, through more stringent legislation or the customers choice to buy safer products or products produced using safer processes.

3.3.3 Global markets

The trend towards global markets also puts new demands on risk analyses. A design that works perfectly well in, say, Central Europe, may be dangerous when the technology is used in the colder climate in the North or in tropical regions. Also the cultural differences between different parts of the world broaden the scope and the need for a risk analysis to be complete. A plant that is safely run and maintained according to European practises may fail in countries or companies where, for instance, preventive maintenance is scarce or the economic resources to buy new spare parts are limited. These things should be taken into account during the design stage of a product or process meant for the global market.

3.4 The use of risk analysis in the local community

Nowadays risk analysis is used not only within companies, but in many parts of the local community.

3.4.1 Emergency planning

Part of the risk analyses needed by the local community must be obtained from the companies, but some studies must be carried out by the community itself. For example, there might be a risk that the drinking water supply will be polluted. Possible reasons for this must be identified, the tolerability of the risk must be established and, whenever needed, steps should be taken to remove or reduce the risk.

In some cases there is a need to combine information from both the private and the public sector. External emergency plans are a well known example of this: information about the risks from a chemical plant has to come from the company operating it, but information about risks connected with traffic, housing, and natural phenomenon must be accessed from public sources.

Information based on safety studies and emergency plans is used more often than before by the local authorities when they make their decisions or they are informing the local community about the existing risks. The trend towards an increasing need in the local community for risk studies will probably continue.

3.4.2 Environmental impact assessments

The obligation to carry out environmental impact assessments is a new requirement for both private and public developments, that might have a major impact on the environment. A risk analysis should be part of any such assessment. And not only for nuclear power plants and oil

rigs, for which the need is obvious, but in many other cases, as well. However, the risk of accidental releases is still neglected in many environmental impact studies.

3.4.3 Land use planning

Risk analyses are increasingly used in land use planning in order to minimise the undesirable effects of accidents in hazardous installations.

An emerging and important aspect of risk based land use planning concerns the aspect of integrated risk assessment and management. IAEA (1994), outlines the philosophy behind integrated risk assessment and management of large industrial areas. Integrated risk assessment is based on the notion that all health and environmental risks within an area should be systematically identified, analysed, and assessed in such a way that rational choices can be made about which risks should be reduced, weighing the social and economic costs of such risks, and the costs of risk reduction. Similarly, integrated risk management is based on the notion that all options of risk management – location, preventive, mitigating, protective, and institutional – should be explored in such a way that the resources committed in the safety management process are utilised in the most effective way.

3.5 International, national and regional use of risk analysis

3.5.1 Legislative and related requirements

Regional, national and international legislation, standards and codes of practices are changing at an increasing pace. Whenever applicable, requirements to assess the risks are now usually included in one form or another in the most recent of these. Examples of this trend are recent changes to European machine and product directives. There is no reason to believe that this trend should change in the near future.

3.5.2 Internal control

Many risk analyses have been carried out by companies – or consultants hired by these – just because this has been required by law. Sometimes even the methods chosen and the scope of the study have been tailored to suite the requirements of the authorities, and not those of the company itself. The implementation of all requirements for risk assessments is now shifting towards self control. In other words, the management of the company is more than before responsible for the quality and implementation of the risk analysis results. The competent authorities have more the role of an advisor or auditor of the safety management system.

Different industrial sectors have introduced international or national programmes to promote safety, health and environmental issues. These programmes include the elements of risk analysis. The best known example is the Responsible Care programme of the chemical industry.

3.5.3 Life cycle assessments

The environmental impact of products during their entire lifetime is nowadays studied using Life Cycle Assessments (LCA). The trend towards better LCAs means that the influence accidents have on the total environmental impact should be included in future LCA-studies.

3.6 Trends affecting the use of risk analysis in different industrial sectors

3.6.1 Process industry

Process industries are becoming larger in terms of production volumes. In basic process industries the economy of scale is a key competition factor. This means high investments and high requirements on safety and dependability. Short disturbances result in larger economic losses and motivate to invest more in risk and dependability management. This has impacts on the use of risk (and dependability) analyses in plant design. In the same time the economy of risk analysis itself must be improved. Better information and results are expected with less manpower and costs.

This means a need to develop flexible risk analysis methods. They have to fulfil conflicting needs, such as high coverage in the identification of important hazards and their causes with accurate assessment of risks and dependability on one hand, and a need for a small amount of manpower and calendar time. New methods to describe production systems must be developed and taken into use providing a better basis for systematic hierarchical risk analysis. Some examples of this trend have already been published.

Another trend in process industry, at least in Europe, is the change towards high value special chemicals and more customer oriented production. This means more investments in the development of new chemicals and in new processes to produce these chemicals. Here, there is a need to study the risks systematically already in the laboratory when new chemicals and new processes are developed. Principles and means of inherently safer technologies will become important in these industries.

The customer oriented production will also require flexibility from the production system itself. It is also possible that the use of batch processes will become more common. These trends put higher requirements on process automation. New methods to extract safety requirements from the process system and to transform these into accurate specifications for automation design are needed. Here, risk analysis can be one important tool to determine the hazards and their causes and then convert this information into a useful form for automation specification use.

Lead times will become shorter in all industrial applications. This will also be the trend in plant design and construction. Here, new methods for process development and plant design are required. One trend will be embedding safety and dependability better in design. Some examples of this development have been reported. This may also result in a new design culture.

Another trend is concurrent engineering where several parts of the process plant are designed in parallel. This puts high requirements on the specification of the design tasks and good understanding of the plant objectives. One effect will also be the requirement for common design data bases where several designers can follow the progress of other design teams. Distributed data systems will be in use where design can take place at the same time in different towns, or even countries. Also the customer can better follow the progress with these distributed data systems.

This requires also more from the designers. They have to better document their design giving a better possibility to other design teams and the customer to follow and to understand their design. Risk analysis may be carried out with distributed data systems on the basis of design

documents. New software tools for carrying out risk analyses based on design documents are needed.

The profits in bulk type processes are decreasing. This will mean less green field investments in Europe and in USA. The investments are focused on bottle-necks at existing plants. Also ways of expanding the economic life time of ageing process plants will be developed. Here, maintenance and systematic engineering will be developed. Risk and dependability analyses together with a more systematic collection and use of operational and maintenance data will be important areas of development.

Process integration in order to reduce the use of energy and raw materials as well as to improve the yields will develop further. Process integration will result in more complex plants and new dependencies between different parts of a plant. When the installations become more complex the design is more difficult. Then, there also is a need for a systematic and more extensive risk analysis to cover all the process parts which may lead to disturbances or which may be influenced by disturbances in different parts of the process.

Management of process disturbances will improve. Today, process automation gives as much information as the user needs, sometimes even more making it difficult to find what pieces of information are the most important for the decision making. The findings of risk analyses, which has been carried out during plant design, may help in the investigation of plant disturbances. They can also form part of the information used for training the operators. These new ways to use risk analysis results will affect the documentation of risk analysis. The results and assumptions have to be documented better than before for later use. The risk analysis results also need to be in an electronic form in order to enable a link with process automation.

New emergency management systems will evolve. Geographical Information Systems (GIS) produce new challenges to collect and store data on process plants, chemicals, and people. When real-time meteorological data are integrated with this system together with gas release and dispersion models, the consequences of releases can be estimated on-line.

When all necessary measures have been taken in the development of new processes and design of new plants the management of the operating plant remains. Integration of safety and environmental factors in plant management systems will become more important. Safety will become a part of the management culture. In some phases of the development there may be a separate safety culture similar to quality culture. However, the ultimate goal will be the integration of safety, environment and quality into the overall management culture of a company at all organisational levels. This trend requires new thinking and new risk analysis tools and practices in different companies and for different company cultures.

Companies concentrate on their core businesses. This leads to a situation where several companies operate on the same industrial site. One is producing chemicals, one energy, one pulp and subcontractors take care of the maintenance. Here, more information exchange, definition of terms of co-operation, and joint management are needed. This means new challenges for the management of operations and safety at the site.

3.6.2 Transportation

In the marine traffic, the International Maritime Organisation (IMO) has developed new requirements which include a Formal Safety Assessment (FSA). This is required when changes in a passenger ship is planned. With FSA the designer or ship owner has to show the

cost effectiveness of the proposed change. This will clearly increase the use of risk analysis in shipyards and shipping companies.

Risk analysis may also be a tool to investigate the hazards of an operating ship and the operations of a shipping company. The aim can be the development of systematic safety management and integration of safety in different operations, such as purchase of new equipment, training of personnel, etc.

For shipping activities an international safety management code (the ISM code) has been developed as a basis for certification and auditing. It is now in an implementing phase, its principles are quite similar to the internal control concept and the management standards in ISO.

For railway transport, the UK legislation was the first to require the preparation of safety cases. This was a part of the privatisation program in the UK in the beginning of 1990's. Later some of these ideas have been in consideration also, for example, in Finland and Sweden. Here, new methods for a systematic investigation of hazards and the assessment of risks are under development.

Safety analysis principles have been used in the last 10 years in some Nordic countries as a tool in developing safety management systems for road safety. These systems include visions, strategies and actions plans, supplemented by the specification of quantitative targets for risk reduction or more specifically accident reduction.

Form the year 2000 an EU effort will be implemented in all member countries on improving the transport of dangerous goods. The initiative is to require involvement of a safety advisor at both the sender, the conveyer and the receiver of hazardous goods, thus requiring the appropriate safety measures have been taken.

3.6.3 Manufacturing industry

Risk analysis has been used only in a few cases in the design of new production lines and plants in the manufacturing industry. Automated production lines have been the first examples where systematic risk analyses have been carried out. The use of new modelling techniques, such as three dimensional plant models and virtual reality, have produced new opportunities to investigate the hazards during the design of new plants and production lines. The first applications have show the obvious advantages of these techniques and their wider use is most likely during the coming years. This will also mean development of new methods and tools to identify the hazards and their causes.

In the manufacturing industry, there is a trend of growing investment cost. This means an increasing interest to study risks and dependability factors during the design. Automated warehouses and production lines as well as investments in expensive machines are examples where this becomes important.

The attempts to unmanned production or partly manned production result in a need to study possibilities of production disturbances in a systematic manner. Risk and dependability analysis will be important tools in the considerations.

3.6.4 Machines and products

EU's machine directive has required the manufacturer to identify the hazards and assess the risks of a machine and to document these considerations as well as to warn the user about

remaining hazards. Checklists have been developed to assist the investigations. However, in complex situations risk analysis is needed.

Companies will develop guidelines for systematic safety management during product development and design. Existing risk analysis tools may be slightly modified and new tools would be developed especially to better consider the user interface and the activities of the user of a machine or a product. The results of the safety studies will be used to improve the product. However, one very important application of the results will be an improved product documentation and especially the development of user information.

There are the first examples where the manufacturer of a machine has been asked to give a dependability guarantee. When machines are used, for example, in construction there may be high penalties if the lead time of the construction site will be longer than what has been agreed in the contract. This development has raised the interest of machine users to ask guarantees for the dependability of the machine. Here, the manufacturers will be more interested in risk and dependability studies. Formal dependability management systems will be developed. The car industry has been a predecessor in this area (cf. Volvo).

In the EU, there have been discussions to extend the use of risk assessment to consumer products. In this area a similar development which already has taken place in machine design and manufacturing after the machine directive can be expected.

3.6.5 Automation

Some of the needs to study risks in the design of process automation was already described under process industry.

There is also a need for cost effective tools to study the dependability of the automation system itself. This can be a time consuming task today and quicker systematic methods would be welcomed.

The design of batch processes and their automation means new requirements for the description of the system due to the time dependencies. This results in new requirements on the methods to investigate the hazards and dependability. Some examples of this development have been reported.

The development and increasing use of programmable electronic systems, field buses, and software in general will require considerable emphasis to develop suitable methods for the systematic identification of hazards. Most likely new ways to describe the automation system and software need to be developed.

3.6.6 Telecommunication, Internet

Telecommunication has achieved high penetration in the Northern Europe and is increasingly taken into use also elsewhere in the world. The same development in the use of Internet has happened.

In telecommunication there are high requirements for security. The same will be the case in Internet in order to launch commercial applications where also economic transactions can be made. The structure of these technologies and the high use of software means a clear need to develop suitable methods to study the risks involved

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3.6.7 Biotechnology

This is a new, tightly controlled technology area. There are European directives which have been developed to guide the national legislation and practices. One part is risk assessment. Today, it is more based on numerous experiments and chemical analyses as well as stepwise approach when, for example, new GMO (genetically modified organisms) plants are developed. There is a clear need for systematic risk analysis tools to be employed during the different phases of the development of new GMOs. This would also give a more rational basis for the planning of experiments and chemical analyses.

4. Analysis of the problem

4.1 Applications of risk analysis

Risk analysis techniques have been used in a number of applications in a number of areas as described in chapter 3. The description of the use and the limitations of the technique is illustrated by the experience from the major industrial hazards area, since within this area several initiatives on the collection of lessons learned have been taken and the results hereof documented.

Risk analysis has been formally required by legislation and its preparation has been supported by documents specifying the requirements and guidelines and developed in a number of areas to ease the process. The purpose is either for the user (the industry) to harmonise the work requirements and avoid unnecessary effort, or for the authority representatives to establish minimum requirements and thereby enhance safety.

Guidelines on how to prepare a safety report, to establish a list of contents, guidelines for producing the chapters of a safety report or methods and procedures to be used describing the safety, were developed. In some areas the requirements were developed and specified at a national level, others at an EU level, and others again at an international level through international bodies or organisations as CEN, CENELEC and ILO (Drogaris, 1993; ILO, 1991; European Committee, 1996; Papadakis and Amendola, 1997; Cassini, 1998).

In the same period (1980-1990) international efforts were laid on improving the quality of products, processes and services. It started with the ISO standards with focus on improving the quality of products. One element in the procedure was to keep track of failed items, to identify failure causes and to suggest suitable countermeasures. A need to develop a system to operate the data collection, review, audit and improvements was an essential part. The activity has a lot of similarity with those of safety assessment; in particular, the reliability based methods. These standards and the management systems were further developed in quality assurance (QA) and total quality management (TQM) systems.

On the EU level the requirement of a safety report has been expressed explicitly within two important areas:

a) hazardous installations through the Seveso Directive (Papadakis and Amendola, 1997)
b) hazardous equipment through the Machinery Directive (European Committee, 1996)

The former was implemented in all EU member countries in 1980-90 and several studies have been carried out with the purpose to extract lessons learned.

4.2 Industry/user problems

Requirements and non-skilled users

The requirements on a safety report are usually written in rather general terms, like "Identify all possible deviations". One lesson was learned in all member countries and by the majority of the users: the uncertainty in how to meet the requirements and the fact that the users generally were non-skilled in safety assessment implied a need to ask for expert consultant services. Therefore, typically the safety reports were written by teams of experts from outside the company. The general observation was that they were of limited or no use, since

1) few persons from the company were involved; consequently, the discussion between employees on safety issues was limited
2) the size and complexity of the safety report made it extremely difficult to read for persons not involved in writing
3) the updating and review was very difficult or impossible; consequently, this task was rarely carried out, so rapidly the document became slightly incorrect or later on outdated.

The result seen was that although the safety reports did meet authority or industry requirements, their use were rather limited.

Large efforts

Another lesson was that the preparation of the safety report did require a large effort and also were very time consuming. This was partly a consequence of the nature of a safety analysis, which is systematic and aims at being complete. The complexity of updating when changes were decided or when new evidence was obtained, consequently was obvious.

Variability of safety reports

The EU through DGXI/Joint Research Centre of Ispra carried out a review of the safety reports submitted to the competent authorities in the member countries to partly fulfil the requirements of the Seveso Directive.

The results were that although the intention was to create a balanced competition in the EU by a uniform legislative framework, the variability was large, both in the contents, in the quality and detail and in the completeness. As an attempt to improve the situation the EU/DGXI has issued a new more detailed set of guidelines.

Benchmark

The EU through DGXII/Joint Research Centre of Ispra (Contini et al., 1991) also carried out an investigation of the state of development within the scientific and consultant community in the member countries. They organised a so-called Benchmark exercise, where teams from almost all member countries prepared a risk assessment for a given plant independently on the basis of a plant visit and given plant documentation.

The results showed a large difference in the assessment of the risk, but more importantly the descriptions were caused by use of data or models, that were not well-suited to fit the purpose. In some cases the data were even totally out of scale and the models were known from literature to be an incorrect model of the given phenomenon. Consequently, the degree of belief by the user in the results was rather low.

4.3 Authority problems

The lessons from the competent authorities showed similar problems and deficiencies.

Review

The competent authorities recognised two problems:

a) although they received a lot of information through the comprehensive documentation, it did not necessarily contain the information, they found essential
b) even when the necessary information was present, they had no operational guidelines or procedures on how to review the report.

Interaction with users

A typical safety report was not well-suited for review and updating and therefore, was not the instrument for discussion and interaction between the user and the authorities, as it was intended.

Competence

A general trend in that period was to leave the responsibility of the safety review with the local authorities with the aim to leave the decision making process with those directly involved or influenced by the actual plant. This created a problem, since the few reports of the kind submitted per administrative unit were insufficient to ensure the build up of a reasonable competence. This caused another attempt to solve the problems by involving external consultants.

The above description of lessons learned in implementing the Seveso Directive is well-documented. Similar findings were obtained in other areas where safety assessment was used and safety reports prepared.

4.4 Public opinion

In the last 10 years or so there has been a general development in making the documents from a risk analysis publicly available and involving the public directly in the decision making process (KVK-case, 1988; Risk and Risk Communication, 1988). Numerous examples have shown that the safety report is definitely not appropriate for interaction between the company, the authority, the public and in some cases the politicians. The format was found too complex, written for specialists and created an atmosphere of uncertainty, doubts and even fear. In several countries there are efforts to improve the situation by involving the public earlier in the decision making process allowing questions and proposals from the public be incorporated in the safety report. Further, some countries have tried to arrange public meetings during the process for discussion of issues of interest to the public.

5. Research challenges for improved industrial risk control and safety management in a risk society

This chapter is based on lines of arguments and reasoning drawn from the above chapters of trends and problem analysis. Those chapters are mainly focusing on *risk analysis* whereas this chapter is more oriented towards *risk management.*

The purpose of the chapter is to reveal and discuss political research subjects and questions on industrial risk control and safety management of significance for safety performance in the Nordic countries.

5.1 The need for successful transfer and implementation of current and new knowledge in the field

Most risk problems in industry are still rooted in a rather simple production technology and linear routine operations well suited for structured, goal oriented feedback systems of risk assessment and deviation control. The overall injury and damage statistics are dominated by the sum of small-scale hazards of accident risks and exposures affecting health and environment, and not by the disasters giving the headlines in the media. A main challenge for reducing the risks produced by industry and transportation is still about how to deal with traditional, everyday occupational injuries and diseases, work stress, etc. Many, especially small enterprises are ignorant and lack motivation for any systematic safety management. For all these, we do not lack knowledge and recommendations regarding their safety problems, but know too little about successful intervention of remedial actions. For these enterprises, even simple guidelines about being systematic, access to tools boxes and just some commitment and caring, may mean a huge difference in safety performance.

We lack knowledge on main constraints for applying and practising knowledge based on scientific evidence in this field, and on how these constraints can be dealt with. A hypothesis for research could be that the dominant change strategies applied fail in improving safety. These strategies are usually based on force, using power to create change by decree and formal authority and/or on rational persuasion using rational and factual arguments. An alternative change strategy could be based on *convincing* industry and people through a democratic dialogue and participative management. A climate for willingness to change in safety practices may evolve.

To get the knowledge of safety science implemented in industry and to learn from practice, risk researchers should work together with reflective practitioners in projects for mutual learning and knowledge transfer. Risk researcher should work closely together with experts on organisational development and learning, and apply principles from theories on knowledge management. *By applying a framework as outlined above, cross-disciplinary research teams could be established for focused action research on risk issues.*

The contributions of evaluation studies and action research in this field have so far been modest. It may partly be due to the fact that most safety related evaluation studies in the research literature are based on a narrow positivistic tradition especially in the process of developing the evaluation criteria. Alternatives may be found in Guba & Lincoln (1989) "Fourth Generation Evaluation" and in the grounded theory approach of field research.

The problems of knowledge transfer and implementation of remedial actions for risk management can also be addressed to the gap between the paradigms of technologists and social scientists in this field, i.e. between normative and descriptive approaches. These two worlds in safety science represent a destructive cleavage between technologists and social scientist. It should be transferred to a creative cross-disciplinary arena with opportunities for learning cycles giving progress both to science and practice.

Finally, risk research should pay more attention to the balance between safety science as an exclusive research discipline and safety/risk control as an integral aspect of all activities in society and general management systems in industry.

5.2 New challenges for risk research

A main task in risk research will be to link the general scientific literature of organisations to risk management. A basic underlying assumption is that most safety problems and their solutions are an integral part of the design and running of the total socio-technical system.

We have indicated the complexity of the subject of risk control and safety management, the variety and richness of perspectives and approaches. Hopefully this report will represent a source for ideas, alternatives and perspectives, a guard against oversimplification, and a background beneficial for analysis and for choosing the right strategy, means and methods when confronted with specific, practical safety problem-solving. However, we also need to structure and simplify reality in generic and logical frameworks, models and formal methods to get results.

There are many proven «best practices» approaches for safety management in industrial organisations, e.g. of problem solving cycles and life cycle analysis, of deviation feedback control models suitable for running safety management systems given a relatively stable context. *But there is no evidence for any best one concept for safety management systems covering all contingencies.*

In the perspective of radical organisation change and risk management strategies and policy for adaptation to challenges of hostile competition and market forces, high performance demands, and new regulatory regimes, the answers and recommendations by current risk research are mostly vague or ambiguous regarding the ability of such systems to perform safely and environmentally.

Some reflections on important questions for current and future knowledge development in the field of safety management, and ways of approaching answers to them seem appropriate, e.g. an idea bank for risk research based on considerations outlined below[2]:

- We know too little about how the general frameworks of learning organisations and of organisation development apply to improvements, learning and adaptation of safety management systems. - Which intervention methods work, - when, how, and where to start?
- It is a gap between our hindsight knowledge of accident causation, incl. organisational factors, and our foresight knowledge on control/warning systems of dysfunctional relations regarding the dynamics and interactions of deviations seemingly normal until the accident happen. Therefore safety management research needs a closer collaboration with the experts on *normal* running organisations and general management. The fragments we discover by (past) accident analysis may be biased.
- A basic assumption underlying most systematic and structured safety management systems is a stable bureaucratic mass-producing organisation or similar transport or other systems with mainly linear interactions. We know too little about how this «best practice» fits the needs of other organisational types and contingencies. A special challenge to assess and control by safety management systems and by legal systems is the trans-organisational alliances and networks.
- There is a need for studying and watching natural decision-making processes in the light of safety implications in order to identify the crucial warning signals before it is too late.

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[2] The list is based on conclusions from book draft chapter by Hale & Hovden (1997)

- There is a need for comparative in-depth studies of organisational behaviour across contingencies, cultures and control regimes. The methodology for such comparative studies is well developed within anthropology, sociology and political science and is applicable within a framework of systemic analysis. That may help identifying the more basic preconditions for tailoring safety management systems to match different types of organisations and contexts. Too much of the empirical literature has methodologically been rather anecdotal single case studies or lean surveys not rooted in theory.

In a global perspective the greatest challenge for risk research can be encompassed in phrases such as:

Strategic uncertainties and structural vulnerability related to the rapid changes in society and social life, economic forces, technology development, new types of production systems and organisational structures in industry which may result in what U. Beck (1997) labels as "produced uncertainty and organised irresponsibility".

As already mentioned the main applied methods and toolboxes for risk assessment and control are based on assumptions of stable, linear systems and interactions and simplistic rational decision-making. These methods and tools are still and will be valid for controlling many risk problems. However, to cope with risk problems in a context of change and complexity related to the socio-technical systems and distributed, multi-purpose decision-situations our common methods for safety management are outdated.

Based on the framework outlined above[3] some main topics and areas for future risk research can be derived and applied as a basis for Nordic risk research project proposals:

- **The challenge of change:** There is a need for new approaches to safety management in order to cope with the pressure on costs and time and safety margins, to develop alternative risk control mechanisms in a context of new profit-sharing contracts and inter-organisational teams, outsourcing, etc. An aspect of that will be to analyse the environmental stressors influencing priorities and incentives of decision making at all levels of this system and the mechanisms of adaptation to such environmental stressors. The perspectives and arguments of Jens Rasmussen (1997) on the need for vertical analysis and on deviation control versus boundary control should be part of the discussion of future risk research scopes. The dynamics and changes in hazardous socio-technical systems will require improved indicators and performance parameters to cope with the needs for continuous risk analysis monitoring of changing operations, modifications of machines and equipment, manning, etc.

- **Risk based regulations, functional requirements and standardisation** – cohesion and cleavages in regulations and risk control approaches at different levels. The dynamic interaction between the level and layers in risk management; what is the effect of the different time constants for adaptation to change at the various functional levels; and the influence of this difference on the interaction among decision making at the various levels and sectors. Analysis of accident and threat scenarios to identify critical decision situations that are sensitive to environmental stressors and inadequate information, i.e., some sort of vulnerability analysis for risk based regulations and control. Identification of

[3] They are to a large extent based on Hovden, J. (1998) *Risikoforskning. En utredning for NFR".* NTNU, Trondheim.

system functions sensitive to improvements from accident commission reports and models of the socio-technical control system is essential.

An important argument for risk based functional requirements was to encourage technological innovations and flexible adjustment that detailed regulations and control hindered. A paradox is revealed: When industry got functional freedom for choice of solutions, they turned to standardisation to achieve cheaper and less time consuming mass produced solutions. Consequences included by-effects of the drive for standardisation and for certification have not been documented as really evaluated and verified in serious research so far. Certification and standardisation have become big business, and an enormous cost factor for industry, and should therefore be critically examined.

- **Knowledge management and decision making.** Here follows some suggestions on research tasks and research questions: Knowledge management related to the development of information systems and experience transfer for decision support. Mapping the decision-making network and information flow within the total socio-technical system involved in projects and operational and risk management, that is, the structure of the distributed decision making network and the information flow found in the different categories of hazard. How is, for instance, the interaction among the engineering design community, the operating community and the regulatory community with respect to risk management. Where, by whom, and when are the decisions made that shape the strategies of the socio-technical system within the various hazard categories? Which are the criteria driving decision making at the various levels and how are the criteria interacting? How is the interpretation and communication of information on system operation and the reference for judgement of system safety propagating in the system?

- **Risk communication and dialogue:** It has been a change in international and national legislation from "need to know" principles to "right to know" principles. Risk communication is about the interface between an expert sphere and a public sphere including media. It is about the arrogance of the risk expertise and power elite on one hand and the emotions and fears of the unknown by ordinary people. In between we have cynical and greedy search for "good news" (disasters, scandals, sex and violence) by the mass media and an "information" about health risks which makes everyone felling sick. Great amounts of money are used on campaigns for affecting safety attitudes and behaviour, normally with very little documented success.

  A basis for improving risk communication is knowledge of perceived risk by psychological studies of mental models for risk judgement. This type of research is well established. To make progress on this subject we may need (1) more cultural/anthropological approaches, and (2) a clarification of the ethical stands, dilemmas and conflicts in the risk dialogue and decision-making processes.

- **Vulnerability related to information technology and infrastructure:** The *vulnerability* of production and transport systems and infrastructures including information technologies is becoming an urgent political issue and worry, e.g. The President's Commission on Critical Infrastructure Protection, Wash., 1998. The vulnerability perspective on risk management merges the safety/accident area and the security/deliberate violation area. Intentional or unintentional acts may have the same effects regarding breakdown of systems, losses, recovery and survival.

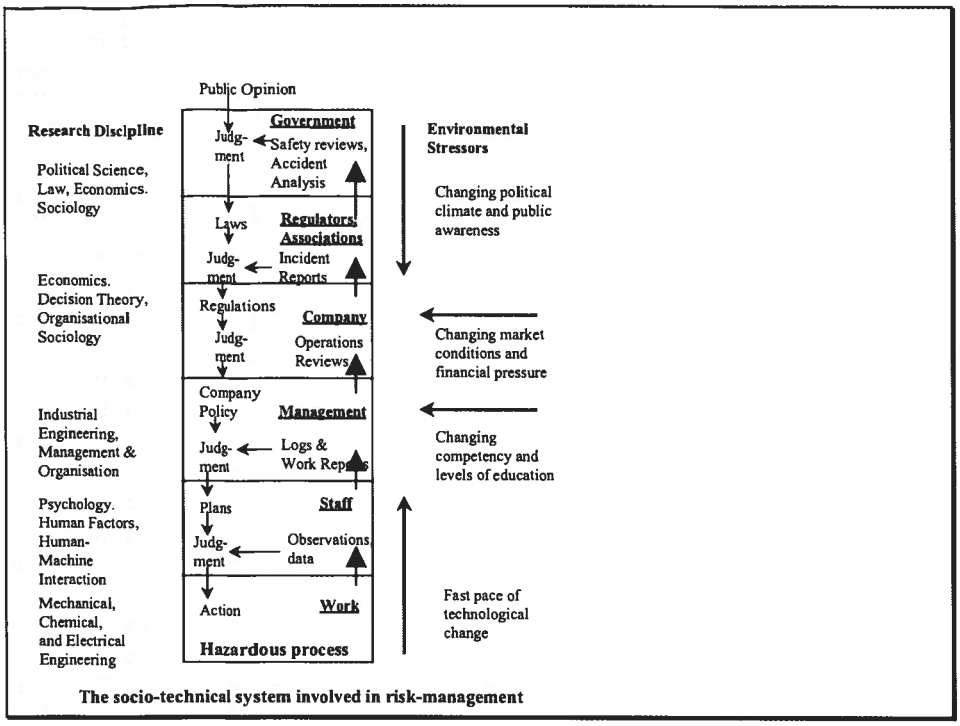
- **Human factors/human resources:** The human factor is commonly attributed as the main causal factor of accidents. This attribution is usually based on a simple and fatalistic understanding of human nature and accident causation. Of cause, humans are unreliable and make errors, and it is little to do about that. But, on the other hand, as demonstrated by high risk industries such as nuclear power, space, and air transport R&D has contributed to the establishment of preventive strategies reducing human errors and their consequences. Research on human factors is especially important in many areas, such as:
  - *Advanced technologies and automation:* What competence, skills and organising are necessary for making humans a safety resource instead of being a safety problem? What are the relevance and utility of the principles for "high reliability organisations" (HRO) in different industries? *How to design and run activities* based on *human recovery* and robustness of systems for correcting errors instead of the traditional focus on human errors in complex and vulnerable systems.
  - *Human factor criteria* for design of safe products and work places, and *human factor criteria* for knowledge and experience transfer

  In relation to emergency and crisis situation we need research to increase the quality of training programs and other types of support for decision-making and crisis behaviour, including alternative ways of organising rescue operations for improved use of human resources.

- **Alternative paradigms for risk and vulnerability analysis, safety auditing and their integration:** A starting point could be to analyse the *characteristics of hazard sources* within the various work domains. Accidents and intentional violations are caused by loss of control of hazardous processes. A taxonomy of hazard sources and related modes of risk management strategies should be developed. The control structure involved in risk management for different categories of hazard sources should be described. Different risk management strategies have evolved for different hazards and we need research to understand and characterise the mechanisms driving risk management behaviour within the different categories of a systematic taxonomy of hazard sources.

  So far, risk research has not managed to integrate the models of probabilistic, technical risk analysis with the models and methods applied for safety management auditing and organisational safety diagnosis. The researchers from each side can not agree on the premises and interface of the models. Alternative integrated methodological approaches such as "risk influence modelling" have been introduced, - but a lot of development and improvements are needed.

In the development of applied risk research project for industry it is important to keep in mind the model of J. Rasmussen (1997) presented in a figure below. At the bottom of the figure we have the hazardous processes to be controlled and the man-machine interface at work. At the top we have societal level of government, regulations and control plus market demands and other contingencies. As demonstrated by the figure there is a need to link risk management studies at the company level both to the context and to the primary processes producing risks by some sort of *vertical analysis.*



(Figure based on Rasmussen, 1997)

As each level represents a domain for different academic disciplines risk research should plan for cross-disciplinary arenas and a forum for communication and knowledge development of the risk research community and advanced safety practitioners.

5.3 Safety culture and ethics: a framework for risk research[4]

In safety decision-making and actions there are no straightforward answer to what is safe enough. The challenge to risk research is being rational within the accepted of facts and logic on one hand, and considering values and opinions of stakeholders and the public on the other.

The application of phrases like «full safety» in laws, regulations can usually be traced back to an ethics of justice, whereas the "ALARP" principle is mainly utilitarian. The safety directives and standards developed by EU's «new method» are also mainly utilitarian regarding ethical basis. In the development of safety laws and regulations and safety objectives, sources from different ethical stands are often combined and not always consistent:

- the justice stand will be consequence and precaution oriented in formulating criteria
- the duty stand will focus on obligation aspects, and is the main principle in criminal law
- the utility stand will focus on a risk-benefit balance
- the discourse stand will focus on the criteria for the process of reaching consensus on acceptance criteria

Risk acceptance is just partly connected with real risk. Primarily, it is a question of confidence in own ability to control dangerous situations and/or confidence in the "system", the safety management systems of trade and industry, or of society. This poses great demands on risk management at all levels with respect to competent efficiency, personal and professional integrity in difficult decision dilemmas etc. With an increasingly complex

[4] This sub-chapter is mainly based on Hovden (1998a)

structure of society, trade and industry, communication, political and administrative systems, technical systems and technological change etc., it is getting more and more important to relate to different ethical and political arguments to keep an image of being in control and for being trusted.

Safety decisions have to be made despite uncertainties and lack of knowledge, or ignorance. Since we cannot choose not to choose, certain arrogance is required to choose in the knowledge of our ignorance about technical risks. The choices will always include value judgements and trade-off based on ethical assumptions. There is a need for developing mechanisms for a path between the positivistic and rational choice founding of risk analysis and the richness of perceptions and judgements of risk issues. Shrader-Frechette (1991) suggests a solution based on what she calls «scientific proceduralism». This concept is built on three ideas:

- Accepting the explanatory and predictive power of risk analysis for decision support, but also be aware the limitations of the approach.
- Adding naturalistic and situation specific criteria, including ethical arguments as legitimate.
- The best answers to risk issues are achieved by exposing risk evaluations and decisions to intelligent debate, criticism, and amendment by the scientific community and lay people likely to be affected by the risk.

6. On Nordic research co-operation

6.1 On the needs and aims for co-operation

Nordic research co-operation should serve a number of needs. Some examples are listed below.

Needs for the society

For the society there is a need for qualified bodies and people as watch-dogs towards risks due to new developments and as proactive experts diminishing risks for large accidents and disasters. There is also a need for qualified bodies and persons who could identify and eliminate risks for the many small accidents that add up to large losses for safety, health, environment and economy. To fulfil these needs a Nordic co-operation could be very cost-effective.

Integration with other disciplines for cross-disciplinary efforts

To integrate risk management into organisations from the top management level to all employees co-operation is necessary with disciplines focussing at topics such as change processes, organisational design, leadership and management, participation and empowerment, quality as TQM and continuous improvements, and human factors. Multi-disciplinary centres and Nordic co-operation could make such integration possible.

Communication between research and application

One important issue is to improve communication between research organisations with industry, authorities and other stake holders. A broad and sufficiently deep research programme could lead to such an improvement, if it obtains high enough priorities. This communication has to be two-way and concerns the identification of important needs, as well as the evaluation and application of results. Also certain knowledge has to be searched in real contexts.

Education at Masters- and PhD-level

To get safety cultures within organisations for competitiveness and for avoiding negative effects and safety, health and environment it is essential that all students from relevant schools as Institutes of technology and Business schools get adequate education on risk and safety matters. There is also a need for special education on masters level as well as at the PhD level. There are large potential for great benefits from a Nordic co-operation within this topic.

Projects on particular subjects

Within a particular application area, there might be experiences from several national projects. In several cases, there could be large advantages to compare results and approaches, in order to obtain more valid results. This might especially be of interest for groups of industries or authorities. Another area includes projects looking on new and "modern" problems. Chapters 3-5 have described a large number of practical problems and challenges facing present risk management procedures in **all** Nordic countries. A targeted co-operation could probably speed up the availability of results with several years, thus keeping Nordic risk management at the international frontier.

Evaluation and support of results

A general need, which comes up frequently, concerns the need of evaluation of research results. Results should here be seen in a wide meaning, e.g. theoretical models, epidemiological findings, practical methods for risk analysis, and concrete technical solutions. Also there is a need to find approaches how the use of "good" results should be supported.

Take advantage of existing traditions

Research in the Nordic countries on Systems analysis (safety) has a long tradition, giving a unique international platform to do interdisciplinary risk analysis work. There are also many similarities in industrial organisation and authority perspectives, which would mean that approaches and results can have a rather common Nordic application.

The responsibility

As advocated above it would be very beneficial for the Nordic countries to co-operate in the field of risk management.

An essential question is, who should be responsible for promoting co-operation? In the Nordic review (Harms-Ringdahl et al, 1997) it was stated:

"*We recommend the research councils and other organisations to initiate and maintain activities to identify, evaluate, and support the utilisation of research results. The responsibility for this should not be thrown upon the individual researchers. It is a societal responsibility.*"

6.2 Possible approaches to co-operation

In general terms, at least three different strategies or approaches to Nordic Co-operation can be defined

- co-ordination of results from projects which have either been brought to completion or are now under execution. This type of co-operation would require a limited amount of development work and resources

- development within a group or groups of senior research staff of tools to facilitate the practical use of existing knowledge. A good example of such a tool could be quality assurance standards for risk analysis procedures. This category would require an amount of developmental work within a rather small group of people
- new research project executed within inter-nordic groups. Preferable such projects should concentrate on areas where previous sections have highlighted the need for new and improved risk management strategies (see chapters 3-5). There is a great need for risk management methodology packed in a form which is feasible for management and participation by all employees and which is driving towards a safety culture. Such 'packaging' requires a multidisciplinary or cross-disciplinary approach. Necessary competences are spread in the Nordic countries.

Within these three broad categories there are a number of complementary formats for co-operation and knowledge dissemination. Some of these are mentioned below.

Concerned parties

There is a large number of potentially interested parties in safety research. It would be of great advantage to find suitable solutions to involve these as much as possible. On a national level, this group includes industries, transport companies, organisations, authorities, research councils, and research groups.

On a Nordic level there are a number of contacts, which relates to this issue. For example, there is co-operation with the Associations of Engineering Industries in the Nordic countries, as well as between the Associations of Chemical Industries.

Co-ordinated research programme

Co-ordinated research effort based on long term co-operation with clear aims. International funding is essential (e.g. as SCRATCH, see Appendix B).

Information support

One approach, which can take on many different shapes, is the support of information about risk research. It could concern information about books and reports, and also projects under execution. One example is the overview of Nordic research in industrial safety management mentioned in appendix B. In order to be useful both for researchers and practitioners, large concern is needed to collect and select information, and make it available.

Information exchange

Informal and free exchange of ideas and reports exists today in many shapes. One example is Nordic accident research seminars mentioned in Appendix B.

Professional associations

Professional associations could be an essential forum. One existing example is Scandinavian Reliability Engineers, which is concerned also with risk issues. Another one is Society for Risk Analysis-Europe, which also has national and regional chapters. However, these kind of organisations are based on voluntary work and fairly vulnerable. They are important mainly for improving their members' professional skills.

Aspect 1: Robustness or vulnerability?

Co-operation is vulnerable in many ways, since it is dependent on several partners. One important aspect is to find a form for co-operation which is robust and enduring.

Aspect 2: Nordic or European?

It could be discussed, if the aim should be co-operation on a Nordic or European level. At the time being, it appears to be a number of advantages to work in a smaller sphere - the Nordic one. It would be more easy to start and also less vulnerable. There are also a number of structural similarities in industry and among authorities. Further, there is already a fairly large network of researchers and interested parties.

6.3 Some recent proposals for risk research programmes

A number of risk research surveys and reviews have recently been carried out in order to prioritise areas for new research. A few of these proposals are

- a framework research programme from the National Swedish Rescue Services Board (SRV)
- a review by prof Jan Hovden for the Norwegian Research Council (NFR)
- research and development needs linked to the new Seveso-directives – a review published by the Swedish Occupational Safety and Health Organisation (ASS)
- the research programme linked to an Australian proposal for "A Centre for Major Hazards and Safety" (Cesare)

An incomplete summary of some projects included in these proposals follows

SRV The framework programme give the following prioritised areas (all described in fairly general terms)

- reviews of existing knowledge for a number of risk management sub-tasks or sub-areas
- development of methods/guidelines for the auditing and identification of risks. LCA (life cycle analysis) and risk assessment
- development of general models and methods for identification, description and communication of risk
- methods to compare risks and assess the outcome of risk-reducing activities
- methods and tools to summarise, develop and synthesise existing knowledge on the information and decision-making processes in risk management
- etc

NFR The main recommendation of the report is the proposal for the funding of a risk research graduate school. The research graduate school is to be closely linked to a number of research projects with the overall objective of developing new risk management tools and methods matching the rapid change in industrial technology and organisational structure

Prioritised projects include

- cross-sectorial vulnerability studies in the public and industrial domain. Vertical analysis of specific technological systems (see figure on page 26)
- organisational aspects of risk management for complex production- and transport systems working in an environment of deregulation, globalisation and intense competitiveness
- risk communication in general
- human factors

ASS The report is confined to the area of Seveso directives and chemical process industry. In headline format some of the prioritised projects include

- research with regard to the impact of different organisational models
- research in the characterisation and impact of company safety culture
- analysis of the impact of different management and leadership structures
- research into design of auditing procedures
- methods for information and knowledge gathering and analysis

Cesare A draft proposal for "A Centre for Major Hazards and Safety" outlines a number of projects with the objective of decreasing the incidence and cost of high consequence events

- research into world leading industrial practices and methods for the prevention of high consequence events
- research into the development of key performance indicators for the measurement of the efficiency of risk management activities
- research into the importance of psychological and organisational factors in hazard recognition
- research into the impact of increased demands for commercial efficiency on company safety culture
- etc

6.4 Some conclusions from project work and the April 15-16 workshop

6.4.1 The selection of and criteria for prioritised research areas

Chapter 3 of this report gives a review of trends influencing the use of risk analysis within work team, within the single company, in the local community and as a tool for risk management on the regional, national and international level. Chapter 4 described the substantial and important difficulties and problems associated with practical use of risk analysis methods and results. Chapter 5 was more directed towards the risk management and research challenges for improved industrial risk control.

It is clear from the description in chapter 5 and preceeding chapters that the basic premises for a successful risk management is changing rapidly both regarding the regulatory climate and the build-up of management structures and production organisation. These developments have been described in Hovden (1998a) by the following list of concepts and catchwords

- outsourcing, downsizing
- management delayering
- contracting, leasing
- strategic alliances, joint ventures or partnership
- just-in-time (JIT), lean production
- business process re-engineering (BPR)
- capital cost reduction
- virtual enterprises, enterprises in networks
- flexible specialisation
- learning organisations, adaptation
- global markets, internationalisation
- deregulation and self-regulation

The recent proposals for risk research programmes summarised in section 6.3 are all to a lesser or larger degree influenced by the developments described by the list above. Or in other

words: there is a close affinity between the description of background factors given in chapters 3-5 and the research proposals outlined in section 6.3. This facilitates for us to list a number of major, prioritised research areas where a co-operative Nordic effort would be particularly beneficial for a more effective industrial risk management:

- organisational aspects of risk management of safety, health and environment (SHE)
- development of information technologies and development of tools to support decision-making in risk management
- quality standards for risk analysis

Before discussing specific co-operative research projects it would be useful to define some general criteria or requirements for such a project. Some general criteria can be given

1. The project should have synergistic effects and have a Nordic dimension
2. The project must be focused on needs and requirements of industry
3. The project should be future orientated and be based on anticipated future requirements
4. The project should where possible be based on co-ordination of ongoing projects and in areas where we have a substantial Nordic expertise

6.4.2 Workshop, April 15-16, 1999

Workshop participation, organisation and result in the form of prioritised research projects are described in Annex. The workshop participants came from industry, regulatory bodies and research institutions. Intensive discussions during the two day workshop produced a list of research projects. An effort to combine this list with the work outcome from the inter-Nordic group has resulted in a number of suggested research areas/projects as outlined in chapter 7.

The main conclusions from the workshop could be summarised as follows

- the participants found the draft report from the project timely, relevant and useful
- the draft report should be the instrument and basis for continued, co-operative Nordic research
- the rapid socio-technological changes taking place in modern industry will require an increased research effort to keep societal vulnerability at an acceptable level. From all aspects, it would be of advantage if this effort could be organised within a Nordic framework

7. Proposed research areas/projects

This chapter is to be seen as a selection and an outline of some prioritised research areas. The intention and hope is that the ideas should be further worked on by interested bodies, resulting in a good Nordic programme. Outlines for mechanisms for the continuation and development of co-operative Nordic research are also given.

7.1 Organisational aspects of corporate safety management

There are three factors that effectively define an organisation's approach to managing risk, those relating to:

- structure – the nature of organisational risk management infrastructure – degree of formalisation, centralisation, etc
- strategy – the nature and combination of techniques used in risk management – avoidance, loss control; retention, transfer of risk

- culture – the beliefs and values that influence the actions of individuals and groups who are responsible (directly and indirectly) for risk management within the organisation

Even a cursory inspection of current research information from journals, conferences, etc shows that research activity in the area of risk and organisational models, risk and safety culture, risk and choice of management system is extensive and expanding rapidly. The European Union project IRISK (Oh et al 1998) is an obvious example of current research.

As pointed out in section 5.2 there is a need for comparative in-depth studies of organisational behaviour across contingencies, cultures and control regimes. It is further advocated that the risk research field could to its advantage exploit methods already developed within anthropology, sociology and political science.

Hale and Hovden in their review define a list of six dominant research purposes
1. Incorporation of a management factor into PRA.
2. Discovery of high-level management/performance indicators for regulatory guidance.
3. Indicators of the structure and functioning of successful risk management systems.
4. Indicators of risk climate, including studies of the risk implications of different organisational cultures.
5. Studies of the development and integration of risk management systems.
6. Studies matching organisation type explicitly to risk management system factors.

A possible structure for an umbrella project would be to systematically analyse the relationship and the importance of the three main factors mentioned above to the six listed research purposes.

7.2 Efficient Risk Management based on the Balanced ScoreCard concept

One of the main topics brought up during the workshop concerned the problem of involvement of the corporate top management in risk management as it was considered crucial for efficient risk management. Furthermore a safety culture which leavens the whole organisation from top to bottom is believed to be of outmost importance for a cost-effective risk management.

There is a growing awareness of the importance of different perspectives in assessing and managing an organisation in the private as well as in the public sector. The Balanced Scorecard (BSC) concept (Kaplan and Norton, 1996) is today widely used as a management tool acknowledging other perspectives than the financial perspective reporting results of past activities. Typical perspectives, in addition to the financial, are the customer perspective, the internal processes perspective and a perspective showing the organisations capacity to cope and develop in the future. The perspectives are of interest for the shareholders and the stakeholders. They are also suitable as a tool for top management. Furthermore the balance scorecard method may be used for the employees' understanding of their roles and for participation.

The aim of this project is to develop and test methodologies for efficient use of Risk management. The use should involve top management and employees.

The balanced scorecard technique will be developed to include risk management and to promote participation, motivation and empowerment. Integration with other management tools as TQM and continuous improvements will be done, if possible and depending on

involved organisations. Means of forming safety and quality cultures are of interest in the project.

Competence from different disciplines are necessary. Furthermore, it is essential to study several organisations in order to develop and study our methodology since there are big differences between different organisations which could explain differences in outcome. Thus at least one centre from each country should ideally take part. Each centre should work together with a couple of companies or rather with a network of companies.

Sustainable changes in corporations take time. The project should run at least 5 years. In the first phase - about one year - methodology will be developed and the companies will be prepared through courses and exercises. Courses on risk management, Balanced scorecard and e.g. safety cultures and TQM will be given. Furthermore the employees will train communication. At the end of this phase a balanced scorecard approach including risk management components will be formed in each company in an iterative process involving both top management, middle management and employees.

In phase two, lasting about 3 years, the technique will be further developed in an interplay with participating companies and the progress will be studied.

In phase three, lasting about one year, the researchers will stop their involvement in the process. The project will be evaluated and a manual will be written. During all phases there will be a close co-operation between the different centres taking part in order to share competencies and experience. Especially during phase three the co-operation has to be close in order to make fully use of the results from different centres.

Personnel. Each centre should have at least one man-year senior researcher and two man-years PhD-students. Each group has to be multi-disciplinary.

References:

Kaplan R.S. and Norton D.P. (1996). The Balanced Scorecard. Harvard Business School Press.

7.3 Risk management under pressures from rapid organisational and technological changes

Both this report and the workshop report emphasise the new impact of rapidly changing production and management structures on corporate risk management: shorter term to market, concurrent design, lean organisation, down-sizing in general, single source supplies, outsourcing, etc. During the workshop there was a general agreement that risk research in the near future would have to study extensively and in depth the effect of these changes. A very urgent project was proposed by SINTEF "Maintaining Safety during Down-sizing", see Appendix 6 in the annex. The project is based around the following research issues

- In what way will an organisation be affected during downsizing and when established structures for safety management disappear?
  - Will some activities be more vulnerable for downsizing than other activities?
  - What are the consequences for knowledge management, organisational learning, experience exchange?
  - What is necessary minimum manning from a safety point of view (a. during normal operation, b. during crisis intervention)?

- How performing effective safety management during downsizing?
- What will be functional risk acceptance criteria regarding manning and downsizing?

- Which evaluations are done regarding competence/resources ahead of, and after downsizing?
  - Change analysis?
  - Compensating measures?
  - "After-the-fact"-evaluations (problems/indicators for subcritical manning).

- Is it possible to define indicators to measure effects of downsizing; which indicators are sensitive for undermanned activities (can e.g. a drop in near miss reporting be an indicator for subcritical manning)?

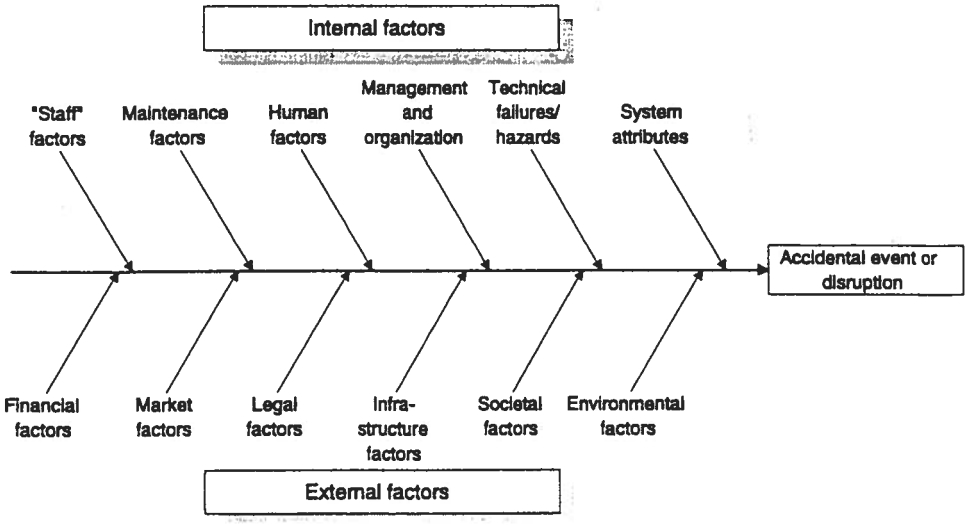
7.4 Vulnerability related to infrastructure and information technology

The *vulnerability* of production and transport systems and infrastructures including information technologies is becoming an urgent political issue and worry, e.g. The President's Commission on Critical Infrastructure Protection, Wash., 1998. The vulnerability perspective on risk management merges the safety/accident area and the security/deliberate violation area.

The infrastructure systems include
- telecommunications
- electrical power systems
- transportation
- water supply systems
- emergency services
- banking and finance
- continuity of government services

Many of these infrastructures have historically been physically and logically separate systems that had little interdependence. As a result of advances in information technology and the necessity of improved efficiency, however, these infrastructures have become increasingly automated and interlinked. These same advances have created new vulnerabilities to equipment failures, human error, weather and other natural causes, and physical and cyber attacks.

Categories of risk factors are exemplified by the figure, taken from Einarsson and Rausand intended to describe the internal and external threats to a complex industrial system.



The design and use of indicators are important aspects of safety management and may form the basis for a quantitative assessment of vulnerability. The problem is to devise an indicator built on the interaction among physical, environmental and social/human subsystems.

A number of approaches are possible. Traditional risk analysis is one. Einarsson and Rausand propose a broader two step methodology, based on identification of scenarios, assessment of scenarios and the construction of a consequence-likelihood matrix, indicating system vulnerability and the influence of internal and external defence resources. A third approach is the use of multi-attribute decision making (MADM) methods. In MADM, the analysis begins by establishing attributes that can measure mission accomplishment. Usually mission accomplishment is described by a hierarchy of goals. A variety of techniques are available for attribute generation, attribute weighting and the transformation and normalisation of data into a decision matrix. The proposal is to organise a Nordic project where, for a given infra-structure system, various alternative vulnerability assessment methods are analysed and compared.

7.5 Development of information technologies and development of tools to support decision-making in risk management

Risk management has been described as decision-making under uncertainty. The following main types of problems may be listed: information flow problems, decision process problems, participation problems, method problems.

The first type concerns production of relevant information, its communication to decision-makers, its interpretation by them (including communication of uncertainty). Decision process problems concern the allocation of responsibility within the management structure, participation problems deal with the question of the participation of different stakeholders. Method problems, finally, include how to measure processes, set priorities, sum or trade different effects, deal with uncertainty. A number of areas may be defined for a co-operative Nordic programme: (1) to develop and synthesise knowledge about the industrial company risk decision making process (2) to conduct case studies of company risk decision making (3) to identify and develop useful decision-aiding tools and (4) to facilitate the development and integration of a Nordic industrial risk information structure.

In an increasingly democratised world, improving decision making means providing relevant information that is accessible and easily understood by people of many backgrounds and educational levels. Networked information systems comprising rapid storage and retrieval capacity, computing capability, and audio, video, and hard-copy outputs are revolutionising the accessibility and utility of tools, techniques, and supporting information for decision makers of all kinds. Many pieces of an decision maker's information and communication system are now becoming available on the Internet. With the advent of WebTV and other inexpensive hardware, such systems could soon be available to essentially all decision makers.

There are hundreds of types of risk management decisions in the industrial and regulatory sector. Again, it would be useful for future co-operative Nordic risk research to define suitable pilot project areas.

7.6 Quality standards for quantitative risk analysis (QRA)

Trends indicate much wider use of quantitative risk assessment and risk management technologies worldwide. As governments reduce their emphasis on prescriptive major hazard controls and switch to goal-setting standards, companies will increasingly use QRA to demonstrate that particular safety controls and mitigation systems are adequate for the anticipated demands. A driving force is the need for companies to identify and implement cost-effective means to prevent accidents so as to obtain realistic cost savings which do not adversely affect risk. This approach can work only if company management and the public (through the regulation system) believe the results obtained from QRA studies.

This trend is requiring the development of formal risk engineering standards, fully equivalent to other engineering codes, that remove many of the individual analyst variabilities that affected early studies. Some of the existing standards such as the IEC standard are quite specific on topics such as documenting the risk study, verification of results, and auditing. The standard states, in regard to verification:

- Check that the scope is appropriate for the stated objectives
- Review all critical assumptions and ensure they are credible
- Ensure the analyst used appropriate methods, models, and data
- Check that the analysis is repeatable by personnel other than the original analysts
- Check that the results are insensitive to the way the data or results are formatted

A suitable Nordic co-operative project would be the production of background material exemplifying and specifying how the requirements in the standard can be met in practical risk analysis cases.

7.7 Tools for HSE-management of small and medium-sized enterprises (SME)

As outlined in section 4.2.1 in the annex, substantial research projects have been carried out in Norway and Finland in order to streamline, improve and make more effective the risk management work. within SME's. It was noted that the Norwegian project was completed while the Finnish PK-RH project was in its final phases. As experiences from the practical field use of these tools, methods and procedures accumulate, an activity should be started along the following lines:

- in a comparative study, advantages and limitations similarities and dissimilarities of the two methods are specified
- in the same study, the potential for a possible joint inter-Nordic development of the two risk management tools should be specified. An important aspect would be to take advantage of emerging information and communication technologies

Such a pilot project or activity could form the base for a continued project where important key words would be exemplified by "communication within companies", "change processes", "leadership", "empowerment" and "participation".

7.8 A Nordic Graduate School on Safety and Risk Management

Coupled to at least one major Nordic project or a Nordic Consortium a PhD school should be created offering high quality courses in a broad area around risk management. Students at as many institutes of technology and business schools should be engaged. Also industry doctoral students should be recruited.

7.9 A Nordic Risk Management Academy (NORIMA)

Tentatively the academy should have the following tasks:

1. Strengthen communication, co-operation and exchange between groups of researchers in the Nordic countries.
2. Arrange activities for initiating and deepening cross-disciplinary research.
3. Identify research areas of importance for society - both for competitiveness and for less risks for health and environment.
4. Establish a Nordic Graduate School on Safety and Risk Management.
5. Serve the society and the Nordic Risk Management Network with Risk Management competence

7.10 A Nordic Risk Management Network

A Nordic Risk Management Network should promote development and use of risk management in both the private and the public sector for a sustainable society and environment and for competitiveness and life quality. Tentatively the network should especially

1. serve as an arena for industry, regulatory bodies and researchers to discuss important and common issues in practical risk management
2. improve communication and co-operation between participating partners and the process of technology transfer in general
3. identify important areas for research and development
4. work for and initiate master thesis projects, PhD-projects and other research projects
5. use the Nordic Risk Management Academy as an expert group on research questions

7.11 Continued work

In a follow-up activity, LUCRAM will contact workshop participants (see section 6.4 and annex) with a view of facilitating the task of transforming the project ideas proposed above into practical research projects. For further information, contact the project leader at LUCRAM or any other member of the expert group (for addresses, se Summary).

8. References

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Appendix A. Summary review of some Nordic risk research activities

A.1 National research profiles

Below is a description over the national profiles in the field of safety research.

A.1.1 Denmark

Research Institutions

UNIVERSITIES:

- Danish Technical University, 3 main areas are covered.
- Institute of Chemical Engineering, a course in risk analysis has been offered the last 10 years;
- Institute of Applied Electronics reliability analysis, in particular reliability of electronic devices;
- Institute of Planning Traffic Safety.
- Copenhagen University, Department of Psychology

RESEARCH INSTITUTES:

- Risø National Laboratory, largest group in Denmark on risk assessment. A research programme deals with industrial hazards and another with man-machine interaction. Both groups with app. 10 researchers and 1-2 Ph.D. students.

- National Environmental Research Institute, monitoring, testing and research concerning air and water quality. (Academic staff app. 100, but no specific group on safety)

- Danish Council of Road Safety Research, 15 scientists active in traffic safety, in particular road safety and driver behaviour.

Private companies

- Novo Nordisk,
  biotechnology,
  interest in safety in lab tests and production.
- Kommunekemi,
  chemical waste treatment.
- Statoil,
  oil refinery.
- DONG,
  oil and natural gas distribution on- shore.
- Mærsk Olie og Gas,
  off- shore activities.
- Kemira,
  fertiliser production.
- Cheminova,
  fertiliser production.
- Great Belt,
  tunnel and bridge safety (from users point of view)

Ongoing research programmes
No Danish comprehensive and broad-covering research programme on risk assessment exists. But there are numerous programmes and projects with some relevance for risk, focusing on decision support systems, cost benefit analysis, economy, emission control and reduction, etc.

There are large research programmes on:
- information technology, including activities on human-machine interaction, advanced production techniques
- environment, including air and water quality
- biotechnology, including safety considerations
- food production, project focusing on safety

Ongoing international research programmes
EU – 4th Framework Programme
Environment Programme with a subprogramme on Industrial Safety (still 5-10 projects active) – Here a specific task is MEG, the Model Evaluation Group dealing with systematic evaluation methods
Also relevant project within BRITE/EURAM, ESPRIT, TRAFFIC

EU – 5th Framework Programme
Likely, that industrial and natural hazards will be merged into one programme.
Traffic research will continue with emphasis on multi-model traffic systems, cost benefit analysis, effect studies, driver behaviour.

A.1.2 Finland

Research Institutions

UNIVERSITIES

- Tampere University of Technology, Tampere
  courses and research in safety engineering incl. e.g. ergonomics and safety management
- University of Turku, Turku;
  cognitive and socio-cultural aspects of risk models and risk acceptance; interested in comparative studies of risks pertaining to information technology and biodiversity

RESEARCH INSTITUTES:
- Finnish Defence Forces Research Centre, Ylöjärvi;
- Finnish Environment Institute, Helsinki;
  environmental risk analysis, chemical risk assessment, risk criteria;
- Finnish Institute of Occupational Health, Helsinki (and 6 regional institutes);
  most aspects of occupational health risks. Interested in co-operation with Räddningsverket (SE)
- Finnish Meteorological Institute, Helsinki;
  risks due to gas dispersion.
- VTT Building Technology, Espoo;
  fire risks.
- VTT Energy, Espoo;

nuclear safety (incl. nuclear waste issues), consequence analysis (incl. gas dispersion and explosions).

- VTT Manufacturing Technology, Tampere;
  most aspects of safety engineering (excl. nuclear safety. Interested in Nordic co-operation in most research areas
- VTT Automation, Espoo;
  nuclear risks (incl. quantitative risk analysis).

Private companies with interest in Risk research

- Fortum
- Jaakko Pöyry Oy;
  risks pertaining to process plant design projects, integration of risk management into general management
- Kemira-Group
- Outokumpu
- Rautaruukki
- Rintekno
- Teollisuuden Voima
- VR-yhtymä Oy;
  risks related to railroads; human error

Ongoing national research programs/projects

No comprehensive listing of these programs and projects exists. Academy of Finland, Finnish Work Environment Fund, Technology Development Centre, Safety Technology Authority and several Ministries fund 10s of risk related projects each year (separately or together). For instance, VTT Manufacturing Technology/Safety Engineering has > 50 ongoing national research projects, most of which deals with the identification, reduction or management of risks. Some programs with risk as one major theme exist, e.g. risk management in SMEs.

Ongoing international research programs/projects

No comprehensive listing of these programs and projects exists, but, for instance, VTT Manufacturing Technology/Safety Engineering has > 10 ongoing national research projects, most of which deals with the identification, reduction or management of risks. Currently by far the most important source of funding is the 4th Framework Programme of the EU. E.g. Nordisk Ministerråd and Nordisk Industrifond only play a marginal role.

National research bodies having risk research as strategic area

VTT Automation

A.1.3 Norway

Research institutions

UNIVERSITIES/REGIONAL COLLEGES:

- Norwegian University of Science and Technology, Trondheim. (a variety of technological disciplines, statistics, management studies and social sciences involved in risk research)
- University of Oslo (mainly in reliability analysis, but also some philosophical and anthropological risk research at the associated Centre for technology and human values)
- University of Bergen (mainly psychological studies of risk attitudes and behaviour, plus stress and coping in emergency situations)
- College of Stavanger/Rogaland University Center (mainly offshore related technical safety research/risk analysis, incl. emergency modelling)

- College of Stord/Haugesund (some activities: fire, emergency, general safety management usually linked to main activities at NTNU/SINTEF)

RESEARCH INSTITUTIONS:
- SINTEF at several institutes and departments
- Rogaland Research
- DNV research
- Institute for Energy Technology/ the OECD Halden Reactor Project

Private companies with interest in risk research
Consultants linked to research activities:
- Dovre Safetec
- Scanpower
- Det Norske Veritas
- Quasar
- PRIDE and others in the field IT support for safety/risk management

Some industrial companies directly supporting/financing risk research:
- Norsk Hydro
- Statoil
- Shell, and other oil companies

Insurance companies supporting/financing risk research:
- Vesta (Scandia)
- Gjensidige

Some important/big companies with revealed interests in risk research:
- Aker Engineering
- Kværner Group ASA
- Orkla
- Norske Skog
- Dyno Industries
- Helikopterservice
- NSB

Ongoing national research programs
I (Hovde) will just mention a new project "SHE consequences of NOROK" dealing with challenges for risk management related to cost and time cutting, new ways of organising business, contracts, alliances, standardisation as co-ordination mechanism, etc. Financed by the Research Council (NFR), a project at SINTEF/NTNU. Budget (for starting 1 ½ year, 1 mill NOK – but will probably result in a number of spin off projects) – As I mentioned at our meeting this may be an actual subject for the Nordic Project.

In 1998 NFR has a break in financing exclusive risk research, but plans to re-activate funding of risk research from 1999 and onward. Quite a lot of risk research is integrated in more general longsighted industrial research programs, e.g. "Productivity 2005").

A.1.4 Sweden

Research Institutions

General
The recent framework programme for research and development in the risk management area produced by SRV (Swedish Rescue Service Agency) and other national regulatory bodies gives a survey of the national research areas and lists research institutions and research groups and research centres involved, more or less directly, with risk management research. Listed by universities, the members are as follows

- Uppsala University, 5 departments/groups
- Gothenburg University, 1 department
- Chalmers Institute of Technology, 3 departments/groups
- Lund University, 11 departments/groups, 1 centre
- Stockholms University, 4 departments/groups
- Stockholm School of Economics, 1 centre
- Royal Technical Institute, 1 centre, 2 groups
- Linköping University, 1 department
- Umeå University, 1 department, 2 centres
- Luleå Technical University, 1 department
- Karlstad University, 1 department, 3 centres

Non-university research groups
The research framework report lists some 10 research groups working outside the university organisation. These include defence research groups, testing- and research laboratory, meteorological and hydrological institute, road- and transport research institute, environmental research institute, etc.

Conclusion
Risk research in Sweden is characterised by a substantial volume and quality and by being, at the same time, highly sectorialised and fragmented.

Appendix B. A perspective on co-operative Nordic risk research

Tradition of co-operation

There has been a fairly long tradition of research co-operation within the field of risk analysis in the Nordic countries. This section gives a short account of some of the experiences and examples on projects. Especially the SCRATCH project has been important for the development of a common view on risk analysis.

The SCRATCH programme

SCRATCH stands for Scandinavian Risk Analysis Technology Co-operation. The programme was run over the period 1979 to 1982. One aim was to establish a good praxis for the procedures for risk analysis of industrial systems. Other goals were to sum up experiences of different analysis methods and of the use of information and databases to be used in an analysis.

The programme was managed by the Nordic research organisation NORDFORSK, which also sponsored part of it. The approach was to associate national projects in the area of risk analysis, and 35 projects from Denmark, Finland, Norway and Sweden were connected. In the programme five work groups worked out different reports, which concerned checklist, terminology, data, methods, and planning of a risk analysis. A large number of work reports and final reports (SCRATCH, 1984) were published.

Nordic experiences of safety reports

An example of a more specific subject for research co-operation was related to safety reports required in the Directive on major-accident hazards ("Seveso directive). The project was sponsored by the Nordic Council of Ministers , and it involved researchers and representatives from industry and authorities from four Nordic countries. The report (Malmén et al, 1992) sums up experiences, and it gives good advice for the preparation of safety reports.

Survey of safety management research

A study has been carried out with the aim to give an overview of Nordic research in industrial safety management and adjacent areas (Harms-Ringdahl et al, 1997). The project was a co-operation between research organisations in five Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. The emphasis was on "integrated safety management", which, for instance, means that the same approaches are used to control accident hazards, health and environmental risks, and quality problems.

The data was collected by sending out a questionnaire to research organisations. Experiences and conclusions from research in the Nordic countries during the past decade were asked for. The enquiry has given 108 descriptions of research topics. This material has been analysed and summarised from different perspectives.

Accident research seminars

For about fifteen years, seminars have been arranged annually (almost) with accident researchers in the field of work environment, traffic and consumer safety. The organisation has been informal and altered between the Nordic countries. This series of seminars has been

essential for a good co-operation and interdisciplinary exchange of information. The short name has been NOFS (nordiskt olycksfallsseminarium).

Nordic input to EU activities

In this account of Nordic research co-operation, also a few European projects with a general scope could be mentioned. They have been of importance for the Nordic participants, who also have played an active role, e.g. being chairman in all the three examples.

Systems of Sociotechnologies and Industrial Safety

One example is "COST A1", which was a project investigating the human contribution in the safety of industrial installations. The project was carried out in the period 1984-1989 within the framework of European Co-operation in the field of Scientific and Technical research (COST). A total of seven European countries participated, of which three Nordic ones (Wahlström et al, 1989).

SHARE

A further continuation of this project was planned by a Norwegian and a Swedish researcher. However, after a discussion with a representative at the European Commission (CEC), a more general type of co-operation was established in the end of 1989. It got the acronym SHARE with the meaning *Safety management and Hazard Assessment Research co-operation in Europe*. The scope of SHARE was to extend over the area of industrial risk within the framework of the European research programme for environmental protection. The aim was to maximise benefits for the management of industrial safety by steering and co-ordinating European research.

The intention was that SHARE should establish a framework within which research actions and activities can take place. A number of objectives were proposed:

- development of a communication network
- development of an overview of research needs
- optimisation of research capabilities and co-ordination of efforts
- directing of research at problems
- dissemination of information and research findings
- promoting the utilisation of results
- development of an integrated approach.

The CEC provided the framework for SHARE and support of funds for travelling costs. SHARE was in operation from the year 1990 to 1994 , when the commission terminated the co operation without any explanation. Many of the objectives were partly fulfilled, especially concerning the development of a communication network.

Model evaluation group

One of the SHARE initiatives concerned the evaluation of "technical models". The objective was to improve the development and the proper application of models used in risk analysis. A European group MEG (Model Evaluation Group) was established in 1992. MEG has developed a protocol for evaluation of any model used in risk analysis and also provided a guideline on development of new models. The work was continued in expert groups on dense gas dispersion, explosions, fires and human factors where more area specific guidance was provided. Since 1996 there has only been very limited activity.

Nuclear safety research co-operation

Nuclear safety is an area we do not address in this proposal. However, it is related to industrial safety in many ways, and experiences can be obtained from how co-operation is organised in that area. NKS (Nordic Nuclear Safety Research) is a co-operative body in nuclear safety, radiation protection and emergency preparedness. Its purpose is to carry out cost-effective Nordic projects, thus producing research results, exercises, information, recommendations, manuals and other types of background material, to be used by decision makers and other concerned staff members at authorities and within the nuclear industry.

NKS has gone through its fifth four-year NKS program (1994 - 1997). The programme is financed by authorities in five Nordic countries. Only projects that are of interest to end users and financing organisations are carried out, and the results should be practical, useful and directly applicable. In 1996 the budget was USD 1.5 million, plus USD 3 million added contributions by participating organisations. The NKS Secretariat is at Risø Research Establishment, Denmark (reference http://www.nks.org/nks-en.htm).

Transport safety research co-operation

In 1970-80 Nordic co-operation on road safety research was initiated. In consisted on both mutual exchange of information and research results and a number of joint Nordic research projects. Due to lack of funding this co-operation is since 5-10 years limited to biannual joint Nordic conferences on an important research aspect.

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ANNEX. Report from Nordic Workshop on "The increasing role of risk analysis of technological systems in decision-making". April 15-16, 1999, Lund, Sweden

1. Welcome and presentation of LUCRAM

The Workshop was opened by Prof. Thomas Johannesson, rector of Lund Institute of Technology, who welcomed the participants and in particular stressed the importance of initiating and organising co-operative Nordic risk research projects. The host organisation, Lund University Centre for Risk Analysis and Risk Management, was presented by its chairman, Doc. Nils Stormby.

2. Programme and list of participants

The workshop programme is described in Appendix 1. Appendix 2 shows the list of participants.

3. Prepared comments

The contents and the proposals of the draft report, which was the basis for the workshop and which had been sent out in advance, was outlined by the project leader. Next, and as a background for the workshop working procedure and actions, a number of prepared comments were delivered. The list of presentation is given in Appendix 3.

4. Group discussions, afternoon 99-04-15

4.1 Organisation of working groups

With the project proposals in the draft report and the introductory presentation from industry, government agencies and research institutions as a base, the workshop participants were divided into three working groups. An attempt was made to have a balanced mixture between industry, government and research as well as between nations in the three groups. Each group was charged with the task of producing a prioritised list of research projects suitable for Nordic co-operation.

The list would have to be based on some general criteria

1. The projects should have synergistic effects and have a Nordic dimension
2. The projects must be focused on needs and requirements of industry
3. The projects should be future orientated and be based on anticipated future requirements
4. The projects should where possible be based on co-ordination of ongoing projects and in areas where we have a substantial Nordic expertise

Below follows the report and the lists developed by the three groups.

4.2 Report of group 1

1. Risk analysis in small and medium sized companies

The group noted that SINTEF in Norway and VTT in Finland have led research projects in order to raise the awareness of safety, health and environmental risks in SMEs. The Norwegian ROS project has had its focus on educational aspects, while the Finnish PK-RH project, which is now in its second phase, has concentrated on producing simple tools to be used by the SMEs in order to assess the risks (not only SHE risks) that the company may face.

The group noted that it might be of great benefit to merge and further develop these two approaches on a Nordic basis. The product would be an IT-tool that can be used by companies all over the Nordic countries and consequently - through a broader acceptance - increase the use of the ideas now presented in the two original tools.

2. Quantitative risk analysis (QRA)

A major aspect of the ongoing risk-management debate turns on the extent to which implementation of risk-reducing efforts should rest on a quantified evaluation of risk as against a more qualitative assessment. One important question for discussion regards which areas or aspects of risk that are most suitable for the application of QRA; another question regards the extent to which administrative/organisational and "human error" factors can be integrated into the QRA-procedure. The technical sophistication to which the QRA approach lends itself fits well with legal and bureaucratic requirements for standard operating procedures and the approach is beginning to be the backbone of "rational" risk management in many industrial sectors. As this happens, the shortcomings and limitations of the method in a technical sense are coming more and more into light: the problem of the (lacking) completeness of the event-trees, the problem of quantifying event probabilities in a credible way, the lack of standardised methods to handle uncertainty, the difficulty in presenting QRA-results to the public in a meaningful way. Adopting a somewhat broader framework, it has been noted that the QRA-approach scores low on the values of equity (fair distribution of risks), public acceptability and links to public risk perception in general. For further comments, see chapter 4 of the main report.

3. Supplier risks

The trend of large corporates to concentrate on their core business has led to a situation where these companies are highly dependent on their suppliers. The amount of suppliers has been reduced to a minimum and today only companies that produce the desired component at a suitable quality and a suitable price are used. These suppliers again use their own suppliers, and so on. This means that probably all supplier chains include one or several single source suppliers.

The group discussed the huge problem an interruption of production due to fire, machinery problem, lack of human resources, etc. at the small single source supplier can cause the end user: the lack of a component worth a few Euros may cause damage for millions at the other end of the value chain. The group identified an urgent need for research: How can the big companies become aware of risks in connection with the facilities of their suppliers, the suppliers' subcontractors, and so on, in order to be able to assess whether this risk is tolerable or not?

4. A need for a robust society

The group realised that in the Nordic countries with the cold climate, all of us are today extremely dependent on a reliable infrastructure - electricity, water, communication, hospitals, banks, food supply, etc. Not only does the local society have a need to be aware of the risk that may face the region should some (or all) parts of the infrastructure fail, but it also needs instructions on how to proceed once this information has been obtained.

The following questions illustrate the problem: How shall the risk analysis be carried out in order to be complete enough? How can we make sure that new risks are identified and assessed in time (e.g. computer related risks)? How can the results of the study be translated into a language understood by the stakeholders (among others the decision makers and the inhabitants). Is there a need for different "languages" depending on the target group? Once the insight about the risks has been obtain, how do we make sure that it is not lost "at the next election" or at other times when the decision makers and the basis for decision making change?

5. Assessment of companies' safety management systems by the authorities

European directives require that hazardous installations have a safety management system in place in order to prevent accidents. Reports are sent to the competent authorities in which companies demonstrate their ability to manage their operations in a safe way.

The group learned that despite the fact that the new legislation is in place, there are no guidelines telling the authorities how to assess whether the steps taken by the companies are acceptable or not (i.e. Are the companies doing enough of the right things?). This may lead to a situation where companies are treated differently.

Since the safety culture in the Nordic countries is quite homogenous, there might be an advantage to start an Nordic project in order to produce a common guideline for the authorities. A similar guideline was successfully produced when EC's first Major Hazards Directive was introduced in Sweden and Finland.

6. Safety culture

The group discussed the problem of risk analysis work and results not being treated as part of day-to-day management activities of many organisation. One problem seems to be that the top management of many organisations lack the understanding of safety, health, environmental and other similar risks on the activities of the company. This, again, leads to a poorly optimised safety culture in the organisation.

The group was told that Risoe and VTT had been involved in the TOMHID project, and that IAEA in Vienna had produced some guidelines, which could be used to identify organisational problems leading to a poor safety culture. The greatest research problem is, however, how to get the risk information translated into figures and/or a language that enables this information to be included in decision making processes of the top management: "the bottom line" only shows the risks once the undesired event has already happened! To combine knowledge about existing tools with detailed knowledge about general management, etc. in order to pinpoint the exact needs and effective solutions is a major task, which can not easily be achieved in one single Nordic country. The group believed that this is one of the most crucial points to be solved in order to come a decisive step further in the field of risk assessment and management in companies and in society in general.

7. Land use planning

Land use planning around hazardous sites has been recognised as being one of the ways to reduce the consequences of explosions, fires and releases of hazardous substances. EU's new Seveso II Directive covers this issue. At present there are no guidelines on how to transform the information given by the companies on their risks into safety distances and similar information needed as a basis for land use planning.

The group agreed that work on a Nordic level would be more fruitful than a pan-European approach, as the acceptance and perception of risk is quite homogenous in the Nordic countries.

8. Concurrent design and shorter time to market

Attention of the group was drawn to the fact that less time is available for product and process development, design of the product and the production facilities and for product and plant risk evaluations and documentation. The old practice of systematically analysing the risks only at a very late stage of the development and design process is no longer working, since no major changes can be accepted after the risk study without having a dramatic and often unacceptable effect on the schedule of the project.

New tools are needed for earlier stages of development or investment projects. These methods must be reliable even if they are used by non-risk-professionals. Experiences from more than one country would be of great benefit for the development of these risk analysis tools and thus a Nordic co-operation may be the correct answer. Due to lack of time, this proposal was not further discussed by the group.

9. Streamlining the implementation of quality, safety, health and environmental management systems in companies

Several management systems have been introduced in Europe during the last decade, e.g. ISO 9000-series, ISO 14000, EMAS, Seveso II Directive, BS 8800 and the resent drafts OHSAS 18001 and 18002. The group identified a need to collect experiences on how these can be effectively implemented in companies. Based on the collected information a Best Practise should be developed and published in order to minimise the resources needed to keep these management systems effective in thousands of companies all over the Nordic countries.

10. Multi-objective decision making

A proposal had been put forward by Birgitte Rasmussen, see Appendix 4, and the group agreed that the proposal outlined a fundamental and important risk research area. (Personal comment by the project leader: The problem of decision-making in risk management is being researched by a large and diverse number of Nordic research institutions and university departments and there should be potential for a co-operative Nordic research effort, at least synthesising and summarising new developments and current research.)

11. Risk analysis and food production safety

Appendix 5 outlines a proposal by Birgitte Rasmussen.

This is potentially one of the most challenging and from an economic point of view important research problem facing the Nordic risk research community. The group felt that expertise and time was lacking to discuss the problem in any reasonable depth. Nevertheless, the project would seem ideal for Nordic co-operation and should be initiated as soon as possible.

4.3 Report of group 2

A Corporate safety management

2.1 Safety culture and management involvement

The importance of a good safety culture and the involvement of top management was addressed in the discussion. The general situation was regarded as highly unsatisfactory from the point of view of an optimally effective safety management. This applies for large companies, but in particular for medium and small companies. Different possible explanations exist, and it is highly important to understand the situation better. This issue was fundamental in all discussions, also regarding the other points in the discussion.

2.2 Organisational changes

Organisational changes were regarded to be of very high importance for safety and environmental issues in the future. For example in a company, informal procedures and tacit knowledge are often essential for maintaining safety, which can be lost in a awkward reorganisation. The overall risk situation can be essentially deteriorated in a pessimistic scenario.

2.3 Risk management support

Although, many guidelines and tools exist for supporting risk management, there is still a need for development. However, this must be based on a thorough analysis of the user's needs and an evaluation of existing support material.

B Users' focus

2.4 Implementation and application of tools

There is a great number of tools, such as methods for risk analysis, checklists, handbooks etc., designed to help the company to work with safety, health and environmental (SHE) issues. However, there is a number of problems associated with this. Examples are that existing and available tools are used only rarely in practical work in companies, and that each country independently develops its own tools. There is also a lack of systematic evaluation of tools, which makes it difficult for a user to find the right way of working. This points at a need to think along other lines. Can the users' real needs call for another way of supporting SHE issues?

2.5 User oriented IT. Net work

There are large potential revenues from IT in user based networks. Many such networks are created and large economic resources are put into this. Can safety research help in developing solutions and solving problems? It can also be a mean to better understand the user's focus.

2.6 Experience data

Examples of net works are co-operation between groups of companies in collecting accident and incident reports. However, a very common problem is that experiences from accidents are not used, inside and between companies.

D Vulnerability and sustainability

2.7 Vulnerability analysis, overall

A company is vulnerable to many risks and factors within and outside the company. SHE-issues are a small part of the company overall risk perspective. Usually different kinds of risks are treated by its own speciality and often as separate issues.

It would be useful with an approach which systematically handles the different risk issues, in order to improve the sustainability and reduces the vulnerability of the company. This is essential for large, as well as small companies.

2.8 Trust and quality of risk analysis

A number of problems is connected with the quality of performed risk analyses. Examples were given, e.g. risk assessments made in connections with CE-marking are often problematic. The low quality can be a large problem, since so many products shall be risk assessed.

4.4 Report group 3

The group noted that their discussion was in most aspects identical to the arguments and items presented by the other groups and concluded that their work could be usefully summarised by the following list of prioritised projects

Risk communication, attitudes and understanding
- management
- other decision makers
- different groups
  selling arguments to different groups

Use of risk analysis
- internal information
- use for different purposes

Combining risk analysis, quality, environmental protection, health and safety. For SMEs

Transportation risk analysis
- dangerous goods
- internal transportation

Cost & benefit use of risk analysis based actions

Automation

4.5 Summary of working group reports

After surveying the results of the group discussions it was felt that a number of important and cost-effective project ideas had been brought forward and formulated. It was the opinion of the workshop that virtually all of these ideas deserved to be investigated further and transformed into project plans. Realistically, a prioritised list had to be produced and the workshop decided to follow the procedure outlined below.

An attempt was made to structure the proposed projects into a number of broadly labelled practical application categories:

- corporate safety management
- users focus
- community applications
- vulnerability and sustainability
- method oriented
- application areas

The application categories are both very loosely defined and to some extent overlapping and after some discussion it was agreed to concentrate the remaining part of the workshop to discussions on two specific items in two new working groups.

5. Final group discussions, morning 99-04-16

5.1 Discussions in Group 1; selected projects

Top management handling of risks - towards better understanding and new approaches

Discussion
Starting points were some problems, which were found to be valid in all the four Nordic countries represented. There is usually a low management involvement in risk issues at companies, which has many explanations. Further, there are many tools (methods, guidelines, handbooks etc.) developed in all the countries, but they appear to be used to a rather small extent. Is the problem the contents or the design of the tools, or the users' low interest? There is a need to understand the situation much better, in particular from a user's point of view.

It is essential also with a historical perspective. Over the years, different issues have got priority; like quality, the environment, Year 2000 etc. On the SHE agenda, we have the "internal control" for which it is unclear if it has lead to any real progress in the SHE-situation.

Issues
These considerations point to a need for a new way of thinking, but exactly how nobody knows. The user focus should, however, be highly pronounced.

One theme is to consider the whole panorama of possible risks in a company. There are usually different specialists arguing for particular interests. There is a need to even more integrate the different perspectives. E.g. it could be essential to involve economists more in the risk assessment procedure, but it does not mean that everything should be assessed in economic terms. One aim is to also include ethical aspects, and to improve the overall safety culture.

One essential application area is organisational changes in companies. It is often found that informal procedures and tacit knowledge are essential for maintaining safety, which can be lost in an awkward reorganisation. How will the risk situation change, and what is a suitable strategy for increasing safety?

Research activities
It was regarded as important to study these issues in a research program. There are clear advantages to do this in a Nordic context, since it would give a richer empirical background from similar but not identical societies. Also, there is a need for a broad research experience, which is not available in only one country. Especially, the need for "new thinking" makes such co-operation essential.

Points in a research programme could be:
1 Understand the safety culture and company approaches
What are the characteristics in approaches and culture in companies where the risk issues are successfully handled? What is the difference compared with companies with poor performance?

2 Understand the tools characteristics
What tools do we have, and what can they do? What approaches are working well? What are the user needs? It is essential not to invent the wheel again.

3 Tool improvement
First after understanding the essential parameters, a specification for general tools should be made. In the group discussion, it was anticipated that some kind of risk based management tool was needed, which could address the whole panorama of risks. It was regarded as plausible that a high degree of user control is needed.

As a part of this activity, a number of demonstration projects would be advantageous. To some extent, the demonstration activities could start quite early and be a help also in understanding company culture and existing tools.

5.2 Discussions in Group 2; selected projects

The group found many of the proposed research areas interesting and well suited for a Nordic research effort. Due to the restricted time available the group concentrated on a very broad topic it decided to call "Corporate Risk Management". This is a highly relevant topic for companies working in many parts of the world and with a network of suppliers and subcontractors.

The group believed that research on a Nordic level is the most suitable despite the fact that many companies operate globally. However, many Nordic companies have similar backgrounds and the management will be likely to accept and adopt similar procedures. Research results meant to be suitable for all companies regardless of their origin (North-European, South-European, American, Asian) will probably be very difficult to achieve.

Corporate Risk Management
The proposed research project (or programme) may contain sub-projects dealing with the following topics:

a) Attitudes and understanding.
In order to improve the usage of risk analysis results and make risk analysis work more frequent the understanding and attitudes of the top management must be changed. It is well known fact that procedures that not only have the approval by, but also involve, the top management are likely to be more successful than procedures managed by the middle management (cf. current risk analysis procedures). Therefore, the benefits of the use of risk

analysis must be demonstrated to the top management. The research needed will involve, for instance, studies of successful organisations with an understanding of risk issues.

b) Risks expressed in financial terms

The involvement of top management requires that they get the information they must know to secure a profitable business. This can only be made by developing methods to present the risk analysis results in a way that not only can be understood by the top management but that also can form an integrated part of current decision making procedures. In other words, a procedure must be developed which present all types of risks facing the company in an uniform way.

c) Risk Communication

Ways to communicate risk issues within large companies must be developed. Communication within companies is believed to become one of the requirements for success. Risk communication between the top management and the workforce and between companies, sites and plants belonging to the same company must form one part of this entity.

d) Internet and intranet solutions for educational purposes

Risk is not a topic that can be easily taught to people. Many undesired events are very rare and therefore many of us are not aware of the consequences and/or frequency of risks. Modern information technology is believed to be a suitable vehicle for providing risk related information to those concerned regardless of their geographical location or hierarchical position.
The Nordic countries have adopted IT-solutions faster than most other parts of the world, and therefore a Nordic forum seems suitable for research in this field.

e) Downsizing

A recent trend in many large companies has been to reduce the staff. Risk professionals have been among those that frequently have been laid off. Once the understanding of the top management and the share holders about all types of risks grows, there will be a better understanding of the dangers connected to downsizing, and how to avoid them. Research on risks in relation to downsizing must, however, be carried out in the meantime in order to be able to provide the companies with the information they will need.

f) Suppliers

One obvious risk with downsizing is the decrease of knowledge in the company. The suppliers and subcontractors now employ the experts that earlier formed a crucial part of a corporations organisational memory (only some of it will remain as written procedures, etc). The company must make sure that it understands the risks and opportunities of this new situation.

One issue that needs special attention is the fact that single source suppliers of the large company may have inherent risks that will affect the whole business of the company. A fire, loss of a key person, liability problems, etc. may interrupt the delivery of key components for a long time, and cause extensive damage not only to the small supplier directly affected, but to large businesses as well. Tools and procedures to handle this risk must be developed and implemented alongside ISO 9000 and similar standards.

g) Streamlining of the practical use of standards, development of cost/benefit methods

There are many procedures and standards used in industry in order to manage risks (e.g. ISO 9000, EMAS, 'Seveso II'-requirements, etc.) and the proposed research programme will

develop more! It is seen as extremely important that the requirements of these systems are such that overlapping work in auditing, up-dating, reporting, etc. can be minimised. There is also a need to develop suitable cost-benefit methods in order to demonstrate that the benefits of carrying out risk studies and risk reducing measures are feasible. These methods should include benefits that today are normally overlooked in cost-benefit analysis, such as image issues, corporate culture, a motivated workforce, etc.

6. Proposals for future work

6.1 General discussion

The workshop was concluded by a general discussion on the best method to proceed and to produce concrete plans for inter-Nordic research project. There was a general consensus that

- a number of economically important project areas could be defined based on already ongoing national research work
- restrictions on time and resources meant that project plans could not be produced within the time frame of the present workshop
- plans should be drawn up for a continued interaction between interested parties (industry and research organisations) with the objective of presenting concrete plans for continued research
- the continued activity should be concentrated to the three areas outlined in section 6.2-6.4 below.

6.2 Activity 1. Maintaining safety during down-sizing

As discussed in several sections of the main report, in chapter 5 of this report and in a special project proposal submitted by SINTEF (see Appendix 6) there is an urgent need for a study of the possibly deleterious consequences of a rapidly changing organisational structure (down-sizing) on company risk management systems. Project background, research objectives and research issues are described in Appendix 6.

Action: Lars Bodsberg volunteered to take the lead in formulating a proposal for joint Nordic research.

6.3 Activity 2. Tools for HSE-management of small- and medium-sized enterprises (SME)

As outlined in section 4.2.1 of this report, substantial research projects have been carried out in Norway and Finland in order to streamline, improve and make more effective the risk management work. within SME's. It was noted that the Norwegian project was completed while the Finnish PK-RH project was in its final phases. As experiences from the practical field use of these tools, methods and procedures accumulate, an activity should be started along the following lines:

- in a comparative study, advantages and limitations similarities and dissimilarities of the two methods are specified
- in the same study, the potential for a possible joint inter-Nordic development of the two risk management tools should be specified. An important aspect would be to take advantage of emerging information and communication technologies

Action: LUCRAM undertakes to find financial means to support the comparative study of the two systems and of the potential for further development and to organise this study.

6.4 Activity 3. Proposal for two networks

As a consequence of the discussions carried out during the workshop there was a general agreement that many of the projects proposed and discussed needed to go through a definition and preparation phase before actual project proposals could be formulated and submitted. It was felt that the best way to go through this preparatory stage or definition phase would be to organise a network with industry, authorities and research institutes as participants. The objectives of this the first network would be to

- serve as arena for industry, regulatory bodies and researchers to discuss important and common issues in practical risk management
- improve communication and co-operation between participating partners and the process of technology transfer in general
- use the project ideas generated by the workshop as a basis and be a platform for the conception, planning and writing of concrete risk research proposals
- be a point of origin for a number of activities outlined in section 6.1 and 6.2 of the main report

The second proposal for a network concerned co-operation between researchers working in the area. Natural objectives for such a network would be for strengthen communication between groups of researches and to establish a Nordic graduate school research education. It was felt that there was a great potential for a Nordic network set up in the risk research and education area as research activities are strongly fragmented and compartmentalised throughout the countries in question

Action: LUCRAM undertook to further explore the potential and possible available financial resources for these two networks.

PROGRAM Appendix 1

Day 1	**15 April 1999**
11.00	REGISTRATION LUNCH
12.30	WELCOME Rector Thomas Johannesson, LTH
12.45	PRESENTATION OF LUCRAM Nils Stormby, chairman LUCRAM Sven Erik Magnusson, director LUCRAM
13.00	PRESENTATION OF THE REPORT The project group
13.45	COFFEE
14.15	PREPARED COMMENTS • Industry • Authorities • Research bodies
15.15	INTRODUCTION TO GROUP DISCUSSION #1
15.30	GROUP DISCUSSION #1 *Selection of projects proposals*
17.00	PRESENTATIONS AND DISCUSSION
18.00	END
19.00	DINNER
Day 2	**16 April 1999**
08.30	INTRODUCTION TO GROUP DISCUSSION #2
08.45	GROUP DISCUSSION #2 *Discussion of selected projects with respect to project contents, funding and execution in a Nordic context*
10.30	PRESENTATIONS Discussion in plenum
11.30	CONCLUSIONS The next steps
12.00	LUNCH

Appendix 2

Nordic Workshop on "The increasing role of risk analysis of technological systems in decision-making" April 15 -16 1999 Lund, Sweden

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Appendix 3

Nordic Workshop
April 15-16 1999

List of presentations

Peter Göransson	Nordic Industrial Fund perspective
Peter Göransson	Criteria for project proposals
Lars Harms-Ringdahl	Role of research and research networking
Yngve Malmén	Trends affecting risk analysis work
Sven Erik Magnusson	Tools for facilitating information flow and decision-making
Kurt Petersen	Quality standards for risk analysis
Ingemar Grahn	Industrial perspective
Roland Akselsson	Some thoughts on risk and industrial competitiveness
Lars Bodsberg	Two strategic research programmes: ROS Living knowledge
Karl Palmér	Robustness and vulnerability

Project ideas:
Ranveig Tinmansvik
Birgitte Rasmussen
Jan Schyllander

Appendix 4

Multi-objective decisions involving risk issues

Planning processes involving risk issues are often complex processes involving actors at different decision making levels with different interests. Examples are:

- land use planning involving chemical sites
- restrictions for transport of goods by rail or road.

These planning processes are essentially decision processes characterised by preparation and evaluation of alternatives where objectives of different types and values are weighed out (where an objective is a statement about the desired state of the system). Risk issues are only one of the objectives of the planning process and other objectives can be environmental impact, societal aspects, economy, cultural heritage etc.

An objective generally indicates the "direction" in which the decision makers should strive to do better. An objective can be characterised as a statement about the desired state of the system. Furthermore, the decision maker shall define the objective attribute(s) related to each objective. An attribute is a measurable quantity reflecting the degree to which a particular objective is achieved. There might be a formal relationship between objectives and attributes, but usually the relationship is informal and exists only in the mind of the people involved.

Research aspects:

- Development of a framework for multi-objective decisions involving risk issues which can support the decision makers.
- How can the decision maker be supported in the preparation of alternatives. A critical point in the decision process is to decide if all relevant alternatives have been considered.
- Development of principles for determination of objectives and attributes. Determination of objectives forms the frame for the comparison of alternatives.

Birgitte Rasmussen, Risø

Appendix 5

Risk analysis and food safety

It appears from the paper that food risks are excluded, but why ?

The concept of risk analysis in relation to food safety is still in its infancy. Food safety is a huge area including production of vegetables (e.g. genetically modified crops) and animal production (e.g. microbiological hazards and foodborne diseases).

The genetically modified crops are met with uncertainty and scepticism, and they have to only a very limited extent found their way to the fields and the markets. There is an uncertainty about the risks and consequences of growing genetically modified crops and even more about what counts as relevant risks and consequences.

What concerns the meat production several risk assessments have been carried out with respect to microbiological hazards and foodborne diseases. A commonly used approach is the development of a risk model in combination with Monte Carlo simulation. This procedure entails generating hypothetical scenarios in terms of the values attributed to the identified factors in the exposure and dose-response assessments. The simulation represents the inherent variability in the process of food production and consumption and the uncertainty in the mathematical model of the process. The outcome is a statistical distribution of risk experienced by the diverse members of the population.

Research aspects:

- The food production is becoming more and more industrialised which might lead to risk issues comparable or similar to other industries, especially the impact of individual, managerial and organisational factors on food safety (e.g. development of predictive indicators).
- Development of holistic risk assessment methods for food products, e.g. by using the LCA approach.
- Risk acceptance, risk communication.

Birgitte Rasmussen, Risø

Lars Bodsberg, SINTEF **Appendix 6**

Project idea to the Nordic Workshop: MAINTAINING SAFETY DURING DOWNSIZING

Background

Due to demands on cost savings, many offshore companies and other organisations at present are accomplishing downsizing, e.g.

- delayering (flatter organisations), reduction of staff personnel, experts, fewer senior personnel
- new organisational structures, outsourcing and contracting (autonomous groups, integrated teams, network organisations).

These changes may lead to:

- reduced maintenance (increased backlog)
- increased strain on operational personnel
- subcritical manning for crisis management

At the same time we experience increasingly complexity of technology and processes, that makes it more difficult to have a full overview of the situation. The role of the control room operator will be ever more critical.

SINTEF has project activities in this area related to the offshore oil industry. However, the subject is also relevant for most industries and transportation activities in all the Nordic countries, and therefore suited for Nordic research collaboration.

Goals

The project goal may be to:

1. Gain knowledge about how the working environment will be affected after downsizing (which activities will disappear/be reduced; consequences for working environment and safety).
2. Develop a scenario method for evaluating the organisation's ability to handle crisis and abnormal situations.
3. Suggest compensating measures (i.e. other SHE controlling mechanisms) to maintain the safety level during reduced manning).

Research issues

The following research issues could be interesting:

- In what way will an organisation be affected during downsizing and when established structures for safety management disappear?
  - Will some activities be more vulnerable for downsizing than other activities?
  - What are the consequences for knowledge management, organisation learning, experience exchange?
  - What is necessary minimum manning from a safety point of view (a. during normal operation, b. during crisis intervention)?
  - How performing effective safety management during downsizing?
  - What will be functional risk acceptance criteria regarding manning and downsizing?

- Which evaluations are done regarding competence/resources ahead of, and after downsizing?
  - Change analyses?
  - Compensating measures?
  - "After-the-fact"-evaluations (problems/indicators for subcritical manning).

- Is it possible to define indicators to measure effects of downsizing; which indicators are sensitive for undermanned activities (can e.g. a drop in near miss reporting be an indicator for subcritical manning)?

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